\Report Defining the Pinios – Karla Use case c : Linking rainfall runoff models to a groundwater model

1. Short description of the use case

Thessaly is located in central Greece and is a plain region surrounded by Mount Kisavos and Mount Pelion in the east, along the coast of the Aegean Sea, Mount Olympus in the north, the Pindus Mountain Range in the west, and the Othrys Mountain Range in the south. Thessaly's total area is about 13,700 km^2. The elevation ranges from sea level at the eastern coastal area to more than 2,800 m at the eastern and western mountain areas. The mean elevation of the region is nearly 500 m. The two larger basins of region are the Pinios River and the Lake Karla basins.

The climate is continental at the western and central side of Thessaly; the winters are cold and the summers are hot and the temperature difference between the two seasons is large. At the eastern side of Thessaly the climate is typical Mediterranean. Summers in Thessaly are usually very hot and dry, and in July and August temperatures can reach 40 °C. Mean annual precipitation over the whole Thessaly region is about 700 mm and it is distributed unevenly in space and time. The mean annual precipitation varies from about 400 mm at the central plain area to more than 1850 mm at the western mountain peaks. Generally, rainfall is rare from June to August. The mountain areas receive significant amounts of snow during the winter months and transient snowpacks develop.

Thessaly plain is the most productive agricultural region of Greece with an area of about 4,000 km^2. The main crops cultivated in the plain area are cotton, wheat and maize whereas apple, apricot, cherry, olive trees and grapes are cultivated at the foothills of the eastern mountains. Pinios river and its tributaries traverse the plain area, and the basin total drainage area is about 9,500 km^2. The waters of Pinios River are used primarily for irrigation. The intense and extensive cultivation of water-demanding crops has lead to a remarkable water demand increase, which is usually fulfilled by the over-exploitation of groundwater resources. The over-exploitation of the groundwater, especially during extended dry periods, has lead to the deterioration of the already disturbed water balance and the degradation of water resources. Over the years, various locations within the Pinios River basin have been proposed for the development of reservoirs, but only the dam of Smokovo has been recently constructed. The only other major surface water storage projects in Thessaly region are a few small reservoirs and lagoons on or adjacent to Pinios River system and the diversion of water from the N. Plastiras reservoir, which is located outside of the Pinios River basin. Over the years, the development of reservoirs within the area of Pinios River basin, the partial diversion of Acheloos River through a series of four reservoirs, and water demand management measures have been proposed to alleviate the water problem of Thessaly.

Lake Karla occupied, until 1962, most of the eastern part of Thessaly plain. It was one of the most important wetlands in Greece and a natural reservoir, which provided significant water storage and recharge to groundwater. The basin surface runoff and the overflowing floodwaters of the Pinios River sustained Lake Karla. The lake area fluctuated from 40 to 180 km^2 due to the very gentle land slope and the inflow-outflow balance. For this reason, significant area of the surrounding farmland was often inundated facing soil salinity problems.

Various technical studies proposed measures for the flood protection and the revelation of agricultural fields. These studies recommended to build flood control dykes on Pinios River, construct a drainage network, which would have drained the lake overflows through a tunnel into the sea, and develop a reservoir in the location of the natural lake. This reservoir would have been used to store the winter surplus surface runoff and the diverted floodwater of the Pinios River for irrigation during spring and summer. However, only the mountain collector ditches, the draining tunnel, and the Pinios River embankments, which cut off the river floodwater inflows to the lake, were constructed. The reservoir and its associated works were never built creating a series of environmental problems: 1) the lake area diminished and the natural wetland deteriorated, 2) the limited natural recharge of the aquifer and the uncontrolled pumping of the groundwater has caused a dramatic drawdown of the water table, which, today, is more than 200 m below the land surface at the southern area of the basin, 3) areas with small land slope were often flooded, 4) large areas remained uncultivated due to salt concentration and soil degradation, 5) the large loads of agrochemicals washed of the fields polluted the Pagasitikos Gulf.

The decision to restore part of the former lake has been taken in the early 1980's by the Greek government but the construction works started few years ago. The project, today, is near completion. The suggested plan for the restoration of Lake Karla proposes the creation of a reservoir in the lowest depression plain of the former lake Karla that will occupy a maximum area of about 38 km^2, through the construction of two embankments, one in the eastern part and one in western part of the lake. Four collector channels will collect the surface runoff from the higher elevation zones of the watershed and directly divert it into the reservoir. The surface runoff of the lower elevation areas will be pumped into the reservoir. After the construction of these works, the drainage area of the restored Lake Karla will be 1171 km^2. The partial restoration of the former Lake Karla is one of the most important environmental projects in the region, possibly in the whole country, that has been planned to reverse the adverse environmental conditions, caused by the lake drainage.

2. Identification of the management / policy issue

By 2015, Thessaly's Competent Authorities have to produce a Water Resources Management Plan for the Pinios River and Karla Basins. OpenMI-LIFE project will provide input to the local and national authorities related to the issues of surface runoff, groundwater runoff, and recharge.

A monthly conceptual hydrological model (UTHBAL) for the calculation of surface runoff and groundwater recharge will be used. The model has been proposed by Loukas and his associates (2003). The UTHBAL model has been successfully applied to watersheds in Cyprus, Crete, Thessaly, and the transboundary

Nestos/Mesta River basin. The required data for the estimation of the water resources are precipitation data, temperature data, and discharge data. The original meteorological and discharge measurements were collected by regional and prefecture water resources agencies and the Greek Public Power Corporation. These measurements have been checked for errors, homogenized and processed according to the World Meteorological techniques and standards.

There is a plethora of existing rainfall-runoff models built for modelling the surface runoff of a watershed in order to assess water resources potential. The selection of UTHBAL as the rainfall-runoff model in this case study is guaranteed from the previous successful application of the model in the area and the limitation of high resolution data (only monthly data are available). Linking such a water balance model to a groundwater model is the ideal solution for the needed river flow, surface runoff to Lake Karla and groundwater calculations.

In the Karla region, the University of Thessaly uses the UTHBAL model to assess surface runoff. This case study will link the existing UTHBAL model for Karla Basin with an existing groundwater model which is OpenMI compliant. At this stage the groundwater model will be the Visual MODFLOW from Waterloo Hydrogeologic Company which is OpenMI compliant. If problems in the application of Visual MODFLOW occured the model MIKE SHE of Danish Hydraulic Institute will be used.

3. Setting the objectives

3.1 Specific use case objectives

- Demonstrate the linking between UTHBAL and Visual MODFLOW models

3.2 Wider perspective objectives

- By linking these models, the following objectives will be achieved:

  1. Integrated water resources planning
  2. Flood control
  3. Evaluation of different land use practices impact on water quantity and quality
  4. Sustainable water management for irrigation and agriculture.

These objectives are met by the combination of the rainfall-runoff model and the groundwater model. By linking these models, interactions between these objectives can be examined and evaluated.

4. Defining the actions

4.1 Preconditions for linking models

- The models (UTHBAL and Visual MODFLOW) have to become compliant with the OpenMI standard interface specifications
  - Prerequisites: UTHBAL and Visual Modflow compilers, as well as OpenMI interface
  - Data for case studies

4.2 Actions for the definition phase

4.2.1 Define the hardware environment

Personal PCs will be used for modelling purposes

4.2.2 Define the interactions to be modelled

- The spatial domain will be set to the common part of the hydrologic and hydrogeologic watershed of the Karla catchment The upstream part of Pinios River Basin diversion into the Karla catchment will not taken into account in the spatial domain since the abstractions of the Pinios River are predefined.
  The surface runoff and the infiltration to the groundwater aquifer will be calculated by the UTHBAL model taking into account the given river flow in the most upstream diversion node of the Pinios River.
- The models will exchange data using a monthly time step.

4.2.3 Define the links

- The common physical variables are :
  - river flow,
  - infiltration,
  - groundwater recharge.

4.2.4 Define and correct the gaps

- Check whether models are OpenMI compliant
- Check whether their variables are linked successfully

4.3 Actions for the iterative phase

- To perform runs with the UTHBAL model in order to produce model results,
- To load these UTHBAL model results as input data into the Visual MODFLOW model,

- To perform runs with the Visual MODFLOW model,
- Link models and perform new runs
- Deal with arising issues and repeat runs

5. Milestones, deliverables, success scenarios

5.1 Technical

- The models (Visual MODFLOW, and UTHBAL) are OpenMI compliant
- The models are successfully linked

5.2 Use case specific

- Compare results between running the models in OpenMI and running them separately
- Provide input to Competent Authorities