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Interreg Greece-Italy BEST European Regional Development Fund | EUROPEAN UNION

BEST INTERREG V-A GREECE-ITALY 2014/2020 PROJECT

Monitoring of Areas

- M01-03 -

University of L'Aquila – Department of Civil, Construction-Architectural and Environmental Engineering (DICEAA), Environmental and Maritime Hydraulics Laboratory (LIam)

Polytechnic University of Bari – Department of Civil, Environmental, Land, Building Engineering and Chemistry (DICATECh)

UNIVERSITÀ DEGLI STUDI DELL'AQUILA

DICEAA Dipartimento di Ingegneria Civile, Edile-Architettura e Ambientale

LIam

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DICATECh

Macro-activity	Report	Revision	Date
M01	03	R03	31st July 2022

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SUMMARY

1. FOREWORD 2

2. Methods for quality control, validation, analysis and elaboration of data from monitoring activities 4

3. Definition of the system for storage, elaboration and forwarding of acquired data 5

4. WEB GIS platform for data browsing 8

5. Preliminary directions on analysis algorithms 20

6. Technical documentation and support manuals for the monitoring system 22

7. Scheduled maintenance plan for the monitoring system and related instruments 23

7.1. Scheduled preventive maintenance 24

7.2. Extraordinary maintenance 27

1. FOREWORD

The Department of Civil, Construction-Architectural and Environmental Engineering (DICEAA) of the University of L'Aquila, through its Environmental and Maritime Hydraulics Laboratory (LIam) and the Department of Civil, Environmental, Land, Building Engineering and Chemistry (DICATECh) of the Polytechnic University of Bari, constituting Temporary Grouping of Companies (RTI) and henceforth denoted as UNIVAQ-POLIBA, have been selected by the Department of Mobility, Urban Quality, Public Works, Ecology and Landscape of Puglia Region (henceforth denoted as "client") as contractors for the service of "*Analisi della dinamica evolutiva del litorale nei tratti di costa dell'area dell'azione pilota 1 ed implementazione di sistemi di smart monitoring nell'ambito del progetto BEST Interreg V-A Grecia-Italia 2014/2020*" ("Analysis of the evolutionary dynamics of the coast in the stretches of coastline in the pilot 1 action area and implementation of smart monitoring systems as part of the BEST Interreg V-A Greece-Italy 2014/2020 project").

Activities began on 31/03/2021 with the start of the contract under urgency procedure.

The service is part of the wider implementation of the BEST project "Addressing joint Agro and Aqua-Biodiversity pressure Enhancing SuSTainable Rural Development" funded by the INTERREG V-A Greece-Italy 2014/2020 program. On the whole, the project's goal is to protect the natural and cultural heritage, restore biodiversity and coastal and rural natural habitats, involve local actors in cross-border projects and common pilot actions through the use of new technologies with a low environmental impact, with the final goal to improve the quality of life of the citizens of the concerned regions.

Starting from the analysis of the state of knowledge, the service's goal is to assess the evolutionary dynamics of the concerned coastlines and to monitor the areas where the action will be focused (Parco Naturale Regionale delle Dune Costiere, Parco Regionale del Mar Piccolo di Taranto and areas of the regional territory affected by Xylella).

Activities entrusted to UNIVAQ-POLIBA are related to two fundamental aspects, mutually related:

- Area monitoring (macro-activity M-01);
- Analysis of the evolutionary dynamics of the coast (macro-activity M-02).

This report refers to the macro-activity concerning the monitoring of areas and the designing of the monitoring network (M-01), with particular focus on what is described by art.4 point a) of the contract Addendum, which mentions "descriptive reports and graphs concerning designing activities for the monitoring network mentioned in art.1 point 4 lett. c) and d) of the contract".

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2. METHODS FOR QUALITY CONTROL, VALIDATION, ANALYSIS AND ELABORATION OF DATA FROM MONITORING ACTIVITIES

The monitoring network aimed to the preservation of the biodiversity of the investigated areas is made up of:

1. a group of distributed sensors for monitoring biotic and abiotic parameters (for a total of 27 measuring points and 75 monitoring stations);
2. a network for transmitting data to a server (based on the network usage);
3. a point/server for collecting data (images, video and data related to environmental parameters);
4. a collection of computational resources with medium-high performances on the data collection server's end aimed at storing data, verifying data consistency, managing station malfunctions, data correlation analyses, data elaboration, biodiversity monitoring, etc.

In summary, information acquired from the stations in the network contain:

- images;
- numerical data;
- audio tracks.

The type of data will depend on the kind of station, which in turn will be function of the biotic or abiotic parameter investigated (birds, mammals, insects, reptiles, flora, weather, water, soil). Table 2-1 shows the types of data associated to each type of station.

Table 2-1: Type of data associated to type of station.

Station type	Data type
Bird monitoring	Images Audio track
Mammals monitoring	Images Audio Track
Flora monitoring	Images Audio Track Numerical Values
Underwater monitoring	Images
Underwater monitoring with measuring of the water parameters	Images Numerical values
Underwater monitoring with measuring of the water parameters and hydrophone	Images Audio Track Numerical Values
Weather Monitoring	Numerical values
Insects or reptiles monitoring	Images Numerical Values

For each measuring point the installation of more than one type of station is required. Generally, information acquired at each measuring point by each station have to be sent to the remote server for data storage(which is managed by a management system on an independent integrated circuit, which provides the required redundance).

In order to manage costs related to data transferring through a mobile network, a station (for each measuring point) will act as an access point to the transmission network for all the other stations installed in the same measuring point. Each station will be equipped with a management system on an integrated circuit, on which the required software will be installed. This software is needed for (i) acquiring information from sensors, (ii) send information to the acquisition server and (iii) monitor the intended monitoring of the station.

"Raw" data will be processed with appropriate algorithms or statistical analyses (specifically developed in the framework of this project's activities), depending on the data type, so that information on the detection of environmental and biotic data can be synthesized.

3. DEFINITION OF THE SYSTEM FOR STORAGE, ELABORATION AND FORWARDING OF ACQUIRED DATA

Data acquired from monitoring station and transferred to the central repository will be organized in different folders (through the definition of a dedicated file system) depending on the monitoring station type (birds, mammals, insects, reptiles, flora, weather, water, soil). Some functional subcategories will be defined (data hierarchy); then, for information that can be translated in tables with data (e.g. MS-EXcel, .dbf files, .csv files and other database types), the structure of the aforementioned tables will be defined (field names, data types, data domain, etc).

It will be possible to access both "raw" data, acquired with specific sampling times, in dedicated folders, and the processed data (i) using algorithms for the animal species and (ii) through statistical analyses for the environmental parameters. In summary, in the short term the memory required for storing images and audio tracks alone is estimated to be about 300 GiB/day, while the required memory for long term is estimated to be account 1TiB/year (table 3-1). Numerical data (transmitted in ASCII format, which means binary format) can be considered having a negligible memory requirement for storage.

The database for the monitoring network will have the following functional requisites:

- It will be scalable;
- It will always be possible in the analysis phase, or while composing a report, to select all data available concerning the territory under investigation;
- The spatial composition of the dataset will be supplied with a spatial index;
- It will have a data structure specifically designed and implemented for managing metadata;
- It will allow the automatic updating of data;

- It will support the acquisition of data structures that can vary in time while having a low impact on the system, meaning that the configurations will be supported without the need of modifying the software (for acquisition, storage, analysis and reporting);
- It will store acquired data implementing a historicization that assigns a version to the level of data/table/flux;
- It will be subject to complete or incremental backup procedures, that will also make use of cloud hosting.

Table 3-1: Estimate of memory requirements for acquired data from the monitoring network

Station type	Number of station	Number of daily images	Number of short term stored images	Duration (in hours) of the daily audio tracks	Estimate of daily memory requirements (GiB)
Birds Monitoring	21	17280	1728	24	15.12
Mammals monitoring	19	86400	8640	24	68.52
Flora monitoring	6	4	4	24	1.78
Reptiles monitoring	15	86400	8640	0	68.52
Insects Monitoring	15	86400	8640	0	68.52
Underwater video monitoring	7	86400	8640	0	68.52
				TOTAL	**290.96**
				TOTAL VALUABLE	**2.91**

Measurements obtained from the various measuring stations and sent to the central repository will be processed so that they can yield useful information on the analysis of biodiversity. Specifically, data acquired will be organized in different folders (through the definition of a dedicated file system) depending on the monitoring station type (birds, mammals, insects, reptiles, flora, weather, water, soil). It will be possible to access both "raw" data, acquired with specific sampling times, in dedicated folders, and the processed data (i) using algorithms for the animal species and (ii) through statistical analyses for the environmental parameters.

Access and visualization of elaborated data will take place through preconfigured dashboards, set up in the implementation phase as per the contracting authority's requests. The home screen for the initial login to the system will be a portal. Once the user has logged in the portal, a list of available dashboard

elements grouped by theme will be shown, together with other useful information such as links to documents and relevant websites.

The system, together with the possibility of browsing available reports on demand, will generate reports on a daily basis related to the functioning of the network (in order to aid network maintenance) and to analyses results (for historical data analysis availability).

The monitoring network that this project intends to implement will be smart, meaning it will allow automated acquisition and cataloguing of data which will then be further elaborated in an automated way through algorithms. These will be implemented in the system during the first phase, that of activation, and the comparison with monitoring forms filled out by a specialized operator will be used to verify that the automated system is functioning properly. The automated elaboration of acquired data can be interpreted as similar to the filling out of forms by a virtual operator corresponding to the algorithm itself. The aforementioned monitoring forms will have the following minimal requirements concerning the biotic component:

- ✓ Definition of the sampling unit:
  - the sampling unit for cameras/microphones/hydrophones consists of continuative watching/listening/recording;
  - sampling geographic coordinates have to refer to positioning geographic coordinates of the considered camera/microphone/hydrophone;
  - direction and amplitude of framing with fixed parameters (to be determined depending on the instrument's characteristics, soil altitude/depth).
- ✓ Definition of sampling effort:
  - Sampling will be carried out in 6 time slots over the course of a day of monitoring. The time slots are:
    - The hour before sunrise*;
    - The hour after sunrise*;
    - The hour from 11.30 to 12.30;
    - The hour before sunset*;
    - The hour after sunset;
    - The hour from 23.30 to 00.30.

Note: sunset and sunrise hours are those listed daily in the Effemeridi section in the Italian Air Force website (https://clima.meteoam.it/Effemeridi.php).

For the environmental abiotic parameters (atmospheric conditions, water parameters, soil parameters) there are no monitoring forms. These will be replaced by reports documenting the temporal evolution of the monitored parameters, which will be combined with the results of the statistical analysis synthesis (i.e. means, monthly maximum and minimum values). Such information will be crucial for the analysis of correlation with results of the direct monitoring of biodiversity and in the setting up of the support system for decision-making and results management. For this system, the use of *Open Source* technologies will be preferred, in order to decrease both subsequent costs related to the management and maintenance for the Administration and the risk of technological *lock-in.*

4. WEB GIS PLATFORM FOR DATA BROWSING

Analysis results will be made available through a geospatial visualization system, in order to allow the decision support system to function properly.

The platform has been designed with the goal of being dynamical (automatically updated by the data management system) and completely based on an open source system.

Specifically, the platform is provided as a virtual system (in the "vmdk" format) based on the linux distribution Ubuntu 22.04, on which all the necessary packages for the correct functioning of WebGis have been installed. System administrators who manage the IT system of the Client will only have to provide an IP address that allows external browsing of the regional network.

The platform is linked to the monitoring system through a shared folder that will allow the user to browse the following information:

1) the latest images acquired from stations with a camera (in "jpg" format);

2) the latest monitoring forms (in "pdf" format);

3) results from the latest analyses (in "pdf" format);

4) reports from recent analyses (in "pdf" format);

5) possible malfunctioning warnings from stations.

The platform will also allow users to browse the results of monitoring carried out on the Parco delle Dune Costiere's litoral (sedimentological analyses and topographic and bathymetric surveys).

In summary, the WebGis platform offers a topological support (whose elements are called "features") and the user can browse each feature's properties and access the latest and most updated relevant information.

The system is composed of three main components:

- The operating system (linux distribution Ubuntu Desktop version 22.04);
- A server (Apache2);
- A mapserver (QGIS server 3.22).

In the following pages, the installation procedure for the server and the mapserver is described. It is important to note that this information is useful for system managers and that the system is supplied as a virtual system (in "vmdk" format). The system can run with both the application "Virtual Box" or, alternatively, with the application "VMware".

The first operations that need to be carried out refer to the mapserver installation.

For that aim, it is necessary to install the required "packages":*sudo apt install gnupg software-properties-common net-tools plocate*

It is then necessary to install the security keys for the installation of the application packages “QGIS” and “QGISserver”:

wget -qO – https://qgis.org/downloads/qgis-2021.gpg.key | sudo gpg –no-default-keyring –keyring gnupg-ring:/etc/apt/trusted.gpg.d/qgis-archive.gpg –import

The output of the command above should be the following:

gpg: chiave '/etc/apt/trusted.gpg.d/qgis-archive.gpg' creata

gpg: chiave 46B5721DBBD2996A: 1 firma non controllata a causa di una chiave mancante

gpg: directory '/root/.gnupg' creata

gpg: /root/.gnupg/trustdb.gpg: creato il trustdb

gpg: chiave 46B5721DBBD2996A: chiave pubblica "QGIS Archive Automatic Signing Key (2021) <qgis-developer@lists.osgeo.org>" importata

gpg: Numero totale esaminato: 1

gpg: importate: 1

gpg: non è stata trovata alcuna chiave completamente affidabile

Because of the latest warning, it is necessary to add the key to the list of trusted keys:

sudo chmod a+r /etc/apt/trusted.gpg.d/qgis-archive.gpg

It is then necessary to add the QGIS repository to the repository list by adding the following two lines to the file /etc/apt/sources.list

deb https://qgis.org/debian-ltr jammy main

deb-src https://qgis.org/ubuntu-ltr jammy main

It is then necessary to install the following packages:

sudo apt install qgis

sudo apt install qgis-plugin-grass

sudo apt install qgis-server --no-install-recommends --no-install-suggests

In order to check whether the installation process was completed successfully it is possible to run the following command:

/usr/lib/cgi-bin/qgis_mapserv.fcgi

If the installation process was successful, the output will be the following:

Warning: Ignoring XDG_SESSION_TYPE=wayland on Gnome. Use QT_QPA_PLATFORM=wayland to run on Wayland anyway.

Warning 1: Unable to find driver ECW to unload from GDAL_SKIP environment variable.

Warning 1: Unable to find driver ECW to unload from GDAL_SKIP environment variable.

Warning 1: Unable to find driver JP2ECW to unload from GDAL_SKIP environment variable.

"Loading native module /usr/lib/qgis/server/libdummy.so"

"Loading native module /usr/lib/qgis/server/liblandingpage.so"

"Loading native module /usr/lib/qgis/server/libwcs.so"

"Loading native module /usr/lib/qgis/server/libwfs.so"

"Loading native module /usr/lib/qgis/server/libwfs3.so"

"Loading native module /usr/lib/qgis/server/libwms.so"

"Loading native module /usr/lib/qgis/server/libwmts.so"

<string>:1: DeprecationWarning: setapi() is deprecated

Content-Length: 0

Location: http:/index.json

Server: QGIS FCGI server - QGIS version 3.22.6-Białowieża

Status: 302

After this, it is necessary to install and prepare the Apache server. It is important to stress that the following instructions do not take into account system security, and that aspect is left to the Client's system administrators.

The Apache server can be installed with the following commands:

sudo apt install apache2

sudo apt install libapache2-mod-fcgid

The WebGis virtual server can be obtained creating the file <alias_qgis_server>.conf that will have to be installed in the folder /etc/apache2/sites-available

In this case the alias for qgis_server is **qgis.best**; thus, the file name is "qgis.best.info".

The file contains the following:

*<VirtualHost *:80>*

ServerAdmin webmaster@localhost

ServerName qgis.best

```
DocumentRoot /var/www/html

# Apache logs (different than QGIS Server log)
ErrorLog ${APACHE_LOG_DIR}/qgis.best.error.log
CustomLog ${APACHE_LOG_DIR}/qgis.best.access.log combined

# Longer timeout for WPS... default = 40
FcgidIOTimeout 120

FcgidInitialEnv LC_ALL "en_US.UTF-8"
FcgidInitialEnv PYTHONIOENCODING UTF-8
FcgidInitialEnv LANG "en_US.UTF-8"

# QGIS log
FcgidInitialEnv QGIS_SERVER_LOG_STDERR 1
FcgidInitialEnv QGIS_SERVER_LOG_LEVEL 0

# QGIS display
FcgidInitialEnv DISPLAY      ":99"

# default QGIS project
SetEnv QGIS_PROJECT_FILE /home/qgis/projects/world.qgs

# QGIS_AUTH_DB_DIR_PATH must lead to a directory writeable by the Server's FCGI process user
FcgidInitialEnv QGIS_AUTH_DB_DIR_PATH "/home/qgis/qgisserverdb/"
FcgidInitialEnv QGIS_AUTH_PASSWORD_FILE "/home/qgis/qgisserverdb/qgis-auth.db"

# Set pg access via pg_service file
SetEnv PGSERVICEFILE /home/qgis/.pg_service.conf
FcgidInitialEnv PGPASSFILE "/home/qgis/.pgpass"

# if qgis-server is installed from packages in debian based distros this is usually /usr/lib/cgi-bin/
# run "locate qgis_mapserv.fcgi" if you don't know where qgis_mapserv.fcgi is
ScriptAlias /cgi-bin/ /usr/lib/cgi-bin/
```

<Directory "/usr/lib/cgi-bin/">
AllowOverride None
Options +ExecCGI -MultiViews -SymLinksIfOwnerMatch
Require all granted
</Directory>

<IfModule mod_fcgid.c>
FcgidMaxRequestLen 26214400
FcgidConnectTimeout 60
</IfModule>

</VirtualHost>

The QGISserver applications requires a series of folders, that can be created with the following instructions:
sudo mkdir -p /var/log/qgis/
chown www-data:www-data /var/log/qgis
sudo kdir -p /home/qgis/qgisserverdb
sudo chown www-data:www-data /home/qgis/qgisserverdb

The virtual server (an apache2 module) must be enabled with the following instructions:

sudo a2enmod fcgid
sudo a2ensite qgis.best

In order to make modifications effective it is required to restart the apache server:

systemctl restart apache2

To be able to access WebGis from the system browser, it is necessary to add the pointer to the server to the file /etc/hosts:
 # Replace 127.0.0.1 with the IP of your server.
sudo sh -c "echo '127.0.0.1 qgis.best' >> /etc/hosts"``.

It is then necessary to install FastCGI wrapper:

sudo apt install spawn-fcgi

and of an X server:

sudo apt install xvfb

It is also necessary to create the X Server service through the "/ect/systemd/system/xvfb.service" file, that should contain the following:

[Unit]

Description=X Virtual Frame Buffer Service

After=network.target

[Service]

ExecStart=/usr/bin/Xvfb :99 -screen 0 1024x768x24 -ac +extension GLX +render -noreset

[Install]

WantedBy=multi-user.target

The service should be enabled and started:

systemctl enable --now xvfb.service

systemctl status xvfb.service

The system can be tested opening the following link in a browser:

http://qgis.best/cgi-bin/qgis_mapserv.fcgi?SERVICE=WMS&VERSION=1.3.0&REQUEST=GetCapabilities

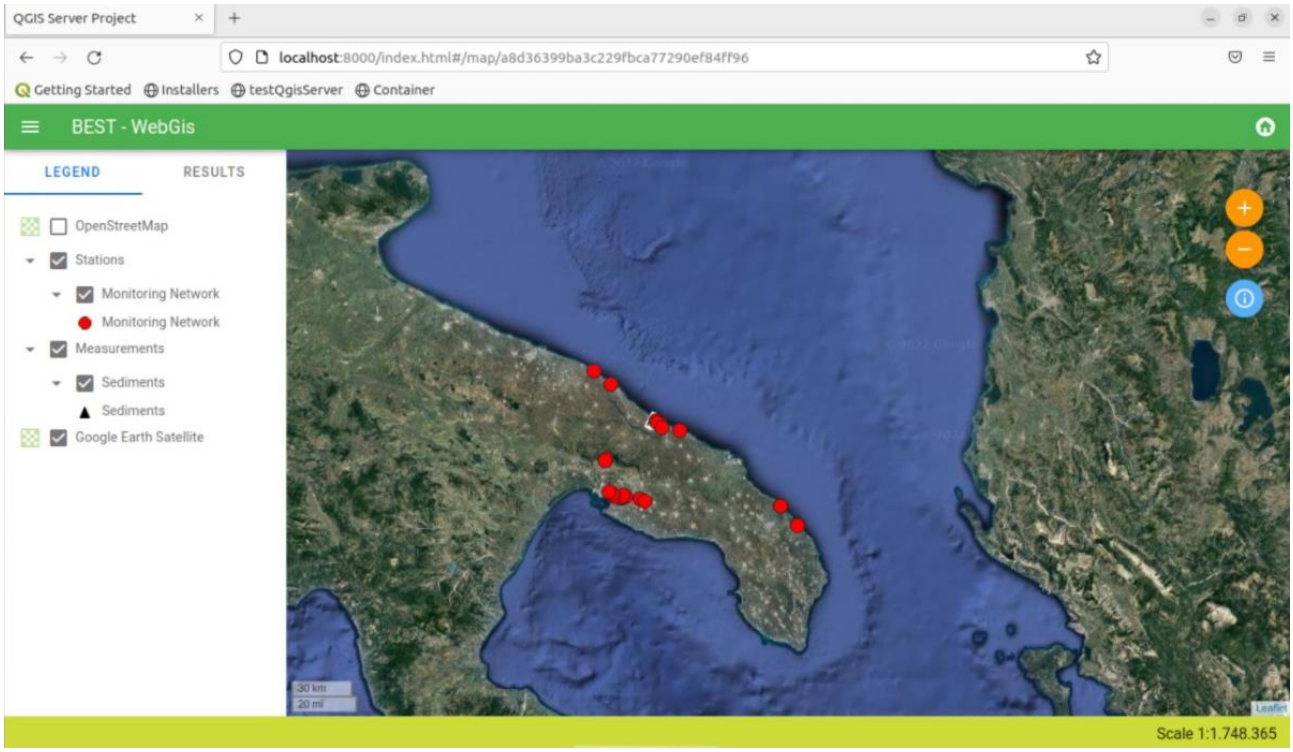
The result should be the display of a xml file (QGIS Server Demo)

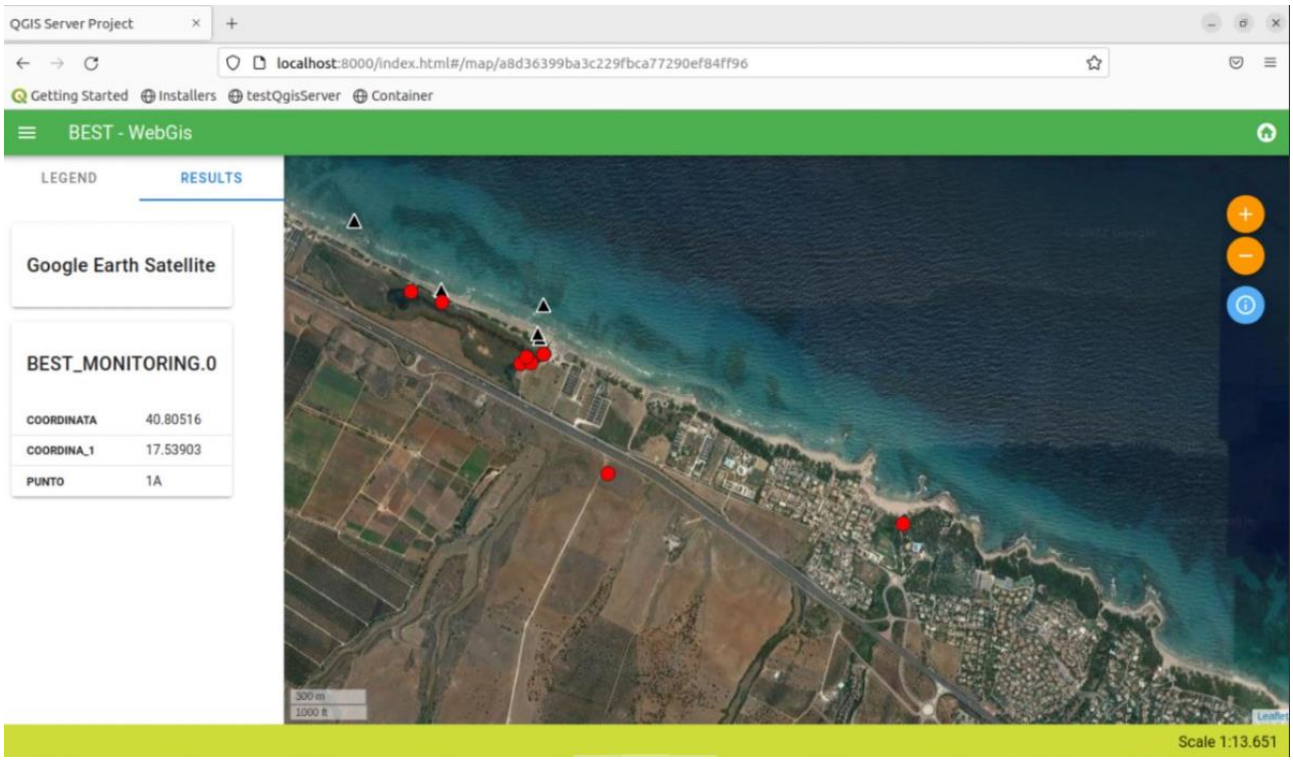
The system should now be ready to display a WebGis made with QGIS.

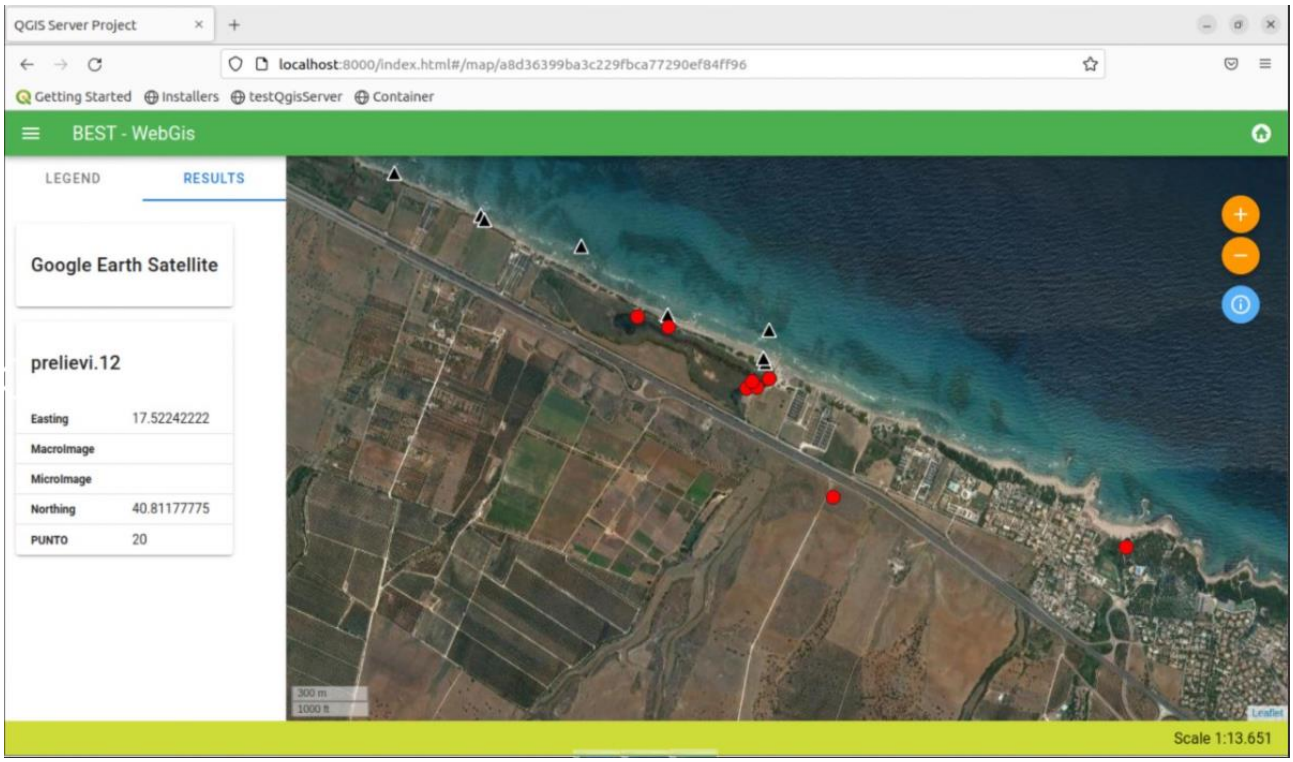
The system attached allows to browse the preliminary version of WebGis visiting the link http://localhost:8000

With the web browser installed (currently Firefox). Opening the browser, the page is set to be the initial page.

In the following pages some screenshots from WebGis are shown, showing the highly intuitive interface, that can be directly experienced using the attached virtual system.




QGIS Server Project
localhost:8000/index.html#/map/a8d36399ba3c229fbca77290ef84ff96
Getting Started
Installers
testQgisServer
Container
BEST - WebGis
LEGEND
RESULTS
Google Earth Satellite
BEST_MONITORING.0
COORDINATA 40.80516
COORDINA_1 17.53903
PUNTO 1A
Scale 1:13.651


QGIS Server Project
localhost:8000/index.html#/map/a8d36399ba3c229fbca77290ef84ff96
Getting Started
Installers
testQgisServer
Container
BEST - WebGis
LEGEND
RESULTS
Google Earth Satellite
prelievi.12
Easting 17.52242222
MacroImage
MicroImage
Northing 40.81177775
PUNTO 20
Scale 1:13.651

In particular, the WebGis platform has a menu with three main sections:

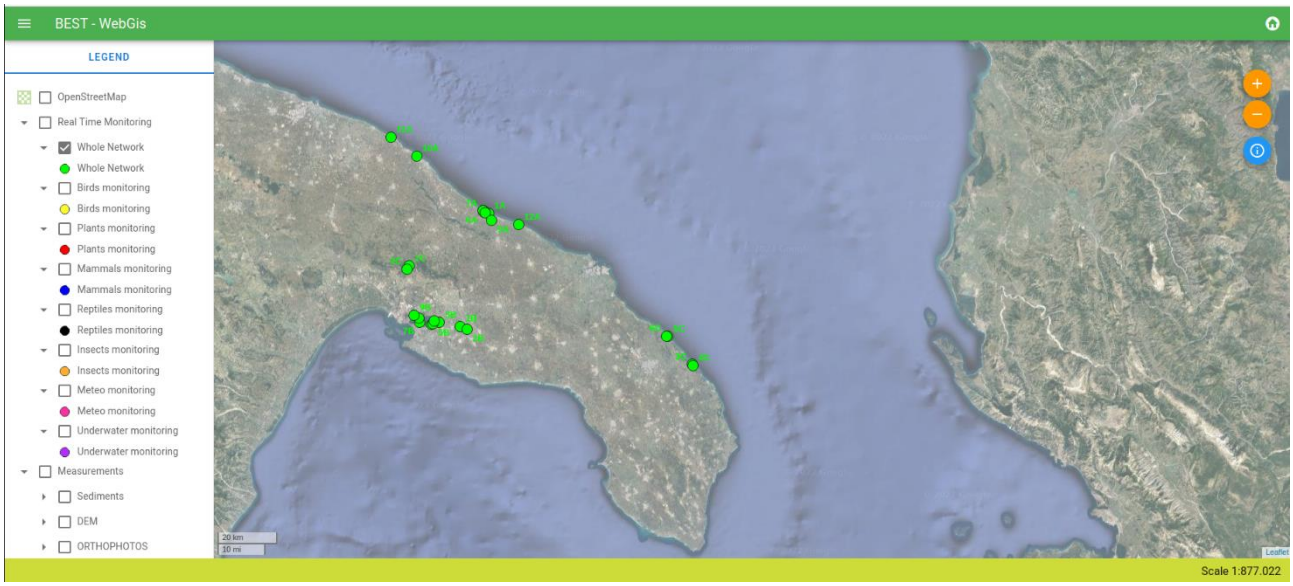
- Basic cartography: contains maps useful to browse information
- Real time monitoring: contains results from the real time monitoring obtained based on the network
- Measures: contains results from the monitoring carried out during the project's activities (e.g. sedimentological measures, coastline measures).

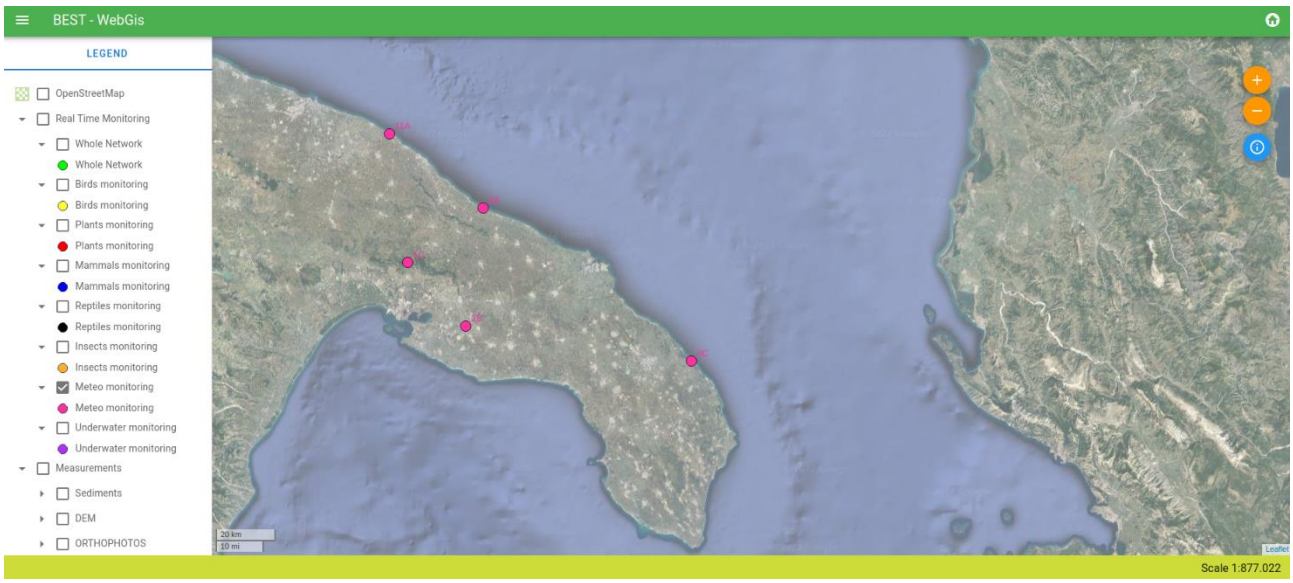
The section "Real time monitoring" contains some subsections, each of them relating to a certain station type (e.g. environmental monitoring, avifauna monitoring, insects monitoring, etc...).

In the following figures the browsing capabilities of the WebGis platform, as described, are shown.


BEST - WebGis
LEGEND
OpenStreetMap
Real Time Monitoring
Whole Network
Whole Network
Birds monitoring
Birds monitoring
Plants monitoring
Plants monitoring
Mammals monitoring
Mammals monitoring
Reptiles monitoring
Reptiles monitoring
Insects monitoring
Insects monitoring
Meteo monitoring
Meteo monitoring
Underwater monitoring
Underwater monitoring
Measurements
Google Earth Satellite
300 m
1000 ft
Scale 1:13.647


BEST - WebGis
LEGEND
OpenStreetMap
Real Time Monitoring
Measurements
Sediments
DEM
ORTHOPHOTOS
Topographic Survey
SHORELINES
Google Earth Satellite
300 m
1000 ft
Scale 1:13.647


BEST - WebGis
LEGEND
OpenStreetMap
Real Time Monitoring
Whole Network
Whole Network
Birds monitoring
Birds monitoring
Plants monitoring
Plants monitoring
Mammals monitoring
Mammals monitoring
Reptiles monitoring
Reptiles monitoring
Insects monitoring
Insects monitoring
Meteo monitoring
Meteo monitoring
Underwater monitoring
Underwater monitoring
Measurements
Sediments
DEM
ORTHOPHOTOS
Scale 1:877.022


BEST - WebGis
LEGEND
OpenStreetMap
Real Time Monitoring
Whole Network
Whole Network
Birds monitoring
Birds monitoring
Plants monitoring
Plants monitoring
Mammals monitoring
Mammals monitoring
Reptiles monitoring
Reptiles monitoring
Insects monitoring
Insects monitoring
Meteo monitoring
Meteo monitoring
Underwater monitoring
Underwater monitoring
Measurements
Sediments
DEM
ORTHOPHOTOS
Scale 1:877.022


BEST - WebGis
LEGEND
OpenStreetMap
Real Time Monitoring
Measurements
Sediments
DEM
ORTHOPHOTOS
Topographic Survey
SHORELINES
2022
2022
Google Earth Satellite
Scale 1:54.592


BEST - WebGis
LEGEND
OpenStreetMap
Real Time Monitoring
Measurements
Sediments
DEM
ORTHOPHOTOS
Topographic Survey
SHORELINES
Google Earth Satellite
Scale 1:3.413

5. PRELIMINARY DIRECTIONS ON ANALYSIS ALGORITHMS

In order to summarize the information acquired from measuring stations, it is necessary to elaborate information acquired through the sensors using appropriate analysis algorithms. Such algorithms have different goals depending on the measuring station type (bird monitoring, mammals monitoring, flora monitoring, weather monitoring, insects monitoring, reptiles monitoring).
As far as image analysis is concerned, algorithms will have two different goals:

- Identifying elements moving through the camera frame(for monitoring birds, mammals, insects, reptiles);
- Identifying characteristics of the elements in the camera frame (flora monitoring).

From the set of acquired images, in order to identify the passage of an element through the camera frame, only images containing an element of interest (bird, mammal, insect or reptile) will have to be selected. The server will be supplied with a script (as already stated, developed in Python and open source) capable of identifying images of interest. This script will be based on the use of the "OpenCV" module (for image analysis) and of the "TensorFlow" module (for the use of Machine Learning techniques).
The algorithm will have two intermediate goals:

- extraction of images containing (at least) one passing element (e.g. a bird, mammal, insect or reptile);
- Identification of the element.

In detail, images transferred from each station to the server will be preprocessed in order to identify frames that potentially contain an element of interest (bird, insect, mammal, etc.) for the monitoring. This preprocessing will initially result in a decrease of the number of images on the server.
This preliminary selection will take place through the use of the "OpenCV" module and the comparison of each image with a mean of the previous images. This technique allows the recognition of movements inside the image (*motion detection*). However, depending on the framing, variation in the image content might not be related to the objects that need to be identified. As an example, it is possible to consider the movement of clouds entering the frame when a portion of the sky is being observed, or the movement of trees in framing the camera frame.
In order to select, among the images in which movement has been detected, those containing specific elements (the subjects of the monitoring) these images will be analyzed using Machine Learning techniques. In summary, these techniques allow to carry out complex tasks downstream of a training process (of the neural network). This training is based on an iterative process applied to cases – in this case, images – whose characteristics are already known. The training of the neural network will be carried out, for each station, using data sets from the scientific community (es. https://research.google/tools/datasets/).
The trained network will then be used for the automated recognition of the elements in the images in which motion has been detected. Training and application of neural network will be carried out using tools available on the platform "TensorFlow" that, among other things, provides a scripting interface for

Python. In this regard, it is important to note that the whole system will be based on a (open source) scripting language.

The algorithm will be defined after the installation of monitoring stations, as it will be based on the training of neural networks (one for each measuring station) obtained from the first series of images obtained by the network.

In regards to flora monitoring, images will be used to estimate the value of the so called Vegetation Index. This parameter, for RGB images, is based on the formulation of Gitelson et al. (2002):

$$VI = \frac{R_{green} - R_{red}}{R_{green} + R_{red}}$$

where R_{green} and R_{red} (reflectance values in the red and green band) can be extracted directly from captured images. The result is a new image representing the spatial distribution (in the image plane) of the vegetation index. This spatial distribution can be synthetized with techniques from descriptive statistics in order to assess the temporal evolution of

In regards to the audio tracks, each audio track will be analyzed with the "Wavelet" analysis technique. Thus, after a preliminary training phase for the algorithm, it will be possible to single out the intervals in which sounds unrelated to background noise are present. In this case, as for the case of images, the platform "TensorFlow" will be used.

As for other types of information, statistical analyses will be carried out in order to synthetize information. Specifically, in regards to information from weather stations, they will be obtained following the technical directives of the WMO (World Meteorological Organization).

It is important to state once again that all information will be made available (in an automated mode) to the storage and visualization system (including the WebGis system).

6. TECHNICAL DOCUMENTATION AND SUPPORT MANUALS FOR THE MONITORING SYSTEM

During this preliminary phase of the design of the monitoring station, everything that is described and defined in this and in the previous reports is by itself a support to the system and to its implementation and realization. The technical documentation and manuals will be addressed upon the purchase of the instruments required for each station and the setting up of said instruments. For each component of the system purchased, technical manuals provided by manufacturers will be provided to the monitoring network managers. Following a first period in which the functionality of the whole system will be checked, a technical manual for post processing procedures for acquired data will be provided, so that they can be employed for the project's goals.

7. SCHEDULED MAINTENANCE PLAN FOR THE MONITORING SYSTEM AND RELATED INSTRUMENTS

The following paragraph's aim is to define the necessary actions in order to maintain the monitoring network and the elements of which the network is made of, in order to maintain its functionality, its efficiency and economic value over time. The definition of the necessary activities to be carried out for maintenance will be derived from the monitoring activities of the network themselves, as already stated in the previous reports. However, in this report some predictions useful for the production of a specific document regarding maintenance aspects, which will be drafted in the executive phase, have been made.

The aforementioned document will be updated and adjusted during the service life of this project and its components. Specifically, scheduled preventive maintenance must be taken into account, as will be described in the following paragraphs. If the Client agrees, an evolutionary mainenance can also be considered, comprising all activities related to the constant updating of the software/firmware components of systems to the latest available release on the market.

Together with the aforementioned physical maintenance for monitoring station a maintenance for software will have to be taken into account, requiring (refer to paragraph 5.5.3 of Report "M01_01") diagnostics and removal of the causes and effects of possible application malfunctions and running programs. These activities will have to be carried out remotely if possible, but it could require an on-site visit contextually to hardware malfunctions.

Activities related to taking charge of the developed tools and their release should also be considered part of the software maintenance, in order to gain the necessary know-how to guarantee the proper operating of the service. In this regards, it is important to note that the network will be used in an experimental configuration for a duration of at least six months from the installation date. This phase will allow the testing and adjustments of acquisition parameters in order to make way for the operative functioning in the following period.

All additional elements, even if not explicitly mentioned, required for the proper functioning of the system, will be added to the aforementioned equipment for the stationary monitoring stations and measuring instruments. The disposal of waste deriving from maintenance and repair activities will also need to be taken care of.

A system "Manager" will have to be designated. The Manager, by verifying the results obtained through the monitoring, will decide to carry out the maintenance that the situation requires (both included in the project and extraordinary). The Manager will be designated among Regione Puglia personnel during the operative phase of the monitoring network. Subjects responsible for maintenance will have to be involved. This involvement will take place through the presentation, sharing and transferring of each information, support or reference useful to the maintenance being carried out. People responsible of treating, authorized for maintenance and use of the facilities and, where it is absolutely required for the goals of this project, to watch recordings, will have to be designated in writing.

The Manager must keep track, on a dedicated (paper/computerized) register, of the type of failures, maintenance and restoration interventions that have been carried out for each of the points above. In the year-end summary the Manager must give an account through a dedicated summary report, analyzing the nature of the events that took place, the causes, the frequency of the observed events and the type of remedial actions undertaken.

The maintenance plan thus links the monitoring network with the operative phases and the lifespan of the elements in the system, with the aim of testing the project requisites and their variations during the lifespan of the network. The aim of maintenance is to guarantee the correct functioning, over time, of the analyzers for the continuous monitoring of biodiversity and of support apparatuses, and the maintaining of data quality goals.

7.1. SCHEDULED PREVENTIVE MAINTENANCE

Scheduled preventive maintenance aims to survey the state of the locations and to maintain the efficiency of the monitoring network as a whole over time. Scheduled preventive (quarterly) maintenance will have to be carried out in the month of January, March, June, September, and they will be followed by the formulation of a technical inspection report with photographic attachments. The service will include scheduled technical interventions which will consist in activities prescribed in user manuals for the instruments and in operating procedures defined in the present document. Table 6.1 shows the main activities to be carried out, depending on the system components.

Table61: Definition of scheduled preventive maintenance and its frequency.

Component	Scheduled preventive maintenance	Frequency
Power supply (solar panel)	• Check mounting • Check power supply • Check frame, focus and possible calibration • Check connections • Check support pole stability • General cleaning	Quarterly
Equipment for Wireless transmission	• Check mounting • Check connections • Check power supply • Possible firmware update	Quarterly
Active network equipment/net work switches	• Check port connections • Check power supply	Half-yearly

	• Check network connections • General cleaning	
Operations Room	• Check functionalities and settings • Check data backup • Check live and recorded images quality • Possible release update • General cleaning	
Instruments - Weather Station	• Check mounting • Check power supply • Possible calibration (see technical manual provided by manufacturer) • Check connections • Check support pole stability • Check mechanical parts • Possible firmware update • General cleaning	Quarterly
Instruments - Insects/Reptiles Monitoring Station	• Check mounting • Check power supply • Check camera frame, focus and possible calibration (see technical manual provided by the manifacturer) • Check connections • Check support pole stability • Check mechanical parts • Possible firmware update • General cleaning	Quarterly
Instruments – Flora Monitoring Station	• Check mounting • Check power supply	Quarterly

	• Check camera frame, focus and possible calibration (see technical manual provided by the manifacturer) • Check connections • Check support pole stability • Check mechanical parts • Possible firmware update • General cleaning	
Instruments – Birds Monitoring Station	• Check mounting • Check power supply • Check camera frame, focus and possible calibration (see technical manual provided by the manifacturer) • Check connections • Check support pole stability • Check mechanical parts • Possible firmware update • General cleaning	Quarterly
Instruments – Mammals Monitoring Station	• Check mounting • Check power supply • Check camera frame, focus and possible calibration (see technical manual provided by the manifacturer) • Check connections • Check support pole stability • Check mechanical parts • Possible firmware update • General cleaning	Quarterly
Instruments – Underwater Monitoring Station	• Check mounting • Check power supply • Check camera frame, focus and possible calibration (see technical manual provided by the manifacturer) • Check connections	Quarterly

	• Check support pole stability • Check mechanical parts • Possible firmware update • General Cleaning	
Instruments – Sensors	• Check mounting • Check power supply • Possible calibartion (see technical manual provided by manifacturer) • Check connections • Check support pole stability • Check eventual mechanical parts • General cleaning	Half-yearly (see technical manual provided by manufacturer)

7.2. EXTRAORDINARY MAINTENANCE

Extraordinary maintenance concerns fixing or replacing component parts of the monitoring network that are malfunctioning. Extraordinary maintenance will be handled by the central data collection system that will, among other things, be able to highlight station malfunctions (see paragraph 5.5.3). Extraordinary maintenance will have to be carried out starting from an automated maintenance request made by the system.

The Manager will have to fill out a list of their procedures, listing actions that are carried out in case of failures. Data concerning interventions that are carried out must be registered on an appropriate form. See table 6.2 as an example.

Table 6-2: Definition of scheduled preventive maintenance and its frequency.

INTERNAL REFERENCE	PROCEDURE SUBJECT	AIM AND CONTENTS

The state of preservation, maintenance and functioning at the time of service interruption will have to be verified. Disposal of waste resulting from maintenance and repairing will also have to be taken care

of. A piece of equipment is considered unable to be repaired further when (i) the replacements are no longer available on the market, or (ii) the price of replacements is 80% higher than the current listed price of the same piece of equipment. If that is the case, the piece of equipment will be considered waste to be disposed of.