EXTENDED ABSTRACT OF THE HYDROLOGIC STUDY OF MEDITERRANEAN TEMPORARY PONDS' CATCHMENTS

'Mediterranean Temporary Ponds' (M.T.P.) is a priority habitat (Natura code: 3170*) in Annex I of the Directive 92/43/EEC. This substantially vulnerable and unstable habitat exists in low-extent areas that due to their specific characteristics are under significant human and natural pressures and have become prone to extinction. This study examined five (5) M.T.P. habitat sites in Crete (Elafonisi, Kourna, Omalos, Falasarna and Gavdos island).

The hydrology of MTPs can be characterised as self-adjusting and presents significant variations, at the length of the ponds' hydroperiod but also at the start of their flooding period. These habitats often occur in small topography depressions with impermeable substratum and usually belong to a relatively small catchment area. They may also occur in karstic areas, where groundwater preferential flow is created out of their catchment area, resulting in the ponds' water level rise.

The length of the hydroperiod defines the developing flora and fauna. These hydrological alterations are totally natural and as the water volume changes, the aquatic developing vegetation and invertebrates change, as well. During the pond's flooding, the aquatic habitat has available trophic resources and the predatorial faunal activity is low. During the drought period, the higher faunal density leads to higher competition and appropriate conditions for predatorial activity.

A hydrologic monitoring network was established at all the habitat sites to provide the necessary data for the hydrologic survey action which is required for the restoration of the ponds hydroperiod. This network comprised water level measurement equipment and meteorological sensors (rainfall, evaporation, solar radiation, humidity, temperature and barometric pressure, wind direction and velocity).

In this study conceptual and distributed hydrologic models have been used to estimate the annual water budgets in two MTP sites in order to assess the anthropogenic impacts on the ponds hydrologic regime and propose restoration measures if necessary.

The classical water budget method was used to understand the main hydrologic processes and estimate their relative weights in the water cycle of each MTP catchment.

A hydrological model (MIKE SHE) was utilised in order to assess hydrological regimes of the MTPs catchments and their water reserves. The model set up can be simplified according to the users' conceptualization of the natural system and the data availability. The outputs of the model include estimations of the area's water balance components as well as the spatial and temporal quantification of water flows (overland, subsurface and underground flows). The representation of catchment characteristics and input data is provided through the discretisation of the catchment horizontally into an orthogonal network of grid squares. In this way spatial variability in parameters such as elevation, soil type (soil hydraulic parameters), land cover, precipitation and potential evapotranspiration can be represented. Within each grid square, the vertical variations in soil and hydrogeological characteristics are described in a number of horizontal layers with variable depths.

Five model simulations have been setup, each for every MTP catchment area, and run for a period of one to four hydrological years, according to the available hydrological and meteorological data.

The guiding principle in the parameterisation was to construct a model with as few free parameters as possible, and subsequently with limited computational/run time. The range of values to define each parameter was rational and based on literature values. Limited groundwater level data (3-5 measurements for 37 wells for a period of 2 years) were available for Falasarna catchment, as well as lake water levels for Kourna catchment and used as calibration targets. Therefore, it was not possible to reproduce a fully representative simulation of the aquifer; instead an average groundwater level trend as close as possible to the observed values was pursued in order to make an adequate water balance estimate for the hydrological catchment. In the case of Gavdos, Omalos and Elafonisi no groundwater level data were available. Therefore, a comparison of the model's water budget with the respective classical approach has also been done to assist in calibrating the model and assess its applicability on each site, while the results were analysed with regard to potential management of water resources for anthropogenic purposes and the associated impacts for the MTPs.

Major components of water balance for the hydrological catchment of Falasarna (surface area of ~12.4km^2), which resulted from the MIKE SHE simulation for the period 1/10/1998 to 30/9/2000 (two hydrological years) include 686 mm of rainfall (8.5 x 10^6 m^3/year), while 331 mm (4.1 x 10^6 m^3/year) of water is lost through evapotranspiration processes in the catchment. Surface runoff from the catchment is 211 mm (2.6 x 10^6 m^3/year), while the aquifer recharge is 154 mm (1.9 x 10^6 m^3/year). As a result of the pumping and irrigation scheme applied about 147 mm (1.8 x 10^6 m^3/year) of water pumping occurs in order to fulfill the irrigation needs of both the olive cultivations and the glasshouses of the area.

Actual evapotranspiration losses value at Falasarna for the classical method as compared to that estimated using the hydrological model MIKE SHE show they are quite close. Differences in recharge and runoff are attributed to the fact that the classical method only takes into account primary recharge and recharge coefficients for each geological unit in order to estimate recharge and surface runoff, while the hydrological model also includes secondary recharge, overland, unsaturated zone and saturated zone parameters (such as Manning coefficient, soil water content at infiltration capacity, hydraulic conductivity, etc), as well as pumping losses in order to esimate groundwater recharge and surface runoff.

During the simulation period groundwater levels at Falasarna fluctuate by 2-3 m from maximum (December) to minimum-start of wet season (September), while maximum rainfall is observed in December, February and January. Poor calibration of the model (low R^2 Nash-Sutcliffe coefficient), observed at some wells was due to the limited number of measurements and can be improved by the application of a more comprehensive monitoring scheme for groundwater levels and surface runoff. As a result, the aim was not to achieve a "perfectly accurate" calibration of the model, bur rather to attain a generally satisfactory simulation of reality as close as possible to the limited measurements of observed groundwater levels.

The water balance for the hydrological catchment of Gavdos (surface area of ~33km^2), which resulted from the MIKE SHE simulation for the period of three hydrological years (1/10/1997 to 31/8/1998 and 1/9/1999 to 31/8/2001), indicate 336.7 mm of rainfall (11.0 x 10^6 m^3/year) and 242.7 mm (8.0 x 10^6 m^3/year) of actual evapotranspiration. The aquifer recharge is 41.3 mm (2.1 x 10^6 m^3/year), while the surface runoff is 52 mm (1.7 x 10^6 m^3/year). Since there were no available groundwater level or stream discharge data for calibrating the model, a classical "lumped" water budget approach as well as a "distributed" sub-catchment approach were used to quantify surface runoff.

The water balance estimated using the classical method as compared to that estimated using the model indicates that values of actual evapotranspiration for both methods are quite close. The estimated recharge according to the model is 12.3 % of rainfall (1.4 x 10^6 m^3/year), while according to the classical method the relative value is 19 %. Relative values for surface runoff are 15.4 % and 8 % respectively.

A GIS-based methodology of estimating subcatchments' surface runoff was used to quantify water recharge and runoff and therefore to assist in designing potential water management practices in Gavdos Island. For the quantification of primary recharge in the catchment, recharge coefficients for each geological formation were assigned in GIS and the volume of water supplying the aquifer was estimated based on annual precipitation values and surface areas for each geological unit. Total (primary) recharge was then estimated and subsequently total surface runoff could be estimated as the remaining parameters of the classical water budget equation were known.

The annual water potential for each subcatchment was found higher (over 40,000 m^3/year) at subcatchments 6, 10-14 (at the edges of Ambelos, Fanari and Vardia hills), at subcatchment 21 (stream west of Ag. Pavlos stream), as well as at 24-26 (low course of Ag. Pavlos stream, high course of Sarakiniko stream and the stream at its west).

The main conclusions drawn from this study are as follows:

- In the study area of Falasarna only 1.9 x 10^6 m^3 recharge the aquifer annually (22 % of rainfall), while the most significant part of inflows is lost through evapotranspiration, which is very intense in the area due to high temperatures and winds and also due to the land use regime (extensive olive groves and cultivations). Thus the exploitable groundwater resources are particularly limited and therefore careful water pumping management will have to be implemented in order to avoid saline intrusion phenomena. Water recharging Falasarna catchment could be increased (artificial aquifer recharge) with small scale works (e.g. enrichment wells and small terraces in the mountainous part of the catchment) while the wetland areas in the coastal zone storing water until the start of the summer contribute significantly to this direction (and prevent saline intrusion). Large scale engineering works and false land use planning should be avoided. There are some impacts from pumping in a local scale for the MTPs.

- As it is shown in the water balance (with the classical methof) estimated for the hydrological catchment (Table 2), from 11 million m^3 of rainfall water entering the catchment, 8 million m^3 are lost through evapotranspiration, 2.1 million m^3 are recharging the aquifers and 0.9 million are lost through surface runoff into the sea. Regarding the annual water potential for each subcatchment, this is found higher (over 40.000 m3/year) at subcatchments 6, 10-14 (at the edges of Ambelos, Fanari and Vardia hills), at subcatchment 21 (stream west of Ag. Pavlos stream), as well as at 24-26 (low course of Ag. Pavlos stream, high course of Sarakiniko stream and the stream at its west). The potential future water management works will therefore have to aim at subcatchments "6, 10-14, 21, 24-26", which present higher reserves compared to other subcatchments. However, due to the small amounts of water, ending in aquifers, small and combined works could constitute a viable and environment-friendly solution, combining rational water management and water use practices. Such works could be small aquifer enrichment dams at subcatchments 24, 11 and 10, together with boreholes in relatively close distance to the watercourse and preferably closed underground reservoirs for the months of August – October, when water shortage occurs. Small aquifer artificial recharge (or storage dams) at subcatchments 24, 11 and 10, together with boreholes in relatively close distance to the watercourse and preferably underground reservoirs for the months of August – October, are the best options to confront water shortage. No significant impacts occur on the MTPs from human activities apart from animals watering since they are rain-fed. Climate change is a matter which needs further investigation.

- In Kournas catchment, the natural water outflows through Delfinas stream (SE of the lake) have been restricted by destroying the sluice gate canal which used to overflow potential excess water towards the sea (1,5x106 m^3 annually). The water management of Kourna lake may affect the hydroperiod of the pond and particularly the irrigation abstractions which will be enhanced under the pressure of Climate change. Water saving measures in irrigated practices are proposed and stakeholders will participate in the water management of the area.

- In Elafonisi there are only few groundwater storages. It is established that there is no hydraulic relation between the ponds and the main aquifer, while climate change impacts on the ponds hydroperiod should be further investigated.

Thoughts about hydroperiod restoration

In Falasarna:
- Identify the amount of water pumped
- Propose management practices for water saving measures in irrigation
- Suggest small scale recharge constructions if necessary

In Kourna:
- Identify the amount of water pumped
- Discuss with the municipality the potential for the sluice gate canal re-operation
- Kourna lake water level monitoring and management to assure flooding at the pre-pumping frequencies?

In Omalos, Gavdos and Elafonisi the watering network construction will eliminate the hydroperiod pressures.