MINISTRY OF RURAL DEVELOPMENT AND FOODS
GENERAL DIRECTORSHIP OF RURAL DEVELOPMENT
DIRECTORSHIP OF LAND RECLAMATION AND SOIL-WATER RESOURCES
DEPARTMENT OF PLANNING OF LAND RECLAMATION WORKS & UTILIZATION OF SOIL-WATER RESOURCES

CHEMICAL QUALITY CHECK OF IRRIGATION WATERS (SURFACE AND GROUNDWATER) OF THE RIVERS CATCHMENTS OF STEREA ELLADA (P. FTHIOTIDA-FOKIDA-BIOTIA-EVRITANIA AND EVIA)

EXTENDED SUMMARY

Consortium:

ΕΛΓΟ-ΔΗΜΗΤΡΑ
ΕΛΛΗΝΙΚΟΣ ΓΕΩΡΓΙΚΟΣ ΟΡΓΑΝΙΣΜΟΣ - ΔΗΜΗΤΡΑ

E. T. ME.
ΠΕΠΠΑΣ & ΣΥΝ/ΤΕΣ Ε.Ε.

ΕΥΡΩΠΑΪΚΟ ΓΕΩΡΓΙΚΟ ΤΑΜΕΙΟ ΑΓΡΟΤΙΚΗΣ ΑΝΑΠΤΥΞΗΣ
Η Ευρώπη επενδύει στις αγροτικές περιοχές

ΠΡΟΓΡΑΜΜΑ ΑΓΡΟΤΙΚΗΣ ΑΝΑΠΤΥΞΗΣ

Athens, January 2020

1. INTRODUCTION

PROJECT TITLE: "Chemical Quality Check of Irrigation Waters (Surface and Groundwater) of the river catchments of Sterea Ellada (P. Fthiotida-Fokida-Biotia-Evritania and Evia)"

CONTRACTING DETAILS: The project was assigned with the document No. 601/15881 / 13-2-2017 (ADA No: 75P84653CP-K7P) Private Contract between the Ministry of Rural Development and Foods and the consortium of the Hellenic Agricultural Organization DEMETER and ETME Peppas & Associates LP. As the Project's Joint Representative was appointed Ioannis Peppas, Civil Engineer with alternate Dr. Christos Tsadila, Senior Researcher of ELGO DEMETER.

PURPOSE OF THE PROJECT: The purpose of this project is the investigation of chemical quality of irrigation waters (surface and groundwater), the determination of the degree of contamination (of waters and sediments), the investigation of the sources of contamination, the investigation of the correlation between contamination and irrigated agriculture and finally the formulation of proposals for the protection and remediation of the quality of irrigation waters.

According to the contract, the project concerns the rivers of Sterea Ellada and it was carried out according to the provisions of the Water Framework Directive 2000/60 and other E.C. Directives or respective scientific guidelines.

IMPLEMENTATION DETAILS OF THE PROJECT: In order to evaluate the existent points of water appearance in the area of interest, a network of open channels, canals, lakes and boreholes' samplings and measurements of water table elevation was compiled. This network was recorded in a dynamic Geographical Information System.

Within a two (2) years period (2017-2019) referred on the present project, the prescribed by the contract samplings and water table measurements were carried out in the approved network and the analyses's results were included in the Technical Bulletin were accomplished.

Besides the water table measurements, piezometric maps were compiled while the possible relations of hydraulic connection between surface and groundwater were investigated.

The results of the analyses were correlated as appropriate with the respective results of the 1st Review of the Management Plans of the Catchments of the Aquatic Systems mainly of the East (EL 07) and West (EL 04) Sterea Ellada and Attica (EL 06).

The analyses performed in the present project are distinguished to:

a) Field measurements taken in situ and
b) Properties measured in the laboratory distinguished in:
    - b1. Properties (ions) measured in the laboratory (except heavy metals),
    - b2. Heavy Metals (HM) and
    - b3. Agrochemicals' residues

2. SYNOPTIC PRESENTATION OF THE PROJECT RESULTS PER CATCHMENT

For the optimization of the project implementation, the study area was divided in eleven (11) catchments. In each catchment a detailed description of the following characteristics was included: basic geological, hydrogeological and hydrological data, land uses, surface water bodies (rivers, lakes and basins) and groundwater water bodies. Also, for each catchment the sampling network covering surface waters, groundwater and sediments was studied and proposed by the consortium and approved by the Authorities.

Field work followed, including sampling from various points (12 in rivers waters, 18 in canals waters, 12 in groundwaters, and 6 lakes' waters with respective sediments' sampling) and water table measurements (about 2.000)). The chemical test of samples was carried out in situ (measuring: *pH, temperature, soluble oxygen, redox potential, total soluble solids, depth of clarity –secchi, electrical conductivity, chlorophyll content, total soluble solids, biological oxygen demand, and chemical oxygen demand*), and in the lab (measuring: *hardness, alkalinity, concentrations of boron, fluorine, chlorine, nitrate, nitrite, phosphate, sulfate, sodium adsorption ratio, ammonium, daphnia magna, heavy metals (arsenic, chromium-total-trivalent-hexavalent, copper, lead, mercury, nickel, cadmium, aluminum), and pesticide residues (organic insecticides, fungicides, acaricides, rodenticides, glucuronidicides)) by the use of* appropriate certified methods.

Subsequently, statistical classification and analysis of the results/measurements was carried out and the waters were evaluated with regards to their suitability for irrigation (based on the internationally acceptable standards and those used in Greece).

Besides, the possible sources of contamination where recorded and their consequences on irrigation waters was investigated.

Finally, environmental indicators were proposed for controlling the contamination and general measures for facing the problems caused by contamination as well as and possible remediation measures were proposed.

The results – conclusions per catchment of the project are summarized below:

- **SPERCHEIOS RIVER CATCHMENT**

In river waters (Specheios, Gorgopotamos, and Vistritsas), the mean values of all the properties studied lay within the desirable range levels, except for EC and Cl^- concentration in some places, which are referred at the Final Report. Practically, these waters are considered **suitable for irrigation** with some restrictions in few places.
In canal waters of Specheios river catchment, besides the above, excesses were recorded in several places in concentrations of heavy metals (As, Ni) and practically these waters are considered **unsuitable** for irrigation of crops as well as for drinking.
In groundwaters (estuary of Spercheios, and Makrakomi-Lamia catchment)**,** the mean values of all the studied properties were found within the acceptable limits and consequently, in general, the quality is considered **good** and all the groundwaters are considered suitable for irrigation, with some exceptions referred at the Final Report.
In all the sediments' sampling points of the Spercheios catchment, several properties exceeded the acceptable standards, which means that it is necessary to be taken seriously n into account in their management.
The above mentioned conclusions are generally in agreement with the respective ones of the 1st review of Management Plans of the catchment.

More specifically, with regards to the environmental impact of the catchment from agrochemical residues, it is estimated that in the waters (surface and groundwater) and sediments is **medium** but in the canal waters it is **significant**, given the fact that in these waters a big number of active substances was found and in several cases high. The active substances often appearing in the catchment are fluconazole, fluometuron, DEET και terbacil.

- **CATCHMENT OF ATALANTI**

In groundwaters of this catchment, some properties exceed the desirable values (EC, NO_2^-, NH_4^+ , As, Cr^{6+}) rendering them unsuitable for drinking and in some cases for irrigation. The results of this study are considered as compatible with approved Management Plan of the catchment. Conclusions are generally in agreement with the respective ones of the first review of Management Plans of the catchment.

Concerning the load of agrochemicals' residues in groundwater, it is considered **low** since only a few active substances were found in low concentrations.

- **CATCHMENT OF MORNOS**

Water quality of the river and lake of Mornos (RIVER Mornos and lake Mornos) as well as the groundwater is characterized as **good** for all uses, with exception of some places (river estuary) where high salinity values were found.
In contrast, the quality of canal waters in relation to some basic properties (EC, concentration of Cl^-, F^-, Na^+, As and SAR values) was related to irrigation and should have serious restrictions.
In regards to river Mornos' sediments, in their liquid phase several properties (EC,F^-, Cl^-, NO_2^- , Na^+, NH_4^+, SAR) and including toxic heavy metals in their solid phase (Cu, As, Ni and total Cr), exceeded the acceptable values, while the situation is better in lake's sediments (lake Mornos), in which only the concentration of some heavy metals (Cu, Zn, As, Ni and total Cr) is high. In the canals, sediments' high concentrations of Ni and Cr were found, the origin of which is considered geological.

With regards to the agrochemicals' load both in waters (surface and groundwater) and sediments, it is considered **low** in the river and lake waters but **a little higher** in canals waters, where several active substances are found, but in low concentrations, with exception of diflubenzuron and terbacil, which were found in somehow high concentrations.
Finally, comparing the results of this study with the approved Management Plan of the catchment, they are considered as compatible.

- **CATCHMENT OF AMFISSA PLAIN**

Groundwater of this catchment presents restrictions for irrigation of agricultural crops to the area in various degrees, due to salinity and high concentration of Cl^-, as it was also noticed in the approved revised Management Plan of the catchment.

Regarding the detection of agrochemicals residues in groundwater, it is considered **low** with several active substances, but in very low concentrations.

- **CATCHMENT OF KIFISOS RIVER**

In general, water quality of Kifissos river and Yliki's and Paralimnis' lakes is characterized **good** and suitable for any use, in contrast to the quality of canal waters, which are subjected to various degrees of restriction for irrigation, due to increased EC values.

In groundwater (catchment of middle-upper Kifisos), the quality differs from surface waters, due to increased concentrations of heavy metals, so that, they are considered unsuitable for drinking, but without restrictions for irrigation.
The sediments (Kifisos river, lake Yliki, and Paralimni, and canals of Kifisos river) in all sites and especially in canals, are characterized by increased concentrations of heavy metals (Cd, As, Ni και Cr) and other properties (EC, F^-, NO_2^-, NH_4^+) and thus their management requires special attention.

The loading of agrochemicals residues both in waters (surface and groundwater) and in sediments, it is considered **medium** in the river (the active substances fluometuron, fenoxycarb, diflubenzuron, metolachlor, terbacil are detected) and in the lakes (fluometuron and propham were detected), but it is considered **significant** in canal waters where a big number of active substances was detected exceeding the allowable limits for drinking waters, especially of the substances fluometuron, metolachlor, terbacil, piperonyl-butoxide, boscalid, chlorpyrifos, fluconazole, pymetrozine. Among the lakes the load was higher in the lake Yliki. The results of this study are compatible with those of the approved Plan Management.

- **CATCHMENT OF ASOPOS RIVER**

Many properties of the **surface waters** of Asopos river with toxic characteristics i.e. ions (EC, Cl^- , NO_2,, NH_4^+) and heavy metals (Cu, Ni, total Cr, and Cr^{6+}) have increased values and are considered **unsuitable** for any use.
Groundwaters of Asopos river have similar characteristics to surface waters being characterized as **completely unsuitable for any use**.
Similarly, the quality of sediments is burdened with toxic ions (EC, Cl^- , NO_2,, NH_4^+) and heavy metals (Cu, Ni, total Cr, and Cr^{6+}) in serious degree.

The environmental load of agrochemicals' residues both in waters (surface and groundwater) and in sediments is **high** with a big number of active substances and several legal threshold exceeded for drinking waters (fluometuron, fluconazole, dimethomorph, DEET, azoxystrobin και propiconazole). In canals waters the substances azoxystrobin, boscalid, carbaryl chlorpyrifos, DEET, fluometuron, metalaxyl, metolachlor, MGK-264 and propham are detected.
The results of the present study were found to be compatible with those of the approved Management Plan.

- **CATCHMENT OF ACHELOOS RIVER**

The quality of both **surface** (Rivers Acheloos, Karpenisiotis, Krikelopotamos, Tavropos and lake Kremaston) and **ground waters** (Karpenisiotis area) of this catchment is characterized as **very good** and the waters suitable for any use, as similarly is mentioned in the approved Management Plan.
With regards to the sediments (Rivers Acheloos, Karpenisiotis, Krikelopotamos, Tavropos and lake Kremaston), although in their liquid phase the values of all properties studied are low, in their solid phase high concentrations are found in some heavy metals (Cu, Cr και Ni).

The environmental load of agrochemicals' residues, in both, waters (surface and groundwater) and in sediments, is considered **low** (the substances terbacil and pypetrozine in individual samples of the rivers Tavropos and Karpenisiotis were detected).

➢ CATCHMENT OF RIVERS MESSAPIOS AND LILANTAS

The quality of both surface and ground waters (rivers Messapios, Lilantas-Xeropotamos) is very burdened in many properties (ions F-, Cl-, NO_2^-, NH_4^+, Na^+ , SAR and HM As and Ni,) making these waters **unsuitable for any use**. The same is true for the sediments (rivers Messapios, Lilantas-Xeropotamos), especially regarding the heavy metal content (As, Ni, Cr), requiring special attention in their management.

The environmental load with residues of agrochemicals in both, waters (surface and groundwaters) and in sediments, is considered **low** while only a few substances in low concentrations were detected.
The results of the present study were found to be compatible with those of the approved Management Plan.

➢ CATCHMENT OF RIVERS NILEAS-KIREAS-BOUDOROS-KIMASI

The quality of both surface (rivers Nileas-Kireas-Voudoros-kimasi) and ground waters (rivers Nileas-Kireas-Voudoros-Kimasi) present restrictions in some properties (EC, F-, Cl- and NH_4^+), so that, they are not suitable for irrigation, while due to their heavy metal content (As and Ni) they are unsuitable for drinking. The results of this study are compatible with the approved Management Plan of the catchment. As for the sediments, in both liquid and solid phases, high concentrations are recorded in the values of toxic substances that must be taken seriously into account in their management.

Concerning the environmental load from agrochemicals residues, in both, waters (surface and groundwater) as well as in sediments, is considered **low** with few substances detected in low concentrations.

➢ CATCHMENT OF RIVER KALLAS

The quality in waters, in both, surface (river Kallas) and groundwaters (Istiaea) classifies them as **suitable** for irrigation with light to moderate degree of restriction due to the high EC, similarly to the approved Management Plan of the catchment.
Similar situation was recorded in the sediments (river Kallas) which did not show a serious loading except for the high concentration of As in their solid phase.
The water load with agrochemical residues, in both, surface and groundwater as well as in the sediments, is **low** (few substances in low concentrations are detected).
These results are compatible with the management plan of the catchment.

➢ CATCHMENT OF LAKE DYSTOS

The waters of the lake Dystos can be used for irrigation, with the respective limitations imposed by the electrical conductivity (EC). It is noticed that the approved Management Plan of the catchment, classifies the total situation of the lake as "**Unknown**".
Concerning the sediments of the lake, although the number of samples is very small, significant concentrations of toxic heavy metals (As, Pb, Ni and Cr), impose a very careful management.
The load of agrochemicals' residues in both, the waters (surface and groundwater) as well as the sediments, is considered **low** with a limited number of findings in quantifiable level.

3. SYNOPTIC DESCRIPTION OF THE HYDRAYLIC INTERACTION OF WATER SYSTEMS

This chapter provides a brief overview of the results of the project, concerning the hydraulic interaction between surface water and groundwater.

AREAS WITH POSSIBLE HYDRAULIC INTERACTION BETWEEN SURFACE WATER AND GROUNDWATER.

• "**Sperchios estuary**" (halfway downstream of the Sperchios Basin).

In the coastal zone, mainly in the north, due to the high depth of groundwater level and the lithological composition of the aquifer.

• "**Makrakomi - Lamia**" central area (drilling location 6-Y-FTH-2).

Due to the significant pumping cone recorded in the area that intensifies during the period of low level aquifer, it is presumed that the deep water movement of the shallow aquifer and the Sperchios run-off.

• **Asopos Basin**

Throughout the basin, due to the lithological structure of the aquifers and the significant pumping cones recorded in the area, that increases during the period of low level aquifer. The above factors presume that the deep water movement of the shallow aquifer and the Asopos run-off, as indicated by the contaminated groundwater chemical data, and the contaminated surface water of the river.

• **"Kireas, Voudoros, Nileas, Kimasi-Xiropotamos"** (northern coastal area)

Due to the high depth of groundwater level, the aquifer lithology and the pumping cone recorded in the area.

• **"Lelandas-Xeropotamos"**

Due to the high depth of groundwater level and the lithological composition of the aquifer.

AREAS WITH DOUGHTS ABOUT HYDRAULIC INTERACTION BETWEEN SURFACE WATER AND GROUNDWATER.

• **“Makrakomi - Lamia”,** western and eastern region.

Due to high depth of groundwater level and the relatively rapid flow of Sperchios waters to its estuary area.

• **"Kireas, Voudoros, Nileas, Kimasi-Xiropotamos"** (central and upstream section)

Due to the high depth of groundwater level.

• **"Messapios"**

Due to the depth of the groundwater level.

• **"Mid-Upper Kifissos"**

Due to the high depth of groundwater level, the small and periodic surface run-off and the relatively intense pumping regime in the area.

• **"Atalantis Basin"**

Due to the depth of the groundwater level, the absence of surface run-off, as well as the bibliographic chemical data on the nitrate charge in the underground aquifer.

It is noted that the karstic aquifer water in the southern reaches of the basin is underground discharging into the sea and possibly into the alluvial aquifer of the area, but is not added to the surface water of the basin.

AREAS WITHOUT INDICATIONS OF HYDRAULIC INTERACTION BETWEEN SURFACE WATER AND GROUNDWATER.

• **"Mornos estuary"**

Taking into account the location of the area and the absence of surface run-off, due to the regulation of the flow of Mornos at its estuary after the construction of the homonymous dam.

• **Amphissa plain**

Taking into account the location of the area in the Mornos Delta and the absence of surface run-off on the basin. It is noted that the water of the karstic aquifer, mainly in the eastern reaches of the basin, is discharged underground into the sea and possibly into the alluvial aquifer of the sea, but is not added to the surface water of the basin.

• **Kallas**

Due to the depth of the groundwater level and the absence of surface run-off in the basin.

4. SYNOPTIC PRESENTATION OF CONTAMINATION SOURCES

The reasons of contamination on a case-by-case basis appear to be **anthropogenic**, as by way of example, are referred to the poor agricultural practices and, in particular, the non-sound management of inputs (fertilizers and pesticides), dumping into drainage channels of untreated municipal or/and industrial and **natural**, such as the seawater intrusion and the chemical composition of the rocks of the study area.

Below are briefly referred the identified sources of contamination which concern:

- ⇨ Contamination of pesticides: agro-supplies, applied by the farmers for plant protection.
- ⇨ Contamination by heavy metals: pesticides (arsenic, copper), rocks (chromium, nickel), industrial activity (arsenic, lead, copper, nickel, cadmium).
- ⇨ Contamination from municipal wastes: Plants of biological treatment.

- ⇨ Contamination from livestock farms.

Concerning especially the contamination problems due to salinization, they were recorded in the following three (3) catchments:

- ❖ Amfissa Plain
- ❖ Asopos river
- ❖ Lilantas river

5. PROPOSED ENVIRONMENTAL INDICES

According to their origin, environmental indicators, were distinguished into three categories [Contaminants - Anthropogenic Contamination Indicators (Chemical markers, Pesticides), Indicators of Agrochemical Contamination and Fertilizers - Soil Conditioners). Based on the existing soil-water systems (surface and groundwater) of all catchments of reference of the rivers and lakes of Sterea Ekkada, the following environmental indicators were proposed per catchment:

1. Catchment of Spercheios:

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Fluometuron, fluconazole, terbacil, DEET
vi. Cl, Ni, NO_3^-, chlorophyll

2. Catchment of Atalanti

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. As

3. Catchment of Mornos

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Diflubenzuron, terbacil.
vi. Cl^-

4. Catchment of Amfissa

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Cl, NO^{3-}

5. Catchment of Kifisos

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Fluometuron, metolachlor, terbacil, piperonyl-butoxide, boscalid, chlorpyriphos, fluconazole, pymetrozine, fenoxycarb, diflubenzuron, propham.

vi. Ni, Cd, Cr, chlorophyl

6. Catchment of Asopos

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Fluometuron, fluconazole, dimethomorph, DEET, azoxystrobin propiconazole, boscalid, carbaryl, chlorpyriphos, metalaxyl, metolachlor, MGK-264, propham.
vi. chlorophyl, NO_3^-, Ni, Cr, Cd

7. Catchment of Acheloos

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Terbacil, pymetrozine.
vi. Chlorophyl

8. Catchment of Messapios-Lilantas

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Cl^-, NO_3^-, As, Ni, Cr

9. Catchment of Lileas-Kireas-Voudoros-Kimasi

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Terbacil.
vi. Cl^-, chlorophyll, NO_3^-, As, Ni, Cr

10. Catchment of Kallas

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. chlorophyll, Ni, Cr

11. Catchment of Dystos

i. Priority substances
ii. Substances of Watch List
iii. Neo-nicotinides
iv. Caffeine
v. Chlorophyl

6. SUGGESTED MEASURES

As it is known, the main impacts of contamination of irrigation waters quality of both crops and soils.

Specifically, from the results of the chemical analyses of surface water samples (rivers, lakes and drainage canals), contamination was identified in certain areas (Asopos, Spercheios, Amphissa) in increasing content: salts, chlorine, nitrates and heavy metals arsenic, nickel, which are mainly caused by anthropogenic (agricultural, industrial activity) and geogenic reasons (rocks with minerals containing toxic heavy metals).

Also, from the results of chemical analyses of groundwater samples, an increase is observed in many areas (Asopos, Messapios-Lilantas, Amfissa, Spercheios), mainly in their nitrate content, which is of anthropogenic origin and is mainly due to agricultural and livestock activity, and in a lesser degree to human sewage (municipal and industrial). Also, increased content in heavy metals of groundwater is observed, while in certain catchments increased Cl^- content. Finally, in many areas (Assopos, Spercheios Kifisos) increased concentration of pesticides was recorded.

These increased contents have been the result of long-term contamination in last decades, and cannot be eliminated immediately and easily, even if these contamination sources stop today. Long-term measures have to be taken which, in order to perform, will need several years to implement, and a great deal of money to be spent.

In general, the most significant measures of contamination facing are the following:

- ⇨ Tracing of the contamination sources in order to identify their origin (agricultural, livestock, urban, industrial). About 90% of contamination comes from agriculture (fertilizers) and livestock, which, however, is limited in the study area. Municipal and industrial wastewater are very few, but the monitoring of the environmental conditions of the respective activities should be continuous and extensive.
- ⇨ Implementation of good agricultural practices by applying irrigation methods that reduce nutrient leaching in the aquifer and especially nitrates. One such irrigation method is drip irrigation.
- ⇨ Continuous monitoring of surface water through certain environmental indicators (pesticides, nitrates, arsenic, nickel), which have been proposed as well, in this project.
- ⇨ Monitoring of groundwater quality in order to know current contents, and to decide when additional protection measures should be taken. A typical case is Asopos, outflow of which is expected to decrease further in the coming years, which favors the increase of contaminants concentration due to the limited dilution of anthropogenic inputs. Therefore the systematic monitoring of the area and the adoption of protective measures is considered necessary.
- ⇨ Protection measures of water drillings and application of their protection zones (in accordance with the River Basin Management Plan proposals).
- ⇨ Preparation of hydrogeological studies aiming at water resources management and investigation of the interaction and combined use of groundwater and surface water. In the context of these studies, alternative management plans of aquifer and determination of zones of impact and protection of hydrolyptic works will be planned.

In the short term measures, we referred only in new drillings which are going to be opened, in which the vertical hydraulic protection must be ensured by isolating the surface aquifers (which are the most contaminated with nitrates), to avoid mixing with the deeper aquifers.

Furthermore, for phasing-out contamination, as well as for the protection of the groundwater, the measures set by the River Basin Management Plan, are applied which are already specialized to be implemented by the respective Services of Decentralized Administrations of the Prefecture.

These measures contain a wide spectrum of actions, which are related, besides the others and to agro-livestock practices in the area, which are referred in detail on to approved Management Plan.

The Program of measures of the Management Plan is distinguished into two categories:

a) The "Basic" measures, which are referred in the article 11.3 of the Directive 2000/60/EC, and where else is required: ,

b) The "Supplementary" Measures, implemented in the case that the implementation of the Basic Measures is not sufficient for the purpose achievement.

The Basic Measures make up the minimum requirements to be met, in order the Environmental Goals of the Article 4 of the Water Framework Directive 2000/60 to be accomplished, while the supplementary measures include individual actions related, among others with:

- ⇨ Codes of Good Practices,
- ⇨ Reconstruction and remediation of wetlands,
- ⇨ Control of perceptions, especially to the direction of facing of over pumping,
- ⇨ Measures of water demand management, among others forwarding the adapted agricultural production, such as low water demand crops, in areas suffering from drought,
- ⇨ Measures of efficiency and reuse, among others technologies of efficient water use in industry and water saving irrigation techniques,
- ⇨ Construction works, which are considered in combination with scheduled works in the water management works,
- ⇨ Desalinization plants,
- ⇨ Rehabilitation works of existing infrastructures, especially works on the improvement of infrastructures, of selection, storage and transport/distribution of water for drinking or irrigation, aiming at the reduction of losses and quality of water,
- ⇨ Artificial recharge of aquifers,
- ⇨ Educational works,
- ⇨ Research, development, and demonstration works.

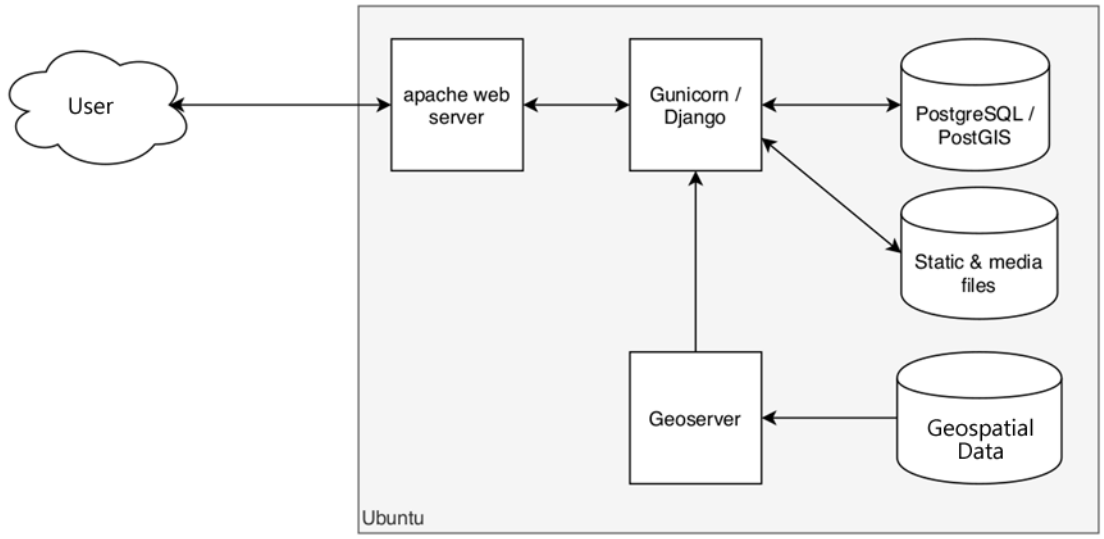
Finally, in order to accomplish the ultimate target of environmental quality protection and through this the quality of the produced agricultural products, it is suggested το update the results of the present research to the respective services of the area. These services include public or private organizations and authorities which are directly related to activities affecting the quality of waters such as the Ministry of Environment and Climate Change, the Prefecture, the Municipalities, the Technical and Geotechnical Chambers, and the farmers with their organizations, as well as the water quality check to be extended in all their sources, and to soils, which are irrigated with contaminated waters, so that the kind and the degree of contamination to be identified and measures of their improvement to be taken.

The same is considered extremely necessary to be done for the cultivated crops producing foods, such as vegetables, which have immediate effect on human health and on national economy.

7. PRESENTATION OF GEOGRAPHICAL INFORMATION SYSTEM – DATA BASE

ChemicalSE was created in compliance with the consortium's contractual obligations. It is a web application and all of its operations are accessible online using a modern browser (e.g. Chrome, Firefox and Edge) regardless of the underlying operating system. The website is the main portal for accessing the GIS and for displaying the network, the measured data, results from search operations etc.

The following figure shows the basic modules of the system and as well as their interfaces.



PosgreSQL, a fast, flexible and constantly evolving relational database management system, was used to store the data. It is based on open standards and is secure, and supports all major Web Frameworks. PostgreSQL GIS extension software (**PostGIS**) is required for PostgreSQL to support geodata. The ChemicalSE application was developed in the well-known programming language **Python**, using the web framework **Django**. Django is supported by **Gunicorn** (a Python application server), which is invoked automatically on system boot by systemd. Geospatial data are published using **Geoserver**. Finally, the **Apache** web server acts as an interface between the web client and Gunicorn. It processes the requests, and also supports download of static files such as images. All these components (Python, Django, Gunicorn, Apache) are free software.

Responding to the project needs, a GeoServer has been installed and connected to ChemicalSE. GeoServer is a free and open source software developed in Java, which allows the sharing of geospatial data between different applications in a flexible and efficient way. This software supports, among others, the WMS (Web Map Service) standard allowing the export of maps in different formats. A WMS request specifies the layers and the area of interest. The response to the request can be projected on a map as part of a website. Many thematic layers (even from different GeoServers) can be overlayed, adjusting the degree of transparency for each layer separately. GeoServer is maintained by an active community of users who are constantly improving its capabilities. It uses open standards, defined by the OGC (Open Geospatial Consortium) and can support all popular map visualization software such as OpenLayers, George Maps, Bing Maps, etc.

For the operation of GeoServer the following systems have been used:

- **Ubuntu Linux**. Although GeoServer can be installed on all known operating systems, Ubuntu, a distribution of the free OS Linux, was the preferred choice. It is supported by a large community of users and has been proven to be reliable in numerous large and complex projects.
- **Oracle Java JRE**. Java Runtime is required as GeoServer is developed using this programming language.

GeoServer supports all layers, except for the locations of measurements. These are stored in PostgreSQL/PostGIS and are handled by Django, using a Django component called GeoDjango. All other layers are stored in an internal GeoServer database. ChemicalSE acts as an intermediary between GeoServer and the user allowing access only to authorized users. If the user has the rights to access a thematic layer, then ChemicalSE simply performs proxy passing.

Users of this website are divided into the following categories:

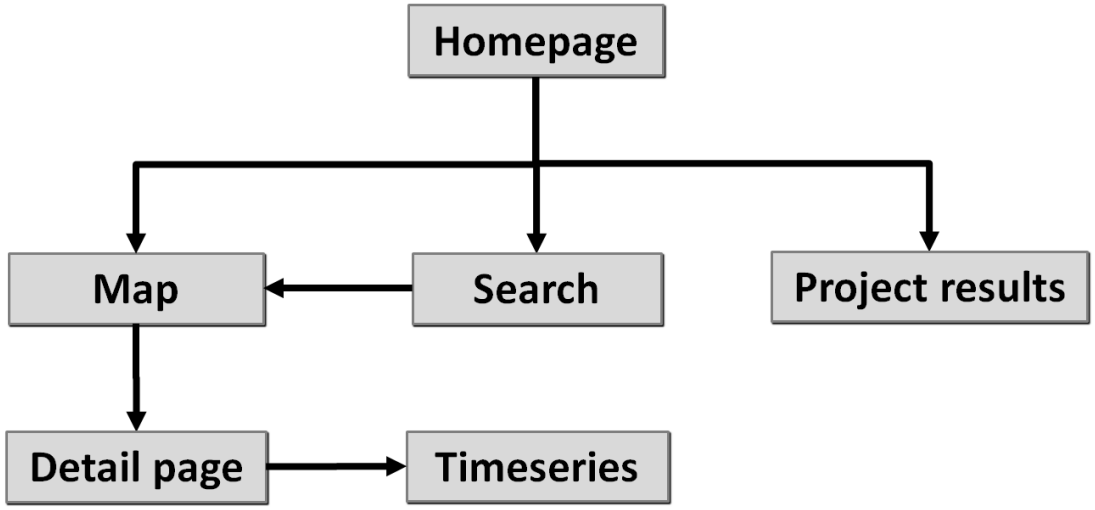
Simple User. All users from the general public belong to this category. They have read-only access to all free pages and can perform operations as described in the respective deliverables.

Registered User. Registered Users are usually staff members of the Agency that manages the system and are able to view all measurement data and thematic layers. However, they have no rights to insert new data into the database or modify existing information.

Editor. Users of this category have the same rights as Registered User and, additionally, they can update the database with new measurements. They also have access to some reference tables, such as Regional Units and Measurement Point Categories.

System Administrator (**Superuser**). System Administrators have the same rights as Editors and, additionally, user management rights, that is, they can register new users, modify their data and roles, or delete their accounts from the system.

The main paths that users may follow while navigating through the site are shown in the image below. According to this, it is expected that most users will access the interactive map. After that, users with sufficient privileges may navigate to the detail page of a specific location and from there to the timeseries of measured parameters.



ATHENS, JANUARY 2020
Common Representative

I.PEPPAS