PIC INTERREG IIIA GREECE-ITALY 2000-2006
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This book on Integrated Information System for natural disaster management: methodologies, approaches, case studies and good practices comes as the outcome of the SFINX project. The SFINX project focused on the development of an advanced information system to predict and manage flood events occurring in the riverside areas of Western Greece and Epirus in Greece and the coastal areas of Puglia in Italy and it was implemented the period 2006-2008 under the INTERREG IIIA Greece-Italy 2000-2006 Community Initiative Programme.

This book includes chapters covering:

- statistical and mathematical approaches to predict flooding incidents; novel intelligent methodologies and their implementation to develop knowledge-based Decision Support Systems for Flood Risk Assessment;
- the designing, utilization and implementation of Geographic Information Systems (GIS) and Dynamic WebGIS along with the corresponding advanced IT services for visualizing and monitoring flood events;
- the development of an integrated information system and the corresponding information services provided through web portal;
- methods, suggestions and approaches for designing sustainable flood risk management strategies;
- good practices and case studies for flood disasters management.

This book makes a significant and valuable contribution to the literature and will appeal to a broad audience including researches, practitioners, members of local and regional authorities, staff of public services and people living nearby flooding areas.

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INTEGRATED INFORMATION SYSTEM FOR NATURAL DISASTER MANAGEMENT | METHODOLOGIES - APPROACHES - CASE STUDIES - GOOD PRACTICES

SFINX

INTEGRATED INFORMATION SYSTEM FOR NATURAL DISASTER MANAGEMENT

Methodologies, Approaches, Case Studies, Good Practices

Edited by
Chrysostomos D. Stylios
Peter P. Groumpos

SFINX

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The editors
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INTEGRATED INFORMATION SYSTEM FOR NATURAL DISASTER MANAGEMENT:
Methodologies, Approaches, Case Studies, Good Practices

INTEGRATED INFORMATION SYSTEM FOR NATURAL DISASTER MANAGEMENT

Chapter 1

Methodologies and approaches to implement **SFINX** project

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Introduction 1.1

Flood is one of the most frequent and serious natural disasters. It is usually caused because of a natural phenomenon like extreme precipitation, thunderstorm, cyclone, monsoon, or even after another hazard, like earthquake, tsounami etc. Flood is considered as a big threat to people's lives and properties, to national economies and local constructions and to society's stability. Recent floods around the world have shown that human activities which are not well planned and the traditional river engineering that is used may result in increasing the frequency and the floods' scales. This, in return, has caused damages to livelihoods, and city properties, particularly in urbanized areas. However, since the floodplains were urbanized, the impact of flood disaster was increased because of structural human activities, such as land use, building, infrastructure, and non-structural ones, like lack of a) public awareness, b) organization and operation of the apposite authorities and services and c) self-organization.

Nowadays, there is a wide effort from the research community to propose innovative methods and to take advantage of the available technologies so that to develop advanced systems for effective evaluation, prediction and risk management of floods. A lot of high tech methods and technologies are availiable that could be integrated and combined so that to develop advanced computer based systems to support authorities and people living along a river so that to predict floods and to reduce the risk from floods.

Actually, mitigation is the heart for managing any emergency situations, where the main aim is to reduce the impact of natural disaster to people and their properties. Researchers have proposed non-structural methods for mitigation of flood events, which cost less in comparison to the structural ones (dams and dikes). Such non-structural methods are some modern flood forecasting systems that are based on collecting data in real time; based on this data sophisticated systems take decisions and predict floods. Advanced Decision Support Systems (DSS) have been developed for flood risk assessment that can infer and evaluate the situation and warn local and regional authorities to take actions on rescue and evacuation. On time forecasting and warning have significant importance on eliminating consequences of floods on people lives, crops and properties.

1.2 SFINX project

Patras Science Park was the leader partner of this project named **SFINX** where an Integrated Information System for natural disasters such as flood was developed under the program INTERREG IIIA Greece-Italy 2000-2006. Main partners of this project were Database Laboratory of Computer Engineering & Informatics Dept., University of Patras; High Performance Information Systems Laboratory of Computer Engineering & Informatics Dept, University of Patras; Knowledge and Intelligent Computing Laboratory, Dept. of Informatics and Telecommunication Technology, TEI of Epirus; Municipality of Arachthos, Artas and Prefecture of Aitoloakarnania from the Greek side. From the Italian side the Municipality of Lecce and the University of Lecce participated.

Within this project an integrated methodology was proposed and developed for predicting and managing risk of natural disasters and more specifically floods. The integrated system is based on Geographic Information System (GIS), which is combined with an Expert System that utilizes human experience and expertise so that an advanced Decision Support System (DSS) was developed. Special equipment and sensors have been installed in the areas at risk next to the rivers, which transmit data on the water level at the river and raining conditions to the main server of the Information System. The transmitted data is presented on line on the website of the project, it is visualized on the GIS and it is the input to the DSS, which evaluates the situation, predicts the possibility of flood occurence and warns the authorities and people. Moreover, according to the warning levels (green, yellow, red alert) special reports and instructions are sent to the authorities and are announced to the website, about the actions that must be taken and how the effects of the flood would be eliminated. In addition recommendations about how to recover as soon as possible are made availiable to the authorities.

In the heart of the Information system is the Geographical Information System which is being implemented by the Data Base Laboratory. The Geographical Information System integrates cartographical and chronological the topographical substratum, the geomorphology of the region, the human factor referred to as roads, thorps, precincts, place names, etc, as well as satellite photographs and aero photographs of extremely high resolution and accuracy. The source of these information is the Hellenic Military Geographical Service Satellite image providers and the participating in the project local authorities. The GIS technology unifies common functions of a data base, such as questions and statistical analysis, with a unique depiction and a geographical analysis which is offered by maps. The GIS application through the Internet contributes significantly to the dispensation of geographical information to the public.

The Decision Support System plays a major role in the whole project and it is used for detecting, evaluating, preventing, encountering, managing risk and preparing the appropriate goverment bodies. The Decision Support System aims to design and develop an intelligent supervision system to detect the possibility of flood occurring, to minimize damages and to support recovery from natural disaster. The Decision Support System has been developed by Patras Science Park's team with the support of the Laboratory of Knowledge and Intelligent Computing (TEI of Epirus). In order to design the Decision Support System fuzzy logic and knowledge based techniques along with the utilization of the existing knowledge and expertise as well as data mining techniques and exploitation of historical data and information are used. The Flood Decision Support System receives as inputs the measurements from the sensors in real time, for the water level in the river bed as well as the rainfall rate and by taking into consideration the morphology of the ground, which is provided by the Geographical Information System and the historical data, it predicts the possibility of a flood as well as the hazard areas along the river. The Decision Support System's goal is to minimize the possibility of the occurrence of such phenomena, by suggesting specific actions to the authorities. The DSS supports two kind of decisions (a) ordering the needs and priorities based on the number of characteristics of the occurred natural disasters and (b) suggesting interferences according to the characteristics of the natural disasters in the respective position as well as the evaluation of the effectiveness of the alternative interferences.

The Decision Support System's conclusions and the information for the existing situation of water are transmitted and they become totally understandable in the least possible time. This is being accomplished by the combination of the GIS technology and of the special water danger prediction sensors, which are being displayed on the website of the project, thus the potential of a prompt reaction is offered by providing to the public and the local authorities with essential and useful information. The Information Transfer and Display Subsystem is implemented by the High Performance Information Systems Laboratory of the University of Patras and it includes the unification of the following services:

- **Special sensors – detectors** have been mounted in water resources and in running water so that to measure the water level and the water flow. The sensors have the ability to send data by using the GSM networks. When the measured values excess some predefined values, then the device automatically sends a danger alert signal
- **Internet Technologies** along with data bases and ad hoc software which gather the measurements, the calibrations and the alert signals, and with the support of the GIS technologies charts the danger and it displays it in many ways (in Web site etc) and it also holds statistical data, historical data and other useful data in the prevention, evaluation and risk management.

Another significant component of the Integrated Information system is the Damage Mitigation and Recovery system. It is a subsystem of the Flood Decision Support

System and it includes all the instructions, the suggesting actions and the measures that should be taken by local authorities and public services in order to effectuate as soon as possible the damages recovery. The phase of damage mitigation includes the design and the application of crisis management approaches in order to reduce the losses during the disasters (in means of property and human lives) and its consequences. The effective management of emergency situations demands consolidation and apportionment of emergency plans, historical data and information in real time. A special emphasis is given in the design of the damage recovery of the service networks of common benefit.

1.3 Conclusions

Every year we become aware of catastrophic floods that lead to significant loss of lives in one part of the world or another. Thus, flood management is becoming more and more important to the society, and advanced flood modeling is seen as an integral part of flood management. Advanced models are used for planning and designing, as well as for forecasting floods, so that mitigating measures can be taken in time. DSS based on advanced models are increasingly being used by engineer scientists and local government bodies in flood management.

Technical solutions based only on old models and methods without utilizing new advanced technologies and methods are not sufficient to ensure solutions to the flood problem. Furthermore, sometimes, they even create false expectations of over-protection among populations in flood prone regions, thus diminishing their preparedness and initiatives. The combination of structural and non-structural responses, including institutional, economic, financial, advanced engineering tools and methods and social efforts are essential. The coordination and packaging of various sets of actions are recognized to be an important element in flood risk reduction. In addition, horizontal and vertical coordination between various institutions and administrative organizations is also very important. It is reported that flood disasters account for about a third of all natural disasters (by number of occurrences and economic losses). Moreover, they are responsible for over half of the deaths associated with all such disasters. This information is reflected in the attention given to floods by the international media.

There are some obvious questions.

What can be done?

What has been done till this day?

What has not been done?

What lessons have or can be learnt from recent devastating floods in areas around the world (Mediterranean, Asia, Russia and others)?

Are there any general and common approaches to flood mitigation in the worldwide context?

In this research book the flood problem is presented and analyzed for the western part of Greece and the area of Puglia in Italy.

Flood management and livelihoods protection in big cities in most countries worldwide are often better protected than small settlements and rural areas. These areas have a number of peculiar topological features and different characteristics of any local decision support system, if it exists. And even if it exists there are many various multi-criteria planning problems, combined with structural and non-structural response under the risk of floods in small settlements. If a methodology or a tool is developed and tested, then it can be applied to various river-basins in the rest of Greece as well as in other similar geographical cases in the Balkan and Mediterranean countries (e.g Italy, Spain, France...).

This research monogram is putting only a small stone of the needed new models and advanced methods to face the serious problem of natural disasters such as floods.

Chapter 2
GIS and advanced IT services for flood monitoring

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Introduction 2.1

During the last decades, people in many countries have realized that the needs for reliable and updated information about the earth, the society and the environment could not be satisfied with the traditional ways of collecting, recording, updating and processing information. Thus, specifically since the beginning of the 80's decade, GIS, acronym standing for Geographic Information Systems, have started to develop in extremely high rhythm.

From time to time, GIS has been given various definitions. In a strict sense, GIS is a digital system used to integrate, store, edit, analyse and display geographically-referenced information. In a more generic sense, GIS is also considered to be a "clever map" tool, which allows its users to create interactive queries, analyse and edit spatial data. According to a rather wide definition, "GIS is a complete system of collection, management, analysis and display information related to geographic nature issues" (Goodchild,1985).

In contrast to other computer-aided design programs (CAD), GIS basic characteristic is that it works with geographic coordinates. GIS basic feature is that they allow the connection between qualitative and descriptive characteristics and spatial information. So, it consists not only a means for producing maps, diagrams or qualitative characteristic lists but also a complete technology necessary for the space analysis and study, as well as a decision making tool regarding people and environment.

Floods are the major disaster affecting many countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time to all rivers and natural drainage systems. It causes not only the loss of lives but also the damage of natural resources, environment and health. Floods impact has been increased due to a number of factors, with the rising sea levels and the increased development to flood plain.

Mitigation is the cornerstone of managing emergency situations. It is the effort to reduce the disasters impact to people and their properties. The non-structural methods of mitigation of flood hazards are more cost effective in comparison to the structural ones (dams and dikes). Among non-structural methods, modern flood forecasting and the systems collecting data in real time have increasingly found favor within countries prone to flood hazards. The development of a Decision Support System for flood risk assessment is of utmost importance to flood forecasting and warning for the administrative authorities involved to rescue and evacuation. The valid and on time forecasting and warning helps significantly to reduce the loss of lives, crops and properties caused by floods.

Within the scientific community, there are a lot of examples where GIS has been developed for monitoring the water levels (rivers, lakes, seas, lagoons, etc) in areas inclined to flood hazards. We can not avoid the flood, but we can reduce damages by implementing effective plans of floods forecasting, if satisfactory information for flood forecasting are given on time. The dynamic use of GIS provides useful measures for being prepared and programmed in case of a disaster.

In the frames of **SFINX** project, the Database Laboratory of Computer Engineering and Informatics Department of the University of Patras has undertaken the development of a geographic information system (GIS) for the effective detection, prevention and management of natural disasters.

In detail, we had to face the environmental phenomenon of floods to Arachthos and Acheloos rivers of Arta prefecture and Aetolia-Acarnania prefecture respectively. During the winter months and due to frequent and intense rainfalls, the rivers' level rises, causing big floods that put in danger many crops, holdings, residences and even lives of people living near the rivers' area.

Therefore, we developed a GIS application aiming to the representation of Arachthos and Acheloos rivers state (from the state of complete calm to the state of increased danger), to the briefing of responsible authorities for all likely dangerous situations, so that they can take on time all the essential measures for direct and successful management of any problems arising, and to the publication of this application in a website where the whole project is presented comprehensively.

In order to achieve our objective, we have used satellite photographs for the digitalization, sensors (level recorders and rain recorders) for the collection of essential information and forecasting models capable to give us the fore coming rivers states with small divergence.

2.2 Study Areas

In order to present the regions of Arachthos and Acheloos rivers, it was considered preferable to use satellite photographs, because of the qualitative and in detail depiction of the rivers, as well as their wider region. We decided to work with satellite photographs from Quickbird, (analysis of 60 centimeters) and Ikonos (analysis of 1 meter) satellites.

The orthorectification was performed before the photographs delivery using ground control points that come from the maps of YPAAT, and a digital terrain model (DTM) produced by SPOT P10 stereo-couples. The planimetric precision of the final product comes to 3.5 - 5.5 meters.

Study Area of Arachthos 2.2.1

The prefecture of Arta is situated on north-western Greece and belongs geographically and administratively to Epirus. Its extension is 1.612 square kilometers and its population is 80.044 residents. It borders with Ioannina and Trikala prefectures to the north, Trikala, Karditsa and Aetolia-Acarnania prefectures to the east, Aetolia-Acarnania prefecture to the south, Preveza and Ioannina prefectures to the west, and, finally, it is rained by Amvrakikos Golf. Arta is the capital of the prefecture. The territory distribution of Arta prefecture is as follows: 18,6% of the grounds are flat, 11% are semi mountainous and 70,4% are mountainous. Arachthos enters the Arta prefecture from the north-western and forms an S in the region of the city of Arta, irrigates the plain and empties into the Gulf of Amvrakikos after a path of 143 kilometers.

Figure 2.1: Arachthos River - Arta

For the presentation of Arachthos River, it was considered preferable to use satellite photographs, because of the qualitative and the detailed depiction of the river itself and of the regions and roads near Arachthos. After research, it was decided to use satellite photographs from the Quickbird satellites (analysis of 60 centimeters). The orthorectification was performed before the photographs delivery using ground control points that come from the maps of YPAAT, and a digital terrain model (DTM) produced by SPOT P10 stereo-couples. The planimetric precision of the final product comes to 3.5 - 5.5 meters. The photographs used, are satellite receptions of 2007 and cover a surface of around 94 square kilometers from the height of Arta until the estuaries of Arachthos to the Gulf of Amvrakikos.

2.2.2 Study Area of Acheloos

The prefecture of Aetolia-Acarnania is situated on the western Greece and belongs geographically and administratively to Sterea Ellada. Its extension is 5.447 square kilometers and its population is 224.429 residents. The prefectures surrounding Aetolia-Acarnania are those of Arta in Epirus, Karditsa in Thessaly, Evrytania to the north-east and Fokida to the east. The capital of Aetolia-Acarnania is Mesologgi. The oblonger and main river of Aetolia-Acarnania is Acheloos which leads to a delta schema to the south-west, while the bigger lake is Trichonida.

Figure 2.2: Acheloos River

For the presentation of Acheloos River, it was considered preferable to use satellite photographs, because of the qualitative and detailed depiction of the river and

the regions and roads near the river. After research, it was decided to use satellite photographs from the Quickbird (analysis of 60 centimeters) and Ikonos (analysis of meter) satellites. The orthorectification was performed before the photographs delivery using ground control points that come from the maps of YPAAT, and a digital terrain model (DTM) produced by SPOT P10 stereo-couples. The planimetric precision of the final product comes to 3.5 - 5.5 meters. The photographs used, are satellite receptions of 2003 and 2008 from Quickbird and satellite receptions of 2007 from Ikonos, which cover a surface of around 214 square kilometers from the height of Dam of Stratos until its estuaries to the Ionian Sea.

GIS Software 2.3

After extensive examination and study, it was decided to use products of ArcGIS software, because of the quality, the portability of products and the support on behalf of ESRI. In order to develop a GIS application, we used the ArcGIS Server package, which is a supplier of territorial data (Spatial Server) and allows the use of geographic elements stored in systems of relational databases (Oracle, Microsoft SQL Server etc.), while at the same time it allows the communication and use of GIS application in the internet. Moreover, it was necessary to use the ArcInfo package, which is the de facto model for GIS professional users. ArcInfo includes all the tools of ArcEditor, ArcView, and ArcReader and adds the advanced territorial analysis, the extensive handling of elements and the high-end cartography tools.

ArcGIS Server 2.3.1

ArcGIS Server is the first enterprise application server, which performs GIS business logic in one, according to the IT standards. ArcGIS Server adds new ways of visualizing information and analytical features in existing operational applications that enhance significantly the decision making process within many organizations. ArcGIS Server offers the organizations the possibility to develop shared applications, which provide powerful GIS applications.

Some of the advantages of this software are the following:

- Serverside GIS features ➔ mapping, spatial queries, spatial data processing, analysis and geoencoding of high quality.
- Lower cost. Updating the software is performed only in the ArcGIS Server. ArcGIS Server clients receive directly the new editions.

- ArcGIS Server features can increase through the memory or the disk upgrade of the already existing server, or through the increase of more ArcGIS Server instances. ArcGIS Server provides specific tools for the management of multiple instances and a server workload.
- An open platform which can provide the maximum compatibility for the use of popular programming languages, development environments and databases management systems.

2.3.2 ArcInfo

ArcInfo, as well as any other version of the ArcGIS Desktop, contains three basic applications: ArcMap, ArcCatalog and ArcToolbox, as well as a series of optional products such as Spatial Analyst, 3D Analyst, Geostatistical Analysis, Arc Press and others.

ArcMap

ArcMap includes applications related to maps. More specifically, ArcMap offers the possibility to create maps from spatial information level, to analyze spatial relations and choose through search spatial and non-spatial elements.

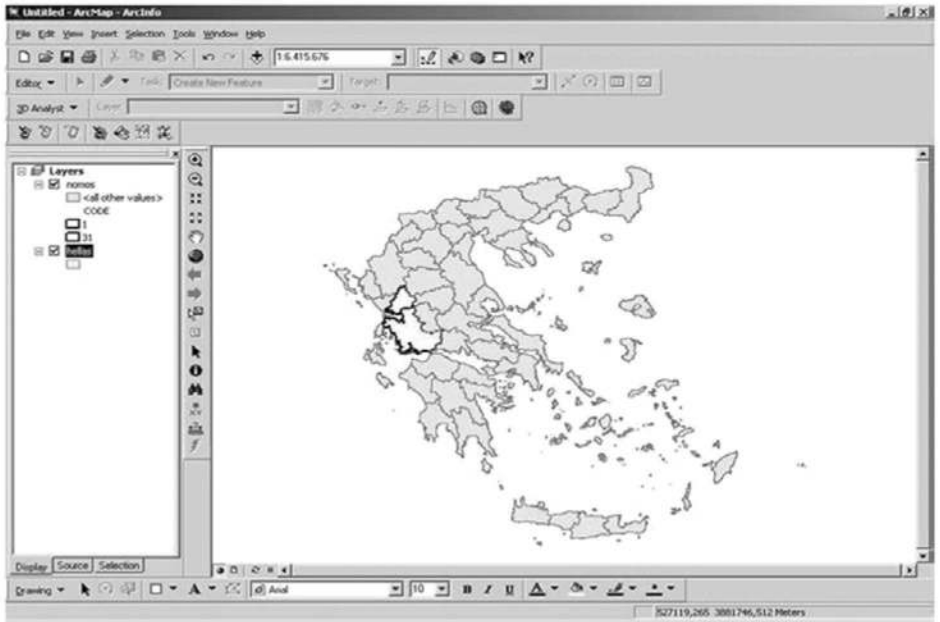

Figure 2.3: ArcMap's Interface

The ArcMap user interface includes a map display area and a table of contents area, which sets out the data names and symbols. It also contains various tool bars and options menu. These tools can be moved according to the user's preferences. ArcMap saves each project in a file called map document (.mxd). Double clicking an .mxd file leads to ArcMap automatic launching.

ArcCatalog

ArcCatalog application is used to geographical data navigation and management. ArcCatalog offers the possibility of accessing and previewing data stored in a local computer system, in a network, even on the internet. Moreover, thanks to the ArcCatalog application, it is possible to perform the organization of a geographical data database. In order to access data through ArcCatalog, connections are made through CatalogeTree, similar to Windows Explorer. After finding the data, these can be previewed, dragged and dropped in the ArcMap application so as to be displayed in cartographic representation and analysis. In addition, ArcCatalog application includes focus, transfer and identification tools.

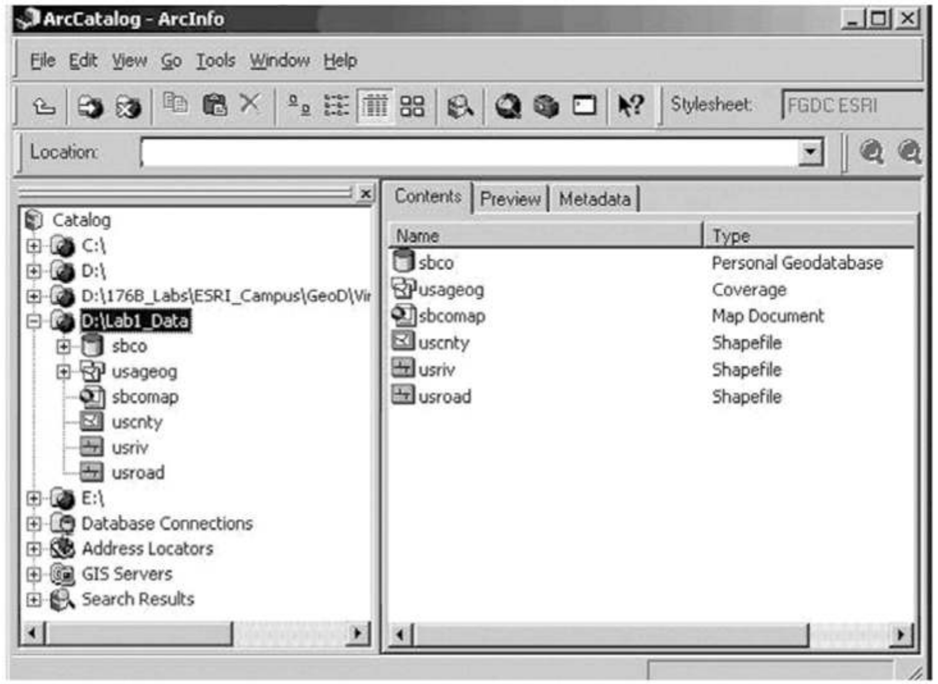

Figure 2.4: ArcCatalog's Interface

ArcToolbox

ArcToolbox is the third application that completes the other ArcGIS applications and includes various geoprocessing tools. This application provides the possibility to convert data from one data format to another and change the data display system through certain tools of spatial data conversion.

Generally, ArcToolbox tools manage the most common data formats, such as shape files, coverages, grids, DEM, DLG, SDTS, TIGER, TIN, descriptive data files and geodatabases. ArcToolbox basically includes tool main groups: conversion tools and data management tools.

ArcPad

ArcPad software has been designed for mobile GIS devices and mapping applications that use mobile and portable devices. ArcPad offers the possibility to capture, analyze and display geographical information without the use of costly and outmoded maps. Some of ArcPad features are the following:

- Performance of a reliable, accurate, and validated data collection.
- Improvement of the GIS database accuracy and possibility to update it.
- Improvement of GIS data collection productivity.
- Sharing of enterprise data with employees in other fields for better information and decision making.

2.4 GIS Hardware

The equipment has been chosen while recording and following the software requirements described above. Taking into consideration the performance, we have selected a computer system with the following features:

Processor → INTEL (R) XEON (TM) 2.8GHz

Memory → 2.0Gb

Operating System → WINDOWS SERVER 2003 ENTERPRISE EDITION SERVICE PACK 2

Digitization 2.5

In order to perform the digitization, our thought was to be able to have a digital representation of each river, the sensors' location, the roads within a radius of 2 kilometres from the rivers banks, the regions that flood and the roads that are excluded when a flood happens. The dangerous regions and the locations where the sensors were installed were defined by the municipalities and the prefectures, to which the rivers' regions belong. Specifically for the Acheloos River, the dangerous regions were defined upon testimony gathered by residents of the river's wider area, since the Prefectural Authority of Aetolia-Acarnania does not dispose registered information for the river flooding, for at least the last years.

The layers manufactured during digitization are the following:

Layer of Rivers: both rivers were digitalized as a union of polygons, with "Medium Azne" color (fill color & outline color) and the width of the polygons outline was 1.00

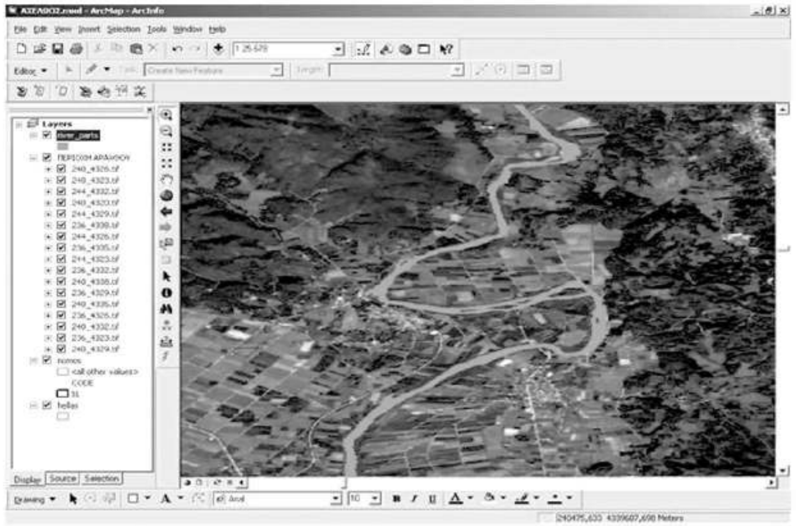

Figure 2.5: Acheloos River's Layer

Layer of Highways: highways in the wider region of the two rivers were digitalized as a union of polygons with "no color" fill color, "Anemone Violet" outline color, and outline width 3.00.

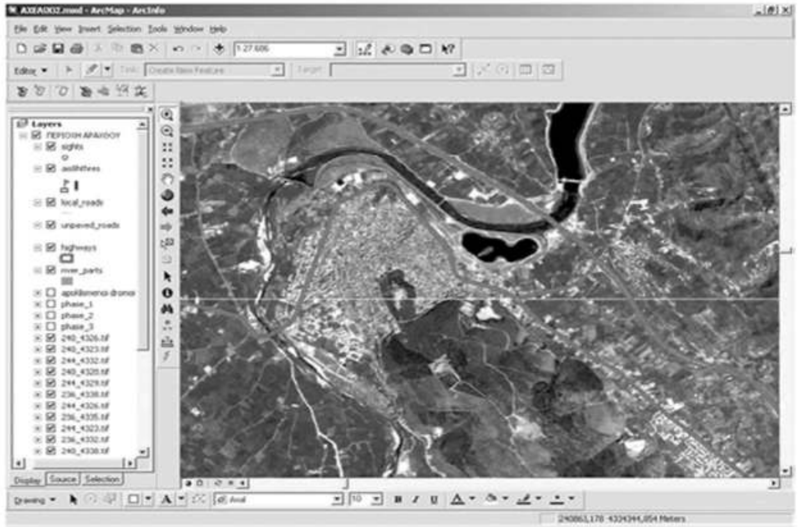

Figure 2.6: Highway's Layer at Acheloos River

Layer of local roads: local roads in the wider region of the two rivers were digitalized as a union of lines with "Medium Coral Light" color and outline width 0.50.

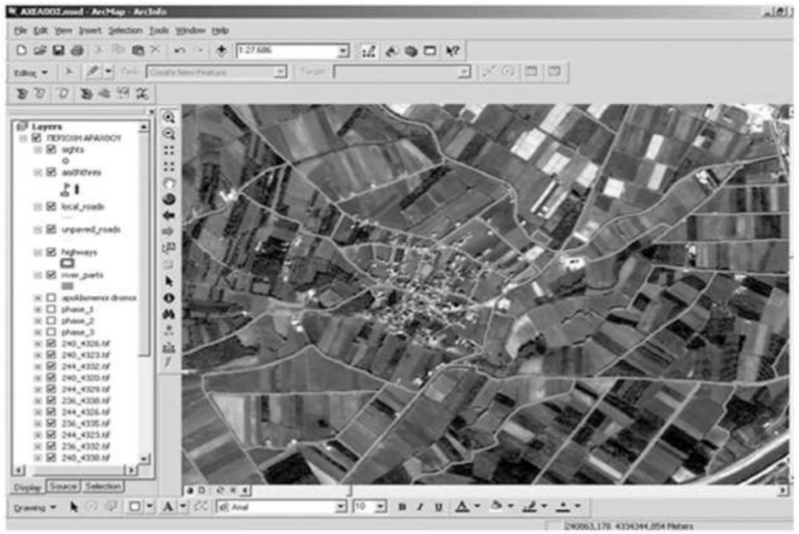

Figure 2.7: Local Roads' Layer at Acheloos River

Layer of farm roads: farm roads in the wider region of the two rivers were digitalized as a union of lines with "Apple Dust" color and outline width 0.25.

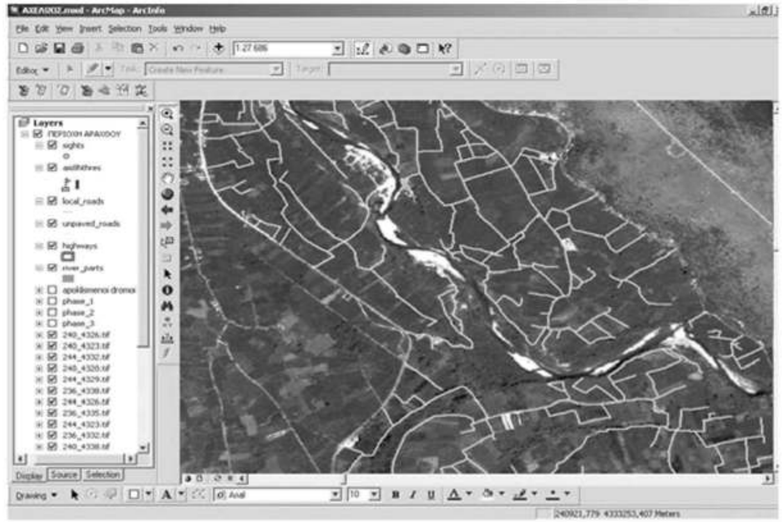

Figure 2.8: Farm Roads' Layer at Arachthos

Layer of Sensors: the sensors installed to the two rivers were digitalized as points that are symbolized with "School 2" symbol, size 30 and "Ginger Pink" color.

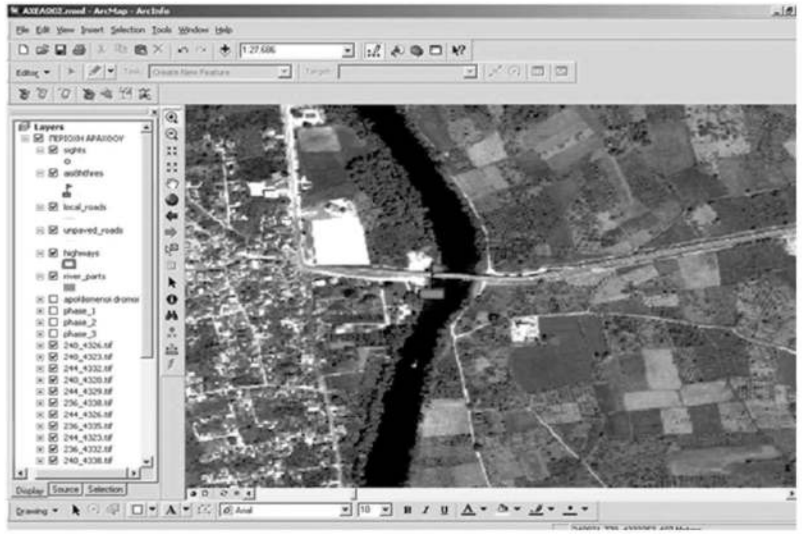

Figure 2.9: Sensors' Layer

Layer of Danger Zone – Class 1: the dangerous region of Class 1 was digitalized as a polygon with "no color" fill color, "Autunite Yellow" outline color and outline width 2.00

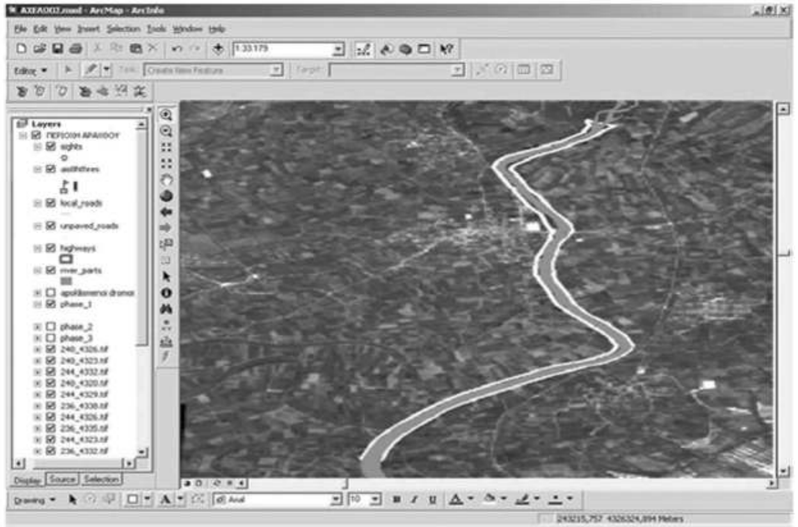

Figure 2.10: Danger Zone - Class 1 (Arachthos)

Layer of Danger Zone – Class 2: the dangerous region of Class 2 was digitalized as polygon with "no color" fill color, "Electron Gold" outline color and outline width 2.00.

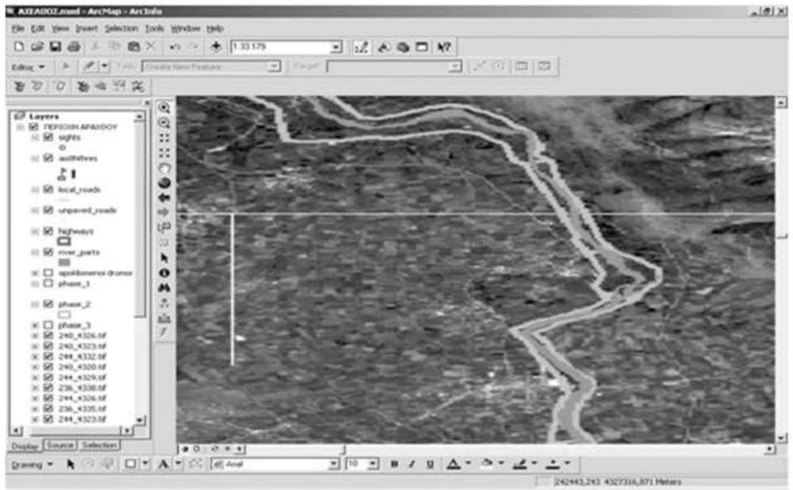

Figure 2.11: Danger Zone - Class 2 (Acheloos)

Layer of Danger Zone – Class 3: the dangerous region of Class 3 was digitalized as a polygon with "no color" fill color, "Poinsettia Red" outline color and outline width 2.00.

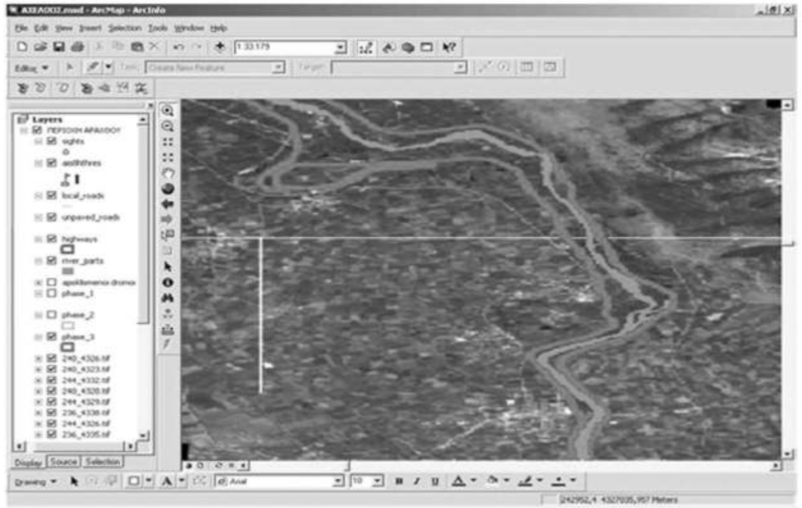

Figure 2.12: Danger Zone - Class 3 (Acheloos)

Layer of Cities, Villages and Agglomerations: cities, villages and agglomerations were digitalized as points that are symbolized with "Cycle 2", size 8 and "Citroen Yellow" color.

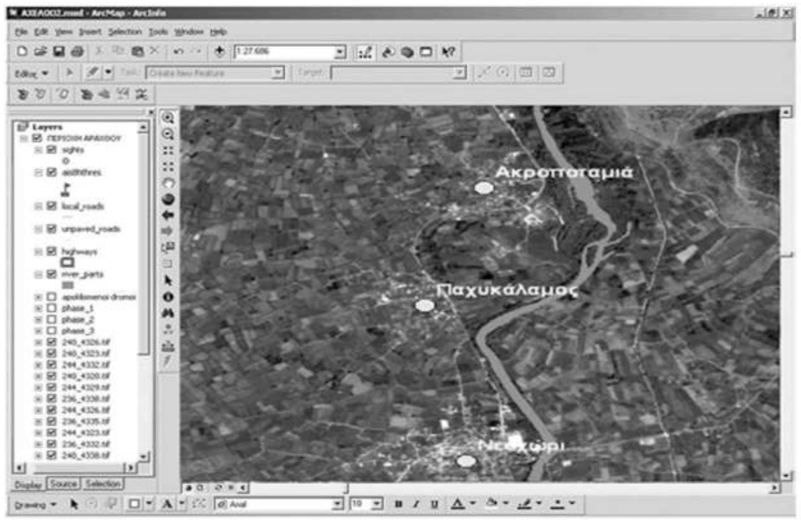

Figure 2.13: Cities' and Villages' Agglomerations

Layer of Excluded Roads: excluded roads in the wider region of the two rivers were digitalized as lines with "Red" color and width 0.50.

We observe that each digitalized element should have a different way of representation, in order to be easily distinctive by a simple user, and to avoid a possible confusion as well.

Finally, we must outline that during digitization, a special application was used (with which we were able to define from which zoom in and after the layers we manufactured would be visible, so as to achieve not only the easy-to-use flexibility of the application but also its sensible perfection.

2.6 Dynamic representation in GIS

The GIS application we developed has the possibility to connect with any database. We installed the MySQL Server to the server that runs the software, in order to create a new database, which would be updated by similar databases of the Forecasting System and the Expert System sensors. This new database will receive a copy with all current values of the other databases. The above mentioned way of updating data has been chosen for safety reasons instead of the direct access to the other databases. The representation of the sensors data (temperature, rainfall level, river level) to the map will be performed dynamically. More specifically, depending on the data sent to the database, the corresponding layer of the dangerous regions is activated (yellow-orange-red). Finally, in case of an emergency situation class 3 (red), the excluded roads layer is activated as well.

2.7 Website development-display

The program also includes a website development, which displays the whole project. The Database Laboratory of Computer Engineering and Informatics Department of the University of Patras decided to design a pilot website under the URL: *www.sfinx.ceid.upatras.gr*, in order to confirm the sound functioning of the developed GIS applications, their assessment, as well as the improvement of any failings arising. This way, we will ensure the best possible performance and quality of our project, and, finally, we will considerably reduce the possibility of the occurrence of any problem during the registration of our project to the final website of the project. Our website includes a number of tools, which facilitate significantly the user during navigation. These are the following:

Zoom in: *approach the desirable region*

Zoom out: *leave a region*

Pan: *better navigation to the map*

Full Extend: *restore the initial scale of map*

Measure: *measure the distance between 2 points of the map*

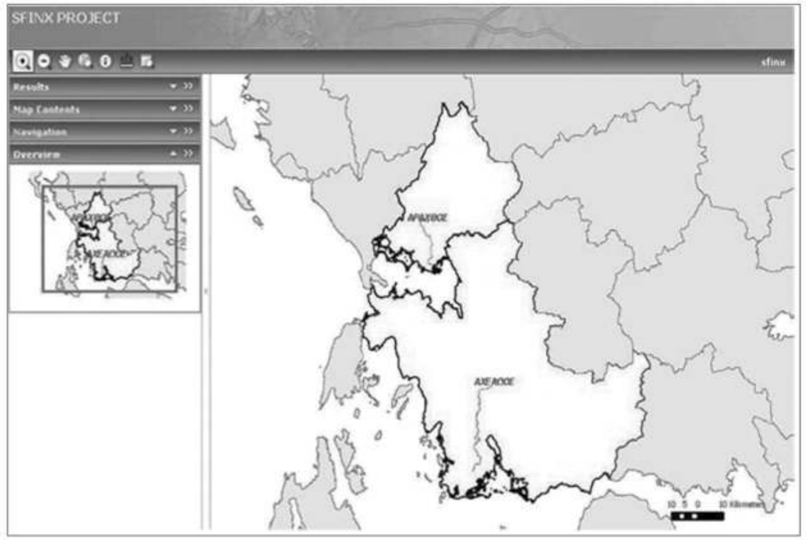

Figure 2.14: Website's Interface

At the same time, there are the following tabs that make our website more easy to use:

Results: *representation of all the elements of a search made while using any of the tools of our website.*

Map Contents: *representation of all the layers names that were developed during digitization.*

Navigation: *a compass that helps us to orientate easily to the map*

Overview: *display of the map of Greece in a reduced scale with a red frame, surrounding each time the region of the map which we study in the main map of the site.*

Conclusions 2.8

Floods are the major disaster affecting many countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems. It causes damage to lives, natural resources and environment as well as the loss of economy and health. The impact of floods has been increased due to a number of factors, with rising sea levels and increased development on flood plain. Mitigation is the cornerstone of emergency management. It's the on-going effort to lessen the impact; disasters have on people and property. Preparedness provides leadership, training, readiness and exercise support, and technical and financial assistance to strengthen citizens, communities, State, local and Tribal governments, and professional emergency workers as they prepare for disasters, mitigate the effects of disasters, respond to community needs after a disaster, and launch effective recovery efforts.

We cannot avoid flood, but by implementing effective flood prevention schemes, we can reduce damages from severity, if sufficient information for flood forecasting is given timely. Dynamic use of GIS integrated with hydrodynamic model provides useful measures towards disaster preparedness and planning. This dynamic model can be automated fully to be accomplished with the existing flood warning system to provide warning for the people without the knowledge of the GIS system to identify the possible inundated areas to take initiative to evacuate people to the safe places on time. It can help to promote public awareness in disaster management activities as a part of focusing the dissemination of forecast at the grass-root level. Therefore, new flood control / management schemes based on dynamic model can be implemented for important disaster management aspects like prevention/ mitigation, preparedness, response and recovery and also planning for operational activities, immediately before, during and after flood.

The GIS system represents Acheloos and Arachthos rivers as well as their wider regions. As a result, the user can be thoroughly informed about the conditions ruling the rivers' regions. More specifically, the authorities in charge (police, fire department, prefecture municipality) achieve the direct and effective tracing, prevention and management of eventual problems.

References

[1] GIS.com - the Guide to Geographic Information Systems <http://www.gis.com/>

[2] Daniel, Larry / Loree, Paula, Inside Mapinfo Professional : The friendly User Guide to Mapinfo Professional

[3] ESRI - The GIS Software Leader http://www.esri.com/

[4] Burrough, P.A. Principles of Geographic Information Systems, 1st ed. Oxford University Press, New York 336 pp. (1986).

[5] Hampson Jack. PBS&J and the Center for Research in Water Resources-University of Texas at Austin.(2003) Enhanced Arc Hydro for South Florida Water Management District., CMS PBS&J 813-282-7275 x251

[6] Hellwegger, F.L., and D.R. Maidment. (1999) Definition and connection of hydrologic elements using geographic data. Journal of Hydrologic Engineering. Vol. 2, n. 1, p 10-18.

[7] Karen Steede-Terry, Integrating GIS and the Global Positioning System

[8] George B. Korte, George P. Koret, The GIS Book: Understanding the Value and Implementation of Geographic Information Systems

[9] Brandon Plewe, GIS Online : Information Retrieval, Mapping, and the Internet

Chapter 3

Knowledge based decision support system for flood risk assessment

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Contents

Introduction 3.1

Flood is the natural hazard that results from the escape of a great volume of water from the body of a river, lake, or sea. It is usually caused because of a natural phenomenon like extreme precipitation, thunderstorm, cyclone, monsoon, or even of another hazard, like earthquake or tsunami etc. The effects of flood could be extremely severe, meaning human casualties during a flood or after, because of diseases, lack of food and water supplies, influencing commerce, agriculture, tourism and traveling. However, since the floodplains were urbanized, the impact of flood disaster was increased because of structural human activities, such as land use, building, infrastructure, and non-structural ones, such as lack of a) public awareness, b) organization and operation of the apposite authorities and services and c) self-organization.

Nowadays, a number of advanced Decision Support Systems (DSS) using advanced technologies are developed, so as to support individuals, authorities and public services in decision-making and managing floods. The general idea of a Flood Decision Support System (FDSS) is the utilization of software to analyze models and process at a large amount of data, and the visualization of the analysis results [1]. More specifically, data acquisition can be realized via wireless sensor networks positioned in the areas of interest [2], [3], satellite systems [4], [5], statistical analyses, etc. Having these data, the main goal is the flood prediction, applying meteorological [6], [7], hydrological, hydraulic [8], [9], and flow models [10], [11], or computational intelligent approaches such as neural networks [12], fuzzy systems [13] and expert systems [14], or a combination of the above [15]. Finally, the results of process data are visualized using web-based user interfaces [16], [17] and Geographical Information Systems (GIS) for flood risk assessment and flood hazard mapping [18].

In this research work, a Knowledge-based Decision Support System (KbDSS) for flood risk assessment for the region of Arachthos River, Artas Greece, is described. The design of the DSS is based not only on the fact that a flood arises from an overflow of Arachthos River because of extreme precipitation, but also on the fact that there are two dams along with the two Hydroloelectric Stations (HS) (Pournari I and II). The existence of the two HS is proved to be an advantage and a drawback at the same time, since it contributes to the increment of flood impact, when, some times, a large amount of water may flow out, due to intensive operation of the HS for covering flow energy requirements, but on the other hand, dams regulate Arachthos River water. In this application, online data acquisition is achieved via two ground water data loggers and a pluviometer, while the data storage is accomplished via a Database in a central station (server). In addition, because of lack of hydraulic and hydrological model of the Arachthos River area, a Knowledge-based System has been developed for the determination of flood danger level and the vulnerable areas. A GIS is used for the visualization of DSS outputs and a web-based user interface for the presentation of the process data. The aim of KbDSS is to help local authorities, public services, and individuals to combine personal judgment with the web-based computer output of DSS, while dealing with a decision-making procedure for flood prediction.

3.2 Flood Causes in the region of Arachthos River

Arachthos is the river that crosses the Municipality of Arta, in the region of Epirus, having a length of approximately 143 Km and flows into Amvrakikos Gulf. Near the mountains where Arachthos River springs, there are two HS; Pournari I and II. The HS of Pournari I was constructed in 1981, having an earthen dam and its power production equals to 300 MW, while the HS of Pournari II was constructed in 2000 with power production of 31.5 MW, aiming to the outflow water management of Pournari I. Both HS of Pournari and the vulnerable areas in the Arachthos riverside are shown in Figure 3.1.

The flood risk assessment is realized based on the fact that a flood occurs in the following cases: a) a heavy rain in the region of Arachthos, b) a large amount of outflows from HS of Pournari, and c) a combination of the above. It has to be mentioned that when the reason of flood is explicitly the great volume of outflows from HS, this is arisen from the intensive operation of the HS because of either increased energy requirements or extreme precipitation on the mountains from where Arachthos springs. Hence, when one or the other cause happen, the flooded areas differ. Definitely, when both of them happen simultaneously, all the areas in the Arachthos Riverside are flooded.

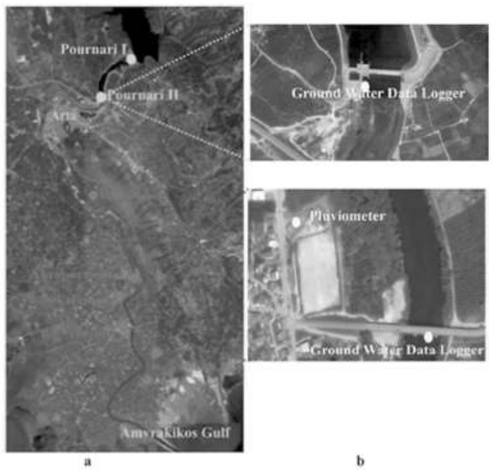

Figure 3.1: a) Vulnerable areas near the riverside of Arachthos and the Hydroelectric Stations of Pournari I and II, b) Positions of pluviometer and the two ground water data loggers.

The selection of sensors and their positions was made relying on the aforementioned causes of flood and the affected areas. Hence, a pluviometer positioned in the city hall of Neochori that estimates the rainfall in this area and two ground water data loggers positioned in the HS of Pournari II and in the bridge of Neochori, as shown in Figure 3.1 are proved to be the best choice for rainfall and water level data acquisition, respectively. Exploiting the online measurement sensor data transferred wirelessly, an intelligent DSS is designed for flood management.

3.3 Knowledge-based Decision Support System

The DSS is characterized as the coordination of software tools being able to analyze different kind of models and process a large amount of discipline data in a short time. DSS is designed for flood management, so as to support public services and local authorities, providing them with suggestions and possible decisions before and during the case of a flood. The corresponding DSS comprises of five subsystems: a) a sensor network that communicates with the central station (server), b) a Database system, c) a Knowledge System corresponding to the 'intelligence' of DSS, d) a Geographical Information System (GIS), and e) a Web-based User Interface. The data flow between the five subsystems is presented in Figure 3.2.

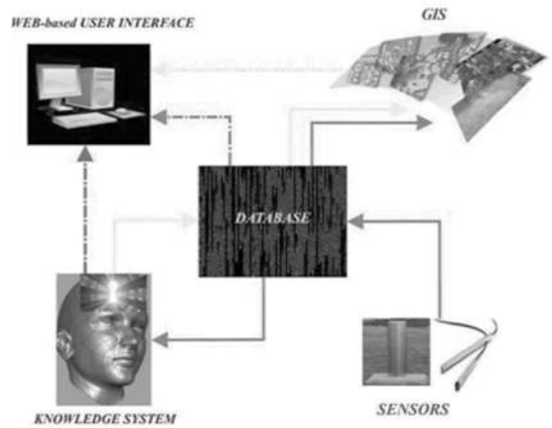

Figure 3.2: Data flow between the DSS subsystems.

Specifically, the data acquisition of sensor measurement is realized via remote data transmission by GSM, utilizing the Hydras 3 Basic as the communication software and the Database is the storage media of the current and historical data in the server. The representation of the sensor measurements either graphically or in data format is achieved after Hydras 3 Basic software processes the meteorology and hydrology sensor data (rain intensity, water level, etc.). Both Knowledge System and GIS retrieve the data from the Database and then: a) the Knowledge System diagnoses online the danger level and defines the areas to be flooded, and its outputs are send back to the Database and, at the same time, are directly presented in the Web-based User Interface and b) GIS, which is a part of the Web-based User Interface, is used for flood risk mapping, taking into account the outputs of the Knowledge System, and displaying the sensor positions and their measurements.

3.4 Knowledge System

The Knowledge System represents the intelligence of the DSS, because it simulates the human behavior and actions, gathering the knowledge, the expertise and the abilities of an expert in a specific field, such as a scientist, a professional and a technician, during the procedure of decision-making and diagnosis [1]. A Knowledge Base and an Inference Mechanism compose the kernel of a Knowledge System, which are implemented in the shell of Knowledge system, meaning the user interface software.

In case of the flood risk assessment, the kernel of the Knowledge System is designed relying on a) the experience of the people who live and work in the area of river Arachthos, and b) the knowledge and the expertise of the people who work in the HS of Pournari. The structure of the Knowledge System and its inputs and outputs are presented in Figure 3.3.

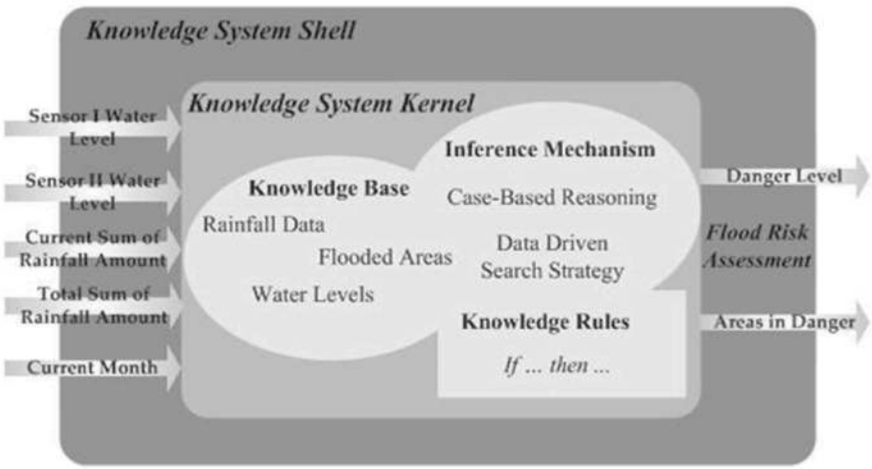

Figure 3.3: The structure of the Knowledge System for flood risk assessment

Knowledge System Kernel 3.4.1

The development of the Knowledge Base is accomplished based on processing the following historical data:

- *Recorded data of daily sum of rainfall amount (mm) from 1981 to 2008*
- *Recorded dates of flood from 1981 to 2008*
- *Recorded areas that were flooded from 1981 to 2005*
- *Recorded dates of intensive operation of HS of Pournari from 1981 to 2005*

The Inference Mechanism is developed based on advanced Case-based Reasoning and the Data Driven (bottom-up) Search Strategy. Here it is implying the utilization of the historical data for inference, instead of the results for determination of causes.

More particularly, the Case-based Reasoning is designed taking into account the information provided by the residents of the area of river Arachthos, employees of local authorities and the staff of HS Pournari. In addition, there was an extensive analysis of the aforementioned data records. The analysis reveals that:

1. The critical period of flood occurrence is between October and March, although the majority of floods occurred between November and February. Definitely, between April and September, there is almost zero probability of flood occurrence.
2. Combining the recorded dates of flood occurrence with the corresponding daily rainfall amount, it is observed that, in most cases, a flood happened because of rain that lasted three days (slow kind of flood event) or because of an extreme heavy rain for one day (flash flood event). For this reason it was decided that the rainfall amount of the previous two days to be taken into account in the design of the Knowledge Based System.
3. One of the ground water data loggers is positioned in the enclosed area after the HS Pournari II, meaning that the water level measured there, could be controllable. It is known a priori that, under normal operational conditions of HS, the water level is below a critical value, while in case of intensive operation of the HS, the water level exceeds this value.
4. The areas near the riverside of Arachthos start to be flooded when the water level in the bridge of Neochori is increased at about 0.5 m. This increment occurs within approximately 24 hours and an increment of about 1.5 m, which results in submerging all the areas in the Arachthos riverside, lasts about 48 hours.

In addition, the Data-Driven Search Strategy was realized hierarchically, as shown in Table 3.1.

	Current month	Current sum of rainfall amount	Total Sum of rainfall amount	Sensor I water level	Sensor II water level
1st phase	Fuzzifying				
2nd phase	Flood risk assessment due to rainfall				
3rd phase	Flood risk assessment				

Table 3.1: Hierarchical structure of the Data-Driven Search Strategy in the Knowledge System Kernel

More specifically, in the first phase of the Data-Driven Search, the system inputs are fuzzified, meaning that the arithmetic values are transformed to fuzzy (language) knowledge. Fuzzifying is necessary so as every set of input values to match with a case from the Case-based Library and the inference mechanism to work properly. In the second phase, the current month, the current and the total sum of rainfall amount lead to the determination of the danger level due to rainfall only, since the main cause of flood is the heavy rain. At last, in the third phase of the Data-Driven Search, the estimated danger level due to rain and the ground water data loggers' measurements are used for the flood risk assessment and mapping.

Fuzzy Rules (if … then…) are adopted for the implementation of the Knowledge Base, because of their ability to model the human knowledge very well, having adequacy of entailments, and being characterized of modularity, incrementability and modifiability.

3.4.2 Inputs and Outputs of Knowledge System

The inputs to the Knowledge System are four: the current month, the water level measured by the two ground water data loggers (m) and the rainfall amount (mm) measured by the pluviometer. However, instead of the rainfall amount, denoted as x_r, measured every T_s, the current sum of rainfall amount is used, given as:

$$x_{crs}(k)=\sum_{j=1}^{k} x_r(jT_s),\ k=1,\dots,\tfrac{24}{T_s}$$

where T_s is the constant sample time (h), k is an integer and $x_D=x_{crs}(\frac{24}{Ts})$ is the daily sum of rainfall amount. In addition, the total sum of the rainfall amount is utilized, computed as:

$$x_{trs}(k)=x_{crs}(k)+x_{D-1}+x_{D-2}$$

where x_{D-1}, x_{D-2} is the sum of rainfall amount of the previous two days.

The outputs of the Knowledge System are the determination of the danger level and the areas that are more exposed in flood. In this work, there are five danger levels:

a. **Zero danger:** is the lowest danger level, in which no area is in danger.
b. **Attention:** is the low danger level, in case of the time period of increased flood probability. It is also characterized as the 'standby' level for the local authorities and public services.
c. **Pre-alert:** is the level in which a small-scale flood is evolved and the areas at risk are Neochori, Kommeno, Pachikalamos, (because of heavy rain or because of overflow of HS Pournari II in the Arachthos riverside,) or Glikorizo. The vulnerable areas are colored yellow in GIS.
d. **Alert:** is the level in which a medium-scale flood is evolved and the areas at risk are Neochori, Kommeno, Pachikalamos, Akropotamia, (because of extremely heavy rain in the Arachthos riverside), or Glikorizo, (because of high overflow of HS Pournari II). The vulnerable areas are colored orange in GIS.
e. **Alarm:** is the level in which a large-scale flood occurs and all the areas near Arachthos River and a number of buildings in Neochori are supposed to be flooded. The vulnerable areas are colored red in GIS.

3.4.3 Knowledge System Shell

The rule engine JESS (Java Expert System Shell), an advanced version of CLIPS (C-Language Interface to Production Systems), written entirely in JAVA, is selected to be the Knowledge System Shell [20],[21]. Its advantages compared to other expert system tools are:

a) its rule scripting language is close to natural one
b) it is more adaptable to operational logic
c) it's easy to be learned and used

An example of productive and deductive rules is shown in Table 3.2. The productive rule is used for fuzifying and the deductive one is used for inference, where ?fact1 denotes an arithmetic value and $fact1,2 denote fuzzy knowledge.

Productive Rule	Detuctive Rule
defrule example-rule 1 ?f1<-(fact1?fact1) => (if(and>=?(fact1 min_val) (<=?fact1 max_val)) then (assert (fact3 $fact3)))	defrule example-rule 2 ? f1<-(fact1 $fact1) ?f2<-(fact2 $fact2) => (assert (fact3 $fact3)) (store RESULT $result))

Table 3.2: Productive and deductive rules written in JESS

3.4.3.1 Knowledge System and Database Interface

JESS uses an advanced version of Rete algorithm for processing rules and implementing JAVA interfaces without compiling any JAVA code. In addition to this, a communication level between JAVA and MySQL is realized, so as the Knowledge System to be interfaced to the Database. The JAVA-based synergy between JESS and MySQL is presented in Figure 3.4.

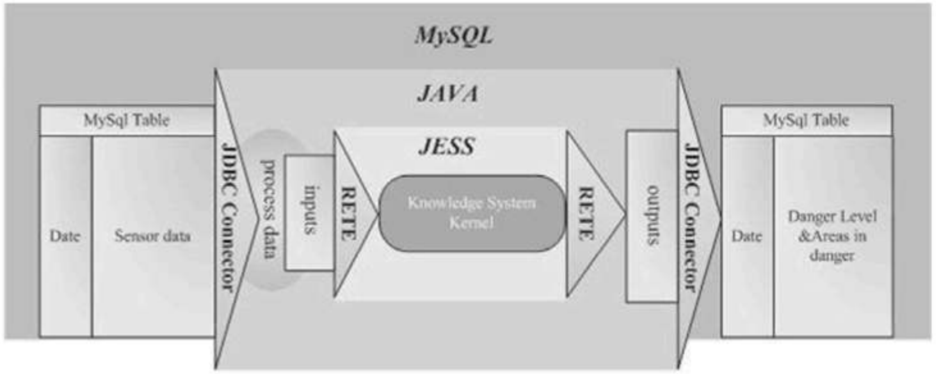

Figure 3.4: JAVA-based synergy between JESS and MySQL

Interface between JAVA and JESS

The Jess. Rete class is a rule engine itself and each object has its own working memory, agenda, rules, etc. To embed Jess in a JAVA application, one or more Jess.Rete objects have to be created, importing the corresponding package (import Jess.*). Several of the most commonly used JESS functions are wrappers for methods in the jess.Rete class, such as run(), reset(), clear(), assertFact(Fact), retract(Fact), and halt(), which can be called from JAVA just as from JESS.

The Rete class Jess.Rete.eval (java.lang.String) method can also be created to easily execute any Jess function call from Java, or construct a definition that can be represented as a parseable String, while jess.Rete.batch (java.lang.String) method is used to execute the Jess file (*.clp). Finally, the jess.Rete.fetch (java.lang.String) method is used to return in JAVA any value stored in *.clp file by the store function *(see Table 3.2)*.

```
Rete r = new Rete();
r.clear();
r.eval("(deffacts fact_example (input1 $input1) ... (inputN $ inputN))");/
r.batch("dir/rules.clp");
String v = r.fetch("RESULT").stringValue(r.getGlobalContext());
```

Interface between JAVA and MySQL

JAVA is interfaced with MySQL utilizing JDBC (Java DataBase Connectivity) connector, embodying in JAVA scripting environment [22],[23]:

```
con = DriverManager.getConnection("jdbc:mysql://host[:port]/DataBaseName",
"username", "password");
```

In the sequel, the ResultSet interface is utilized, which provides methods for retrieving and manipulating the results of executed queries and its objects can have different functionality and characteristics, such as result set type, result set concurrency, and cursor holdability. Also, a table of data representing a database result set is usually generated by executing a statement that queries the database, as shown below:

```
Statement stmt = con.createStatement();
ResultSet rs = stmt.executeQuery("SELECT [----] FROM table_name [----]");
```

After that, the ResultSet interface declares getter methods for retrieving column values from the current row (getBoolean, getLong, or in general, getXXX).

```
XXX var_name=rs.getXXX("name"); or
XXX var_name=rs.getXXX(column_number);
```

3.5 Conclusions

In this chapter, a Knowledge-based Decision Support Systems (KbDSS) is developed so as local authorities, public services and individuals in the region of Arachthos River to be supported in the flood management procedure. The system requires only a simple web browser, in which flood-related data and flood risk mapping are presented via a User Interface and a GIS, respectively. A brief description of the flood causes and conditions is provided, based on which the determination of flood risk and the vulnerable areas via a Knowledge System is accomplished, using the water level and rainfall data, measured by two ground water data loggers and a pluviometer and stored in a Database. The design of the Knowledge System and the way it is interfaced with the Database is described in details.

References

[1]. E. Todini, An operational decision support system for flood risk mapping, forecasting and management, Urban Water, pp. 131-143, 1999

[2]. J. Luo, L. Xu, J. –P. Jamont, L. Zeng, Z. Shi, Flood decision support system on agent grid: method and implementation, Enterprise Information Systems, vol.1, pp.49-68, 2007

[3]. J. K. Levy, J. Hartman, K. W. Li, Y. An, A. Asgary, Multi-Criteria Decision Support Systems for Flood Hazard Mitigation and Emergency Response in Urban Watersheds, Journal of the American Water Resources Association, vol. 43, pp. 346-358, 2007

[4]. P. Prastacos, ANFAS: a Decision Support System for River Floods, Proceedings of 16th International Conference: Informatics for Environment Protection, paper. 120, 2002

[5]. E. Onate, J. Piazzese, Decision Support System for Risk Assessment and Management of Floods", Proceedings of 7th International Conference on Hydroinformatics, 2006

[6]. M.-H. Ramos, J. Bartholmes, J. Thielen-Del Pozo, Development of decision support products based on ensemble forecasts in the European flood alert system, Atmospheric Science Letters, vol. 8, pp. 113-119, 2007

[7]. M. B. Butts, A. Klinting, M. Ivan et al, The FloodRelief Internet Based Flood Forecasting Decision Support System, Proceedings of International Conference on Innovation Advances and Implementation of Flood Forecasting Technology, pp. 1-10, 2005

[8]. S. Simonovic, Computerized Decision Support for Flood Management: Red River Basin Case Study, International Flood Network (IFNET) Action Report, 2006

[9]. D. Mioc, G. Liang, F. Anton, B. G. Nickerson, Decision Support for Flood Event Prediction and Monitoring, Proceedings of IEEE International Geoscience and Remote Sensing Symposium, pp. 2439-2442, 2007

[10]. A. J. Abebe, R. K. Price, Decision Support System for Urban Flood Management, Journal of HydroInformatics, 2005

[11]. M. Aqil, I. Kita, A. Yano, S. Nishiyama, Neural Networks for Real Time Catchment Flow Modeling and Prediction, Water Resource Manage, vol. 21, pp. 1781-1796, 2007

[12]. R. Garcia-Bartual, Short term river flood forecasting with neural networks, Proceedings of IEMSs 2002 Integrated Assessment and Decision Support, pp. 160-165, 2002

[13]. M. Aqil, I. Kita, A. Yano, S. Nishiyama, A Takagi-Sugeno Fuzzy System for the Prediction of River Stage Dyanamics, JARQ, vol. 40, pp. 369-378, 2006

[14]. S. Ahmad, S. Simonovic, An Intelligent Decision Support System for Management of Floods, Water Resources Management, vol. 20, pp. 391-410, 2006

[15]. H. Qi, M. S. Altinakar, Y. Jeon, A decision support tool for flood management under uncertainty using gis and remote sensing technology, Proceedings of the 7th International Conference on HydroScience and Engineering, 2006

[16]. X. Zhao, X. Zhang, T. Chi, H. Chen, Y. Miao, Design and implementation of a web-based flood simulation and decision support system, Proceedings of the 6th Conference on WSEAS International Conference on Applied Computer Science, pp. 59-64, 2007

[17]. L. Wang, Q. Cheng, Design and Implementation of a web-based spatial decision support system for flood forecasting and flood risk mapping, Proceedings of IEEE International Geoscience and Remote Sensing Symposium, pp. 4588-4591, 2007

[18]. A. J. Hassan, A. Ghani, R. Abdulah, Development of Flood Risk Map Using GIS for SG. Selangor Basin, in Proceedings of 6th International Conference on ASIA GIS, 2006

[19]. I. Vlahavas, P. Kefalas, N. Bassiliades, F. Kokkoras, I. Sakellariou, Artificial Intelligence, 3rd Edition, V. Giourdas Publications, 2006 (in Greek)

[20]. Online JESS Documentation

[21]. E. Friedman-Hill, Jess in Action: Rule-Based Systems in Java, MANNING, 2003

[22]. MySQL Documentation

[23]. Hamilton, Cattell & Fisher, JDBC Database Access with Java, Addison-Wesley, 1997

Chapter 4
Mathematical methods of decision support system

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Contents

Introduction 4.1

Flooding incidents are directly dependant to the impact of physical phenomena. According to the literature, flooding is a result possible of heavy rainfall, which causes the water level of rivers to rise over the banks and cover the nearby areas [1]. Three types of flooding exist:

- Flash Floods, which come as a result of storms with rain that does not last more than a few hours. These floods often occur in the Pacific Ocean areas due to the specific climate conditions of the region [2].
- Rapid-Onset Floods that occur after several hours of heavy rainfall. The phenomenon may be active for several days and is specific to medium-sized river catchments [1].
- Slow-Onset Floods that require extreme weather conditions occurring for a long period of time. In terms of river size, they happen in large river systems [3].

Clearly, in the case of Arachthos River the corresponding type of flooding incidents, after the study and the examination of relevant historical data for the last 30 years, is the Rapid-Onset Flood.

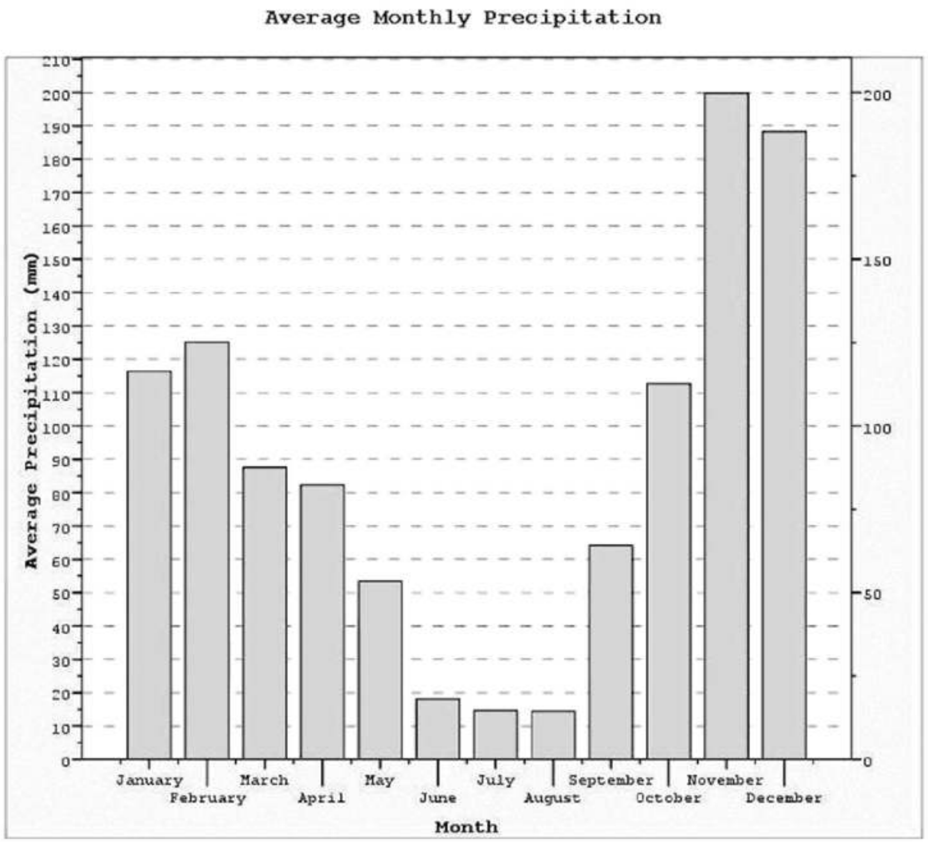
The river Arachthos used to show flooding behaviour in extremely rainy days. However, two dams have been built along the river 30 years ago, which play a significant role in the river water level. Thus, a monitoring and prevention system should take under consideration the rain precipitation and the water level as independent parameters.

Several systems have been developed to monitor flooding events identifying the rainfall as the key-factor for flood occurrence, since it causes the water level to overcome the height of the river basins [4] [5] [6]. The evaluation of the historic data combined with the real time monitoring from the sensors can provide a satisfactory decision support system to predict and evaluate a possible flooding incident. The nature and restrictions of the given problem for predicting floods in Arachthos River utilizing the **SFINX** data resulted to the selection of two widely popular methodologies, the Binary Symmetrical Decision Trees (BDT) [7] and the Hidden Markov Models (HMM) [8]. Other attempts of classifying and predicting flooding incidents include the use of Artificial Neural Networks (ANN) [9] and neuro-fuzzy techniques [10]. The following sections will describe the approach of modelling the rain precipitation using BDTs and the water level with HMMs.

4.2 BDT for Rain Precipitation

4.2.1 Data description

Precipitation levels were recorded from January 1981 to January 2008 at the area of Pournari damn. Also the number of flood events detected throughout this time period and the date of occurrence, as well as the place of occurrence were available. Graph 4.1 and Table 4.1 depict the average monthly precipitation and flood events observed respectively.



Graph 4.1: Average monthly precipitation at the area of Pournari damn

		SFINX	
		Flood Events	
		Frequency	Percent
Month	January	18	16,07%
	February	8	7,14%
	March	2	1,79%
	April	0	,00%
	May	0	,00%
	June	0	,00%
	July	0	,00%
	August	0	,00%
	September	0	,00%
	October	5	4,46%
	November	35	31,25%
	December	44	39,29%

Table 4.1: Frequency distribution of the flood events in Aracthos River (1981-2008)

The highest precipitation average is observed during November when it reaches about 200mm per day but this is not greatly different from the average daily precipitation observed in December. The daily average remains high for the months February, January and October in that order, and for the rest of the months the average precipitation is significantly lower. Observing Graph 4.1 in comparison to Table 4.1 where the number of flood events by month is presented it becomes apparent that there is a correlation between the two measurements.

In total, for the examing time period, 112 flood events were observed at the areas of Kommeno, Glykorizo and Neochori. After the examination of the precipitation levels measured at the area of Pournari damn, it becomes apparent that flood phenomena are usually observed at the time period from October to February as shown on Table 4.1. The relationship between the two measurements is obvious, leading planning for the prevention to be made on monthly basis. But still no clear relationship is detected between precipitation levels and the occurrence of a flood event. Thus it has proven that flood events are caused due to intense storms lasting for a relatively short time space, but when there are 3 or 4 days of high average precipitation. This is also related to absorbance level of the ground around the river and therefore to each reference month.

Based on the kind of available data and the aim to propose a methodology for predicting flood events, it was decided to use binary decision trees and Hidden Markov Models (HMM). Binary decision trees can lead to indications regarding the estimation of the possibility of a flood phenomenon and HMM models can predict with significant accuracy the water level and its variation.

4.2.2 Binary Decision Trees (BDT)

Binary Decision Trees (BDT) are structures that give suggestions and propose decision for a given problem definition [7]. In more formal terms, BDTs are binary tree structures with binary states that they reach a conclusive state starting from an initial state. BDTs are widely used in classification problems, and they correspond to the decision process for any problem specification [11]. Furthermore, a BDT utters that the questions corresponding to the tree's nodes must by satisfied by a given "yes" or "no" answer. The architecture of the nodes dictates the reason behind every question from the root node downwards.

A BDT comprises of a set of body nodes which are attached to a root node and which terminate at *n* leaf nodes. The root and each body node are the nodes that have connections to two other nodes; otherwise they are classed as terminating nodes where a decision outcome state has been reached [13].

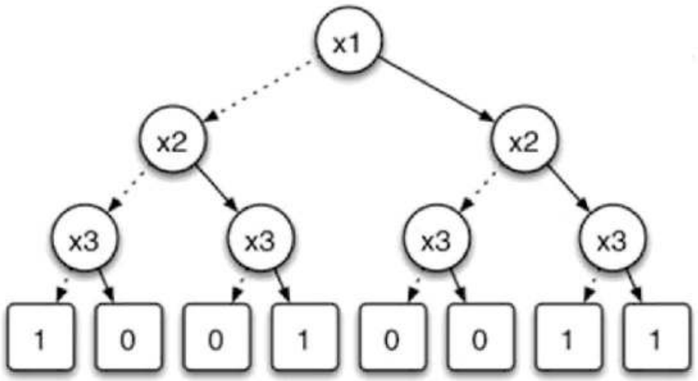


Figure 4.1: Structure of a Binary Decision Tree

To assess the nodes and the conditions that will form the structural basis of the binary decision tree a subset of the database with the records was used. This subset consisted of the precipitation average data from year 1981 to 1996, which is almost 60% of the whole dataset. 67 flood events were reported during that time period.

This subset was used as a training data set in order to design the BDT and to assess the nodes that will comprise the tree and its conditions after the necessary statistical analysis.

The correlation observed between the average precipitation levels and the flood events proved us that the tree could be based on the precipitation mean. The average precipitation of a single day was initially recorded, and then the average of that day and the preceding day and subsequently the average of the last three days and the average of the last ten days were calculated. A statistical procedure suitable for mean differences taking into account the correlation between the repeated measurements showed that significant variations were not detected in all cases. The average of the single day did not differ greatly from the average of the two-day sum. Subsequently the two-day sum was not significantly different from the three day sum. Still the single day and the three day sum were significantly different. Following this procedure of comparisons, we came to the conclusion that it is futile to use all averages that could be estimated but instead the necessary information should be limited according to the criterion of a statistical significant variance between subsequent days. This fact led the binary tree to take into account the precipitation levels observed on a:

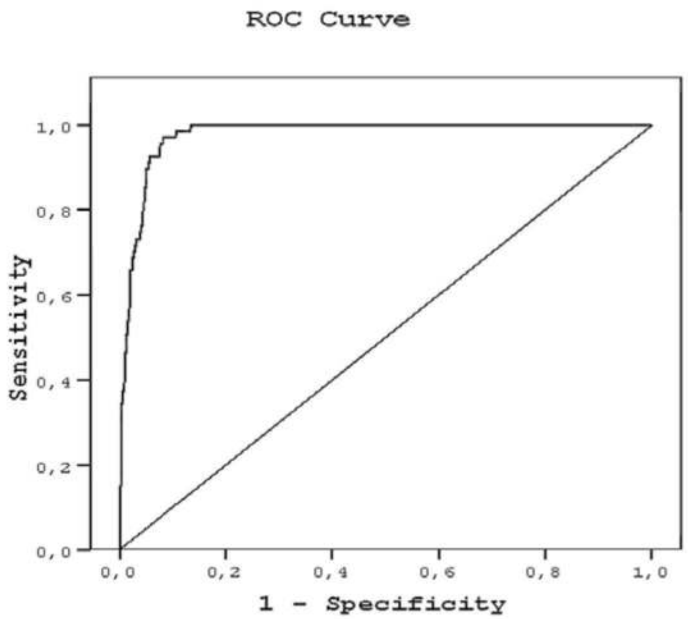
- *Single day*
- *Three day sum*
- *Five day sum and*
- *Ten day sum.*

The next step was to determine the nodes of the decision tree. For each of the four measures a Receiver Operating Characteristic Curve was estimated so as to determine the Sensitivity and the Specificity of all possible thresholds that actually correspond to precipitation levels. In all cases it was assumed that it is of major importance to detect a possible coming flood than to underestimate the true risk of a flood event. In other words, it was more important not to miss a flood event than to have a false alarm. In statistical terms it, was more important to achieve a high Sensitivity score than a high Specificity score. As no flood was ever observed when the daily precipitation level was less than 10 mm the first threshold was set at that value, so as to eliminate all rainy days to the ones that have been historically proven to have even the slightest probability of causing a flood. Only 536 rain days were then included in the test dataset from the 912 rain days of that specific time period (January 1981 – December 1996).

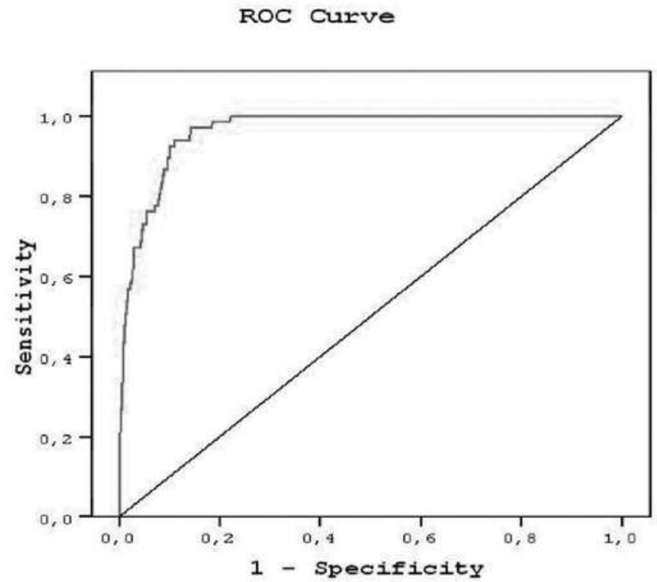
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no flood	452	84,3	84,3	84,3
	flood	67	12,5	12,5	96,8
	already flooded	17	3,2	3,2	100,0
	Total	536	100,0	100,0	

Table 4.2: Flood events from January 1981 until December

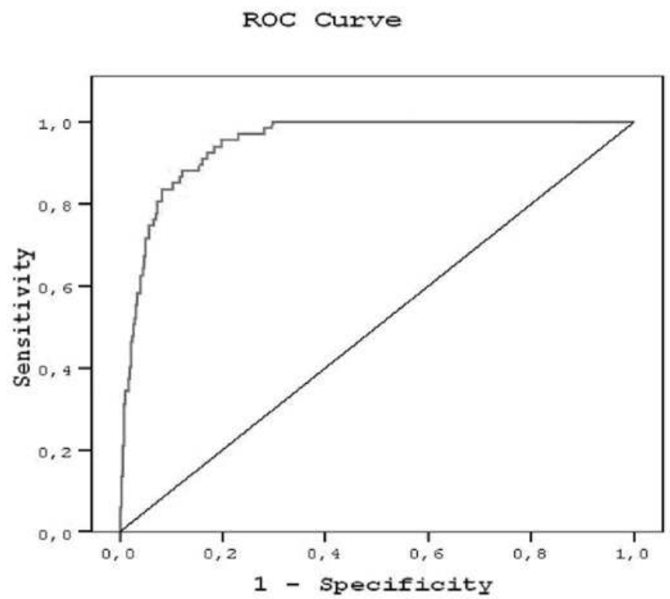
It must be mentioned that there were cases where the river remained flooded for several days and measurements deriving from these days were not taken into account when training the binary tree as it would mislead classification. These days are coded as "already flooded" and for this time period their frequency was 17 as shown on table 4.2.



Graph 4.2: ROC curve for the THREE day precipitation sum



Graph 4.3: ROC curve for the FIVE day precipitation sum



Graph 4.4: ROC curve for the TEN day precipitation sum

4.3 Binary Decision Trees (BDT) Design

The implementation of the BDT initiates by creating the root node, which dictates the beginning of the process. According to the proposed methodology the system reads each data entry and puts it in a vector, which then calculates the values of one, three five and ten day values of the rainfall. The root node represents the incoming data and the question of whether the value rain precipitation is higher than 10 mm. It must be mentioned, that all body nodes are attached to the root node. Each body node is represented by an object creation, which takes place at the node with a specific ID found by a search from the root node. As indicated by the binary decision tree theory the engine of the tree acts with the relevant queries from the root node to the body nodes, which terminate at the leaf nodes. The body nodes are separated into two reference points answering to the questions of rain precipitation higher than 60 mm and 90 mm respectively. The implementation of this binary decision tree terminates when both the yes and no answers at a node returns NULL, which occurs when the tree reaches the nodes that handle the value of rain at the reference point of 100 mm.

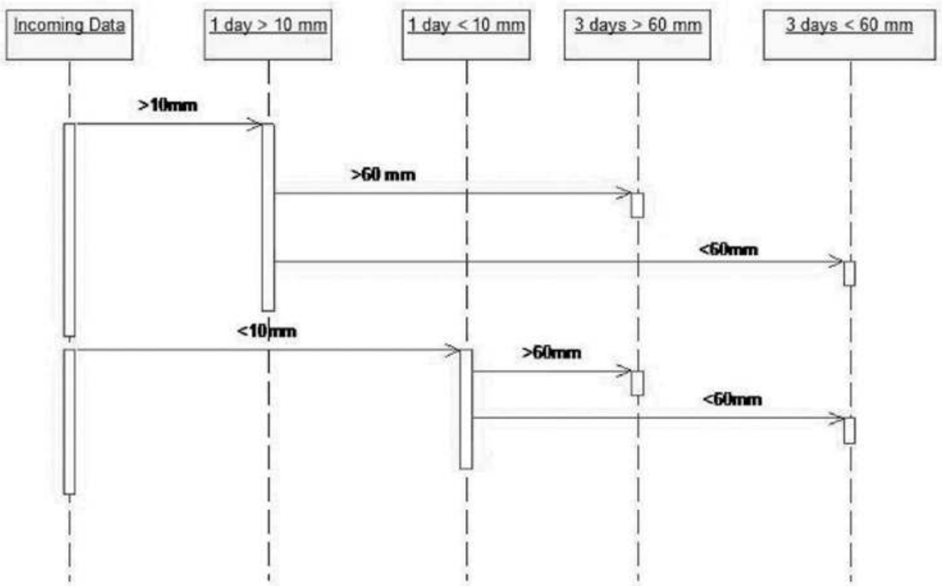


Figure 4.2: Sequence diagram of BDT until the point of 60 mm leaf node reached

Discussion 4.4

According to the historical data that have been analyzed, one hundred and twelve (112) flooding incidents have occurred from the year 1981 to 2008. We used the aforementioned training data set (January 1981 – December 1996), in order to check the percentage of flooding incidents captured by the BDT. The obtained results indicated that there were floods only when the condition ***"1 day > 10 mm"*** was satisfied; hence, only eight cases were of interest. The following table presents the probability of having a flooding incident in the aforementioned eight cases:

Training Data Set 1981 - 1996	
Condition Satisfied	**Flood Probability**
A>10 && B>60 && C>90 && D>100	66.2 %
A>10 && B>60 && C>90 && D<100	0%
A>10 && B>60 && C<90 && D>100	58 %
A>10 && B>60 && C<90 && D<100	12%
A>10 && B<60 && C>90 && D>100	44%
A>10 && B<60 && C>90 && D<100	33.3%
A>10 && B<60 && C<90 && D>100	12.2%
A>10 && B<60 && C<90 && D<100	3.5%

Table 4.3: Flooding Incidents Probability (1981-1996)
Where A = 1 day rain, B= 3 days rain, C = 5 days rain, D = 10 days rain

In order to evaluate the designed BDT, we used as an evaluation data set, the data set from the year 1996 to 2008 so as to check whether the designed BDT would give us similar results with the current data set. The results are given in Table 4.4.

Training Data Set 1996 - 2008	
Condition Satisfied	**Flood Probability**
A>10 && B>60 && C>90 && D>100	72.8 %
A>10 && B>60 && C>90 && D<100	16.6 %
A>10 && B>60 && C<90 && D>100	40.7 %
A>10 && B>60 && C<90 && D<100	8.5 %
A>10 && B<60 && C>90 && D>100	38 %
A>10 && B<60 && C>90 && D<100	20 %
A>10 && B<60 && C<90 && D>100	13.9%
A>10 && B<60 && C<90 && D<100	3.2%

Table 4.4: Flooding Incidents Probability (1996-2008)
Where A = 1 day rain, B= 3 days rain, C = 5 days rain, D = 10 days rain

The evaluation results were not satisfactory. This implied that there was another factor that affected the flooding events, which was independent of the rain, in several occasions.

The river Arachthos has its source in the mountains where the microclimate is different than the areas that flooding events occur. Thus, it is not possible to embark only the rainfall but other factors, such as the snowmelt. The most important factor who influence floods is the operation of the two damns. Sometimes, huge amounts of water in days without rain are released, in order to relieve the dams or to keep the turbines running to provide electricity. This could be an important factor of the non-identifiable flooding events. In order to be able to verify this possibility, one of the water level sensors has been placed a few meters after the dam. The other one has been installed near the area of interest, about 14 km distance from the dam. This will give us the amount of water that is released at all times and we will be able to cross-examine it with the rainfall in future dangerous situations.

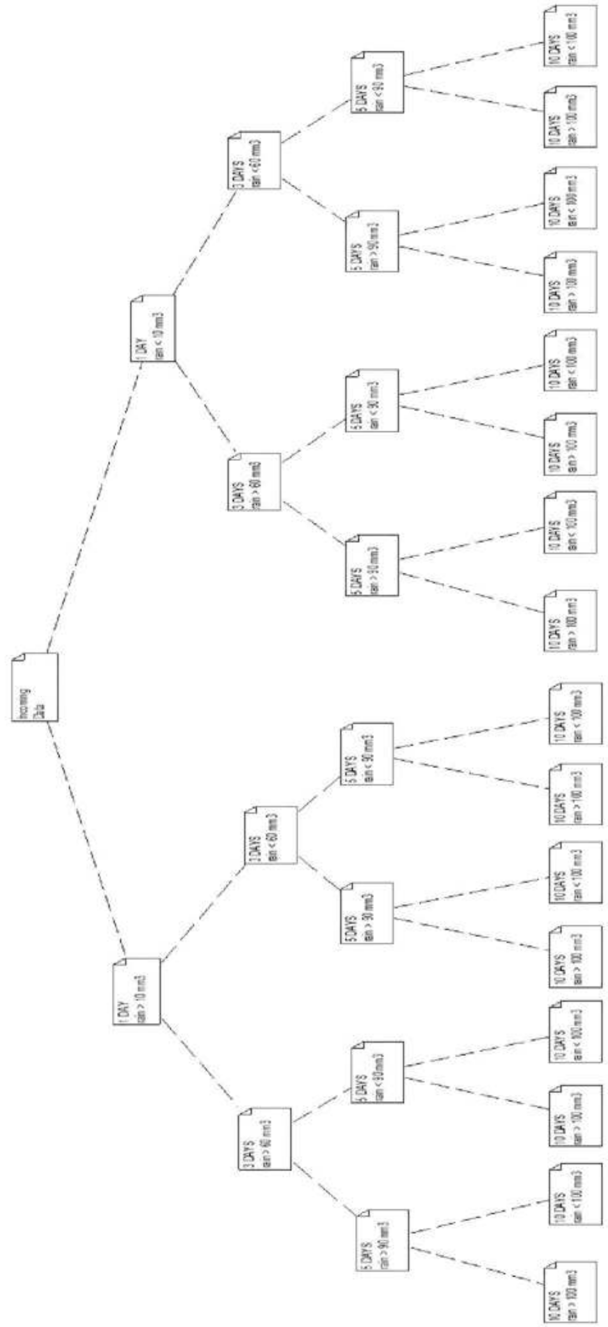


Figure 4.3: Diagrammatic presentation of the BDT

4.5 Hidden Markov Models (HMM) for River Water Level

The lack of historical data about the water level does not permit the utilization of known methodologies, such as neural networks for the prediction of the water level at the location of interest. The literature dictates that the Hidden Markov Models can predict the next value without any prior knowledge of the phenomenon [14].

Hidden Markov models (HMMs) are the most popular means of temporal classification. Informally describing it, a hidden Markov model is a variant of a finite state machine. However finite state machines are not deterministic. A normal finite state machine emits a deterministic symbol in a given state. Further, it then deterministically transitions to another state. Hidden Markov models do neither deterministically, rather they both transition and emit under a probabilistic model [15].

The Hidden Markov Model consists of a finite set of states, each of which is associated with a specific probability distribution. http://jedlik.phy.bme.hu/2 gerjanos/HMM/node4. html [14]. The term "hidden" corresponds to fact that states remain hidden as opposed to the outcome, which can be observed. Transitions among the states occur in respect to relevant probabilities called transition probabilities. The associated probability distribution is responsible for the production of an outcome in a particular state [16].

In order to formally define an HMM, the following elements are needed [15]:

- ***The number of states of the model, N.***
- ***The number of outcome symbols in the alphabet, M[1].***

$$\Lambda=\{a_{ij}\}$$

- ***A set of state transition probabilities.***

$$a_{ij}=p\{ g_t+1=j \mid g_t=i \},\ 1\leq i,j \leq N,$$

Where g_t refers to the current state.

The transition probabilities should satisfy the following constraints:

$$a_{ij} \geq 0,\ 1 \leq i,j \leq N$$

and

$$\sum_{k=1}^{M} b_J(k)=1 \quad ,\ 1 \leq i \leq N$$

[1]. *If the outcomes are continuous the M is infinite.*

- **A probability distribution in each of the states[2],**

$$B = \{b_j(k)\}$$

Where:

$$bj\ (k) = p\{ot = vk \mid gt = j\},\ 1 \leq j \leq N,\ 1 \leq k \leq M$$

Where v_k refers to the k_{th} outcome symbol in the alphabet, and ot the vector of the present parameter.

The probability distribution must meet the following constraints.

$$b_j(k)\geq 0,\ 1 \leq j \leq N,\ 1\leq k \leq M$$

and

$$\sum_{k=1}^{M} b_j(k)=1 \quad ,\ 1 \leq j \leq N$$

A specific HMM methodology has been employed which is called the Extensible Markov Model [17]. Essentially, the EMM is a time-varying Markov Chain. The Extensible Markov Model consists of entities that perform tasks and they can be used to reach a predicted value.

The tasks that the EMM performs are presented in the sequence diagram of Figure 4.4.

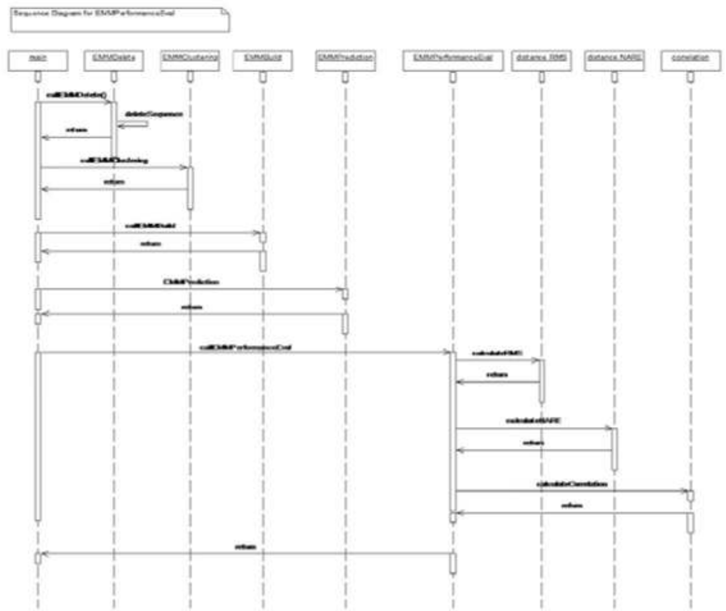


Figure 4.4: Sequence Diagram of tasks and interaction between EMM entities until Performance Evaluation metrics are reached

[2]. *If the outcomes are continuous probability density function is required.*

4.6 EMM Clustering

EMM is used to perform the clustering action. The current data that comes from the sensors join a specific cluster labeled by the centroid method, which corresponds to a vector resulting from the mean of all the incoming values of every vector for each sensor recording. Note that the alternative method that could be used instead of the centroid is the medoid; however, it is not preferred, since it produces 10% more states. The centroid is calculated using the following formula:

$$\overline{x} = \sum_{i=1}^{n} \frac{x_i}{n}$$

Equation 4.1: Centroid calculation formula

Where x_i is a set of N points of a dimension *d {xi}, i=1,2…N.*

In order to cluster an incoming value into a cluster, it is essential to calculate the distance between already existent states and the incoming value. The distance is found using the Euclidean norm which is shown in Equation 4.2.

$$\sqrt{(p_1-q_1)^2+(p_2-q_2)^2+...+(p_n-q_n)^2} = \sqrt{\sum_{i=1}^{n}(p_i-q_i)^2} \quad \sqrt{\sum_{i=1}^{n}(p_i-q_i)^2}$$

Equation 4.2: Euclidean distance calculation formula

The incoming value is declared as a new state if the value of its distance with the already existent states is bigger than the value of the threshold. On the other hand, the incoming value is added to an existent state, whose values are closer to the incoming value. The interaction between the entities that form the clustering of the EMM is shown in Figure 4.5:

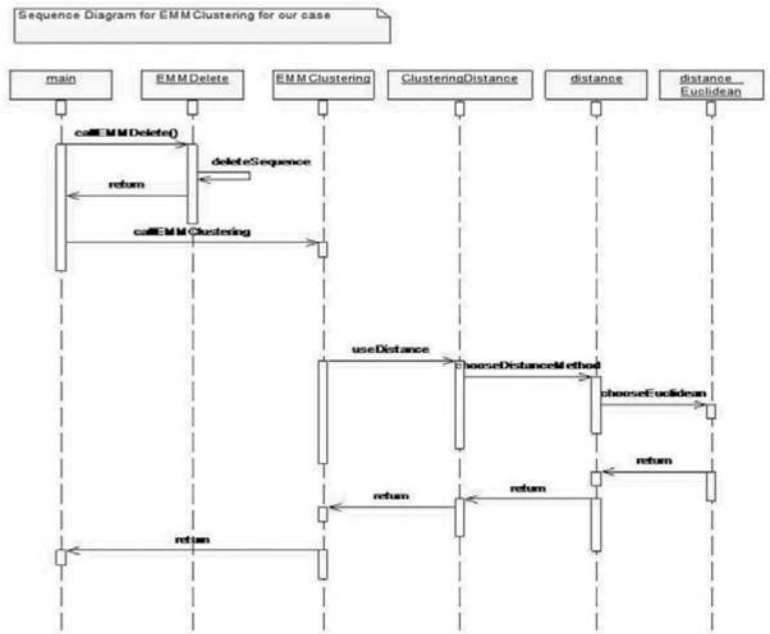


Figure 4.5: EMM clustering entities interaction

4.7 EMM Build

The completion of the clustering initiates the building of the EMM. The EMM Build counts the number of occasions that a node has been determined to be the current node. Given the Markov Chain at time t and the clustering result at *t+1* the EMM Build updates the Markov Chain at time *t+ 1*. First, the state transition probability between two successive points is calculated. Thereafter, the time sequence is updated with the state transition probability. The state transition probability is given by Equation 4.3.

$$P_{ij} = (CL_{ij} / CN_i)$$

Equation 4.3: *state transition probability formula*

Where: CN_i is the cluster size referring to the node N_i

CL_{ij} is the number of occurrences of the transition probability from N_i to N_j.

4.8 EMM Performance Evaluation

The next stage of the EMM implementation includes the procedure of self-evaluation by calculating certain metrics of its performance [17]. These are:

- **Normalised Absolute Ratio Error (NARE)**

$$NARE = \frac{\sum_{e=1}^{N} |(O(t) - P(t))|}{\sum_{e=1}^{N} O(t)}$$

Root Means Square

$$RMS = \sqrt{\frac{\sum_{e=1}^{N} |(O(t) - P(t))|}{\sum_{e=1}^{N} O(t)}}$$

where *O(t)* is the observed profile, *P(t)* is the predicted profile, *N* is the length of the dataset, *t* is the time variable or the t^{th} tuple in the input dataset.

- ***Correlation***

These metrics represent the similarity between two points using the Overlap method.

4.9 EMM Prediction

The successful building of the EMM brings the system to the final stage, which is the prediction phase. Initially, the transition probability of the current state is calculated. The product of the transition probability with the states vector for each sensor recording provides the predicted value of the water level at each sensor position. If a node has no connections with another node, then the EMM assumes that the current node is connected to itself.

EMM Deletion 4.10

Initially, the EMM checks whether the input data is the first that handled. Then the previous created nodes are deleted by merging, when there is a problem with the memory space or if certain states of the EMM are not applicable. When a node is to be removed, each incoming arc is substituted by the number of outgoing arcs that this node had. The corresponding transitions probabilities are the products of the probabilities found in the incoming-outgoing arc pairs [17].

EMM Experiments 4.11

In order to test the EMM, we used the data of Arachthos river level. Our tests showed that the prediction was satisfactory. A set of indicative actual and their predicted values for both sensor locations, as well as specific metrics, such as the number of states and the NARE, RMS and the clustering threshold, are shown in tables 4.5 and 4.6.

Pournari Dam						
Actual Value	2.403	2.403	2.403	2.403	2.403	2.403
Predicted Value	2.0779	2.5246	2.0383	2.5621	2.4384	2.3951
Threshold	0.5	0.67	0.57	0.79	0.4	0.43
States	9	6	8	5	13	12
RMS	0.0820	0.0818	0.0828	0.1060	0.0674	0.0706
NARE	0.0292	0.0309	0.0314	0.0353	0.0247	0.0258

Table 4.5: Metrics of EMM for Pournari Dam

Neochori						
Actual Value	1.076	1.076	1.076	1.076	1.076	1.076
Predicted Value	1.1281	0.7810	1.1543	1.0850	0.7014	1.0889
Threshold	0.5	0.67	0.57	0.42	0.87	0.40
States	9	7	8	13	2	13
RMS	0.0884	0.1074	0.1065	0.0794	0.1354	0.0776
NARE	0.1032	0.1301	0.1294	0.0934	0.1480	0.0926

Table 4.6: Metrics of EMM for Neochori

The results from the area of Pournari dam show that as the threshold increases the difference between the actual and its predicted value increases as well and the states that are produced are very few. Furthermore, when the threshold is just above 0,5 we get a significant distance between the values as well. Further experiments clarified that the best threshold value and states analogy, giving the optimal predicted value, is the 0,43 that produces 13 states.

In the Neochori case, we can observe that as the threshold value increases the predicted value falls quite lower than the actual value. Experiments constituted the optimal solution for the prediction was the 0,42 that resulted to 13 states.

A general conclusion is that both cases show require a similar threshold and produce the same number of states.

4.12 Predicted Values Classification

By taking the necessary measures in both sensor locations we managed to determine the appropriate limits that would assist in the classification of the predicted values extracted by the EMM.

In the Pournari dam, the information that was acquired is related to the level of functionality of the hydro electrical factory and how it relates to the water level. The Table 4.7 highlights the rules for the predicted values classification:

A1	*Height* $\geq h^{cr}$	**Extensive functionality**
A2	$0 \leq$ *height* $\leq h^{cr}$	**Normal Functionality**

Where h^{cr} stands for the water level value of 2.797m

Table 4.7: Rules for classification of predicted values in Pournari dam

In the Neochori location, the measures taken resulted to the characterization of five levels of the water level. These include rules that classify the predicted values as low, medium or high risk cases. The rules are shown in detail in the Table 4.8:

B1.	$0 \leq$ **height** $\leq h^0$	**Zero Risk**
B2	$h^0 \leq$ **height** $\leq h^0 + 0.5m$	**Attention**
B3	$h^0 + 0.5m \leq$ **height** $\leq h^0 + 1m$	**Warning**
B4	$h^0 + 1.0m \leq$ **height** $\leq h^0 + 1.5m$	**Notice**
B5	**height** $\geq h^0 + 1.5m$	**Alert**

Where h^0 stands for the normal water level value of 0.5m

Table 4.8: Rules for classification of predicted values in Neochori

The water level parameter may classify the predicted values of the EMM in a quite simple reason. A decision tree has been implemented, in order to achieve the determination of the levels of caution. The EMM produces a predicted value for the Pournari dam and in the case that the A2 condition stands, there is no flooding possibility. However, if the condition A2 is satisfied then the tree jumps to the branches representing the B1-B5 conditions, which evaluate each EMM predicted value of the Neochori sensor.

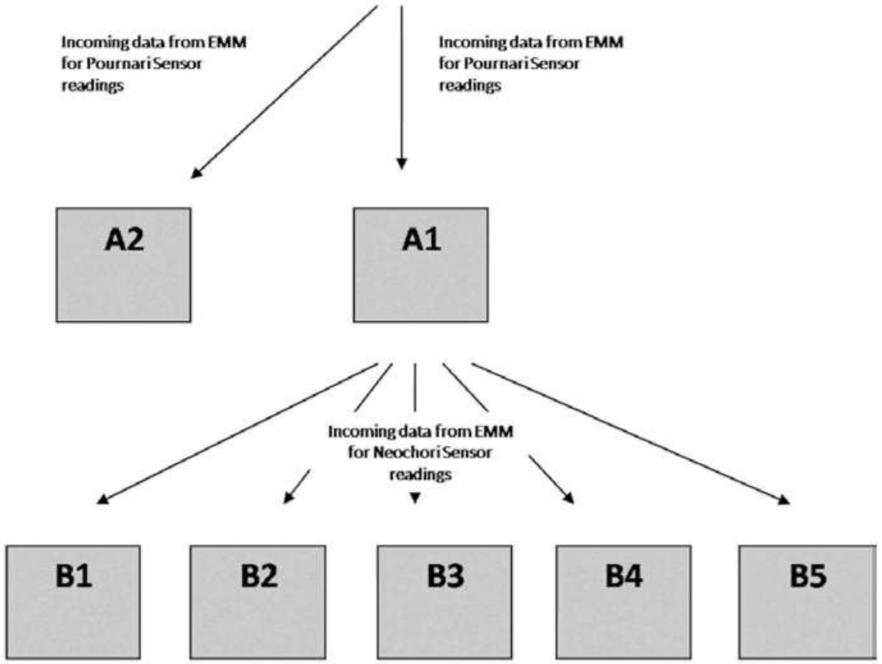


Figure 4.6: Decision tree for EMM predicted water level values

4.13 Rain and Water Level Integration

Previously, experiments on the classification of the rainfall and water level as independent phenomena have been made. However, it is common sense that the flooding incidents occur as a result of the cooperation of rain and water level rise. Thus, an integrated system that utilises the BDT for the rainfall and the decision tree of the EMM predicted values is necessary.

As it has been determined previously, the rainfall study identified four cases where danger of a flood is observed. These are:

H1	A>10 && B>60 && C>90 && D>100	***Dangerous***
H2	A>10 && B>60 && C<90 && D>100	***Warning (Strong)***
H3	A>10 && B<60 && C>90 && D>100	***Warning (Medium)***
H4	A>10 && B<60 && C>90 && D<100	***Warning (Soft)***
H5	The remaining cases	***Warning (Non)***

Table 4.9: BDT outcomes characterization

By attempting to cross-reference the **H1-H5** with the **B1-B5** and **A1-A2** cases we conclude to the following integrated system:

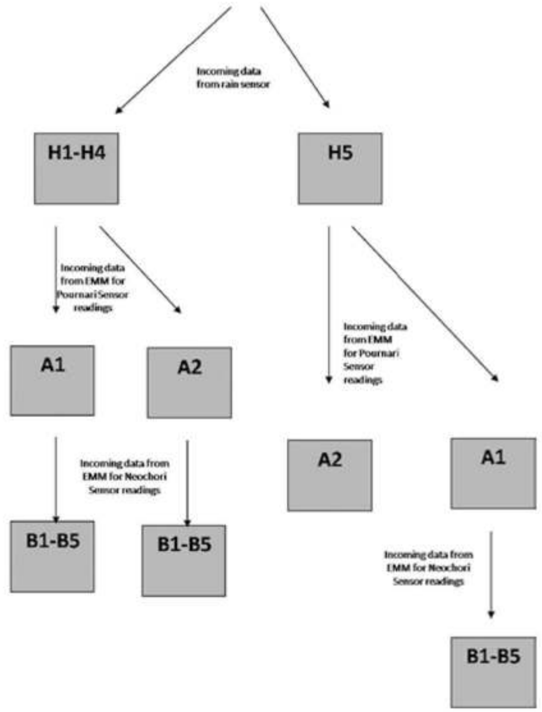


Figure 4.7: Rainfall and water level integrated decision tree

As we can see from the diagram of Figure 4.7, initially the rain conditions are evaluated giving a probability of flood occurrence. The cases **H1-H4** result in the evaluation of the EMM predicted water level in the Pournari dam. In both cases **(A1, A2)**, the system checks the predicted water level in Neochori, in order to classify the risk level in that location. In the case that **H5** is satisfied, the system jumps to the Pournari cases as well. If **A2** is satisfied, there is no possibility of a flood. On the other hand, if **A1** is satisfied, the system jumps to classify the EMM predicted value of the Neochori sensor recording, in order to produce the level of risk.

References

[1] *Pacific Islands Applied Geoscience Commission, "RIVER FLOODS – Natural Hazards in the Pacific", SOPAC, Sept 2006.*

[2] *M. Castillo-Effen, D. H. Quintela, R. Jordan, W. Westhoff, W. Moreno, "Wireless Sensor Networks for Flash-Flood Alerting", In Proc of the Fifth IEEE International Caracas Conference on Devices, Circuits and Systems, 2004.*

[3] *Charles Sturt University, "Hazards, Disasters and Survival – A booklet for students and the community", EMA, 1997*

[4] *FloodSite Consortium, "Development of DSS for Long-term Planning: REVIEW OF EXISTING TOOLS", 2007, FloodSite Project Report*

[5] *B. Gouweleeuw, P. Reggiani, A. De Roo (eds), "A European Flood Forecasting System EFFS", 2004, Full Report, European Commission EUR 21208 EN, 2004*

[6] *van der Knijff, J.M., J. Younis and A.P.J. De Roo. "LISFLOOD: a GIS based distributed flood and water balance model for European catchments", submitted to, International Journal of Geographical Information Science, in press.*

[7] *S. R Safavian, D. Landgrebe "A Survey of Decision Tree Classifier Methodology", IEEE Trans. Systems, Man, &Cybernetics, 1991.*

[8] *J. Li, "Hidden Markov Model", Data Mining Lecture Notes, Department of Statistics, Penn State University.*

[9] *R. Garcia-Bartual, "Short term river flood forecasting with neural networks", in Proceedings of IEMSs 2002 Integrated Assessment and Decision Support, pp. 160-165, 2002*

[10] *M. Aqil, I. Kita, A. Yano, S. Nishiyama, "A comparative study of artificial neural networks and neuro-fuzzy in continuous modelling of the daily and hourly behaviour of runoff", Journal of Hydrology, vol. 337, pp. 22-34, 2007*

[11] *K. Jensen, J. Arnspang, "Binary Decision Tree Classification of Musical Sounds", In ICMC, 1999.*

[12] *J. Nauratil, Q. Jin, W. D. Andrews, J. P. Campbell, "Phonetic Speaker Recognition Using Maximum-Likelihood Binary-Decision Tree Models", IBM research.*

[13] *P. Thomson, "Binary Decision Tree Implementation in C++"*
http://www.generation5.org/content/2004/bdt-implementation.asp

[14] *J. Li, "Hidden Markov Model", Data Mining Lecture Notes, Department of Statistics, Penn State University.*

[15] *L. R. Rabiner and B. H. Juang. "An introduction to hidden Markov models" IEEE Magazine on Acoustics, Speech and Signal Processing, 3(1):4-16, 1986.*

[16] *Mohammed Waleed Kadous, "Temporal Classification: Extending the Classification Paradigm to Multivariate Time Series, PhD Thesis, University of New South Wales, 2002.*

[17] *M. H. Durham, Y. Meng, J. Huang, "Extensible Markov Model", Proc of the Fourth IEEE Inter. Conf. On Data Mining, 2004.*

Chapter 5
Sustainable flood risk management strategy

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Contents

Introduction 5.1

Flood is the natural hazard when overflow of water is arisen from a natural body of water, due to natural phenomenon, that time flood prevention is regarded to be just impossible. Feasible artificial solutions for flood prevention can be applied only in case of dam break due to human mistake and not because of another natural hazard like a powerful earthquake. Instead, flood risk management is proved to be the most effective solution, aiming to the elimination of human casualties and minimization of material, socio-economic and environmental damages.

In order the risk management to be successful people in floodplains must learn to live with floods [1], [2] and everyone should be involved in the process of flood risk management and rehabilitation [3]. Based on this, flood risk management is a holistic procedure, consisted of flood risk assessment, determination of vulnerability and exposure, allocation of human roles and responsibilities, flood hazard mitigation and flood alleviation [4]. In addition, flood risk management is divided into three phases: a) pre-flood planning and activities, b) operational flood risk management, and c) post-flood activities [5].

The first phase includes structural activities [6], meaning the infrastructure (levees, wells, bridges etc) and the accoutrements (lifeboats, pump water tenders, etc) that should be made for flood defenses, and nonstructural plans [7], such as allocation of human resources, determination of organizational responsibilities [8], socio-economic analysis [9] etc. The operational flood risk management is the combination of technologies for flood detection, forecasting and warning and the decision-making of individuals and local authorities [10] for their actions during a flood, such as salvage properties [11] or evacuation [12], [13]. Finally, the immediate economical and psychological support of the affected population [14], the reconstruction of damaged buildings and infrastructure, the environmental regeneration, the recovery of economic activities in the affected areas and the review of the applied flood risk management procedure consist the post-flood activities [15].

The last decade, the aforementioned guidelines for flood risk management have been adopted both at European [16], [17] and worldwide level [18] and have been enhanced with the concept of sustainability [19]. A sustainable flood management plan implies that the pre-flood and post-flood actions should rely on the sustention of the environmental, social, economic and cultural well-being of communities [20]. In this chapter, a sustainable Flood Risk Management (FRM) plan is customized so as to confront flooding in the region of Arachthos River, in Greece, which collaborates with the Knowledge-based Decision Support System (DSS) for flood risk assessment. (chapter 3).

5.2 Flood Risk Management Plan (FRM) Roles and Responsibilities

As referred in chapter 3, the causes of flood in the region of Arachthos are the extreme precipitation in the riverside of Arachthos, the overflow of the earthen dam of HS Pournari, or a combination of the above. So far, the only existing FRM Plan takes into account only the case of the dam break and . That means that there is no plansfor the frequent cases of flooding due to the aforementioned causes. A sustainable FRM Plan is designed in this work based on the facts that:

- *The dams of HS Pournari I and II have the role of water management of Arachthos River. Because of that, there were many cases in the past in which floods were prevented*
- *Arachthos River crosses the whole prefecture of Arta. This means that a large part of the prefecture is vulnerable to floods and a number of communities have to be involved and coordinated for flood management*
- *Although there are no recorded human casualties, a number of houses in Neochori have been damaged because of the flood waters*
- *Arta is characterized of the smallest rate of development between the four prefectures of Epirus, based mainly on agriculture and stock farming. Hence, there is a great economical damage in these sectors, after a flood.*

The rate of the exposure to floods is another parameter that has been taken into consideration in the development of the FRM Plan. For this reason, the maximum submerged area is demarcated and the possibly blocked local roads are recorded, as shown in Figure 5.1.

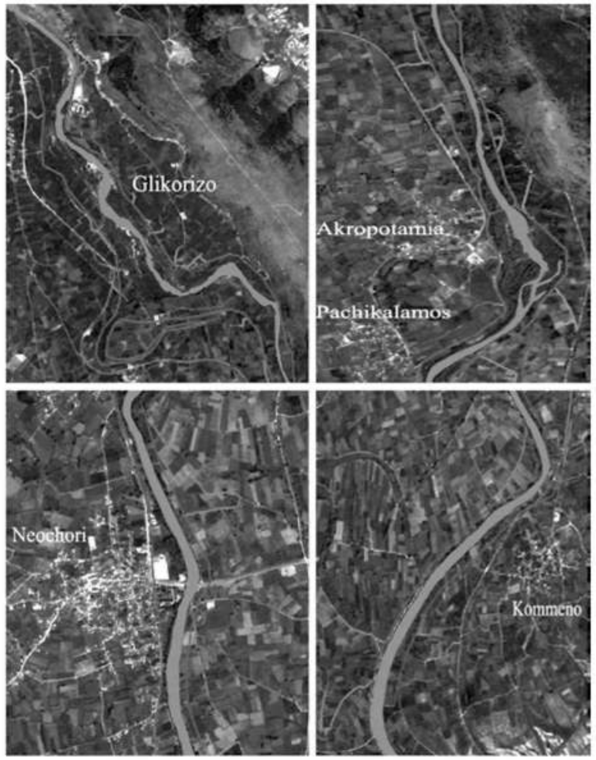

Figure 5.1: The boundaries of the maximum submerged area (red line) and the possibly blocked local roads (green line)

The determination of the plan participants and the allocation of their roles are realized based on the previous analysis and are presented in details in the following subsections.

5.2.1 Public

The public involvement in the FRM Plan is very important for the proper functionality and effectiveness. So, public is categorized into directly and indirectly involved groups, due to their different roles in the plan. Specifically, the people who live and work in the demarcated areas shown in Figure 5.1 belong to the first category and they have to be directly aware of the flood risk via telephone or SMS, while the residents in the rest of the region of Arachthos and the visitors constitute the second category, and they can be informed about the flood risk via the web-based user interface of **SFINX** or via radio announcements. It is also crusial, mostly for the directly-involved public, to aim at self-organization and follow some flood defense guidelines, depending on the flood management phase. Hence, it is proposed to:

I. Pre-flood plan

- never build in less than 100 meters from Arachthos riverside,
- try to estimate the possible flood water level and find a safer place to go so as not to be blockaded by flood waters
- when they go outdoor, their cars have to be full of fuels.

II. Operational flood management

- carry some furniture, objects or even foods upstairs, if there is enough time,
- they should take valuable things, mobile phones and money and get to safer place, as soon as they are informed to evacuate their houses,
- cut the electricity and close the water and gas valve in their houses,
- leave the doors of livestock buildings open so as the flood waters cross them and not submerge them,
- never cross a flooded area,
- never cross a watercourse, when the water level equals to their knee,
- never drive a car in a road that has been submerged,
- never panic so as to do the right things for their safety.

III. Post-flood activities

- never eat food that has been wet and check the potable water,
- never use electrical equipment that has been wet or has been positioned in a flooded room, before they are checked and get dry,
- never use candles or matches during house checking, because there might be a gas leakage,
- never visit destroyed areas alone, unless they are asked from the local authorities.

Local Authorities 5.2.2

The vulnerable areas in the region of Arachthos River are Glikorizo, which administratively belongs to Municipality of Arta, Akropotamia, Pachikalamos, Neochori which administratively belong to Municipality of Arachthos and Kommeno, which belongs to the Community of Kommeno. As for the responsibilities of the local authorities, Prefecture of Arta has the central role and coordinates the services, municipalities and communities. In detail:

I. Pre-flood plan

- Prefecture of Arta should be responsible for the public awareness for flood protection and mitigation, which can be realized providing handouts with best practices and a list of useful telephone numbers, organizing advising seminars for kids and adults.
- Municipalities and Communities should update the list of the telephone numbers of the directly-involved public and inform the apposite services if they notice that some flood defense infrastructure are damaged.

II. Operational flood management

- Prefecture of Arta should inform immediately the Municipalities and Communities about the operational flood activities and be responsible for public and animal transfer to safe places, public evacuation and for the coordination of the rescue activities. Moreover, they should be responsible for providing the local media with the appropriate instructions for flood protection.
- Municipalities and Communities should immediately inform the directly-involved public what to do in a flood situation, following the instructions provided from Prefecture.

III. Post-flood activities

- Prefecture of Arta should dispense to Municipalities, Communities and Public Services a form in order to review the applied procedure of FRM and assess its effectiveness,
- Municipalities and Communities should record the damage in individuals' properties.

Public Services

5.2.3

The public services that participate in the FRM Plan are the Hydroelectric Stations of Pournari I and II, the Fire Service of Arta, the Police Department of Arta, the General Hospital of Arta and the departments of:

a) Civil Planning for Emergency Needs

b) Land Improvement

c) Technical Services

d) Rural Development, all ofwhich belong to Prefecture of Arta.

I. Pre-flood plan

- Civil Planning for Emergency Needs department should make a strategic plan and determine the safe places where citizens and animals should be transferred, and record the human resources and equipment for flood defense,
- Land Improvement and Rural Development departments should be responsible for the sustainability of the region, controlling the land use and building,
- Technical Services department should check the maintenance of the flood defense infrastructure,
- Fire Service and Police should check the human resources and equipment.

II. Operational flood management

- HS of Pournari I and II have an active role during a flood, since they can intercept a flood, managing small amount of outflow, so as to eliminate the risk of dam break and large flood disaster, because of a great volume of outflow. Moreover, they should cooperate with the Prefecture of Arta,
- Fire Service should be standby for water pumping and rescue assignment,
- Police should be responsible for the public awareness about the flooded roads and the traffic control,
- Technical Services department should be standby for repairing destroyed infrastructure.

III. Post-flood activities

- Land Improvement and Rural Development should record the damages in agriculture and stock farming,
- Technical Services should repair the flood damages,
- Police should patrol in the flooded areas to avert robberies of the evacuated houses or businesses.

An overview of the FRM Plan is presented in Figure 5.2.

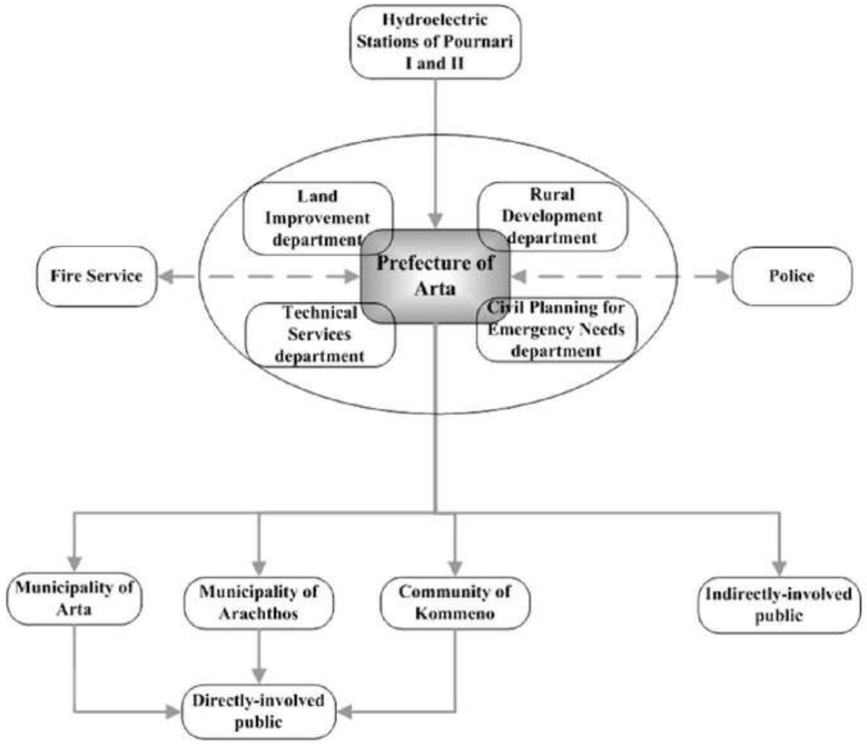

Figure 5.2: Overview of the FRM Plan

5.3 Technical Specifications of Flood Risk Management (FRM) Plan

5.3.1 Knowledge-based Flood Risk Management

The FRM Plan is a part of the Knowledge-based Decision Support System described in Chapter 3 [21]. The inputs to the Knowledge System are the current month, the current and total sum of rainfall amount measured via a pluviometer and the water level measured via the two ground water data loggers, while its outputs are the danger level and the areas at-risk.

The rule-based process for the flood risk assessment is divided in three sub-processes: a) input fuzzifying, b) determination of the danger level due to rainfall ('rain-zero danger', 'rain-attention', 'rain-pre-alert', 'rain-alert' and 'rain-alarm') and c) determination of the danger level and the areas at risk.

During the first sub-process, the water level measured via the data logger positioned in HS of Pournari I is fuzzified in two process sets, 'intensive HS operation' and 'normal HS operation', while the water level measured by the second data logger in the bridge of Neochori is fuzzified in five process sets, 'water-zero danger', 'water-attention', 'water-pre-alert', 'water-alert' and 'water-alarm'.

- **Automated FRM based on the danger level due to rainfall**

When the danger level due to rainfall is defined as 'rain-alert' or 'water-alarm', then the local authorities are notified via email containing the current and the total sum of rainfall amount and a list of proposed flood management guidelines based on the analysis of the previous section. The Fire Service, the Police and the Technical Services are also notified via email so as to be on standby and the HS of Pournari are recommended to decrease the water supply that flows into Arachthos.

When the danger level is defined as 'rain-alert', withdrawal emails are sent to the local authorities and emergency services.

- **Automated FRM based on the water level in the bridge of Neochori**

When the water level is defined as 'water-alert' or 'water-alarm', e-mails are sent to the subscribers of the web-site of **SFINX** and sms are sent to the directly-involved public, informing them not to get close to the riverside of Arachthos and to be standby for the next 24 hours. The local authorities and the services are informed via email containing the water level measurement and the guidelines described in sections 5.2.2, 5.2.3 respectively. When the water level is defined as 'water-alert', alert e-mails are sent to the local authorities and emergency services.

- **Automated FRM based on the water level in the HS of Pournari II**

When the water level exceeds a critical value, it's characterized as intensive HS operation'. If this happens for about 1½ hours, then special announcements are sent to local authorities containing the measured water level and informing them for possible flood in Glikorizo. If this happens for about 4½ hours, then e-mails are sent to local authorities, containing the measured water level and informing them for possible flooding along Arachthos.

Web-based Flood Risk Management 5.3.2

The proposed instructions for public so as to deal with decision making during the three phases of flood risk management, a list of the useful telephones of the local authorities and public services and the vulnerable areas with the possibly blocked local roads are available in the web-site of **SFINX** *www.sfinx.gr*. In addittion, the visitors of the web-site of SFINX are able to subscribe so as to receive by e-mail information about the flood risk level and the vulnerable areas.

For post-flood assessment of the procedure of FRM, there is also available a review form, as described in the previous section, which will be filled by the local authorities and the services. In the sequel, the valuable recorded information will be stored in a database for internal use between the participants of the FRM Plan and for enhancement of the Knowledge Base.

Finally, the Web-based FRM procedure can be extended by the utilization of an Expert System, which will assess the activities of the participants of the FRM Plan and propose a list of instructions to the users for its personal flood preparedness via a web-based 'question and answer' process.

Conclusions 5.4

In this chapter, a Flood Risk Management (FRM) Plan was designed taking into account the vulnerability, exposure and sustainability of the region of Arachthos. The plan participants were determined and an analytical description of their roles and responsibilities during the three phases of flood management was provided. Finally, the incorporation of the FRM plan into the Knowledge-based DSS and the Web-based User Interface are presented.

References

[1]. G. Fleming, How can we learn to live with rivers?, Philosophical Transactions: Mathematical, Physical and Engineering Sciences, vol. 360, pp. 1527-1530, 2002

[2]. Final report of the Institution of Civil Engineers' Presidential Commission, Learning to live with rivers, 2001

[3]. C. Emdad Haque, M. Kolba, P. Morton, N. P. Quinn, Public involvement in the Red River Basin management decisions and preparedness for the next flood, Environmental Hazards, vol. 4, pp. 87-104, 2002

[4]. M. Adamson, Floods: causes, management, and relief, in Proceedings of Chartered Institution of Water and Environmental Management, Ireland, 2003

[5]. P. G. Samuels, RIBAMOD: River basin Modelling, management and flood mitigation, Final Report, 1999

[6]. S. Simonovic, Computerized Decision Support for Flood Management: Red River Basin Case Study, International Flood Network (IFNET) Action Report, 2006

[7]. S. P. Simonovic, Proceedings of the International Workshop Non-structural measures for water management problems, International Hydrological Programme, UNESCO, 2001

[8]. M. Malcolm, D. Parkin, Flood Risk Mitigation Plan, Environment Waikato Technical Report, 1997

[9]. H. Haynes, R. Haynes, G. Pender, Integrating socio-economic analysis into decision-support methodology for flood risk management at the development scale (Scotland), Water and Environmental Journal, vol. 22. pp. 117-124, 2008

[10]. R. Gkekas, K. Mitsou, Flood Effects Mitigation- New Methods for Flood management and the Lead Role of Local Authorities, National Centre for Social Research, Institute of Urban and Rural Sociology, 2007 (in Greek)

[11]. I. Kelman, Decision-making for flood threatened properties, Flood Risk Management in Europe, Springer, Netherlands, 2007

[12]. S. P. Simonovic, S. Ahmad, Computer-based model for flood evacuation emergency planning, Natural hazards, vol. 34, pp. 24-51, 2005

[13]. H. Rasid, W. Haider, Post-flood assessment of emergency evacuation policies in the Red River basin, Southern Manitoba, The Canadian Geographer, vol. 44, pp. 369-386, 2000

[14]. S. Lin, D. Shaw, M.-C. Ho, Why are flood and landslide victims less willing to take mitigation measures than the public?, Natural Hazards, vol.44, pp. 305-314, 2008

[15]. S. P. Simonovic, R. W. Carson, Flooding in the Red River Basin-Lessons from Post Flood Activities, Natural Hazards, vol. 28, pp. 345-365, 2003

[16]. Commision of the European Communities, Flood Risk Management, Flood Prevention, Protection and Mitigation, 2004

[17]. http://ec.europa.eu/environment/water/flood_risk/flood_risk.htm

[18]. Proceedings of the World Conference on Disaster Reduction, International Strategy for Disaster Reduction, 2005

[19]. D. Lumbroso, D. Ramsbottom, M. Spaliveiro, Sustainable flood risk management strategies to reduce rural communities' vulnerability to flooding in Mozambique, Journal of Flood Risk Management, vol. 1, pp. 34-42, 2008

[20]. J. Parkinson, Drainage and stormwater management strategies for low-income urban communities, Environment and Urbanization, vol. 15, 115-126, 2003

[21]. AFORISM, A comprehensive forecasting system for flood risk mitigation and control, Final Report, 1996

Chapter 6
Integrated information system

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Contents

Introduction 6.1

In this chapter the methodology of integrating the several subsystems of the **SFINX** project into the common functional framework of the Web Site is presented.

The Web Site except from a variety of informational services offers to the Internet user services and data which are being produced by the expert system, the data sensors, the GIS component, the e-learning system and the rest of the subsystems implemented by the **SFINX** project.

In the following sections at first a synopsis of each subsystem is included and then an in depth analysis of the functional integration of these subsystems in one ontology, the Web Site, are presented.

Systems Integration 6.2

The section includes an analysis regarding the integration of the several subsystems of the **SFINX** project. In particular, the methodology of the functional integration of the sensors, the GIS system, the Expert Decision Support System, the services for flood danger management, the informational services and the e-learning and e-working systems which have been implemented during the project, are being presented. In the following paragraph a brief description of each subsystem is included which presents how the functional integration of each subsystem towards the development of an integrated information system for managing and dealing flood dangers is taking place.

Data Sensors 6.2.1

The data sensors subsystem is based on the next devices:

The sensor OTT Orpheus Min, which is based on an instrument for water pressure measurement, produces and stores reliable data for the water lever. The Orpheus Min is installed underwater into open seas of tubes and water storage facilities.

It is also equipped with a cell for measuring temperature.

The Orpheus Min is able to store 500.000 measurements in each 4MB memory. The above sensor communicates with OTT ITC (intelligent top cap), which is able to transmit the sensor data. Data are being transmitted through an OTT ITC station asynchronously through SMS or during defined time intervals.

The rain meter PLUVIO is based on a highly accurate and reliable rain drop measurement methodology using a high detailed methodology of weighing water.

The aforementioned devices support the on-site measurement of water level, temperature and rain drop level and at the same time data transmission through GSM and GPRS networks to a computer with internet access occurs. When the on-line computer receives the important data, data are stored to a database for further exploitation and management by the other subsystems of the **SFINX** project.

6.2.2 Geographical Information System

The Geographical Information System of the **SFINX** project incorporated maps, morphological backgrounds, high quality satellite pictures and civil information (roads, population etc.) and serve as a basis for managing the flood danger through Internet based maps and navigating tools. The sources of information are the Region of Western Greece, the Army Geographical Service and corporation which are active in the GIS sector. The GIS system bases its functionality on a database and common GIS tools so as to offer the danger visualization upon maps.

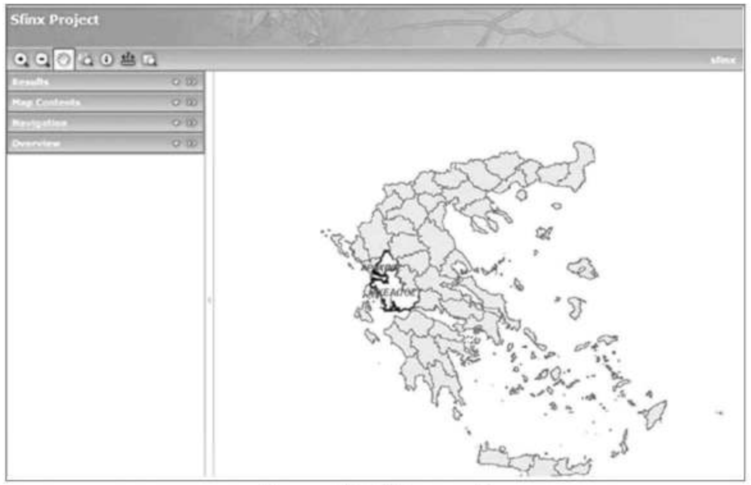

Figure 6.1: GIS map data

In addition, the GIS is a tool which can use data from sensors and the expert system which are stored in a database so as to illustrate the danger on a detailed map

of a satellite picture of the area. For this reason the GIS can be used through all the flood danger management life cycle. The geographical information should also be presented and used by the authoritative agencies and people teams which are involved in dealing with the danger in an effective and quick way. For this reason the use of the GIS maps and information through the Internet is very important. Towards this goal the **SFINX** GIS uses a web component tools which allow the user to navigate through the maps and satellite images of the endangered areas using only a Web Browser. This web component was finally incorporated to the Web Site so as the GIS to be available through the Internet.

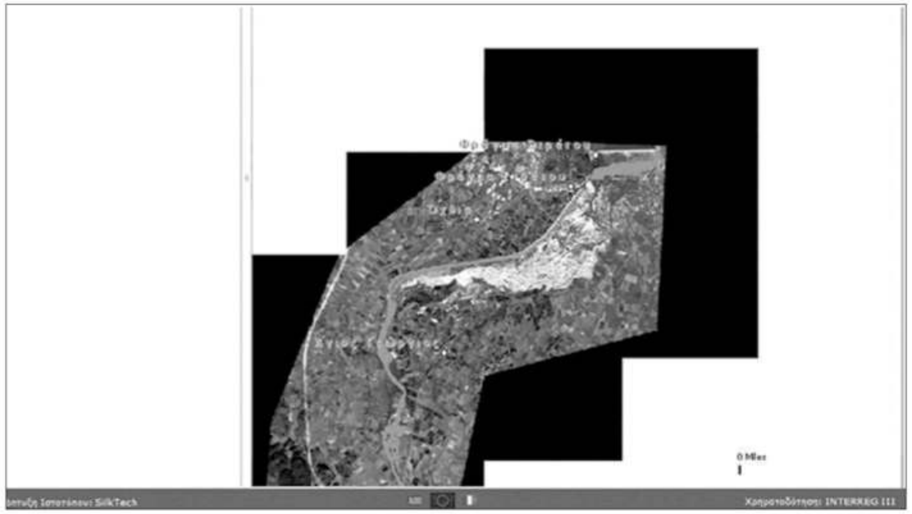

Figure 6.2: Satellite image data

Decision Support System (DSS) 6.2.3

The DSS is a bridge between the data sensors network, which measures the water level the temperature and water drop level, the database in which data are being stored and the GIS which visualizes danger on the endangered areas.

The goal of the DSS is to support the authoritative agencies to deal with and manage the flood danger without substituting the people decisions but improving the effect of its decision to the ultimate goal which is to deal with the danger. The DSS has the following important subsystems, (figure 6.3).

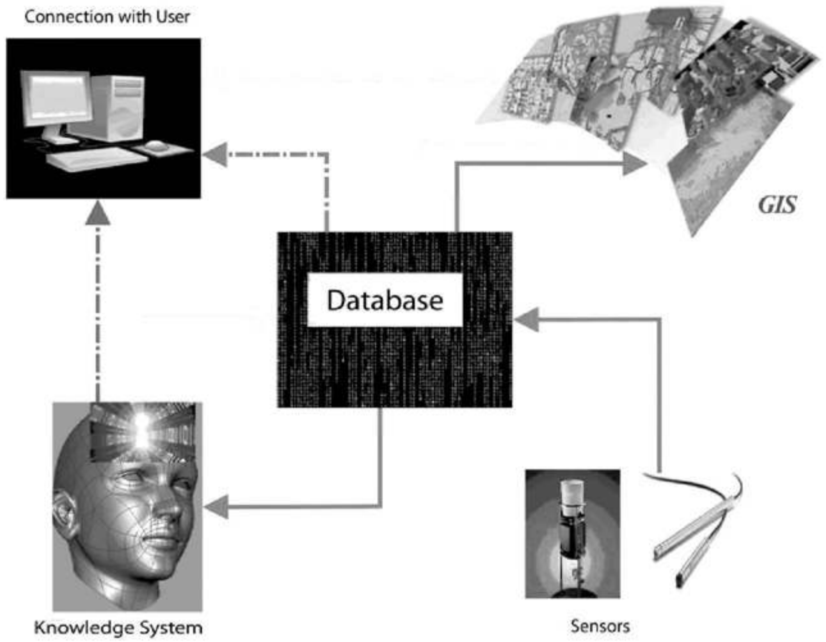

Figure 6.3: Overview of the integrated system

Knowledge System

The implementation of the knowledge system aimed at the simulation of the actions taken and behavior of people who are experienced in managing floods. The two main parameters which affected the development of system are:

- The relational database which uses data from relevant cases and supports modeling the environmental circumstances (raindrop, water level etc.) under which floods happened in the past. The circumstances are represented through decision trees and procedural guidelines (e.g. if (circumstances) then (conclusions / actions)).
- The JESS cell which is engaged when rules have to be executed and is based on the CLIPS tool and uses an advanced version of Rete algorithm to identify rules and actions. The tool is interacting with JAVA language through which the connection with the database is being implemented.

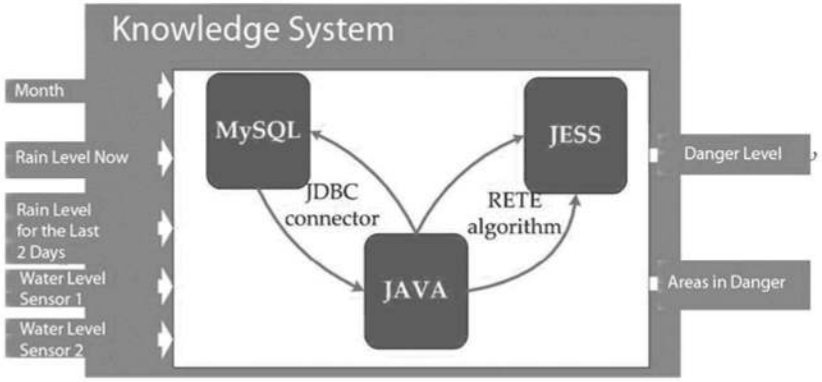

Figure 6.4: Knowledge System

The system's inputs are the following:

- Month (there is no flood danger for every month per year).
- The rain level now (at this time point).
- The cumulative rain level for the last 2 days.
- The water level for the rivers in the 2 areas where sensors have been installed.

The system's output is the following:

- The Danger Level in 5 different levels:
  - No Danger: is the lowest danger lever (in the **SFINX** Web Site is shown in the alarm section in green color and this level is not visible from GIS system).
  - Alert: is the danger level in "endangered months" and when a relevant increase in the system's inputs exists (in the **SFINX** Web Site the level appears in the alarms section in green colour and is not visible from the GIS system).
  - Pre-Warning: is the danger level in which a flood exists in small scale (appears in the **SFINX** Web Site in the alarms section and in the GIS system with yellow colour).
  - Warning: is the danger level in which the flood is evolving in a medium scale. (appears in the **SFINX** Web Site in the alarms section and in the GIS system with orange colour).
  - Alarm: is the danger level in which the flood is evolving in a large scale. (appears in the **SFINX** Web Site in the alarms section and in the GIS system with red colour).
- The areas under danger: in dependence with the aforementioned danger levels the areas which will be affected by the flood are being defined and coloured.

6.2.4 Danger Management and Information Services

The specific services are presented through the **SFINX** Web Site and are mainly based on the presentation of the sensor data and the values which are measured every time interval and at the same time the correspondent alarms which are produced when the predefined value boundaries are being exceeded.

Data presentation is achieved on a daily, monthly and annual basis. In parallel the Internet users can search for values, create graphs and produce summary tables for the requested values. In detail, data presentation includes the next categories:

- Current Values, which present the last values measured by the sensors categorized by sensor and parameter.
- Daily Forms, which present the measurements of the current day. The presentation is being achieved with the use of a graph and a table of values based on the user's preferences regarding the sensor and the parameter measured. There are also links to the measurements of the next and previous days.
- Monthly Forms, which present the measurements of the current month. The presentation is being achieved with the use of a graph in which for each month day the maximum and minimum values are being shown and with the use of a summary table of the values for each sensor and parameter. The presentation is supported with links to the next and previous months.
- Annual Forms which present the measurement of the current year. The presentation is being achieved with the use of a graph in which for each month the maximum and minimum values are being shown and with the use of a summary table of the values for each sensor and parameter. The presentation is supported with links to the next and previous years.
- Through the search facility the user can retrieve all the measurements for each sensor and for every desired time interval.
- In the page Graph Creation the user is able to create his own graph choosing the sensor, the parameters measured and the desired time frame.
- The page with the measured and stored alarms details for these alarms is being presented. This service gives the ability to present in detail the core elements and measurements of an alarm based on the sensor, the date and the value of the parameter.
- Page of in-detail reports and history of alarms for the eligible areas.
- Search service for alarms and at the same time production of graphs. The search service is supported by a search engine which gives the ability to choose and search for alarms based on the sensor, parameters and date.
- Current Measurements tool. This tool gives the total picture of the current values of each sensor.

- Alarm tool. The tool presents summarized information for the last alarms produced by the sensors.

As a result the danger management services are adequate and exploit data sent by sensors which are being presented through the **SFINX** Web Site.

Tele-working and Tele-education services 6.2.5

The Tele-working and Tele-education services for the **SFINX** Project are based on open source software which is distributed and support relevant functions. Specifically the system is functioning through the Internet and provides specialized services for tele-work and tele-eduction which are accessed through the **SFINX** Web Site.

Figure 6.5: The access point to tele-work and tele-education

The system provides a variety of tools and services for tele-work and tele-education such as calendar, versioning, creation of courses, implementation of specialized seminars etc.

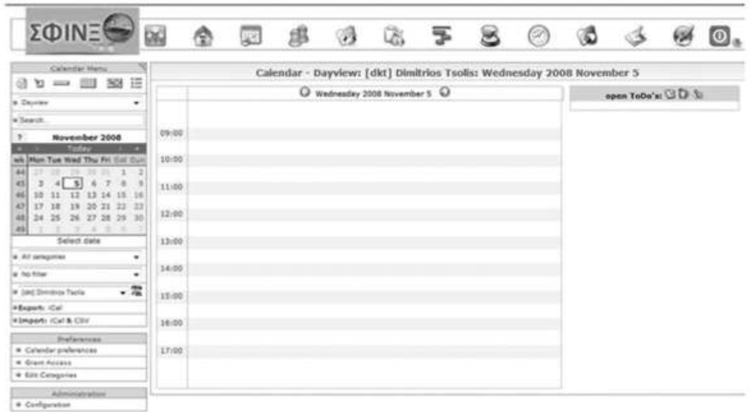

Figure 6.6: Tele-work and tele-education Services and tools

6.3 Systems Integration Schema

The methodology for the systems integration is presented in 6.7 figure.

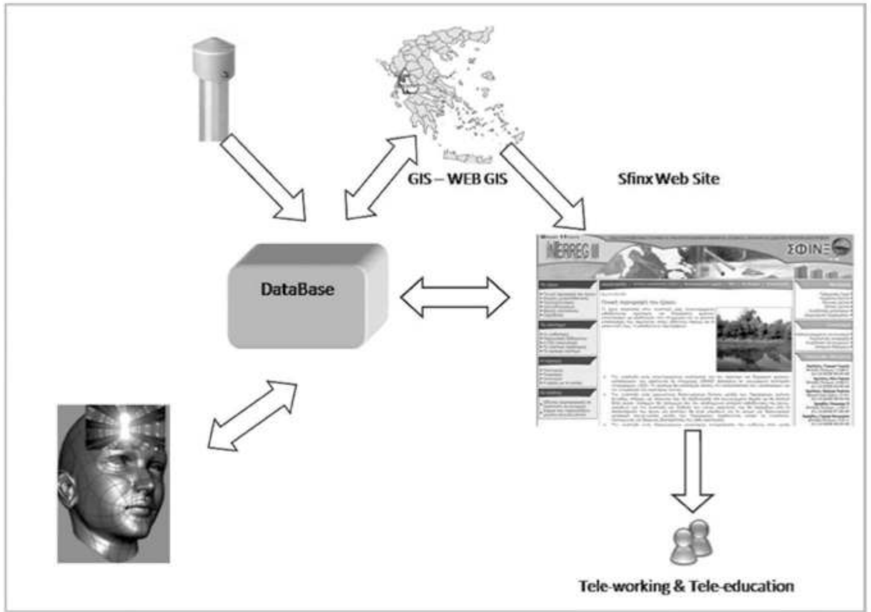

Figure 6.7: Systems Integration Schema

As observed, the most important factor on which the systems integration is based, is the database in which data and information coming from the sensors, the Decision Support System and the GIS system are stored and exploited. The **SFINX** Web Site uses this database so as to implement the danger management services and at the same time to provide the tele-working and tele-education systems. For this reason the database system supports all the necessary data types and provides all the required fields for storing and managing the large volume and variety of information distributed between the rest of the independent systems.

The high efficiency and stability of the database system serves as a platform and as a functional technological infrastructure on which **SFINX** project's services, subsystems and tools rely.

Chapter 7
Web portal and advanced information services

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Contents

Introduction 7.1

Within the framework of the **SFINX** Project "Integrated Information System for Natural Disaster and Management this chapter presents in detail the methodology and the technologies used for the design and the development of an innovative WebSite, which apart from a set of information services, presents in a categorized manner the digital content, sensor data, alarms and other environmental data which are constantly collected and distributed through the technological infrastructure of the project.

The proposed solution was implemented by the High Performance Information Systems Laboratory of the University of Patras which provided services for the suitable presentation and dissemination of the flood dangers and the correspondent scientific and statistical elements, as well as management services for the Site through the use of web technologies.

The implemented system supports multilevel security and controlled access of the users to the services and information in accordance with their access rights.

In the framework of management tools the authenticated users have the ability to categorize, sort and search for information and data. The searching services range from basic to advanced capabilities both for the sensor data and alarm data.

Special focus has also been given on informing people for issues concerning flood dangers and the environmental protection at large. In this sense, a set of services are available which in combination with WebGIS tools give the ability to alarm people regarding flood dangers in certain geographical locations.

In addition, the WebSite includes a number of educational applications, advanced communication and tele-working services. These services indicatively include forums, announcements, faqs, courses, calendars, file versioning etc.

During the design and implementation of the WebSite and its services several usability and quality principles were applied so as to ensure the high quality of the produced results. Specifically the implementation was based on the next principles for usability and quality:

- Usability guidelines and principles for WebSites by Jakob Nielsen (Designing Web Usability –New Riders Ed.).
- Quality Principles for Cultural Websites: a Handbook of the Minerva Project *(www.minervaeurope.org)*

7.2. The SFINX WebSite's Implementation

The WebSite's implementation was fully harmonized with the international usability and quality standards for web development. The current section presents the aesthetic design and the implemented services for managing and dealing with flood dangers in detail, as well as the informational services provided to the general public.

7.2.1 Aesthetic Design

The aesthetic design of the WebSite is being presented in the following picture:

Figure 7.1: The WebSite's aesthetic

It is observed that in agreement with the international quality and usability standards the web pages are being divided in four main sectors which include the main menu, the services menu and the informational menu, as well as the main body department which included the texts and presented the services. The three menus are constantly visible throughout the user's navigation so as to give the ability to access any service provided and to have a clear picture of what is his current position in the WebSite. This technique makes easy for the internet user to point and select the next desired web service and/or page. The project's logo is constantly visible from all the web pages and the same stands for the language menu.

The Web Site is divided in three main menu areas. The upper menu, the left menu and the right menu of selections:

- **The upper menu includes the main choices for the user / visitor of the web page, such as:**
  - o Returning to the home page.
  - o The GIS visual presentation.
  - o The photo archive
  - o News
  - o Hyperlinks and
  - o Contact page

- **The left menu includes the informational services, mainly about:**
  - o The project
  - o The system
  - o The area
  - o The citizens

- **The right menu includes the specialized services for dealing and managing flood dangers. Specifically the menu includes:**
  - o Measurements
  - o Alarms
  - o Most current measurements
  - o Most current alarms

The elements which enforce usability are:

- The correct choice of colors, font types and graphics.
- The Active Passage which the user has followed (e.g. Home Page ⇨ The Project ⇨ Deliverables) which gives a clear picture for the current position of the user in the web site and how he could turn back to his starting point.
- The menus and services are visible and selectable throughout all the web pages of the Intern Site.

In the following paragraphs analytical elements could be found for every available choice and service provided by the **SFINX** WebSite.

7.2.2 Services – Menus and Selections

The services to which the user has access are being presented.

Home page

Returning to the home page can be achieved by the upper menu of the Web Site and is constantly available from every web page. In every case the user can return to the home page and restart his navigation.

Figure 7.2: The Web site's Home page

Visual Representation through GIS

The visual representation through GIS is the access point of the internet user to the main GIS platform of the **SFINX** project and to the cartographical systems through which the flood danger is being represented. The visual representation provides the users with certain navigational abilities through maps in the eligible areas. The user has the ability to zoom in and out the map, navigate to the national roads and to be informed about what roads have been affected by the flood and in addition the user is able to navigate to the points where the sensors are installed and tobe informed about their condition and current measurements. This visual representation through

The GIS informs people and the authoritative agencies by giving a full and clear picture about the danger in order to coordinate the actions and to deal effectively with the flood. A sample figure of the GIS representation is following.

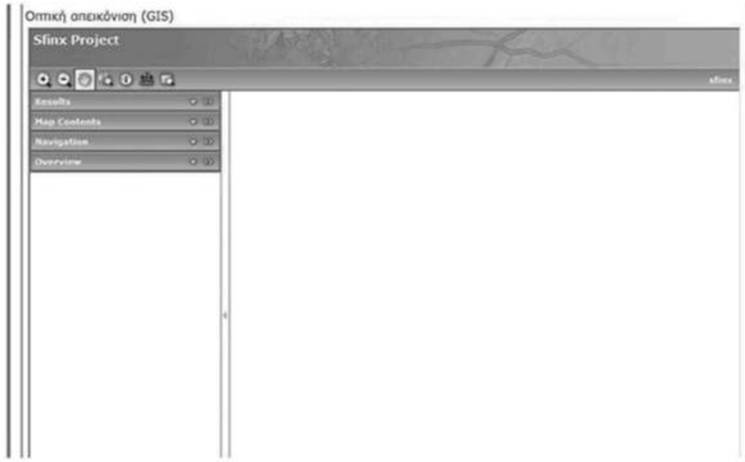


Figure 7.3: Visual representation through GIS

Right after this web page the next map is being presented.

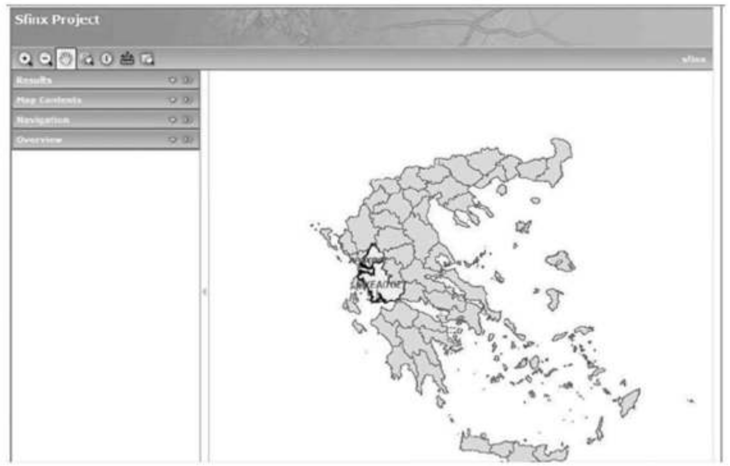
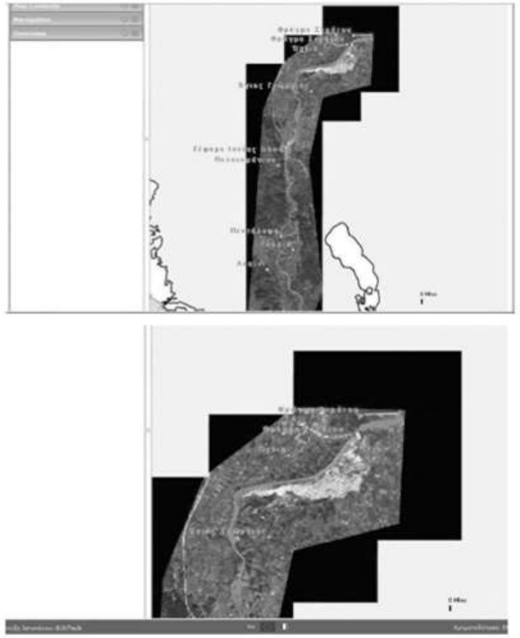


Figure 7. 4: Visual representation through GIS

The zoom in level is being presented in the next figures:



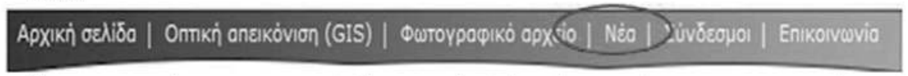
Figures 7.5, 7.6: The zoom in levels of the maps

Photo Archive

In this web page the photo archive is being presented enriched with images from the areas where the data sensors are installed. An indicative screenshot follows:

Figure 7.7: The Web page of the photo archive

News



The news web page presents the very last developments, announces and meetings of the **SFINX** Project. An example is presented in the next screenshot:

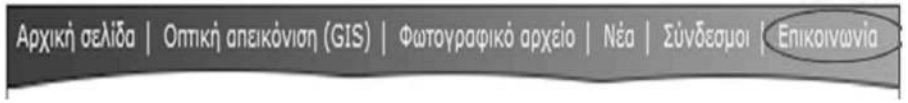
Figure 7.8: The Web page of News

Hyperlinks

This web page includes important hyperlinks relevant with the **SFINX** Project, the full address of the external hyperlink and a summary of their objective.

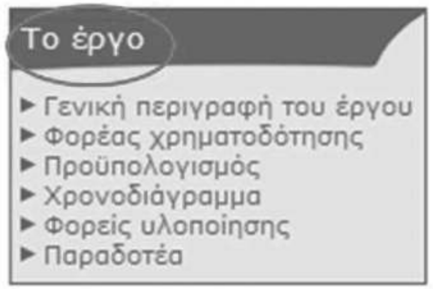
Figure 7.9: The web page of Hyperlinks

Contact Us



The "contact us" form is a communication tool for the internet user with the people supporting **SFINX** Project. The form collects specific data from the internet user, stores them to a database and at the same time the user has the ability to send a message to the responsible for the WebSite people.

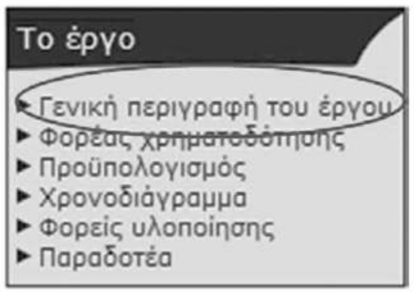
The Project



These web pages are aiming at describing the main objectives of the **SFINX** Project, present the organizations responsible for its implementation and include issues like the budget, timelines, deliverables etc.

The web pages which describe the project in general are the following:

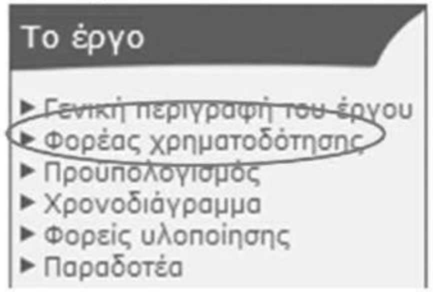
General Description



The "general description" web page which includes information about the aims, ambitions and the project's implementation methodology.

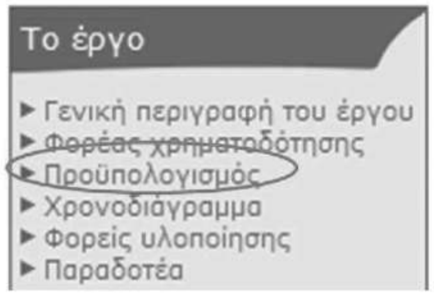
Figure 7.10: The Web page of the project's general description

Funding



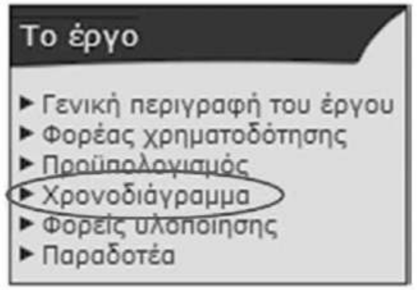
The specific web page presents the funding organization.

Budget



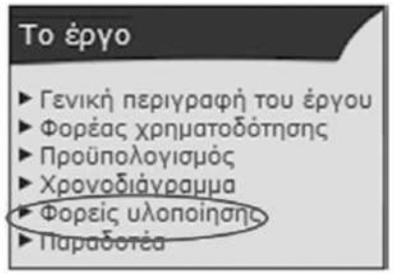
The web pages refer to the project's budget.

Timelines



The web page informs about the project's timelines.

Organizations



This web page includes information about the organization responsible for the project's implementation.

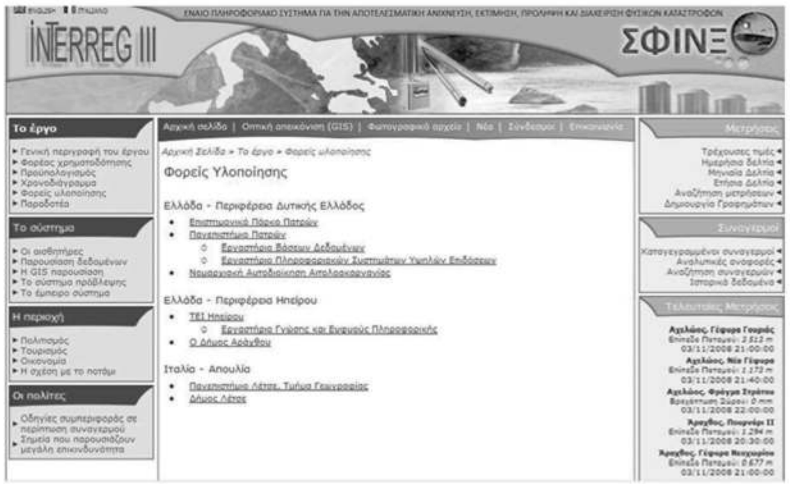
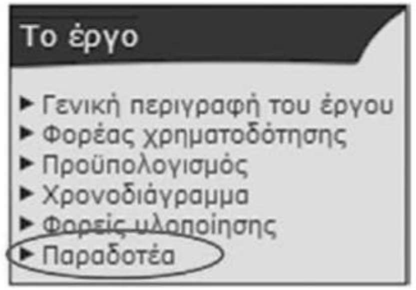


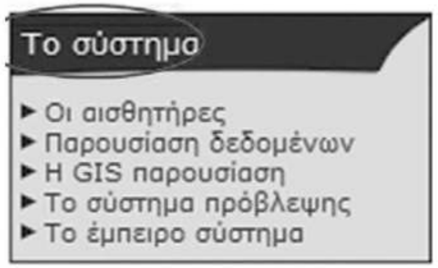
Figure 7.11: The web page with the project's partners

Deliverables



The web pages include all the project's deliverables.

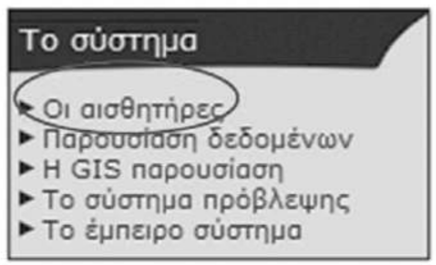
The System



This set of web pages includes information about the integrated information system of the **SFINX** Project and its subsystems. The aim of the web pages is informational for the internet user and specifically they give a full description of the technologies used for the system's implementation.

The set of web pages for «the system» include:

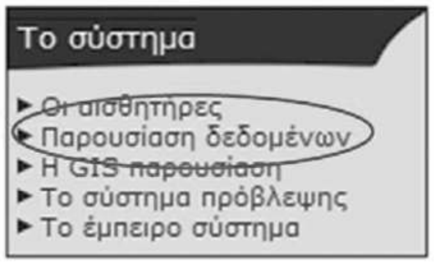
Sensors



The web pages which describe the data sensors, the technology and the installation procedure (a screenshot is following).

Figure 7.12: The Web page depicting the sensors

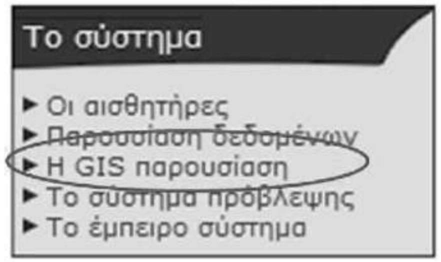
Data Presentation



The web page which describes the methodology of data presentation.

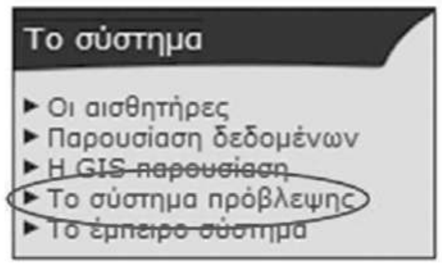
Figure 7.13: The Web page depicting the project's data

GIS Representation



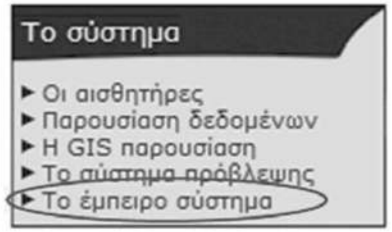
The web pages describe the GIS system and the GIS visual representation.

Prediction System



Prediction System displays the web page which describes the flood prediction system.

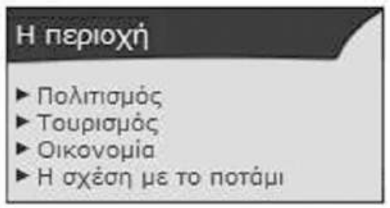
Decision Support System



The web page which describes in detail the Decision Support System used for dealing and managing flood dangers.

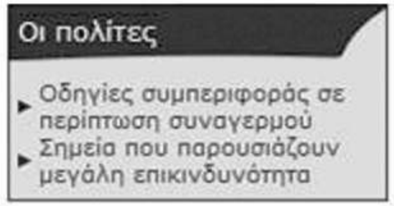
Figure 7. 14: The web page of the Decision Support System

The Area



This particular web page set includes information for the eligible areas. Specifically information about Culture, Tourism and Economy is included.

The Citizens



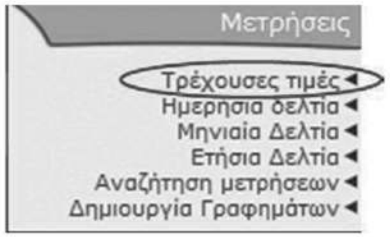
These web pages include information referring to the citizens and to the flood dangers in the eligible areas. The first web page presents guidelines for the citizens in case of an alarm and the second areas which are highly endangered.

Figure 7.15: The web page presenting guidelines for the citizens in case of an alarm

Measurements

The web pages which present the sensor measurements are very important for illustrating and managing flood dangers in the eligible areas. The user has the ability to view the current measurements and values of the several parameters that the sensors are measuring. In addition the user has the ability to produce and exploit sensor data regarding a day, a month and / or a year. At the same time, the user has the ability to search for measurements based on search criteria, e.g. searching using dates and to create its own graphs based on these dates (e.g. the rainfall graph for a certain date).

Current Values



The first web page presents the current values for the data sensor. These values can be viewed based on the area which the sensor is installed. For each sensor the water temperature, the water level and the rain fall level is being retrieved and presented through the **SFINX** WebSite.

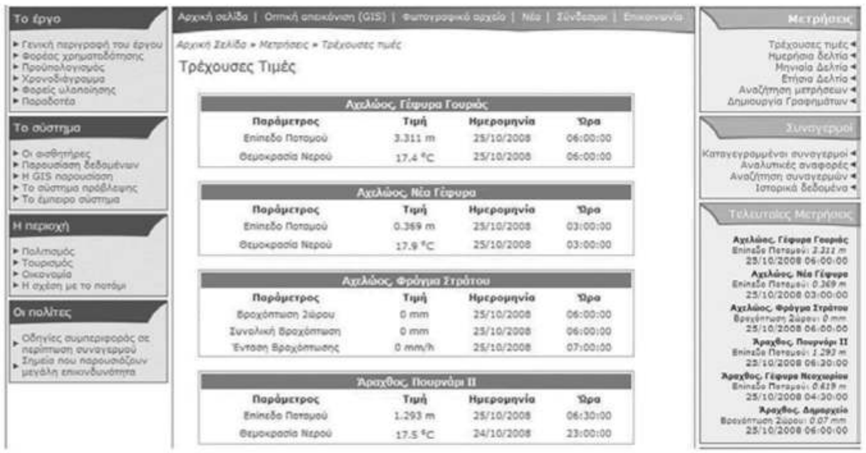
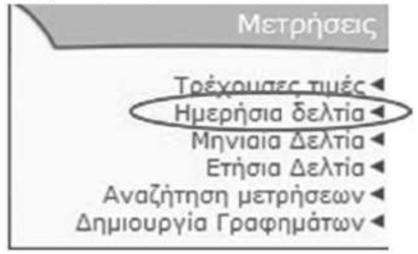
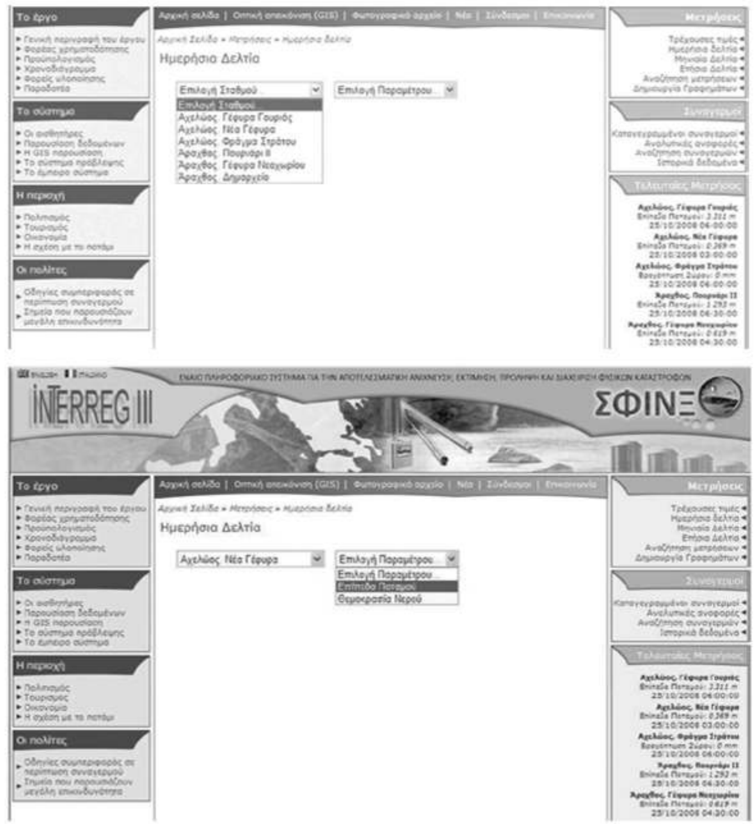


Figure 7.16: The Web page depicts current measurements of the sensors

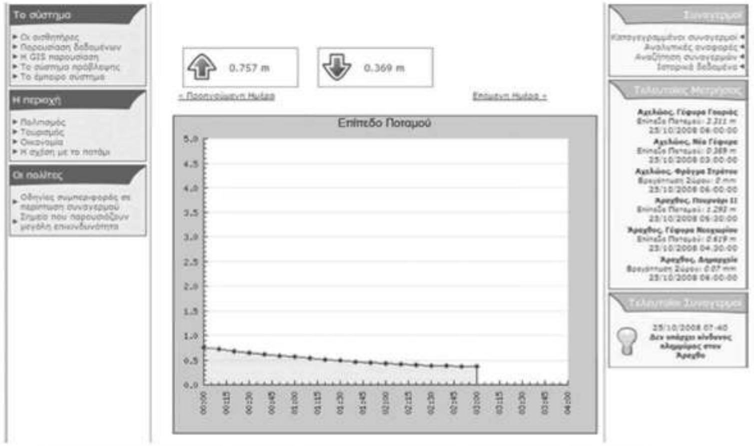
Daily Reports



The daily reports present the values for all the measurements of the sensors during a specific day. While the user is navigating through each day the daily report is being produced. At first the sensor is being selected, then the value measured and base on these three criteria (including the date) a daily report is being produced which includes a graph and a table with values. The user has the ability to select another day (next or previous of the current day). An example is shown through the next images.



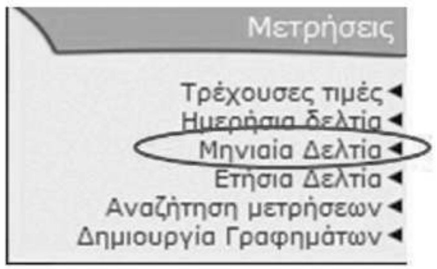
Figures 7.17, 7.18: The web page to choose the daily report



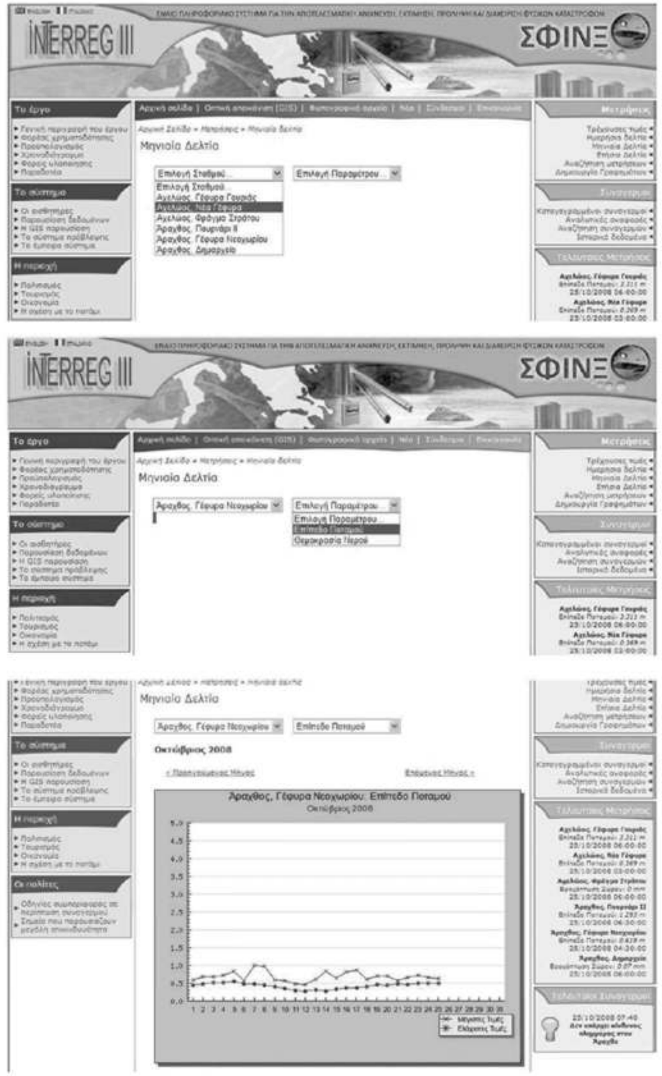
Επίπεδο Ποταμού		
Ημερομηνία	Ώρα	Τιμή
25/10/2008	03:00:00	0.369 m
25/10/2008	02:50:00	0.375 m
25/10/2008	02:40:00	0.383 m
25/10/2008	02:30:00	0.391 m
25/10/2008	02:20:00	0.401 m
25/10/2008	02:10:00	0.413 m
25/10/2008	02:00:00	0.428 m
25/10/2008	01:50:00	0.446 m
25/10/2008	01:40:00	0.464 m
25/10/2008	01:30:00	0.489 m
25/10/2008	01:20:00	0.513 m
25/10/2008	01:10:00	0.538 m
25/10/2008	01:00:00	0.562 m
25/10/2008	00:50:00	0.591 m
25/10/2008	00:40:00	0.614 m
25/10/2008	00:30:00	0.648 m
25/10/2008	00:20:00	0.681 m
25/10/2008	00:10:00	0.722 m
25/10/2008	00:00:00	0.757 m

Figures 7.19, 7.20: Daily measurements

Monthly Reports



The monthly reports present data from the measurements of the sensors during a month. When the user navigates through the monthly elements a report is being produced. At first the sensor is being selected and then the value measured. The monthly report includes the graph of the produced values and a summary table with all the measurements. At this point the Internet user has the ability to navigate through all the months (with a previous – next facility). An example is being presented in the next screenshots.

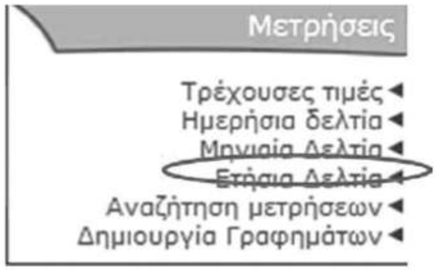


Figures 7.21, 7.22, 7.23: Monthly reports and measurements

Επίπεδο Ποταμού		
Ημέρα	Μέγιστη Τιμή	Ελάχιστη Τιμή
1	0.593 m	0.443 m
2	0.683 m	0.476 m
3	0.686 m	0.522 m
4	0.719 m	0.527 m
5	0.829 m	0.56 m
6	0.581 m	0.483 m
7	1.006 m	0.485 m
8	0.969 m	0.446 m
9	0.584 m	0.407 m
10	0.582 m	0.35 m
11	0.486 m	0.299 m
12	0.464 m	0.276 m
13	0.606 m	0.311 m
14	0.84 m	0.283 m
15	0.654 m	0.331 m
16	0.822 m	0.367 m
17	0.873 m	0.371 m
18	0.603 m	0.415 m
19	0.696 m	0.47 m
20	0.703 m	0.437 m
21	0.566 m	0.48 m
22	0.665 m	0.47 m
23	0.722 m	0.502 m
24	0.661 m	0.509 m
25	0.623 m	0.493 m

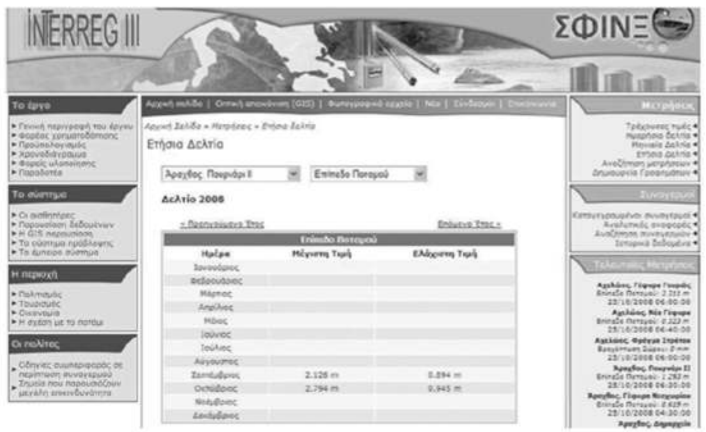
Figure 7.24: Monthly measurements

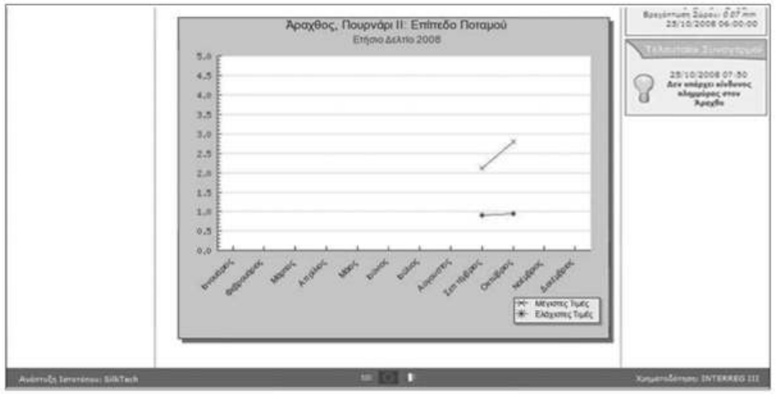
Annual Reports



The annual reports present the measurements from all the sensors on an annual basis. The annual report includes the graph and the summary table of all the measurements of the sensors during the year. At first the sensor is being selected and then the value measured. The Internet user has also the ability to navigate through all years (with a previous – next feature). An example is being presented in Figures 7.25 and 7.26.

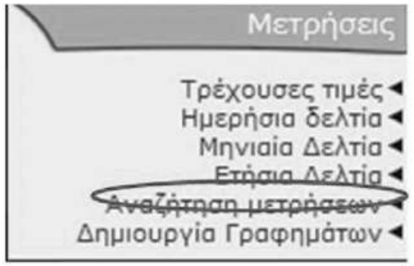
Figures 7.25, 7.26: The web pages to choose the annual reports





Figures 7.27, 7.28: Annual reports and measurements

Measurement Search

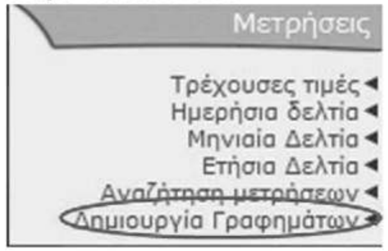


Searching the archive of data, information and measurements is based on a search tool with which the user is able to find values of parameters in accordance with certain criteria. These criteria include the sensor, the parameter measured the dates, key words etc. A sample search is being presented in the next figures.

Figure 7.29: The web page of searching the archive of data

Figure 7.30: The research results page

Graph Creation Tool



The graph creation tool is providing the capability to the user to construct automatically graphs based on certain criteria such as the parameters, the values, the area etc. An example of graph creation is presented in the next screenshots.

Figure 7.31: Selecting the parameters to create the graph

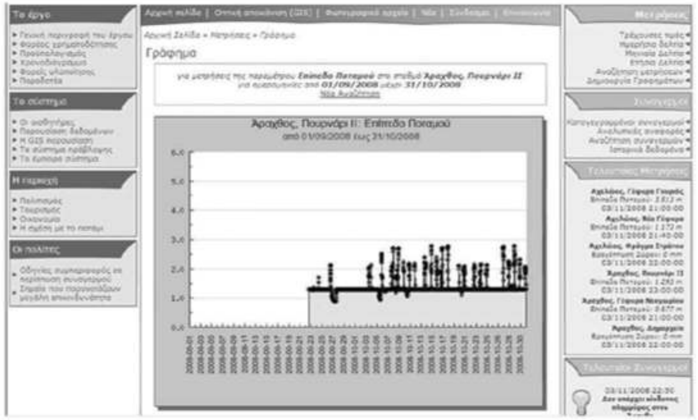
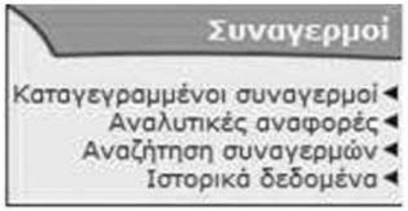


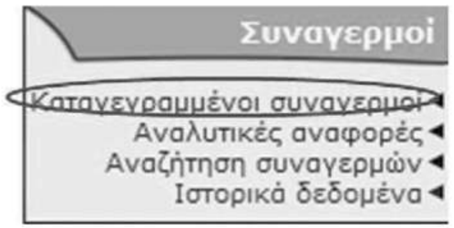
Figure 7.32: The created graph

Alarms



The web pages regarding the alarms are very important as they contribute significantly to dealing and managing the flood danger. The user has the ability to navigate through important information relevant to produced by the sensors alarms, the reports and historical data, while at the same time is able to search the past alarm data so as to compare previous values and facts. Following an in detail presentation of the web pages regarding the alarms is included.

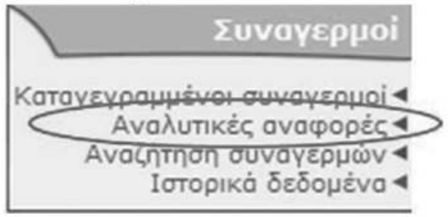
Stored Alarms



The web page presents the produced by the sensors alarms.

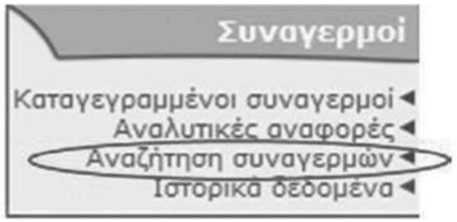
Figure 7.33: Past alarms

Detailed Reports



The detailed reports are presented for each alarm based on values, dates and the areas under consideration.

Alarm Search

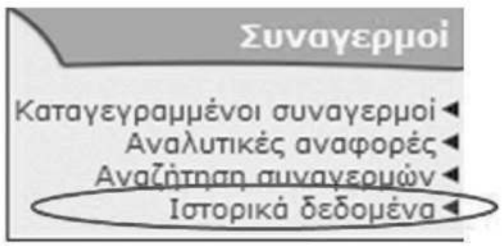


A tool to search for alarm data is available to the internet user with which the ability to find alarm data based on criteria is supported. The search criteria include dates, areas, sensor data etc.

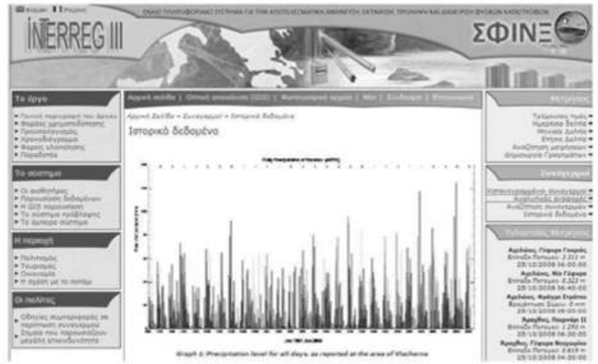
Figure 7.34: The tool to search for alarm data

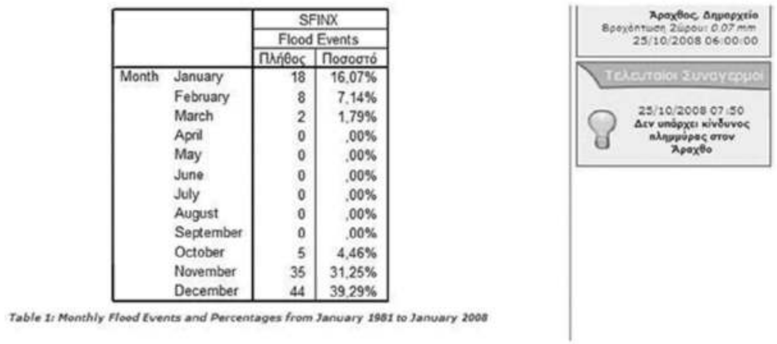
Figure 7.35: The search results

Historical Data



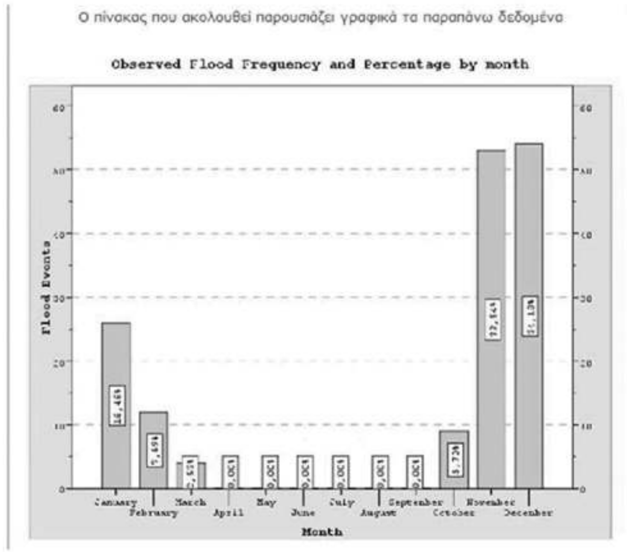
The web page presents the historical data of the alarms and is very interesting as every historical report includes full elements and information about flood dangers in the areas under examination.





		SFINX	
		Flood Events	
		Πλήθος	Ποσοστό
Month	January	18	16,07%
	February	8	7,14%
	March	2	1,79%
	April	0	,00%
	May	0	,00%
	June	0	,00%
	July	0	,00%
	August	0	,00%
	September	0	,00%
	October	5	4,46%
	November	35	31,25%
	December	44	39,29%

Table 1: Monthly Flood Events and Percentages from January 1981 to January 2008



Figures 7.36, 7.37, 7.38: Historical data of alarms

Current measurements

The last measurements are being presented to the internet user so as a clear and whole picture of the current situation regarding floods to be provided to people and authoritative agencies. It is noted that the measurements are automatically publiced through the site whenever new values are produced in the sensors. The same stands for every service for managing and dealing with flood dangers provided by the Sfinx Web Site and is related to sensor measurements, the daily, monthly and annual reports, search capabilities etc. The next figure presents the current measurement window.

Figure 7.39: The current measurement window

Current Alarms

In a special window, the last alarms that have been produced by the sensors are presented. The window is automatically updated when a new alarm is produced in the sensors. The same stands for every service for managing alarms provided by the **SFINX** WebSite and is related to sensor measurements, the daily, monthly and annual reports, search capabilities etc. The next figure presents the current measurement window.

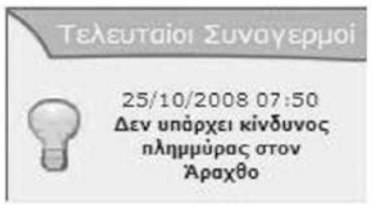


Figure 7.40: The current measurement window

Chapter 8
GIS and dynamic WebGIS for enviromental risk management and monitoring

Luigi Russo
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Contents

Introduction 8.1

The present research, developed by the University of Salento - Lecce, Italy, deals with G.I.S. and the dynamic applications of WebGIS, especially those which aim to monitor and manage environmental risks both in urban and extra-urban areas.

The system makes use of fixed sensors and, or mobile equipment for data-gathering in order to transmit some environmental indicators tailored for the single kind of risk monitored (i.e. temperature, humidity, rain level, capacity, tide level, direction and intensity of wind, etc). In this way, it is possible to point out any potential risk for the population and the environment, by transmitting via Internet the level of the previous indicators.

The whole process is presented using a realistic model of the territory, published in real time and provided by an automatic refresh of the G.I.S. web page.

The technical solution has been developed starting from a dbase Mysql where all significant environmental data is stored. The specific data is then visualized exploiting the open-source base of Mapserver (University of Minnesota) / Pmapper (Armin Burger).

A further development of the system could be the realization of software which carries out territory analysis which blends together the most relevant environmental indicators, offering an essential contribution to the management of the Decision Support System (D.S.S.).

Synthetic description of environmental data acquisition and elaboration system 8.2

The aim is to create a historical series of data, geo-referenced to the area of study, which could help understanding the highlighted phenomena and anticipating, managing and monitoring, via a technologically advanced communication system, the risks of flooding and subsidence of buildings

Categories of phenomena to be observed:

- Atmospheric phenomena (precipitation)
- Endogenous phenomena (bradyseism)
- Phenomena relating to the coastal and marine environment (tidal ranges, sea surges)
- Modifications to the coastline (erosion).

The integrated system which is installed in the territory of Lecce was designed according to the following scheme:

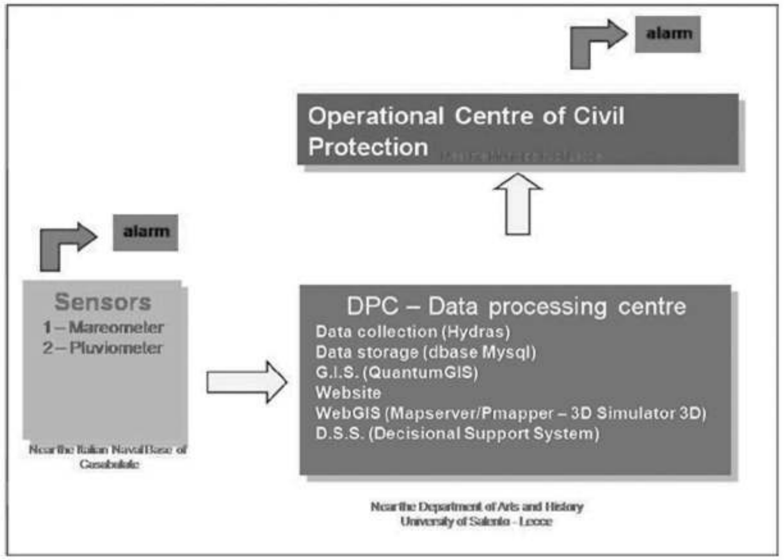

Figure 8.1: The design of the integrated system

Figure 8.2: The installed sensors

The installed sensors near the Sector of the Italian Naval Base of Casabalate, deliver the registered data of the sea level (1) and rainfalls (2). Both of them are autonomous regarding power supply, being provided with a solar panel and a buffer battery. In the interior of the data system (3) a data-logger stores the data while a GSM modem is available for the teletransmission of data and the posted alarms on the basis of predetermined level limits.

The frequency of data acquisition and registration is variable and could vary from remote computer.

The alarms that are managed directly from the data system are addressed to the officers of the Data Processing Centre (DPC).

DPC – Data processing centre

The D.P.C., which is installed near the Department of Arts and History, is composed by:

- Control station (system's server) having the following principal characteristics: Processor Intel Xeon 5130 (2.0 Ghz.-1333Mhz-4MbCache) – S.O. Windows XP Professional SP2 – Graphic board ca 128Mb nVidia NVS285 – RAM 2Gb. DDR2 667 Quad
- HD n.1 320 Gb. 7200 rpm SATA 3.0Gb./s – Monitor;
- Modem GSM Dual Band SIEMENS mod.TC35 ant.GSM – serial cable RS232 - SIM card
- Colour laser printer
- U.P.S. 1000 VA/600W

8.3 Software used in D.P.C

Within the system's server is installed and activated the following software:

I. HYDRAS 3 standard

The program permits the management of the sensors, the exchange of data, the visual display of results in various ways, the export of results, the management of the user groups, of the various alarm levels and the automatic submission of alarm messages.

II. QUANTUM GIS

Software open-source for the management and visual display of cartographical data

III. MYSQL Database

Software open-source for the database management of the data which is exported from Hydras

IV. MAPSERVER

Software open-source for the management of WebGIS

V. P-MAPPER

Application which interfaces with the mechanism Mapserver for the visual display organised by the WebGIS

VI. JOOMLA Application

Advanced Interface for the management of the WebSite.

VII. SIMULATOR

Simulation program created for the occasion, capable of inserting altered data from recorded levels in a way that would cause alarm situations in WebGIS; this program has been and still is very useful for testing the functionality of the Dynamic WebGIS, with the function 'reset' that eliminates altered data inserted in the database and restores the existing ones.

Everything functions according to the following scheme:

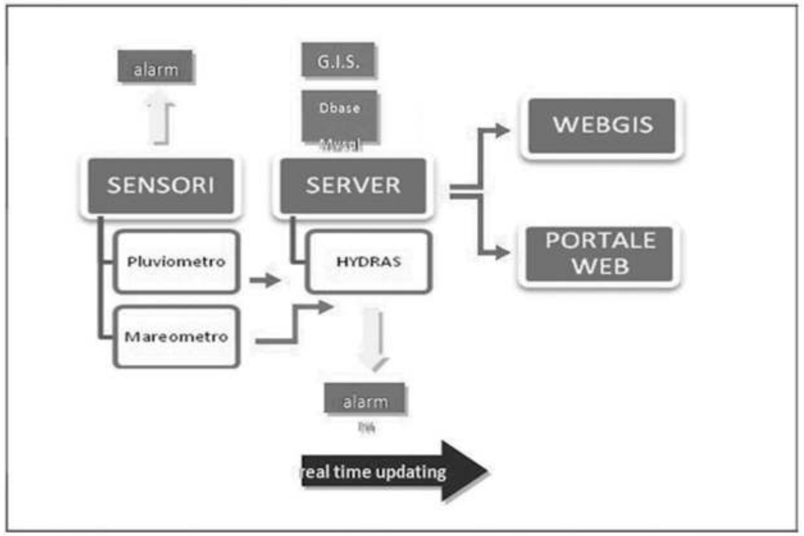

Figure 8.3: Simulation

8.4 Synthetic description of the system adopted for the creation of G.I.S in which the environmental data is reported

The University of Salento operates in Geographic Information Systems for many years using the software platform ESRI – Arcgis. Even in this case, the topographic surveys which took place in the study zone, along with the existing cartography, were first drafted in CAD environment and successively transformed into the form of shape files that were then imported in Arcgis. The G.I.S basis of ESRI is rich of functions such as topological overlay, space-query, buffering, network analysis etc so that to ensure an incredible number of data space-analysis.

Previously, a close examination had been conducted in order to establish the necessary requirements that a G.I.S structure has to be able to offer for the evaluation and management of natural disasters.

The survey is linked to the necessity of producing a platform that could be able to get, almost in real time, the indications which are related to emergencies linked to the two factors (rainfalls – sea level), rendering them into interactive maps ready for successive assessments.

In case of review the recorded evaluations of topographical data, in order to be verified in relation to the event, have to be able to provide important elements such as:

- delimitation of the area which is affected by marine flooding or inundation;
- determination of the built-up area of interested;
- study regarding the recession of road network.

The first phase has been the finding of the most suitable cartographic bases and accordingly the development of various information layers for the G.I.S. With reference to the study zone (area of Municipality of Lecce, location Casabalate), the following have been analyzed:

- Municipal cartography in 1997 scale 1:2000 and 1:5000;
- Municipal cartography in 2004 scale 1:5000;
- Coloured and high resolution air photographs of 1994.

Subsequently, the following operations have been conducted:

- Verification with topo-cartographic layer carried out with GEOXH equipped with GPS for the cartographic verification and the outline of discreet points in the territory;
- Georeferencing of the air photographs with colours and photo-mottling of themselves;
- Selection in CAD environment of the most significant layers for the creation of GIS.

Some example slides are following.

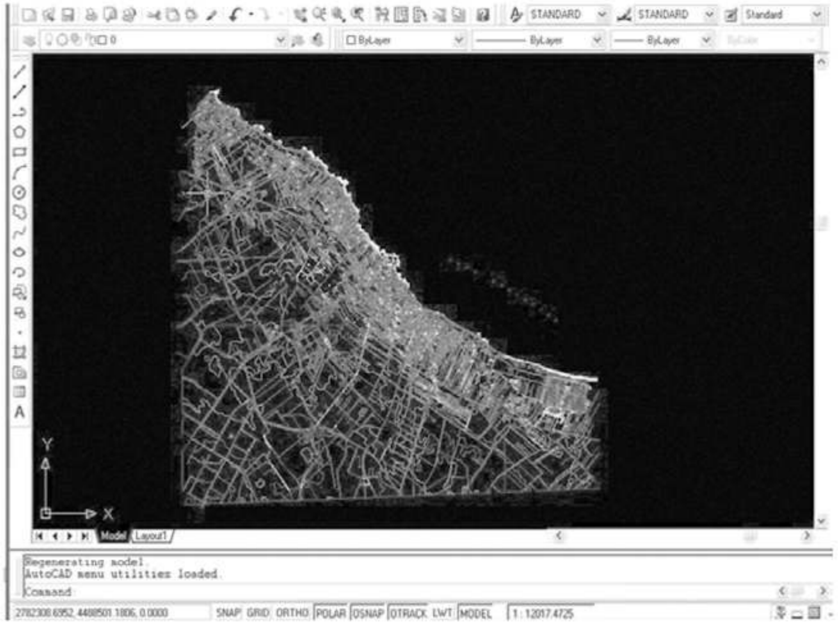

Figure 8.4: Evaluation CAD for the extraction of layers which are referred to the zone of study

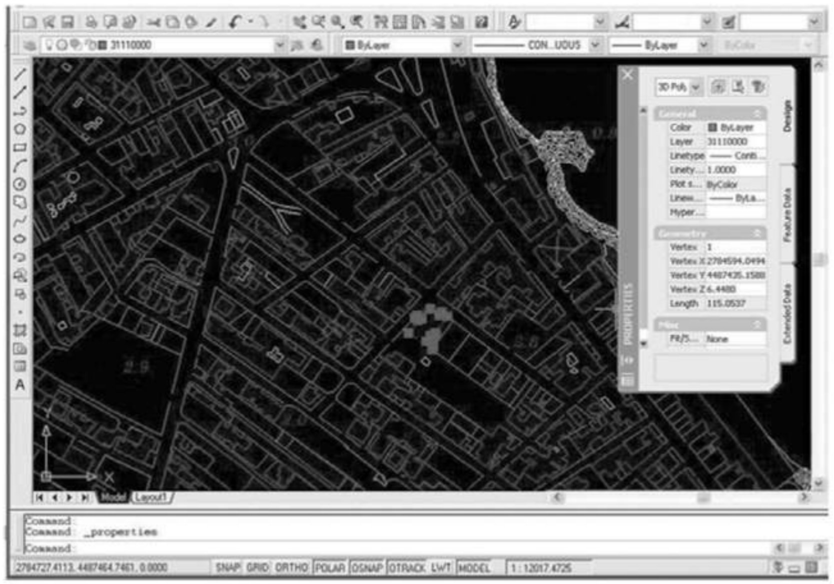

Figure 8.5: Evaluation CAD for the verification of the space information of the elements

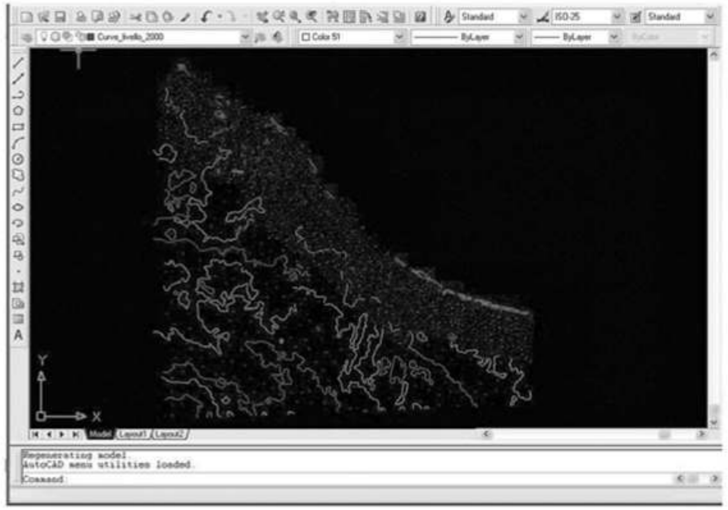

Figure 8.6: Evaluation CAD for the extraction of the necessary information for the creation of the territorial digital model

Subsequently the export of CAD files (.dwg) in the GIS file has been conducted by using the format shape (.shp) and associating, as table data, the located territorial information.

The reference software has been the ARCGIS of ESRI already in use from the Department.

For a greater diffusion of GIS products the migration of information towards an open-source product like QUANTUM GIS has been predicted.

The various information layers have been related per category and precisely:

- RASTER (georeferenced air photographs and other grading raster);
- ADMINISTRAIVE LIMITS (Nations, Regions, Province, Municipalities, municipal Limit of Lecce) ;
- CARTOGRAPHY OF THE BASE (Statement of road network in municipal roads, country and main roads – Buildings – Contour lines);
- ENVIRONMENTAL AND GEOLOGICAL INVESTIGATIONS (There have been reported the predicted areas and points of investigation in a project which is in course of implementation from the side of the Municipality of Lecce);
- HYPSOMETRICAL PROFILES and CENSORS POSITION**;**
- 3D MODEL.

In particular, it is emphasized that for the creation of the GIS has been used the reference system MONTE _MARIO_Italy_2 with the following parameters:

Monte_Mario_Italy_2
Projection: Transverse_Mercator
False_Easting: 2520000.000000
False_Northing: 0.000000
Central_Meridian: 15.000000
Scale_Factor: 0.999600
Latitude_Of_Origin: 0.000000
Linear Unit: Meter
GCS_Monte_Mario
Datum: D_Monte_Mario

With the routines today available in the GIS mechanisms it is possible to transfer all information to another coordinate system. This is particularly important in the transboundary sharing of data and resources.

In relation to the objectives aimed to be achieved with the G.I.S and to the available databanks, the Department of Arts and History of Lecce decided to realize the following information layers, divided into thematic groups:

ADMINISTRATIVE LIMITS	Nations / Regions / Provinces / Municipalities
CARTOGRAPHY	Shore line / Municipal roads / Country roads / Main roads / Municipal limits / Buildings (cartography year 2004)
RASTER	Georeferenced air photographs
GEOLOGICAL INVESTIGATIONS	Hydrogeological observations / Geoelectric methods / Ground-penetrating radar methods / Seismic prospecting (predicted investigation routes from a further project which is in course of implementation from the side of the Municipality of Lecce)
SENSORS	Position
HYPSOMETRICAL PROFILES	Transverse sections realized along the coast

Figure 8.7: Layers and thematic groups

Some example slides are following.

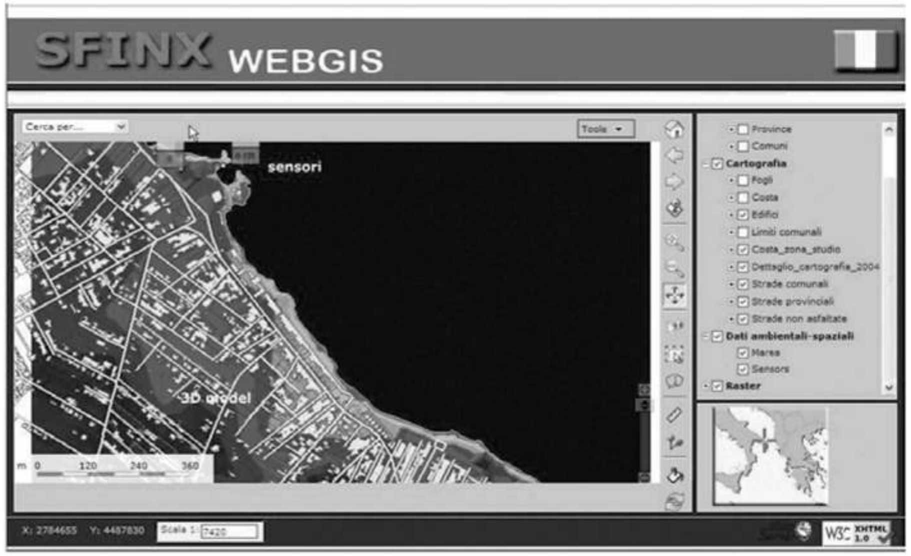

Figure 8.8: Layer "Nations" with a selection of identification data and data of the Italian territory region

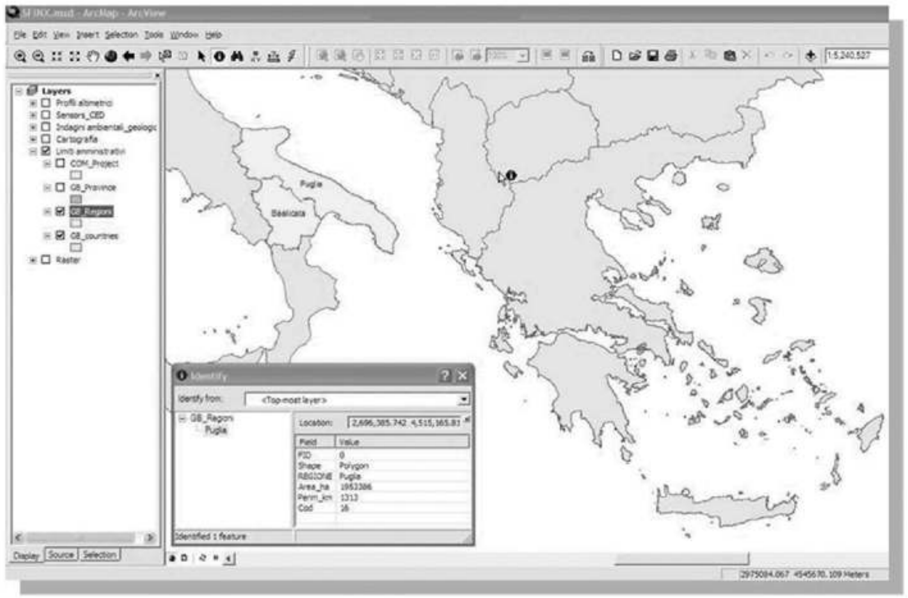

Figure 8.9: Layer "Regions" with a selection of identification data and data of the Puglia and Basilicata regions

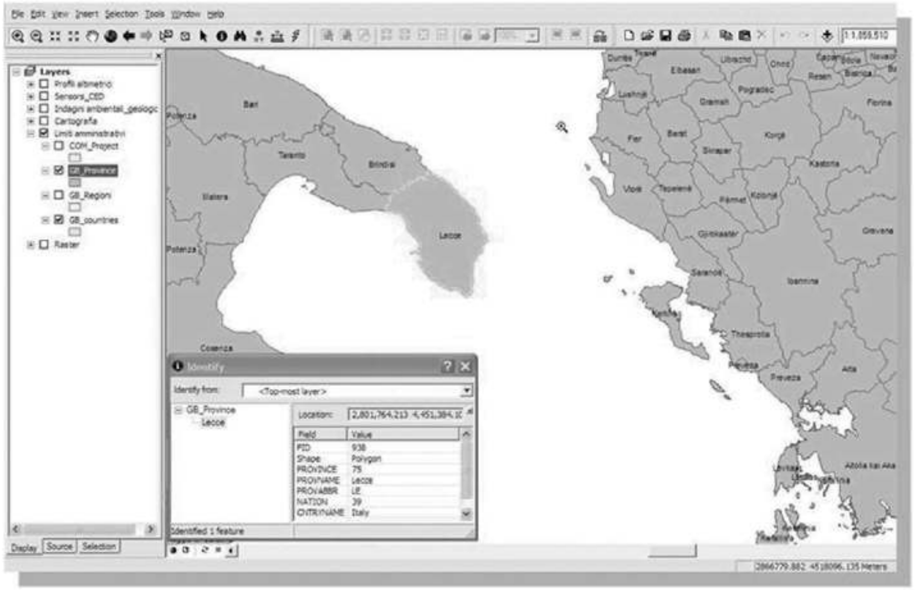

Figure 8.10: Layer "Provinces" with a selection of identification data and data of the area of the Province of Lecce

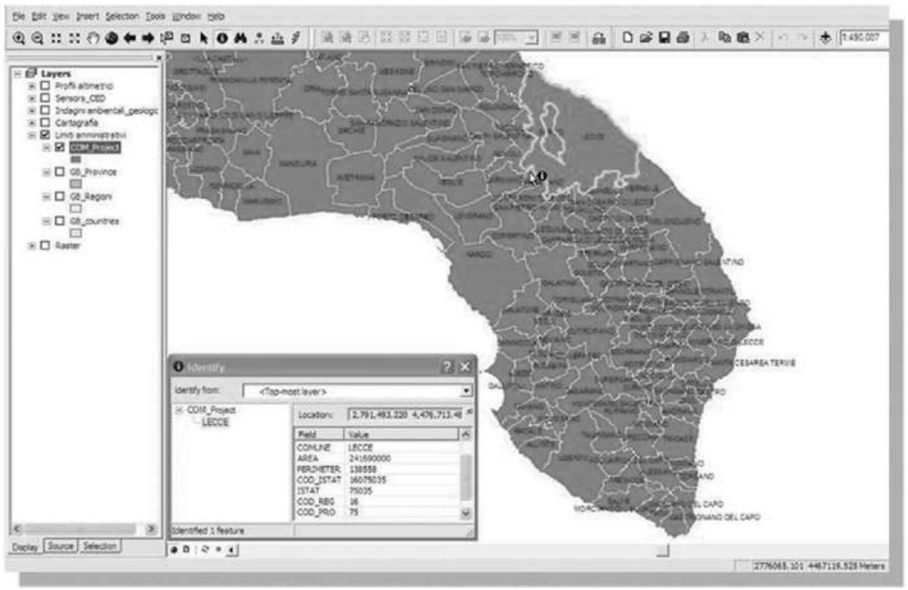

Figure 8.11: Layer "Municipalities" with a selection of identification data and data of the area of the Municipality of Lecce

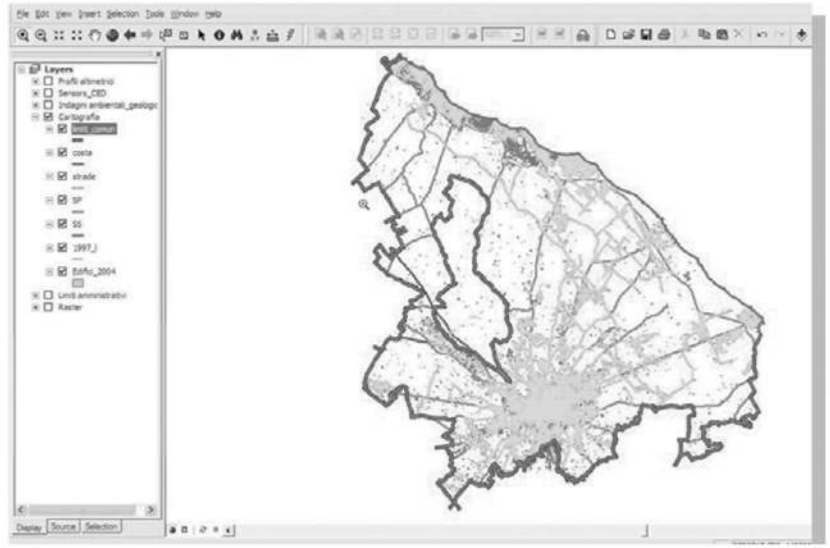

Figure 8.12: Layer "Municipal limits of Lecce" with a selection of the Adriatic Sea coast, municipal roads, country and main roads and of the clearance diagrams of the existing buildings

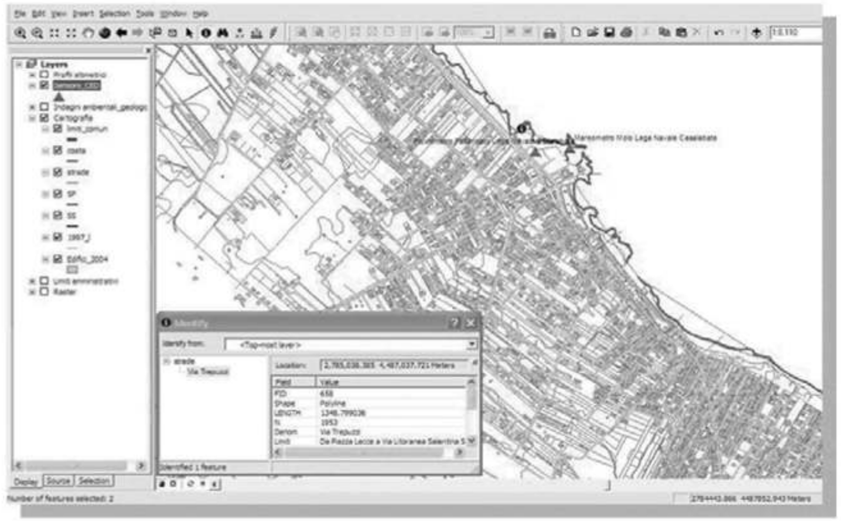

Figure 8.13: Layer "Study zone" with a selection of data and the location of an important access road, with small red triangles, and of the location of the two installed sensors (mareometer and pluviometer) near the Italian Naval League – section of Casabalate. The existing roads are indicated in green while the buildings have a bright brown colour.

Figure 8.14: Layer raster of the "Study zone" with a selection, with small red triangles, of the location of the two installed sensors (mareometer and pluviometer) near the Italian Naval League–section of Casabalate. The total raster was obtained from the mottle and the successive georeferencing of coloured images taken from an aeroplane (year 2004).

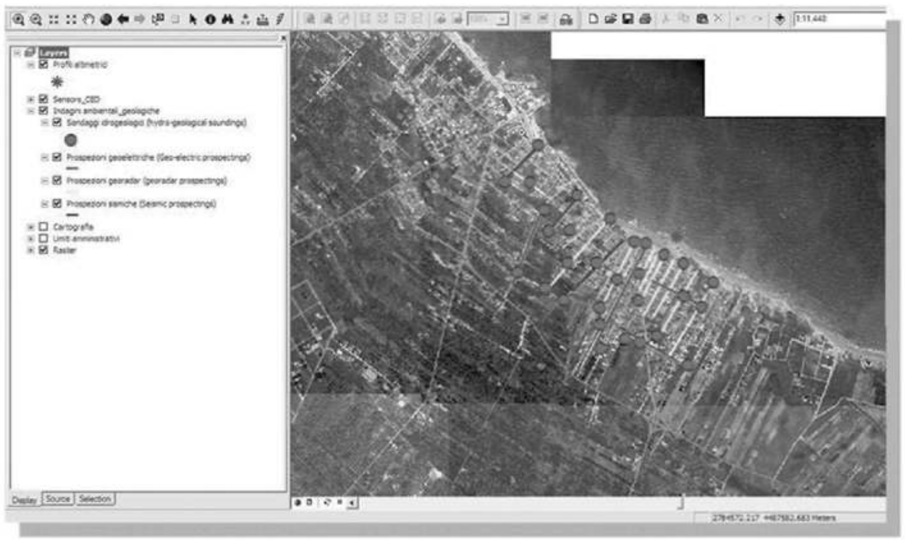

Figure 8.15: Layer raster of the "Study zone" with a selection of environmental and geological images developed by the Municipality of Lecce with another project. They consisted of: hydro-geological soundings and geo-electric, georadar and seismic prospectings.

Characteristics of the dynamic WebGIS 8.5

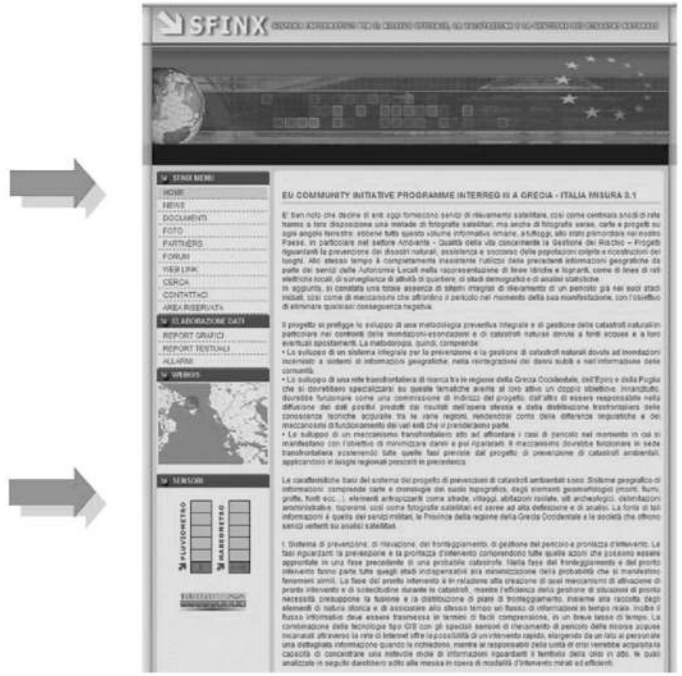

Figure 8.16: The WebSite

The particular characteristic of the system is constituted by dynamic WebGIS which is accessible to all through the home page of the WebSite *www.SFINX.unile.it*.

As it is shown from figure 8.16, the visitor of the site can have direct access to dynamic WebGIS and can also very quickly watch the parameter level which is recorded by the sensors in real time (in our case through two small columns connected to the pluviometer – mm. of rainfalls – and to the mareometer – positive or negative difference of level in mt. compared to zero l.m.m.).

Both in the home page and in the dynamic WebGIS, the recorded from the sensors level and transmitted in real time, is displayed in the site and the updating is being made in a continuous mode with the automatic refresh function, without the need of the user to update the current web page.

This is significant for the accomplishment of the target, easily reproducible even in different fields and not only in terms of "civil protection". It can be applied to an unlimited number of environmental sensors and even more in the telecontrol via Internet.

With regard to WebGIS, it is necessary to state that it has been created in a full open-source environment, taking advantage of the "mechanism" MAPSERVER, originally developed in the mid-90s at the University of Minnesota, within the framework of PMAPPER of Armin Burger. The graphic interface can be seen in figure 8.17:

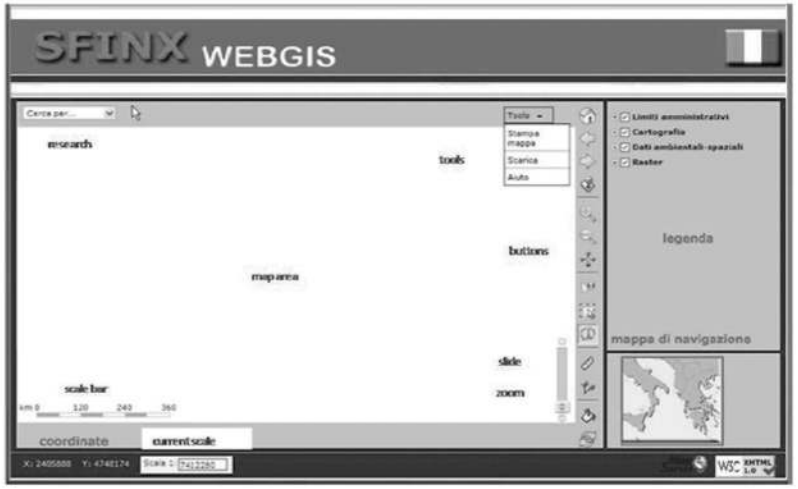

Figure 8.17: The graphic interface

While in the subsequent, it is remarked: on the right (in the legend), after the "static" layers, are listed the environmental space data (dynamics); in the area of the map, in the upper side, they are partially seen "the small columns" which are connected to the two sensors.

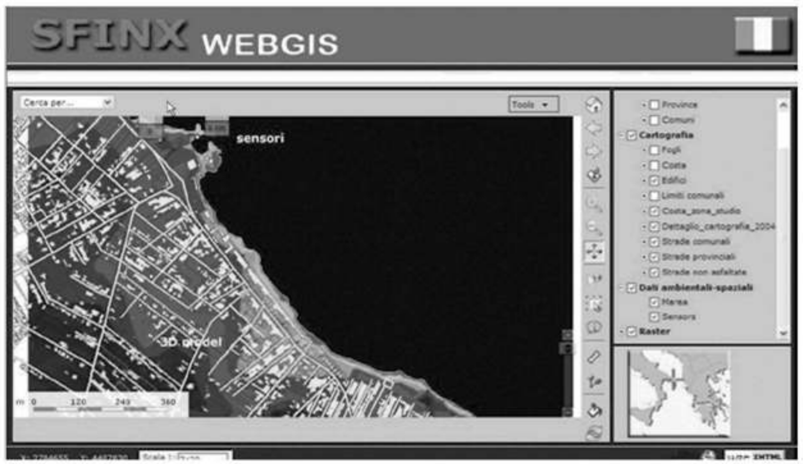

Figure 8.18: The graphic interface

In figures 8.18-8.20, a representation of a possible calamitous incident is displayed.

The **"**generic visitor" on the web, in order to follow a flood incident, has activated static layers such as the coastline, the buildings and the existing roads in the zone of study and dynamic layers such as small sensor columns and the horizontal representation with colours of the territory on a tridimensional model, created on the basis of space information extracted from the existing cartography and verified on the territory.

For a verification of the dynamic WebGIS function, the "simulator" has been introduced which is capable of, as already mentioned before, altering artificially the rates of the tide by increasing them progressively, in a way that would cause an inexistent flood.

The effects in the WebGIS are detailed depicted, in the three images that follow, without having the need to update the web page: the progressive process of the blue colour of the sea is remarked, overcoming the bright line which represents the coastline before the incident.

Figure 8.19: Representation of a possible calamitous incident

Figure 8.20: Representation of a possible calamitous incident

Figure 8.21: Representation of a possible calamitous incident

The use of dynamic WebGIS in Internet could, as it is easy to perceive conclusions, permit the employees in the ministries of the civil protection Service to undertake all operational decisions in order to prevent risks for the population and organize the assistance.

However, the great innovation comprises the continuous information that the population itself can receive by connecting to Internet from its own house, from laptops, palmtops or mobile smartphones, assessing in this way on a continuous basis which areas could be "secure" to approach and the road networks that are not already at risk.

From the examination of the phenomenon in action, the number and the location of the buildings implicated in the flood are also appreciated and, by noting the heights of the buildings themselves, additional data is assessed which is useful considering assistance.

In the specific case-study the only environmental parameter modified in the simulation has been that of the sea level, nevertheless, based on a precise tridimensional model of territory, it is always possible to study the effects resulting from the variations of more parameters.

Finally, there is no point in underestimating the targeted use of the "simulator", which is an instrument that, by verifying a calamitous incident and noting the current environmental parameters, is able to reproduce a scenario of possible development of the phenomenon and, accordingly, give the possibility of undertaking with noticeable speed all the useful decisions for the restraint of risks for the population and the consequent reduction of damages, functioning indeed as a fundamental contribution to the management of the Decision Support System (D.S.S.).

Chapter 9
Italian coastal erosion and the study of Casalabate in the province of Lecce

Anna Trono
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Contents

Introduction 9.1

Natural risk is defined as the damage expected from a hypothetical scenario triggered by natural phenomena or happening subsequent to a natural event. Natural phenomena that are a source of risk for humans and the environment can be divided into two main categories depending on the causes: endogenous phenomena and exogenous phenomena. The former are capable of unleashing enormous quantities of energy from inside the Planet, and manifest themselves essentially as earthquakes and volcanic eruptions; exogenous phenomena, such as landslides and floods, accelerated erosion (of beaches and river beds), etc.; these are often, but not necessarily linked to extreme meteorological events and act on the earth's surface, tending to flatten the landscape. Such phenomena are clearly an expression of the internal and external dynamics of our Planet and represent the natural evolutionary processes of the terrain. However, by interacting with human components (population, settlements, infrastructure, etc.) they frequently determine risk conditions. (ISPRA, 2007, p.1233)

Floods, landslides, instability of the coastline, abrupt subsidence due to the presence of cavities in the subsoil, and those natural events which are generally grouped together under the heading of hydrogeological phenomena are the results of interaction between meteorological events and the geological, morphological and hydrological environment, in which humans play an important role. Clearly, natural phenomena can cause disasters but more often the actions of people make them more severe. A disaster can become a catastrophe because of human factors and/or inadequate risk management and a lack of preparation in responding to the event.

The geological conformation of Italy for example, can be considered responsible for hydrogeological risk and serious damage, in addition to this, factors linked to human activities must be added, such as the gradual abandonment of mountain areas, the failure to maintain slopes and drainage works, the presence of settlements in flood plains or on unstable terrain, and the intense exploitation of the coasts for tourism and industrial purposes, one aspect of which is the demolition of the dunes to make way for bathing centres, holiday camps and marinas for pleasure craft.

Against this background of environmental "disorder" resulting from increasing exploitation of the coastal strip, adverse meteorological events periodically occur that are characterised by heavy rains, swollen rivers and sea surges, all of which worsen the deterioration not only of the coastal strip. Events that the mass media often portray as natural catastrophes – unpredictable because of their "exceptional" nature – are indeed catastrophic, but not exactly "unpredictable". If, for example, one considers the last 40 years, it is clear that such phenomena have become increasingly frequent in the Po river plain: the Polesine flood of 1951, the destruction of the Venetian "murazzi" (sea defences) in 1966, the exceptional "high waters" in Venice throughout the 1960s. These are just some of the most famous events in a long period of generally bad weather, responsible for the destabilisation of the coastal strip, which has clearly been affected by the periodic variations in climatic conditions but also by the ever-more intense human impact on the natural environment.

This chapter analyses some examples of human pressure responsible for coastal erosion, indicating possible measures to remedy the situation.

9.2 Coastal erosion

Beaches are delimited on the seaward side by a demarcation line (the shore line), which from a morphological point of view represents a form of terrain dependent on a delicate equilibrium between the action of the sea and the availability of sandy sediment along the coast. This equilibrium is particularly sensitive to certain phenomena that have assumed worldwide importance and are structurally linked to the constant human pressure on the coastal strip and its use as a form of economic asset.

We allude here to the creation of coastal infrastructures that have affected longshore drift (wharves, ports, sea walls, emergent breakwaters) and have caused the loss of sediment from the beach as a result of wave motion (erosion). Human activities have reduced the flow of sediments from water courses (dams, diversions, dredging of the river beds, structures to counteract soil erosion, the paving over of roads and other surfaces). Urbanisation has led to the dismantling of natural defence structures (posidonia meadows, sand dunes, autochthonous coastal vegetation). There has been senseless destruction of the coastal dunes and relative psammophile vegetation, caused by the building of roads and dwellings, reducing the resilience of habitats to erosion processes.

The strong demand for coastal space has grown and has accentuated the periodical or seasonal retreat of the coast line.

The impoverishment of the input of solid material from rivers to the coast as a result of the indiscriminate removal of material from river beds; subsidence accentuated by the extraction of hydrocarbons and water in areas too close to the sea (for example in the Po delta and the Lagoon of Venice) provide a framework in which the rapid destabilisation of the coastal environment can easily be explained.

Italy is heavily affected by natural events, especially those associated with hydrogeological risk (landslides, floods), which are second only to earthquakes in terms of the damage they cause (Barberi, Santacroce, Carapezza, 2004, p-51). The Italian "hydrogeological disaster" is due to the soil being used in a way (as a result of demographic and socio-economic growth) that ignores the characteristics and the delicate hydrogeological equilibrium of Italian territory. The process of urbanisation and the uncontrolled growth of residential and industrial areas in low-lying regions in

the post-war period are well-known. This form of development has had undeniable socio-economic benefits but has led to large stretches of territory being concreted over, with increasingly invasive structures (dikes, dams, canals, drainage systems and walls), and has prevented the evolution of the territory in accordance with its natural dynamics.

The blight of the coastal environment has consequently emerged in all its seriousness. One of the most obvious aspects of this disaster has been the retreat of the coastline and the growth of erosion, which can have devastating effects on sea-coast interactions and create the conditions for a new dynamic equilibrium that is quite different from the natural state before the intervention of human beings. The coastal environment is a highly complex system, closely linked to the river network which supplies the beaches with solid material, compensating for the destructive action of the sea.

A well-documented example of this situation is the coastal strip of the northern Adriatic, which is affected by progressive degradation, seen in the retreat of the coastline. This is generated by the action of waves during rough seas, the main factor responsible for the destabilisation of the coastal strip, already compromised by intensive human activities along the coast and the rivers that flow towards it. Such activities have resulted in harmful interference with the natural environmental equilibrium, a phenomenon which began to have devastating consequences in the 1950s and 60s after a long period of stability of the coastal area (Marabini, 2000).

Recent studies conducted by ISPRA indicate that for about 30% of Italian territory the erosion risk is above tolerance levels[1]. 20% of the Italian coastline (8,350 km) suffers from a clear state of erosion and is at risk of flooding. Since the 1970s sandy coasts have been in retreat. Currently about 1,500 Km of the 4,600 km of low-lying coasts (including coastal plains) are threatened by rising sea levels; they suffer from a clear state of erosion and are at risk of flooding. This means that the problem affects 20% of the roughly 8,350 km of total Italian coastline (see Figure 9.1).

The problem of coastal erosion, as stated by the Servizio Difesa Coste (Coastal Defence Service) of Ispra, affects many parts of the Italian coastline.

Studies conducted on long-term trends show that for the whole of the North-Adriatic coastline there has been a reduction of gently-sloping stretches and an increase in steep stretches. We are thus looking at a situation that is evolving negatively. Erosion has developed gradually via a continuous increase in the slope of the seabed, which has led to the retreat of the coastline (Marabini, 2000).

The problem has also manifested itself with violence along the coastline of Basilicata. It was Enea that drew attention to this situation, showing that it is affected by serious problems of erosion; the stretch of coast on the Ionian Sea in South-western Basilicata adjacent to Puglia (and the beach running from Metaponto to Scanzano in the province of Matera in particular) appears to be highly compromised. The main cause of the retreat of the coastline is a deficit of material resulting from reduced in-

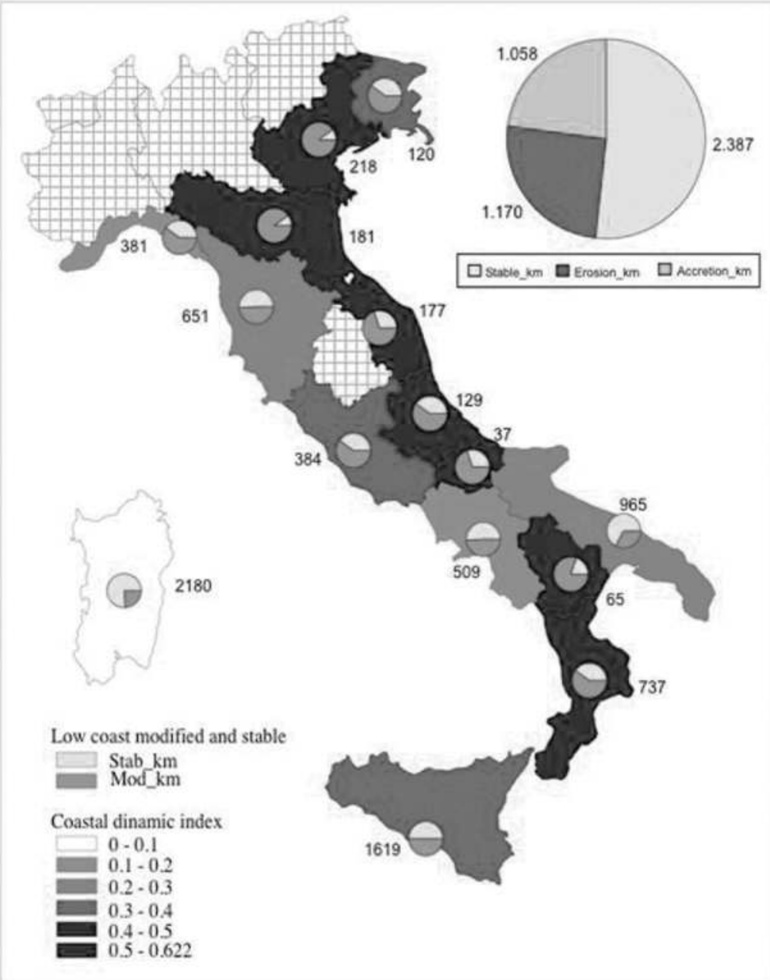

Figure 9.1: Variation > 25m of the low-lying coastline and the index of coastal dynamic Fonte, Apat, Environmental Data Yearbook, 2007

puts from the main water courses, which studies indicate has intensified particularly in the last ten years. On the main rivers 18 dams and weirs have been constructed with the aim of trapping and storing water for agricultural, industrial and civil use.

In Sicily 70% of the 865 kilometres of coastline between Capo Passero and Capo Feto (522 areas) are at risk of erosion and of these, 105 kilometres (234 areas) are in a serious situation. According to the monitoring carried out by regional officials, the island's coasts have retreated visibly in the last thirty years and an average of 60 metres of beach has been devoured by the sea. In many places 20% of the beach has

already disappeared, with 135 metres of erosion in Patti.

In Puglia, in the Salento peninsula and particularly the Bay of Gallipoli along the Ionian coast and the stretches of coast between Torre dell'Orso and Torre S. Stefano and between Casalabate and Torre Rinalda on the Adriatic, coastal erosion has devoured the coastline, causing the disappearance of bathing beaches and tonnes of sand, which will need to be offset by taking sand from other parts of the coast of Puglia. The areas indicated extend inland for 3 Km, and offshore for about 2 Km. In general the morphology of these areas is fairly compromised due to the coastline's tendency to instability, which is worst in those places where the coastline has been most intensively exploited for tourism (Refolo, Sterponi, et al, 2007).

In Gallipoli the coastline is seriously compromised by intensive and devastating use by people. To provide tourists with every single imaginable bathing service, operators have not hesitated to systematically flatten the dunes, resulting in serious reductions in their area and the disappearance of psammophile vegetation (see Figures 9.2 and 9.3).

Figure 9.2: Flattening of dunes in Gallipoli

Figure 9.3: Flattening of dunes in Gallipoli

Figure 9.4: Erosion of the coastline along the coast near Gallipoli

The massive use of the coastal strip of Salento, and in some cases of the beach itself (see Figure 9.4), has contributed significantly to the modifications of the coastline seen in the last few years.

Figure 9.5: "Beached" homes on the dunes in Porto Cesareo

Figure 9.6: Overall picture of Porto Cesareo

Erosion has also been favoured by the lack of controls on the use of farmland near the coastline, the covering of surfaces with concrete and the reduced presence of containment structures such as dry-stone walls, which, by no longer holding back waters that otherwise flow to the sea, increase their erosive effects.

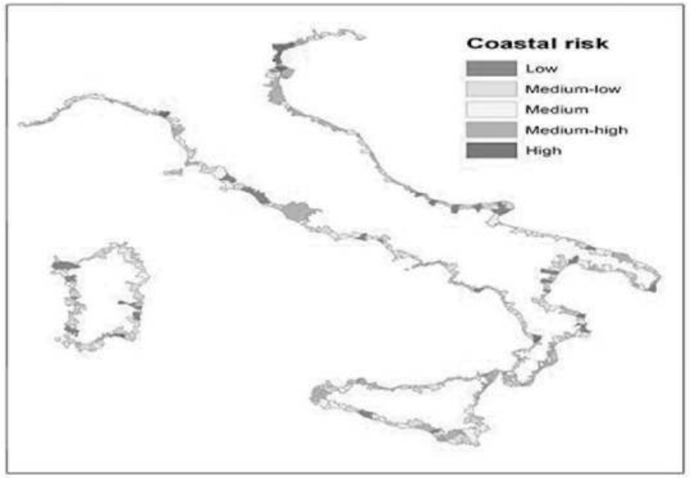

Figure 9.7: Map of coastal risk by municipality Fonte, Apat, Environmental Data Yearbook, 2007

The assessments and predictions of risk conditions in Italian coastal areas produced as part of the *Eurosion* project are not very positive either. Eurosion formulates numerical indices, necessary for the integrated management of the coastal areas, and proposes measures to combat the problem. It predicts that 3.17% of the national territory of Italy (954,379 hectares), involving 9.12% of the population (5.3 million inhabitants), will potentially be affected by erosion and flooding in the next 100 years. In addition, it has estimated that within this area, 336,746 ha (equivalent to 1.12% of the national territory) with a population of 2,133,041 inhabitants (i.e., 3.69% of the national population) will be exposed to high or moderately high risk (see Figure 9.5).

9.2.1 A case study: Casalabate in the province of Lecce

Casalabate, in the North of the Municipality of Lecce is a striking example of an area affected by serious hydrogeological disturbance. The study area is a stretch of coastline in the northern part of the Municipality of Lecce: the main settlement is Casalabate.

Casalabate lies about 15 Km North of Lecce. The coastal area has been heavily affected by human activities since the 1950s, and practically all the buildings were constructed without authorisation.

The physical landscape of the study area is mainly flat. There are two distinct subareas. The higher one is 12-15 metres above sea level and is divided from the lower area by a clear escarpment running roughly parallel to the current shoreline. The whole of the urban area of the resort of Casalabate slopes down gently towards the sea, from a height of 15-20 metres above sea level inland to less that than 1 metre above sea level near the shore.

The lowest-lying areas are a few metres above sea level. Near the shore these areas are covered with beach deposits, together with the remains of the dunes and marshes, all of which are affected by erosion or removal by human beings. Consequently the original karst features have been partially re-exposed.

In the stretch closest to the shoreline the modifications made by humans over the last 50 years have largely obliterated the natural morphology of the area, which today is clearly visible only in very small patches.

Along the shore there are only sandy beaches. There is just one line of dunes, in many places deliberately demolished, at the foot which is a modest escarpment, shaped by the action of the waves. The crest of this residue of dunes, partially eroded, is a few metres above sea level.

The mainly carbonatic composition of the underlying rock (which outcrops in places) has clearly favoured the development of karst features in the deeper Mesozoic calcareous rock and para-karst features in the quaternary calcarenite rocks closer to the surface.

The most important environmental processes active in the study area affect the strip closest to the shoreline and concern the action of the sea and karst processes.

These processes are conditioned by the intense human pressure, which is neither coordinated nor planned, consequent on the near total urbanisation of the coast which has taken place over the last 40-50 years. The area is clearly at risk.

In the urban districts closest to the shoreline there is a high risk of subsidence due to the presence of cavities. The risks affecting the area are hydrogeological. The main causes lie in the obstruction of watercourses, the poor functioning of the drainage network, and the widespread problem of hydrogeological disturbance arising from unregulated building. It is an area at risk because it is subject to intense coastal erosion; there is serious damage to buildings from repeated cases of subsidence in the last 10 years. Many buildings have been abandoned and declared unsafe.

Significant soil subsidence due to cave-ins of underground cavities was seen in Casalabate in 1993 and 2000. These episodes took place in an area blighted by unauthorised building and affected some civil dwellings. In general, the morphology of this area is fairly compromised due to the general instability of the shoreline, which tends to be most serious where the coast has been subject to intensive use for tourist purposes, often unregulated.

Indeed, the massive use of the coastline and its immediate hinterland has contributed significantly to the modification of the coast seen in the last few years.

To this may be added the fact that in the town of Casalabate itself there are no structures for channelling or draining rainwater falling on the road network. Such waters often end up directly entering the subsoil through wells in the surface (such as the one in Piazza San Pio).

Figure 9.8: Buildings evacuated and declared uninhabitable in Casalabate

These point discharges of runoff waters going directly into the subsoil inevitably increase the local erosive force of subterranean waters, especially in those areas where the calcarenite rock is particularly crumbly (e.g. fossil dune deposits).

Figure 9.9: Upheavals of the land and homes at risk Casalabate

The data currently available are not sufficient to create any genetic or evolutionary model for these phenomena. Regarding coastal dynamics, there is a clear tendency for the coastline to retreat. Near Posto dei Trepuzzini a coastal defence structure has been built. The tendency for the coastline to retreat is particularly pronounced in some places.

Figure 9.10: Urbanisation of the coastline

Along the coast near Casalabate the system linking the beaches, the dunes and the area behind them has become less flexible due to widespread urbanisation; this has reduced the capacity of the system to adapt to new environmental conditions (see Figures 9.6, 9.7 and 9.8).

9.3 Possible measures to contain and control coastal retreat

The erosion that continues to afflict much of the otherwise beautiful Italian coastline, causing untold damage to the environment and the economy, is present to a lesser or greater extent in all countries with coastlines and can be contained by means of three types of intervention:

- *high geo-environmental impact* (with use of barriers and breakwaters set at right angles to the coast; construction of sea walls for the diffraction of wave motion and coastal currents);
- *medium geo-environmental impact* (with replenishment of sand on the stretches of coast subject to erosion by distributing sediments taken from elsewhere; this entails dumping sand of suitable grain-size along the length of rivers that discharge at sea);
- *low geo-environmental impact* (including the construction of submerged breakwaters i.e., artificial barrier systems, and the recovery of typical vegetation along the backshore to act as a "sediment trap").

More specifically, the kinds of measure to be implemented may include *protection of inner coastal areas* by fencing off wetlands, protection of coastal dunes by setting up Nature Reserves or Protected Areas, and tree-planting to form sediment traps. A

fundamental measure to enhance efforts to reinforce the coastline consists in the recovery of the ancient line of dunes. The dunes are reconstructed by deposition of suitable sand and consolidated by transplanting large quantities of grasses and shrubs, especially psammophile plants and tamerisks, characteristic of coastal areas.

Other measures serve to enhance *protection of beach areas* by means of: beach nourishment by distribution of sediment; barriers or groynes & jetties i.e., piles of blocks or "armour units" (rarely cemented together), attached to the shore and almost always perpendicular to it. Examples include the shores of Pellestrina and Cavallino (Venice Lagoon). Pellestrina is the most eloquent example of the effects of erosion: the beach had completely disappeared and the width of the island had been reduced, in some stretches, to a few dozen metres. This then was a coastline exposed to high risks, subject to seawater flooding and damage to the rocky shoreline. To counter these phenomena, a series of reinforcement measure were adopted which included: the creation of a new, wide beach, more than 9 km long, using nearly 5,000,000 cubic metres of sand. The new beach is protected by 18 groynes set perpendicular to the coast, connected to each other by a submerged breakwater running parallel to the coast, 300 m from the shore, along the entire 9 km of coastline. Other measures include breakwaters composed of lines of armour units such as "tetrapods" a short distance offshore running parallel to the most frequent wave front. The beach nourishment measures in Cavallino entailed the broadening of 11 km of beach, with the input of more than 2,000,000 cubic metres of sand, taken from the sea bed about 20 km from the Venetian coast. The new beach is protected by 32 breakwaters made of rocks, running perpendicular to the coast, with the distance between them, dimensions and orientation all designed to create the most effective resistance to erosion. The beach nourishment was conducted from South to North and required the prior construction, every 300 m, of all the breakwaters – made of boulders and gravel – and then the laying of sand between them.

Other measures ensure the *dissipation of the wave motion* by means of emergent and/or submerged barriers, i.e., systems of artificial barrages, and beach nourishment via distribution of sediments.

Traditional rigid structures, such as rubble-mound breakwaters and sea walls, have proven to be inadequate in providing comprehensive solutions to the problem of erosion. Traditional heavy structures such as sea walls and breakwaters entail high maintenance costs and do not always succeed in preventing the erosion of the coastline; on the contrary in some cases they even accelerate it.

In many areas of the European Union the national and regional authorities have begun to realise that it is quite useless to build artificial barriers to prevent natural erosion. In some places they have opted for a policy of "managed retreat", which consists in gradually reducing the presence of human activities in those parts of the coastal strip that will one day be lost beneath the waves sea. In the regions in which managed retreat is not practical (for example in areas of high economic or historic value), the authorities have frequently opted for light coastal protection instead of traditional dykes and breakwaters.

Technically and environmentally superior are methods of beach nourishment using marine gravel or sand[2]. An example of this is the coastline of Pisa (Marina di Pisa, San Rossore etc.), which began to show signs of erosion after the Unification of Italy as a result of modifications to the mouth of the Arno and the significant reduction in the transport of solid material following the installation of drainage infrastructure in the forests of the river's catchment area in that period. The town of Marina di Pisa had been defended since the beginning of the 20th century with rocks on the seaward side of the coast highway, and since 1950 with emergent breakwaters, which were found to no longer provide any real protection for the town and its infrastructures. To counter the erosion of the seabed beyond the emergent breakwaters, the Municipality and the relevant local boards planned recovery measures based on beach nourishment with gravel.

Beach nourishment with fossil sands today represents the best way to tackle the problems of coastal erosion and the one with the least environmental impact. In Emilia Romagna it has been estimated that beach nourishment needs to be implemented every five years on average. Marine sand deposits, such as those identified 60 km off the coast of Rimini at a depth of 50 metres thanks to Beachmed-e (the European Union project for the defence of the coastal areas of the Mediterranean) constitute a strategic reserve of high quality sand for future beach nourishment measures[3].

In the Flanders region of Belgium, the authorities are trying to adapt the management of the highly built-up coastline to its natural dynamics. Where possible, they are trying to manage the problem of erosion in a more subtle, nuanced way, eliminating the protection barriers and replacing them for example with sand dunes covered in vegetation that are able to naturally absorb the energy of the sea. This solution is being adopted for the Adriatic coast of the Salento (Casalabate and San Cataldo near Lecce).

A new approach to control the coastal erosion and the safeguard of the beaches involves drainage. This system seeks to lower the water table near the shoreline, with the consequent stabilisation of the sand and a noticeable reduction in backrush, thus favouring the deposit of sediment on the seashore[4].

9.4 Challenges and changes

Of all the issues relating to the defence of the coastal strip, that of marine erosion - together with the measures for the reconstruction of the coastline that it requires - is one of the most complex, in terms of environment, economics and law; such intervention entails considerable costs, due to the difficulties of obtaining suitable sand). And it is likely to become even more important in the future, due to the growing frequency of floods and rising sea levels linked to the well-known question of climate change. (Garzia 2007, p.2).

From the environmental point of view, there are problems linked to the reconstruction of the coastal strip. Problems of economic nature include the interests of companies operating in the tourist sector who are involved in beach nourishment projects and the effects of the measures on coastal navigation and maritime traffic in general.

In legal terms the complexity derives from the need to tackle the question on an international level and from the plurality of interests (public and private) which are inevitable affected by the implementation of beach nourishment projects.

Saving the coastline is obligation not just for the bodies who are charged with tackling the problem: an adequate knowledge of the behaviour of the coastline is indispensable from the point of view of the construction of defences, but greater awareness among the general population of the need to reduce our environmental impact can also help to ensure that the coast does not retreat too rapidly.

Taken together, the various forms of vulnerability involve significant retreat of the coastline and serious environmental and economic damage. However, the processes of coastal erosion are common to all Mediterranean coasts and require coordinated, comprehensive, long-term intervention strategies to conserve and protect a habitat that is increasingly fragile and at risk.

The issue of coastal erosion constitutes a priority for the European Union, which has conducted detailed studies and produced recommendations on Integrated Coastal Zone Management (ICZM). Considerable funding is now being allocated to the solution of this problem. The Eurosion project demonstrates that in the five-year period from 2000 to 2004, EU spending on coastal defence has increased by 28% and is now running at an estimated 3.2 billion euros a year. More than half of this sum has been spent on "rigid" engineering projects, which generally speaking have had the effect of simply shifting the problem to some other stretch of coastline. Some regional projects have been conducted in collaboration with other European countries.

Coastal erosion is also at the heart of measures adopted under the Integrated Coastal Zone Management Plan, which represents the main means by which the Emilia-Romagna Regional authorities are attempting, in line with European guidelines, to comprehensively tackle the many problems that affect the coastal system of the region. It is a tool that serves to steer all activities that are practiced on the coastline towards full environmental sustainability and concerns not only erosion processes but also pollution of the waters, protection of the typical natural habitats of the marine areas, infrastructure, residential areas and tourism.

It is a good idea to focus on four points, as the Eurosion project suggests, the first of which is *Restoring the sediment balance and providing space for coastal processes*, but also to *Make responses to coastal erosion accountable*. The management of coastal erosion should move away from piecemeal solutions towards a planned approach based on proven principles, above all by optimising investment in the items at risk, increasing the social acceptability of the measures and keeping options open for the future. This approach should be guided by the need to restore coastal resilience and the Equilibrium Beach Profile and should be supported by a Coastal Sediment Management Plan. A further recommendation is to *Internalise coastal erosion cost and risk in planning and investment decisions.*

It is just as important to *Strengthen the knowledge base of coastal erosion management and planning.* Basic knowledge of the planning and management of coastal erosion needs to be enhanced via the development of strategies for managing information. These should include the dissemination of "best practice" (what works and what doesn't), promote an active approach to data and information management, specifying the offices that are responsible on a regional level.

The management of the problems and risks of coastal erosion in Italy require the drawing up of a Strategic National Plan for Integrated Coastal Zone Management.

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[1] *These are approximate estimates, which refer to the whole of Italian national territory. Regional projects are seeking to modernise and harmonise the information by ensuring that the data reflect the real situation, as part of the SIAS Project, coordinated by the APAT (regional environmental protection agencies) with the participation of the CRA and JRC research agencies and the Italian regional authorities.*

[2] *For some time now the Marches-based company Eurobuilding SPA has been conducting research on this state-of-the-art technique, with surprising results. The company operates in the fields of Environmental Engineering, civil and industrial construction, infrastructure and environmentally friendly construction. Its partners in the research are the Bologna-based Ismar Geologia Marina - CNR (marine science institute), and the Nomisma SpA company.*

[3] *The objective of the Beachmed-e project is to develop strategies for the adoption of coordinated measures on a European level to conserve and protect the coastal habitat, which is increasingly fragile and at risk throughout the Mediterranean. It involves the Italian Regions of Lazio, Liguria, Toscana and Emilia-Romagna, the French Conseil General de l'Herault and Direction Regionale de l'Equipement Languedoc-Roussillon, the Spanish Generalitat de Catalunya, and the Greek Regions of Crete and Eastern Macedonia-Thrace.*

[4] *These studies were conducted under the aegis of the Italian ministerial project known as "Piani di potenziamento della rete scientifica e Tecnologica" Piano Ambiente Terrestre – Cluster C11 – B Progetto n. 9 "Drenaggio delle Spiagge" – BDS (RIS 1), co-financed by MIUR, the Italian ministry of education and research. The work benefited from the contribution of researchers from the Politecnico of Bari, the University of Calabria, the University of Salerno, the University of Barcelona, the Institute of Geology in Copenhagen and private companies operating in the sector.*

Bibliography

[1] APAT. Agenzia per la protezione dell'ambiente e per i servizi tecnici (2007), Key Topics Environmental Data Yearbook. Environmental Protection Agencies Of The Regions And Autonomous Provinces

[2] Barberi F., Santacroce R., Carapezza M.L., 2004, Terra pericolosa, Pisa Edizioni ETS.

[3] Dacquino C., Mandrone S., Vicini C. (2007), Trend e mappatura del rischio lungo le coste italiane secondo la metodologia del progetto EUROSION. Ministero dell'Ambiente e della Tutela del Territorio e del Mare. Palermo 27/28 Giugno.

[4] European Commission (2004) Living with Coastalerosion in Europe. Sediment and Space for Sustainability Results from the Eurosion Study.

[5] Garzia G. (2007) "L'erosione costiera e gli interventi di rinascimento del litorale: il quadro giuridico attuiale e le prospettive di riforma" in Federalismi.it n. 15, pp. 1-17.

[6] Istituto Superiore per la Protezione e la Ricerca Ambientale. ISPRA (2007), Annuario ambientale. http://annuario.apat.it

[7] Istituto Superiore per la Protezione e la Ricerca Ambientale. ISPRA (2007), Environmental Data Yearbook http://annuario.apat.it/annuario_en.php.

[8] Marabini F. (2000) "Effetti sull'erosione costiera dei fenomeni climatici recenti: l'esempio del litorale Nord Adriatico", in Mare e cambiamenti globali, pp. 119-134.

[9] Özhan, E. (1995) "MEDCOAST initiative: contributing to environmental management of coastal and sea areas of the Mediterranean and the Black Sea", J. Ocean & Coastal Manag, Elsevier, 26, no.1, pp.73-76.

[10] Özhan E. Present Status and Future Perspectives of Coastal Management in the Mediterranean. International Center for the Environmental Management of Enclosed Coastal Seas. http://www.emecs.or.jp/englishver2/topics/tech2002/ozhan.htm

[11] Refolo G., Sterponi L.,.Moschettini F., Urrutia C., Ciurlia S. , Perrone R. (2007) Sistema di monitoraggio satellitare delle aree costiere della Provincia di Lecce. http://digilander.libero.it

Chapter 10
Good practices and Case Studies

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Contents

Introduction 10.1

This chapter presents the most important best practices that are similar to the **SFINX** project. Several methodologies have been proposed and designed around the globe, aiming to develop complete systems for the prevention and management of flooding events. Most systems that emerged focus on the disaster mitigation and the recovery of the areas of interest. The literature reports projects, which use the meteorological variables as inputs to systems, along with topographic and hydrological inputs for better predicting modeling of the flooding events, there have been proposed stochastic and deterministic methods for predicting floods and recently geographical information systems for the display of the phenomena to digital maps.

The next section will provide statistics of the impact of natural disasters in a global scale as well as in Greece. In section 2, a description of specific flood prevention projects will be presented, and section 3 will elaborate on good practices for the disaster recovery and mitigation.

Natural Disaster Statistical Data 10.2

The "International Strategy for Disaster Reduction" recorded the natural disasters that every continent faces during the period 1991-2005. The statistics show that flooding events are the most common phenomenon with 49%. In figure 10.1 we can observe the distribution of the natural disaster types globally [1].

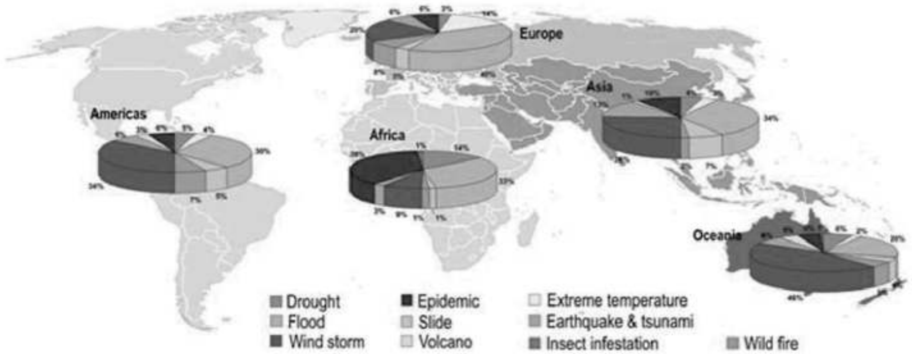


Figure 10.1: Global Distribution of Natural Disaster by type

Climate change is responsible for the increase of natural disasters. Every year, lives are lost due to the presence of such physical phenomena across the globe.

The largest percentage of deaths caused by natural disasters in Europe is related to the hydro-meteorological phenomena as opposed to the biological and geological phenomena [1]. In Greece, according to the Secretariat of Civil Protection, flooding events increased to forty one in 2007 from twenty five in 2006 [2].

	Hydrometeorological	Geological	Biological
Africa	1.30	0.37	7.31
Americas	6.23	0.31	1.13
Asia	5.19	7.54	0.39
Europe	4.77	0.23	0.03
Oceania	1.92	5.06	0.62

Figure10.2: Average of deaths per million inhabitants per continent

Furthermore, the financial impact of natural disasters is quite large. More specifically, according to the "International Strategy for Disaster Reduction", the financial damage due to natural hazards during the period of 1991-2005 in Greece was estimated to 8.09 billion dollars.

The correct encounter of natural hazards implies their prevention and identification at an early stage. Technology may assist towards this direction.

The literature presents some good practices for the encounter of natural hazards. Universities, companies and public authorities have collaborated in order to provide solutions against natural disasters.

10.3 Systems for Prevention, Identification, Encounter and Management of Natural Disasters

In this sub-section, a variety of solutions is presented that target the prevention and management of flooding crises as well as the recovery of the flooded areas. These solutions have been developed for various places in Europe, including rivers and shores.

European Flood Alert System (EFAS) 10.3.1

After the floods at the river banks of Elbe and Danube in August 2002, the European Committee announced the creation of a European Forecasting Alert System (EFAS). The EFAS has the capability of simulating medium scale floods across Europe, using a three to ten days head start. The system gathers information in order to warn countries upon flooding events, as well as to support them to do preparation activities before these events occur.

Since the beginning of 2003 the Joint Research Centre (JRC) of the European Committee, is developing a prototype in cooperation with institution of the member states. The JRC already has the previous experience of the European Flood Forecasting System (EFFS) project [4]. The EFAS is based on the LISFLOOD model [5], which has been implemented in order to simulate flood in large banks of European rivers. This particular model is distributed in space, enabling the inclusion of various changes into the simulation, such as changes in land use. The LISFLOOD model is grid-based where the typical size of each grid cell is one per kilometer. However, the model may run using larger or smaller analyses if required.

The actions that can be simulated with this model include:

- Interception of rainfall from flora (Int)
- Evaporation of the intercepted water (EW_{int})
- Drainage of leaves (D_{int})
- Inflow and snow melt
- Direct evaporation from surface (ES_a)
- Implosion and transpiration from plants (T_a)
- Infiltration (INF_{act})
- Preemptive flow through macro-resources ($D_{pref,gw}$)
- Surface outflow (R_s)
- Gravitational vertical flow in ($D_{1,2}$) and out of ($D_{2,gw}$) of the surface
- Rapid (Q_{uz}) and slow (Q_{lz}) outflow of the surface water
- Routing of channels using kinematic wave.

The LISFLOOD system requires the input of space distributes maps in topography, on the network of the river channel, the land coverage and the depth of the land. The meteorological variables are essential: the rainfall, the possible evaporation and the annual average of air temperature.

The outputs of the model, these are the following:

- Maps for the drainage surface as a whole.
- User-defined timelines.
- Timeline average in relation to the surface that contributes for each station.

10.3.2 Modeling and Decision Support Framework (MDSF)

The Modeling and Decision Support Framework (MDSF) was created by the following partners:

- HR Wallingford
- Halcrow
- The Centre for Ecology and Hydrology
- The Flood Hazard Research Centre (FHRC)

The development of the system targeted the support of the Catchment Flood Management Plans (CFMPs) implementations, which constitute a major innovation of the following partners:

- The Department for Environment, Food and Rural Affairs (Defra)
- The Welsh Assembly Government and the Environment Agency (EA) of England and Wales.

The CFMP is a state of the art tool, which aims to the cooperation with other decision support systems, in order to locate risks and decide on policies for risk management in flooding events [3].

Initially, the MDSF provided the infrastructures for the collection and management of data taken from the places of interest, provision of guidance for the prediction of floods from the water level in the whole area of interest, calculation of the depth and the degree of floods, financial damages and impact of the phenomenon to the people and finally, a system for the evaluation of the policies and calculation of the uncertainty [6].

The MDSF contains:

- The MDSF software, which is a custom GIS tool created to work with the ArcView 3.2a.
- A manual of the software, which provides specific instructions for the use of the GIS tool.
- The MDSF Procedures that explain the functions of the software so that the users may acquire understanding of the results. The processes give advice for the correct use of the MDSF.
- The hydrological programs 'CEH Packman'.

The MDSF software provides the following functionality [7]:

- Installations for the management and display of data in space.
- Evaluation of the degree and the depth of the flood.
- Calculation of the financial damages due to floods.
- Calculation of the social impact of the floods.
- Financial evaluation of the corrosion damages.
- Presentations of the results for a range of cases, aiming to assist users choose the optimal action. Each case is a climate scenario combination, land use scenario and flood management selection.
- Procedure for the evaluation of uncertainty of each policy results.
- Development of a framework for damage comparison and social impact, which assists the users to evaluate every action.
- Storing of the results and cases.

There are several advantages of the MDSF system. Initially, it is an open architecture GIS tool, which makes it independent of the type of model used. It does not have limitations when analyzing data and it can be applied to every scale. Furthermore, it provides a valuable system for the establishment of targets at risk. Finally, it outputs financial data regarding the fore coming damage and it follow a simple approach for uncertainty.

However, the MDSF has a few weaknesses, like the use of the ArcGIS software, which is very expensive. In addition, the system does not evaluate the performance of the defensive policies, for instance, the means for credibility and failure. Finally, it does not contain tools for the procedures after the flooding incidents, which include the analyses of multiple criteria, cost-benefit analyses, e.t.c.

RAMFLOOD 10.3.3

The RAMFLOOD project has been developed by six partners from Spain, Germany, and Greece. Its main objective was the implementation and the verification of a decision support system for the evaluation of risk and the management of dangerous scenarios due to extensive floods.

The RAMFLOOD system combines environmental and geophysical data taken from the observations of the earth, satellite systems, sensors located at the areas of interest and finally, from advances simulations and methods of graphical display. The purpose is the production of knowledge, in order to contribute to the risk forecasts and damages from floods, as well as the design of effective actions for the safety maximization of infrastructure safety and human lives [8].

The RAMFLOOD system embeds quite a few innovative methods and efficient tools, which are the following:

- Advanced method for the recording, correction and integration of geographical and environmental information with at least five meters resolution.
- Analysis and distribution of high resolution data, which are acquired by optical radar measurements of earth observations. The data are classified and utilized in a flood simulation system.
- Computational methods for the fast and precise evaluation of the alternative scenarios results, which respond to the flood events.
- Innovative tools for the production of data, necessary for the simulation of floods and the display in 3D models coming from the results.
- The utilization of an Artificial Neural Network (ANN), which is the basis of the decision support system. The ANN is trained using Monte Carlo simulation tools. The ANN model constitutes the core for the real-time assistance of the authorities.

One of the most important drawbacks of this system is the integration of all the various technologies employed, without the likelihood of a malfunction. Furthermore, the ANN training requires time, in order to provide a secure prediction of the phenomenon and the production of 3D models [3].

10.3.4 ANFAS

The ANFAS project has been developed as a joined project between the European Union and the People's Republic of China. The decision support system, which is the main objective of the project, may be employed at the authorities' service for the simulation of river floods and the evaluation of fore coming damages.

Its main characteristic is the web-based environment that is based on a distributed architecture. This particular architecture has been adopted due to the easiness of the availability of the data towards the users, since data is stored on the server. This gives the opportunity to utilize mathematical models in other terminals, thus, saving valuable time. The efficient comparison of possible flood scenarios and the evaluation of the damage are accomplished through the integration of different parts of the system. These parts include:

- Remote Sensing and computational vision. The topographic data are prepared by a number of sensors, SAR, LiDAR, SPOT.

- GIS system and relative databases.
- Mathematical Hydraulic Models. The present models are the CARIMA και FESWMS (2D).
- Damage evaluation procedures. This procedure is utilized for the evaluation of the impact of the flood in the neighboring to the flood areas.
- Capability towards the users, in order to replace certain models with their own data.

The system accepts topographic, hydrological and socio-economical data, which are retrieved using the aforementioned techniques. The data gets into the databases, which exist in different sub-systems. Users may download the produced maps into their own terminals. The ANFAS corresponds to technical personnel, authorities and civilians, but not to hydraulic specialists. The system has been deployed and all the necessary checks have been made in three pilot locations. These are: the Loire River in France, the Vah River in Slovakia and the Yangtze River in China [9].

10.3.5 Short term river flood forecasting with neural networks

This project utilized the Artificial Neural Network methodology for the research and re-production of the unknown relationship, which connects the distributed rainfall with the inflow at the Beniarres dam, located in the Northeast Spain [10]. These networks aim to the real-time prediction of the floods, using the available rainfall data, which have been collected by the dam during an event. The sample data, which have been employed to the training of the networks, include two historic flood events and twenty two composite, stochastically produced patterns of rainfall and water from melted snow. The model used is the RAINGEN.

The input data for the development of the ANNs regarding the flood prediction of one, two and 3 hours were:

1) *The water inflow at the Beniarres dam.*
2) *The rainfall at the Alcoy area.*
3) *The isochronic analysis of the area, which is responsible for the dictation of the chronic delay of the flood event as it is expanded along the river.*

The output data of the ANNs for the flood prediction in a one, two, and three hours timelines were:

1) *The predicted inflows to the dam for the immediate future hours (1, 2, and 3 hours),*

2) *The proposed outflows or controlled evacuations by the Water Service, based on two different scenarios of danger for the security of the dam. These actions are functions of the present water level to the dam and the angle on the inflow hydrograph,*
3) *The future state for the fore coming hours, based on any hypothetical scenarios of the dam functionality.*

The result of this project was the development of a flood warning system with a time window of one, two and four hours, which will assist the authorities to the decision taking in relation to the dam water management and functionality, without the proposal of operations before, during and after the flood.

10.3.6 An operational decision support system for flood risk mapping, forecasting and management

This project reports that there are four basic measures that must be applied, in order to achieve flood management [11]. These are: a) the identification of the high risk areas and the creation of flood danger maps, b) the installation of reliable real-time prediction systems, so that pre-flood operation time becomes available, c) the definition of extreme situation actions, which is enhanced by the preparation and the availability of an integrated manual of such actions, the visualization of endangered areas and the selection of who should be warned, d) the development of an integrated decision support system that aims to the retrieval of information from an action team, as well as the surveillance and the coordination of actions from all teams, given that the major problem, during the appearance of flooding incidents is the lack of coordinated actions taken by all involved parties. A diagrammatic display of the decision support system is given in the Figure below:

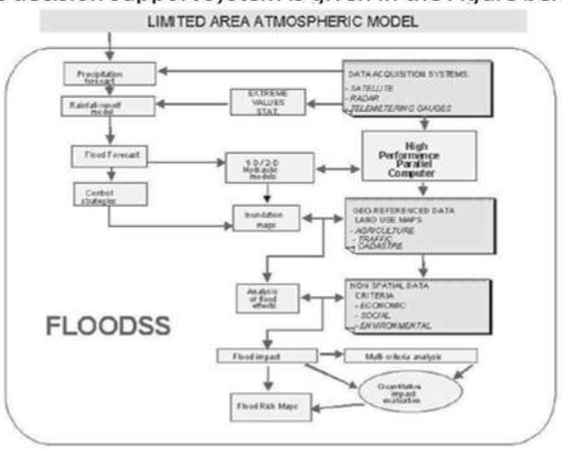


Figure 10.3: Decision Support System diagram

A dictated by the diagram, the major parts of the system include:

- **A collection of mathematical and relational models:** a) a statistical model of extreme rainfall values, b) a hydraulic semi-distributed model of rainfall-inflow (PAB), c) a basic one-dimensional flood model d) a combination of a one-dimensional and two-dimensional storm model of the areas that may flood (CVFE), d) a socio-economical and environmental model,
- **A knowledge-based system,** which manages data to and from the database. The system runs the mathematical models, organizes and compares the scenarios and guides the users to decide on the appropriate actions,
- **A database management system,** which includes a series of prime and secondary data procedures and is designed to manage optimally the historic series of the meteorological information (rainfall, temperature, e.t.c), the information concerning the rivers and so on, the socio-economical and environmental data.
- **A geographical information system(GIS)**, which cooperates with the knowledge-based system procedures and displays the geo-referenced data on digital maps,
- **A user interface**, which supports the quantitative analysis and explanation of the results.

10.3.7 An intelligent decision support system for management of floods

This decision support system includes hydro-dynamic financial and prediction models that reproduce models through their inner communication [12]. It provides assistance for the necessary actions upon danger by employing an expert system. Furthermore, it elaborates on a flood prediction utilizing artificial neural networks. The functionality of the flood control units is modeled and a description of the flood impact in space and time is exported. The flood management procedure consists of three phases, which are, the pre-flood preparation, the extreme situations management during a flood, and the post-flood operations.

The decision support system includes the graphical user interface, the knowledge-based system, the model base and the database. The dynamics of this architecture is the ability to complete the knowledge of the problem level, the model base and the display tools for the provision of assistance on a decision making. More specifically:

- **Graphical User Interface (GUI):** It has been developed with Visual Basic and is a standard data management application, which cooperates with the GIS. The GUI may communicate directly with the database, the model base and the knowledge base.

- **Knowledge Base**: The combination of the human experience and knowledge are a valuable source when integrated with the modeling tools, in order to decide on the actions to manage floods. The results of the conclusion mechanism of the knowledge base consult the model base and help on deciding the appropriate alternative for the reduction of damage in a particular area.
- **Model Base:** It comprises of a collection of tools for the hydro-dynamic modeling, the civil and financial analysis, as well as flood prediction. In order to simulate the outflow procedure the one-dimensional HEC-RAS and the two-dimensional MIKE 21 are utilized, while the HEC-FDA is used for the financial damages.
- **Database**: It contains all the necessary data related to flood management. The data are separated to topographic data, hydrological data, surface-volume curves, functional rules and infrastructure data. The GIS processes and provides topographic data related to the river and the flooded banks as inputs into the hydro-dynamical and financial models.

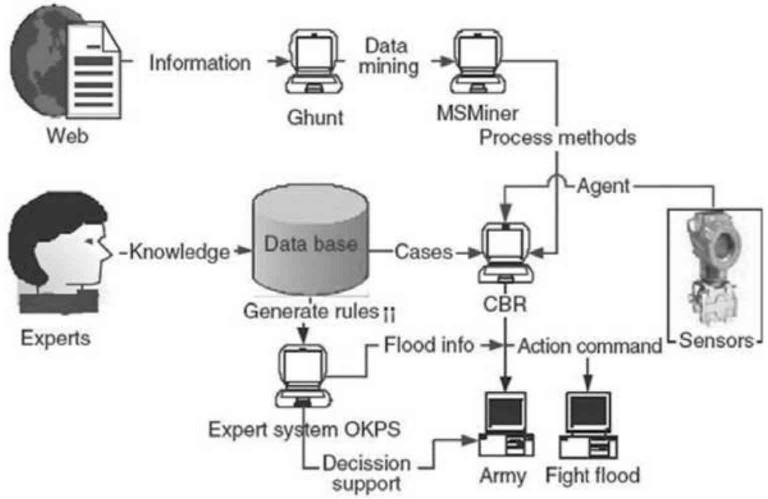
10.3.8 Flood decision support system on agent grid: *method and implementation*

This particular approach employs the Agent Network Architecture AGrIP [13]. An Agent is an entity, which monitors its surrounding environment with the use of sensors. Furthermore, it utilizes action mechanisms in order to accomplish certain goals by acting on the environment. Agents correspond to a human-based software architecture. The Agent Network is an intelligent platform, which provides the ability to independent agents to interact, targeting the processing of dynamic services on the Network. This platform was the base of a decision support system for flood, which combines a wireless sensor network for data retrieval and agent technology software used for the development of an inherent system.

The decision support system guarantees high level infrastructure for the development of distributed systems.The interaction between heterogeneous distributed systems simplifies the distribution and retrieval of data, supports the decision process and enhances the dynamic connection and disconnection of networks in an environment with mobile emergency systems.

Initially, the information retrieval toolbox, Ghunt, collects a series of information from the internet and stores them in the MSMiner data mining toolbox. Thereafter, the MSMiner automatically classifies the information, which is stored into the library of cases. When a new case of emergency occurs, the system checks the library. Then,

if the library does not contain similar emergency cases, the expert system is applied to assist on the decision according to the specified rules. As soon as the initial decisions are made, the AGrIP transmits the result to the first action party, in order to manage the flood. At the same time, the current decision is stored in the case library for future use. Upon retrieval of the instructions, the army and the police mobilize the



appropriate teams to places that are retrieved by the GIS.

Figure 10.4: Decision support system architecture

The wireless sensor network is used to monitor the rivers and transmit the real-time data to the mobile agents. After the collection of the information, the agents send the message to the control center, which possesses software for the information analysis.

Wireless Sensor Networks for Flash-Flood Alerting 10.3.9

This project aims to the assistance of the people of Merinda town in Venezuela [62]. Hydrological and geological studies show that this area is of high risk for flooding events. The primal target of the system is the collection of environmental data and the immediate warning of the local authorities and population for the danger level of a possible flood situation.The achievement of this target becomes reality with the disposal of the necessary information to a central station, in order to process and distribute the warnings.

The system must be active at all times, even when some of its individual parts seize to operate. Naturally, the system must be distributes, in order to secure its reliability in relation to the functionality of its individual components. Usually, the locations where the monitoring and data collection units are located lack of communication and electricity infrastructure. Thus, the autonomous operation of the system is essential. The use of sensors must be accompanied with easy installation at strategic points, in order to avoid mistaken recordings [64]. Finally, the system must monitor the phenomenon with minimum false alarms, in order to maximize reliability, since the alarms will be distributed to terminals and PDAs for immediate actions.

The philosophy of the system comprises of the following operations, which are exported from the challenges that such a system faces:

- Collection of meteorological and hydrological data from the places the flood initiates.
- Collection of data from the sensor monitored points.
- Export and display of the data for the assistance of decision making.
- Storing of the collected data for later use.
- Alarm signals production.
- Interaction between users and the system with portable devices.

The monitoring system runs the collection of data and employs internal connections, in order to send the data to a hub. This will enable the alarm creation, which requires a subsystem with enough computational power to analyze the incoming data. In fact, four sectors have been identified to ensure successful monitoring of the flooding events and the transmission of alarms. These are:

A. Flood Analysis

There are five flood analysis phases identified, and they are:

- **No sign of flood.** The wireless sensor devices show stable parameters, like dry-weather, normal water level and flow, high barometric pressure and static behavior of mountains.
- **Rain formation**. Pressure falling indicates the possibility of rain. This will wake the wireless network up to check the wider area for rain drops.
- **Rain**. The rainfall is vital, since it may result to river overflow or detachment of bank soil.
- **Earth parts detachment**. Rainfall, seismic activity and unstable soil, result to detachment. This is also monitored to verify whether a device has been carried away.
- **Dam formation**. Earth detachment is responsible for dam formations. This case causes an alarm of high priority, since water level rises rapidly and river flow slows down.
- **Flood**. This case is difficult to monitor and it demands the production of most alarms prior to the phenomenon. Characteristics of this case are the device loss and extreme recordings.

B. Sensor Devices

The sensor devices that form the wireless sensor network are the following:

- **Hydrological devices.** Their installation takes place along the river banks and they monitor the water level and flow.
- **Meteorological devices.** They are installed around the river. Each station monitors the brightness, temperature, barometric pressure, wind speed and direction.
- **Earth detachment devices.** Installed in areas at the neighboring mountains, they contain a geophone, soil moisture and creep sensors.

C. Alarm Production

The production of alarms implies the existence of floods. The automated system may employ two prediction mechanisms, in order to handle false alarms through the comparison of predictions' results. A mechanism to export conclusions is utilized, based in fuzzy logic or expert system theory, which attempts to classify a situation from the aforementioned six. Thereafter, another mechanism, which uses sophisticated models of the flood and the hydrological behaviour of the area of interest, compares the previous results.

D. Geographical Information System (GIS)

The GIS provides all the necessary information for the visualization of the environmental models and the display of alerts' location. The GIS combined with the wireless sensor network, gives vital real-time information on geo-referenced maps. Finally, it can be transferred to portable devices, such as PDAs or mobile phones.

Flood Impact Mitigation and Recovery System 10.4

Flood Risk Mitigation Plan 10.4.1

A report originated from the Waikato Regional Council for the Environment presents the classification of the responsibilities of different authorities, except the ones dictated by the legislation [41]. This report aims at the abolition of every legal obstacle, in order to optimize the danger management from flooding events. Moreover, it emphasizes on the approach, which will be followed to reduce the vulnerable points of society, as far as its protection against a flood is concerned. Thus, proposals of management alternatives are made, which evaluate danger, give advice, set priorities and elaborate on their development. Finally, pre-designed proposals on actions for the reply and establishment take place, in order to minimise the impact of floods. However, these proposals may include a certain risk, since they are made at the prediction level.

Danger Management

At this phase, initially, the responsibilities of the Environmental Council, the Local and Regional Councils and the public are defined. Secondly, an effort is made to commit the aforementioned authorities and the public to remain loyal to their roles, as well as to communicate between them.

Reduction of Flood Impact

Essentially, there are two types of flood dangers a) the danger originating from the physical phenomenon, as well as its extent, and b) the danger involving the vulnerable points of the societies, hence, personal possessions, buildings and infrastructure. Therefore, prior to the evaluation of the danger that the society faces, precise information regarding the aforementioned expressions must be collected. The Figure below elaborates schematically on the exchange of information and its distribution between the Councils and the public.

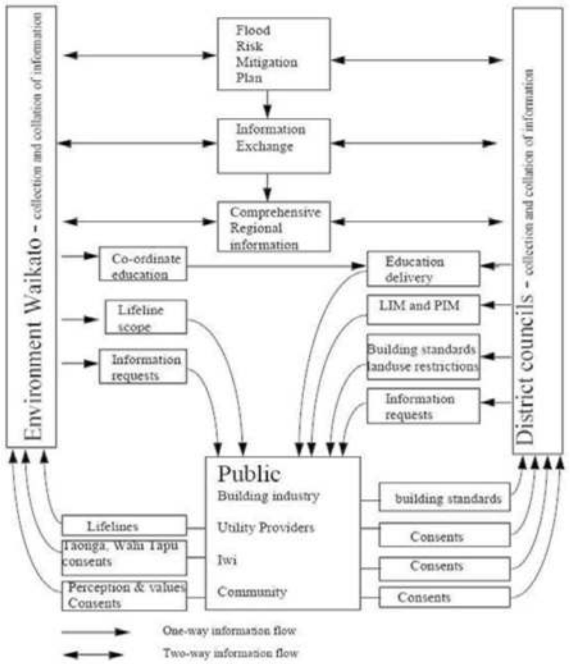


Figure 10.5: Exchange and Distribution of Information

Response and Recovery

The basic target on this phase is the planning for the immediate response and recovery, which is coordinated with the services of immediate action, in order to guarantee a fast and efficient respond to a flood. The Environmental Council possesses plans and procedures for emergency need cases. Furthermore, the Environmental Council forwards the warnings for a flood directly to the public. Meanwhile, the local councils are simply aware of the warnings and they remain alert. Moreover, the Environmental Council is responsible for the evaluation of the civil protection plans taken by the local councils.

The local councils have the main role for the transmission of the persons' needs, in order to get prepared for a flood, become aware of the necessary actions that they must take during a flood, and have information on where to seek for assistance after a flooding incident. In addition, the Environmental Council and the local councils are responsible for the information of businesses, in order to have strategies to recover from a flood.

Monitoring and Evaluation

The program responsible for the encounter of natural disasters should check the danger-related information, as well as the vulnerable points of the protection and danger priority, on a regular basis. Furthermore, the natural disasters program should develop and implement a system for the continuous production of advice to the local councils, in order to evaluate the efficiency of their plans. Finally, cooperation with the local councils should be established for a regular preview of the overall plans.

10.4.2 RIBAMOD: River Modeling, Management and Flood Mitigation

The RIBAMOD project [40] is financed by the European Union and it covers issues, such as, the construction of a model and a decision support system, current policy and practice, integrated systems for the real-time prediction and warning, impact of climate change to flood formation, continuous management of rivers and the large flood at the river Oder in the summer of 1997. The aforementioned issues have been analysed in three basic directions. The first two directions include modeling the river basin, and management of the river basin, as well as flood mitigation. The third direction will be presented in the following section.

10.4.2.1 Flood Impact Mitigation

Flood impact mitigation is an issue that depends on more parameters than the model of the river basin, the application of the model for flood prediction and its employment on the planning and flood protection. On the contrary, there is the need of an overall approach for flood management. More, specifically, flood disaster mitigation takes place in three phases

Actions before flood

- Flood danger management for all possible flood cause.
- Planning for a possible disaster, which includes the definition of evacuation routes, critical decision thresholds, public services and demands for emergency need infrastructure.
- Maintenance of the present infrastructure.
- Planning and management of the land use at all the areas close to the river banks.
- Limitation of the improvident building at the areas that face floods.
- Information and training of the public regarding the danger and the necessary actions for the encounter of such incidents.

Flood Operational Management

- Detection of a hydro-meteorological probability of flood formation.
- Prediction of future conditions of the river flow from hydro-meteorological observations.
- Warning disposal to the appropriate authorities and the public, as well as the severity and time recording of the flood.
- Correspondence from the civilians and the authorities in case of emergency.

Actions After Flood

- Immediate relief of the flood victims.
- Rebuilding of the damaged structures and the flood protection infrastructure.
- Recovery and rebirth of environmental and economic actions at the flooded areas.
- Evaluation of the actions taken during the management of a flood, in order to improve the procedure and plan response to future events.

Project Evaluation

A basic conclusion arisen from this project is that the entire infrastructure must be regarded as a part of a strategic plan for the entire river basin and must be developed, taking under consideration the impact that they will have including the hydraulic and sedimentary impacts, the environmental impact, and the cost operability. In addition, there is the need for wide financial evaluations that they will contain undefined costs and benefits, in order to evaluate the non-building views of the actions for the civil protection, resulting to a common methodology for the evaluation of flood disasters.

Risk Evaluation and Communication

The overall evaluation of danger may provide an appropriate framework for the decisions and the investment on the activities for flood protection. Various opinions concerning flood risk management include the appropriate form for the evaluation of risk, the display of areas at risk, the procedure and the probability of destruction of an embankment, the transmission of the danger level to the public and the special procedures for the places of high risk, which are located at areas vulnerable to floods.

Experts in the field and engineers undertake the design and the development of the infrastructure for flood protection. However, since no measure is entirely safe, the appropriate communication with the public is essential, in order to be informed about the level of danger, the probability of a flood from a simple storm or in a specific area, and the necessary actions to prevent personal loss of property or casualties.

Social Factors

Floods constitute great danger for the public. A temporary cataclysm at the river banks is a natural process and is considered as a part of the river's functionality as a drainage way out due to extensive outflow. Floods become serious problem when they conflict with land use, such as agriculture, industry or living. Non-expected floods bring undesired consequences to society, hence, the atomic or commercial disaster, resulting to financial damage, months or years of unhappiness and destruction of infrastructure.

The efficiency of the warnings and public acceptance may be influenced by the following issues:

- Awareness of a warning, meaning whether a warning has been received prior to the flood.
- Availability for response, meaning whether the land owner can reach it and act.
- Capability for response, meaning whether the owner is naturally capable to limit the disaster.

- Effective response, meaning whether the owner knows what to do and acts effectively.

The establishment of the system must be accompanied by plans of local distribution of warnings, recognition of the areas at risk even if they are at low risk, the public's understanding about the level of danger and the necessary actions that are essential after wach warning, and, the means for the wide transmission of alert warnings at specified areas.

The first priority after a flood is assistance to the victims. A large flood may cause disruption of public transport, severance of telecommunications, as well problems on the water supply, sewer system and health services. Thus, communities may have to self-serve for a few hours or days until assistance arrives.

10.4.3 Floods: causes, management and relief

Initially, this project analyses the causes of the floods, especially the human activities that result in the increase of flood impact. Thereafter, strategies and techniques are analysed for the management of the future danger of flood formations in Ireland [43].

10.4.3.1 Flood Danger Management

Flood danger management includes a variety of strategies, studies and actions, which may be banded to the following fields:

- Identification of an existing danger
- Reduction of an existing danger
- Definition of future dynamic dangers
- Planning for the mitigation of future dangers

The second of these fields concerns the reduction of the degree and the extent of the danger through several mechanisms, such as flood mitigation or enforcement alternatives, which are parts of a general design for the enhancement of the protection from flooding events.

Plans for Flood Management in the Catchment Area

The plans for flood management in the catchment area will constitute the basis of: a) the evaluation of danger, b) the environmental and social conditions in relation to the floods and, c) the production of solutions related to the above, such as:

- The necessity and the dynamics for structural or non-structural measures for the enhancement of flood protection and the reduction of the impact
- The viability and the demands of the warning alternatives for a flood
- Plans or notes for a coordinated response in emergency situations
- The impact of future development and possible climate change
- Areas in which development would be highly harmful due to flooding events
- Areas that are in danger from floods, which will have to control or limit infrastructures and buildings
- The positions and the details of environmental sensitivities or dangers, as well as the dynamics for environmental enhancement
- Engagement of society and training of the public, campaigns for the information and preparation from possible floods
- Land use and best practices in relation to the drainage management

Figure 10.6 shows that the design of the catchment area management may play a crucial role in the distribution of multiple solutions, in order to accomplish the targets of the current policy for the protection from floods, the forwarding of basic information and the recording of the major areas of activity, which require coordination.

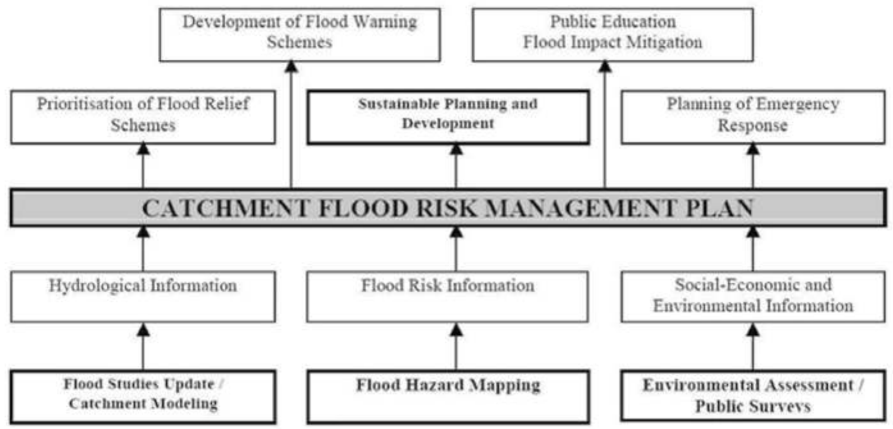
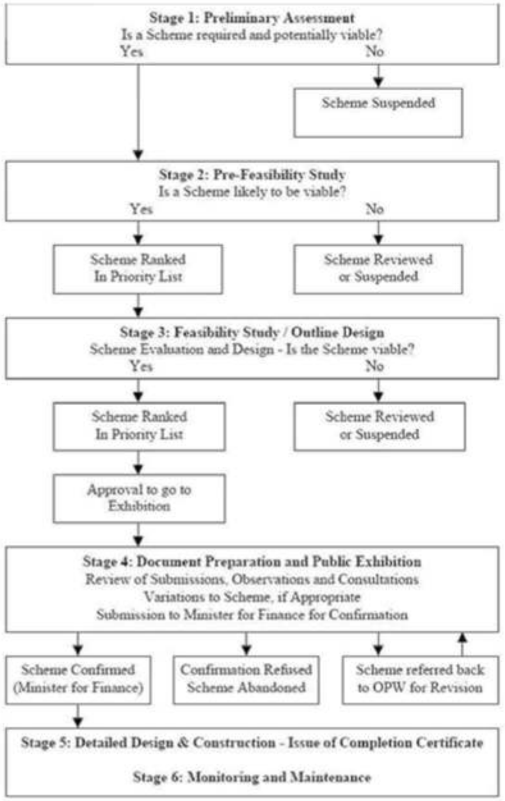


Figure 10.6: The role of the plan for the management of the catchment area

This strategy, which highlights the importance of the public's and authorities' participation, deals with a series of issues. Nevertheless, it emphasizes on the flood management and mitigation. Finally, the strategy completes with the definition of a fifty year plan that includes:

- Additional development of the technical setting of a flood management at the catchment area, using a GIS as well for the decision making,
- Detailed analysis with a perspective of enhancement of the warnig systems and natural protection from floods,
- Setting of the new development at the catchment area, in order to avoid danger from floods,
- Improvement of the practices for water and land management,
- Enhancement of the present naturally protected areas and housing development in a controlled environment.



Plans for the Enhancement of protection from floods

Figure 10.7: Development procedure of the flood protection plan

The enhancement of flood protection includes every means, which reduces the danger or the impact of a flood. This comprises intervention to the hydraulic control

or the levels of flood due to the chain reaction of the causes. Figure10.7 highlights a simplified flow diagram of the flood protection development procedure, by the Office of Public Infrastructure of Ireland. This procedure initiates after a request from a local authority, even though a strategic system for flood management should recognize the need for a plan, which would evolve with the recognition of the present danger and could be integrated to the flood management plan.

Plan Stages

The stages of the plan are given below:

A. Preliminary Assessment

The objective of the initial evaluation is to examine the cause and the degree of a flood danger. Also, it has to clarify whether the problem can be solved by using the aforementioned plan or it would be more appropriate to solve the problem at a local level.

B. Pre-Feasibility Study

The objective of the Pre-Feasibility Study is to provide a sign on whether the application of the plan, based on the available information, is feasible. The details or the accuracy of the study must be balanced in relation to the cost, since the purpose is not the definition of whether a plan should be developed or not. However, a justification of whether the necessary resources can be bounded must be given for a complete Feasibility Study. Everything that is related to this stage is quantified with great accuracy and always within the limitation of the available resources.

C. Feasibility Study/Diagram

As stated above, the feasibility study essentially is the recognition, evaluation and planning of a diagram, which is applicable on a technical, environmental, financial and social basis. The fesibility study examines the same issues as the pre-feasibility study. However, the examination is a lot more thorough and it provides a general plan.

C.1 Data Collection

The procedure of evidence collection at this stage is thorough and includes all the necessary data, in order to provide a complete, accurate and extensive evaluation from all aspects of the possible plan. The evidence collection and the research conducted include the following:

- Historic Data of Flood Recording
- Hydrometrical and Meteorological Data
- Representative Channel Samples
- Topographic Data of Flooded Areas
- Geo-technical Data

C.2 Evaluation of the Existent Danger Degree

In order to develop the appropriate solution of flood protection from floods, it is initially necessary to understand the given problem, which include the flow area, the frequency and level of danger, as well as the mechanism from which the danger came.The evaluation is based on:

- Hydrological Analysis
- Hydraulic Analysis
- Evaluation of Flood Danger

Based on the aforementioned analysis, the data and the maps of the existent danger may be defined using models that are executed with designed flows and topographic and/or DTM data.

C.3 Evaluation of the Possible Damage from Floods

The evolution of the plan depends on the financial justification. A complete evaluation of the damages for flood scenarios design is necessary for the definition of a value of the expected Average Annual Disaster (sum of the product of the disaster events and the annual event probabilities) for control (or "Do Nothing"). This calculation of damages includes immediate financial damages (e.g. property, resources), indirect damages (cost of emergency services, disruption of traffic e.t.c) and unexpected damages (victims stress, e.t.c.).

C.4 Preview of Limitations

The design of a plan requires the setting of boundaries and limitations.These limitations have been defined in detail by the local authorities and include:

- Basic environmental study of the river passage
- Finishing
- Aesthetic Limitations
- Archeology
- Geo-technical Limitations
- Territorial Limitations
- Other Issues of local interest

C.5 Environmental Evaluation

The environmental evaluation is done in three stages:

- Basic Evaluation
- Alternatives Evaluation
- Environmental Impact Evaluation

C.6 Alternatives Evaluation

The possible means for the enhancement of flood protection are:

- Flood Limitation (walls, embankments, e.t.c.)
- Increase of flow capacity
- Water Storage
- Direction Change
- Water fences and drawing mechanisms
- Flood warning system
- Private Property protection
- Reduction or obstruction of outflow
- Controlled re-establishment
- No action ('Do Nothing')

C.7 General Planning

When one of the aforementioned alternatives is selected, plans are developed, which include positions, general dimensions (embankment angles, underground sewer sizes, bridge arch sizes, e.t.c.). These are required for the stage of exposure to the Public.

C.8 Feasibility Report

The report, which gets circulated among the authorities and especially the local authorities, ends up with a proposal for a plan, accompanied with a justification and relative comments. Other issues included in the report are:

- Proposed actions for short-term reduction of flood danger, such as conservation or repair,
- Installation of additional hydrometrical monitoring devices for further adjustment of the model,
- Impact from the further development at the catchment area or the flooded bank,
- Any further research, in order to clarify uncertainties related or not to the Diagram / Plan.

C.9 Summation of the feasibility stage and general planning

The feasibility study, which is typically performed within a year, is a detailed evaluation of the alternatives for the enhancement of protection from floods, justified and generally planned towards a proposed schema.

D. Document Preparation and Exposure to the Public

The objective of this document is the information of all groups of interest of the Schema by giving detailed descriptions of the projects that have been proposed. The documents that will be delivered consist of:

- Detailed Supplement,
- Maps,
- Plans,
- Intervention Notes,

After the document is prepared, it must be forwarded to the local authorities. The project coordinator of the local authorities organizes a public exposure of the documents in a public building. Also, announcements are given to the press.

10.4.4 Decision-making for Flood-Threatened Properties

This project analyses the actions taken by a house or business owner when threatened by a flood [42]. This particular project corresponds mainly to the decision makers and the scientific personnel, who prepare, transmit and distribute the information to the property owners. The suggested actions that must be done are:

- Dry waterproof protection of a property, meaning the effort to hold the water out, which can be achieved with the sealing of openings or the levitation of the property,
- Wet waterproof protection of a property, meaning the allowance of the flood water to invade the premises with minimum damage, which may be achieved by using flood-resistant material and special layers,
- Re-establishment of a property or community,
- Design of a community, in order to prevent a significant flood impact. Examples of such design are the creation of a drainage system and the road design, which will prevent the water to burst with great speed,
- Alternatively, change of parameters that influence properties and communities through a) construction works for flood protection such as, dams, walls, anti-flood embankments, and b) non-construction works of protection such as parks,
- Efficient and Effective activities for the properties to return in the pre-flood situation.

Due to many of the aforementioned actions, it is clear that buildings are not sufficient for resisting or avoiding floods. The relative recovery and long-term endurance are necessary, in order to secure a longer life cycle and recovery, as well as endurance of the people and the community, in general.

References

[1] EM-DAT: The OFDA/CRED International Disaster Database, http://www.em-dat.net, UCL - Brussels, Belgium.

[2] General Secretariat of Civil Protection, "Natural Disatsers in 2007", http://www.civilprotection.gr/index_gr.php?nodeid=96&PHPSESSID=5da197f9986930fee9d3f6ff927bbcf8 Ministry of Internal Affairs.

[3] FloodSite Consortium, "Development of DSS for Long-term Planning: REVIEW OF EXISTING TOOLS", 2007, FloodSite Project Report

[4] B. Gouweleeuw, P. Reggiani, A. De Roo (eds), "A European Flood Forecasting System EFFS", 2004, Full Report, European Commission EUR 21208 EN, 2004

[5] van der Knijff, J.M., J. Younis and A.P.J. De Roo. "LISFLOOD: a GIS based distributed flood and water balance model for European catchments", submitted to International Journal of Geographical Information Science, in press.

[6] Modelling and Decision Support Framework, "History and overview of MDSF", 2004, http://www.mdsf.co.uk/downloads/procedures_and_userguide.shtml

[7] Modelling and Decision Support Framework, "MDSF User Guide", 2005, http://www.mdsf.co.uk/downloads/procedures_and_userguide.shtml

[8] RAMFLOOD Project, "Decision Support System for Risk Assessment and Management of FLOODS brochure", http://www.cimne.upc.es/ramflood/documentation.asp

[9] Prastacos P., Castaings W., Courtois N., Hluchy L., Houndry P., Tran V., "ANFAS: A Decision Support System for Flood Risk Assessment", In Prastacos, P., U. Cortes, J.L.D. de Leon and M. Murillo 2004 (eds) e-Environment: Progress and Challenges, Instituto Politecnico Nacional, Mexico.

[10] R. Garcia-Bartual, "Short term river flood forecasting with neural networks", in Proceedings of IEMSs 2002 Integrated Assessment and Decision Support, pp. 160-165, 2002

[11] E. Todini, "An operational decision support system for flood risk mapping, forecasting and management", Urban Water, pp. 131-143, 1999

[12] S. Ahmad, S. Simonovic, "An Intelligent Decision Support System for Management of Floods", Water Resources Management, vol. 20, pp. 391-410, 2006

[13] J. Luo, L. Xu, J. –P. Jamont, L. Zeng, Z. Shi, "Flood decision support system on agent grid: method and implementation", Enterprise Information Systems, vol.1, pp.49-68, 2007

[14] H. Haynes, R. Haynes, G. Pender, "Integrating socio-economic analysis into decision-support methodology for flood risk management at the development scale (Scotland)", Water and Environmental Journal, vol. 22. pp. 117-124, 2008

[15] M. Aqil, I. Kita, A. Yano, S. Nishiyama, "A comparative study of artificial neural networks and neuro-fuzzy in continuous modelling of the daily and hourly behaviour of runoff", Journal of Hydrology, vol. 337, pp. 22-34, 2007

[16] E. Triana, J. W. Labadie, "Geo-Modsim: Spatial Decision Support System for River Basin Management", in Proceedings of 2007 ESRI International User Conference, 2007

[17] M. Aqil, I. Kita, A. Yano, S. Nishiyama, "Neural Networks for Real Time Catchment Flow Modeling and Prediction", Water Resource Manage, vol. 21, pp. 1781-1796, 2007

[18] J. K. Levy, J. Hartman, K. W. Li, Y. An, A. Asgary, "Multi-Criteria Decision Support Systems for Flood Hazard Mitigation and Emergency Response in Urban Watersheds", Journal of the American Water Resources Association, vol. 43, pp. 346-358, 2007

[19] X. Zhao, X. Zhang, T. Chi, H. Chen, Y. Miao, "Design and implementation of a web-based flood

simulation and decision support system", in Proceedings of the 6th Conference on WSEAS International Conference on Applied Computer Science, pp. 59-64, 2007

[20] L. Wang, Q. Cheng, "Design and Implementation of a web-based spatial decision support system for flood forecasting and flood risk mapping", in Proceedings of IEEE International Geoscience and Remote Sensing Symposium, pp. 4588-4591, 2007

[21] M.-H. Ramos, J. Bartholmes, J. Thielen-Del Pozo, "Development of decision support products based on ensemble forecasts in the European flood alert system", Atmospheric Science Letters, vol. 8, pp. 113-119, 2007

[22] D. Mioc, G. Liang, F. Anton, B. G. Nickerson, "Decision Support for Flood Event Prediction and Monitoring", in Proceedings of IEEE International Geoscience and Remote Sensing Symposium, pp. 2439-2442, 2007

[23] H. El-Sersawy, "Development of Decision Support System (DSS) for High Aswan Dam Reservoir Sedimentation", International Congress on River Basin Management Book, chapter 39, 2007

[24] S. Simonovic, "Computerized Decision Support for Flood Management: Red River Basin Case Study", International Flood Network (IFNET) Action Report, 2006

[25] S. Ahmad, S. Simonovic, "An Intelligent Decision Support System for Management of Floods", Water Resources Management, vol. 20, pp. 391-410, 2006

[26] A. J. Hassan, A. Ghani, R. Abdulah, "Development of Flood Risk Map Using GIS for SG. Selangor Basin", in Proceedings of 6th International Conference on ASIA GIS, 2006

[27] M.-J. Adler, G. D. Anderson, D. McKinnery, "Decision Support System for Integrated Water Management in Romania: Recent Developments and Future Plans", in Proceedings of Conference on Water Observation and Information System for Decision Support, 2006

[28] M. Aqil, I. Kita, M. Macalinao, "A Preliminary Study on the Suitability of Data Driven Approach for Continuous Water Level Modelling", International Journal of Computer Science, vol. 1, pp. 246-252, 2006

[29] M. Aqil, I. Kita, A. Yano, S. Nishiyama, " A Takagi-Sugeno Fuzzy System for the Prediction of River Stage Dyanamics", JARQ, vol. 40, pp. 369-378, 2006

[30] L. Wang, Q. Cheng, "Web-based Collaborative Decision Support Services for River Runoff and Flood Risk Prediction in the Oak Ridge Moraine Area, Canada", in Proceedings of SPIE Geoinformatics, 2006

[31] M. B. Butts, A. Klinting, M. Ivan et al., "The Floodrelief Internet Based Flood Forecasting Decision Support System", in Proceedings of International Conference on Innovation Advances and Implementation of Flood Forecasting Technology, pp. 1-10, 2005

[32] H. Changwei, Y. Ximin, L. Shu, Z. Hongpin, "Flood Control Decision Support System in Dongtiaoxi Basin", in Proceedings of World Water Congress, 2005

[33] J.-Q. Li, L. –P. Wang, C. –M. Ji, Y.-S. Zhang, "General Design on Intelligent Decision Support System of Risk Management for Flood Diversion and Storage", Journal of North China Electric Power University, vol. 32, pp. 95-98, 2005

[34] A. J. Abebe, R. K. Price, "Decision Support System for Urban Flood Management", Journal of HydroInformatics, 2005

[35] D. S. Bowles, J. Dean Mathias, S. S. Chauhan, J. D. Countryman, "Reservoir Release Forecast Model For Flood Operation of the Folsom Project including Pre-releases", in Proceedings of the 2004 USSD Annual Lecture, 2004

[36] M. Matthies, J. Berlekamp, S. Lautenbach, N. Graf, S. Reimer, "Decision Support System for the Elbe River Water Quality Management", in Proceedings of International Congress on Modeling and Simulation, pp. 284-289, 2003

[37] P. Prastacos, "ANFAS: a Decision Support System for River Floods", in Proceedings of 16th International Conference: Informatics for Environment Protection, paper. 120, 2002

[38] M. Bruen, "Multiple Criteria and Decision Support Systems in Water Resources Planning and River Basin Management" in Proceedings of National HydrologySeminar, 2002

[39] H. Qi, M. S. Altinakar, Y. Jeon, "A decision support tool for flood management under uncertainty using gis and remote sensing technology", in Proceedings of the 7th International Conference on HydroScience and Engineering, 2006

[40] P. G. Samuels, "RIBAMOD: River basin Modelling, management and flood mitigation", Final Report, 1999

[41] M. Malcolm, D. Parkin, "Flood Risk Mitigation Plan", Environment Waikato Technical Report, 1997

[42] I. Kelman, "Decision-making for flood threatened properties", Flood Risk Management in Europe, Springer, Netherlands, 2007

[43] M. Adamson, "Floods: causes, management, and relief", in Proceedings of Chartered Institution of Water and Environmental Management, Ireland, 2003

[44] H. Haynes, R. Haynes, G. Pender, "Integrating socio-economic analysis into decision-support methodology for flood risk management at the development scale (Scotland)", Water and Environmental Journal, vol. 22. pp. 117-124, 2008

[45] D. Lumbroso, D. Ramsbottom, M. Spaliveiro, "Sustainable flood risk management strategies to reduce rural communities' vulnerability to flooding in Mozambique", Journal of Flood Risk Management, vol. 1, pp. 34-42, 2008

[46] S. Lin, D. Shaw, M.-C. Ho, "Why are flood and landslide victims less willing to take mitigation measures than the public?", Nat Hazards, vol.44, pp. 305-314, 2008

[47] P. Γκέκας, Κ. Μήτσου, "Περιορισμός των Επιπτώσεων από πλημμύρες-Οι Νέες μέθοδοι αντιμετώπισης των πλημμυρών και ο πρωταγωνιστικός ρόλος των Ο.Τ.Α", Εθνικό Κέντρο Κοινωνικών Ερευνών, Ινστιτούτο Κοινωνικής και Αγροτικής Κοινωνιολογίας, 2007

[48] S. Simonovic, "Computerized Decision Support for Flood Management: Red River Basin Case Study", International Flood Network (IFNET) Action Report, 2006

[49] A. J. Hassan, A. AB. Ghani, R. Abdulah, "Development of flood risk map using GIS for SG. Selangor Basin", in Proceedings of 6th International Conference on Asia GIS, 2006

[50] S. P. Simonovic, S. Ahmad, "Computer-based model for flood evacuation emergency planning", Natural hazards, vol. 34, pp. 24-51, 2005

[51] Proceedings of the World Conference on Disaster Reduction, International Strategy for Disaster Reduction, 2005

[52] "Διαχείριση του κινδύνου πλημμυρών, Πλημμύρες: πρόληψη, προστασία και μετριασμός των επιπτώσεών τους", Επιτροπή των Ευρωπαϊκών Κοινοτήτων, 2004

[53] S. P. Simonovic, R. W. Carson, "Flooding in the Red River Basin-Lessons from Post Flood Activities", Natural Hazards, vol. 28, pp. 345-365, 2003

[54] E. Onate, J. Piazzese, "Decision Support System for Risk Assessment and Management of Floods", International Center for Numerical Methods in Engineering, 2003

[55] J. Parkinson, "Drainage and stormwater management strategies for low-income urban communities", Environment and Urbanization, vol. 15, 115-126, 2003

[56] G. Fleming, "How can we learn to live with rivers?", Philosophical Transactions: Mathematical, Physical and Engineering Sciences, vol. 360, pp. 1527-1530, 2002

[57] C. Emdad Haque, M. Kolba, P. Morton, N. P. Quinn, "Public involvement in the Red River Basin man-

agement decisions and preparedness for the next flood", Environmental Hazards, vol. 4, pp. 87-104, 2002

[58] S. P. Simonovic, "Proceedings of the International Workshop Non-structural measures for water management problems", International Hydrological Programme, UNESCO, 2001

[59] "Learning to live with rivers", Final report of the Institution of Civil Engineers' Presidential Commission, 2001

[60] H. Rasid, W. Haider, "Post-flood assessment of emergency evacuation policies in the Red River basin, Southern Manitoba", The Canadian Geographer, vol. 44, pp. 369-386, 2000

[61] AFORISM, "A comprehensive forecasting system for flood risk mitigation and control", Final Report, 1996

[62] M. Castillo-Effen, D.H. Quintela, R. Jordan, W. Westhoff, W. Moreno, "Wireless Sensor Networks for Flash-Flood Alerting", Proceedings of the Fifth IEEE International Caracas Conference on Devices, Circuits and Systems, Dominican Republic, Nov.3-5, 2004

[63] Giovanni Rosales, "Lugares Con Riesgo Potencial," Internal Report of the Fire Department Merida -Venezuela, March 2004.

[64] Deborah Estrin, Lewis Girod, Greg Pottie, Mani Srivastava, "Instrumenting the world with wireless sensor networks," Proceedings of the International Conference on Acoustics, Speech and Signal Processing (ICASSP 2001), Salt Lake City, Utah, May 2001.