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TELEMETRY NETWORK FOR MONITORING QUALITY OF IRRIGATION WATER IN KAVALA (N.GREECE)

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Abstract

In places where primary and secondary economic sectors are significant proportion of local economy, the quantity and quality of irrigation water has not only environmental but also economical and social affects in local society. A rational management of water resources demands reliable and quick information of the quality of irrigation water especially during summer. The monthly scheduled samplings that are usually followed by the state services in some cases are not adequate. A telemetry network of four stations for real-time monitoring the quality of irrigation water was designed by Directorate of Land Reclamation/Prefecture of Kavala. It covers the most important agricultural areas of prefecture, including the island of Thassos. Stations are equipped with modern and robust instrumentation (multiparameter sensors, data loggers, modems, ups, sophisticated software, etc) to measure physicochemical characteristics of surface and ground water. The records are 24 hours a day and they are transmitted via GPRS. It consists an innovative initiative for local authorities to have the ability of real-time information about the quality of irrigation water and hereupon plan their actions. The system is expected to provide useful scientific data and an effective tool towards a policy of rational management of local water resources.

Key words: *irrigation water quality, telemetry network, real-time monitoring, design criteria, Prefecture of Kavala – N. Greece.*

1. Introduction

Kavala is located in the northeast of Greece and is the easternmost prefecture of geographic region of Macedonia. Nestos river from east, Strymonas river from west and Paggaeo mountain, from north, are its natural borders. Kavala is not the typical agricultural region, but there are 500.000 stremmas of cultivated land and about a quarter, out of the total population of 145.000 people are farmers. This is the reason why the supply of good quality irrigation water is a priority issue for local authorities.

The national programme of irrigation water quality monitoring, supervised by Directorate of Geology-Hydrology/Directorate General of Land Reclamation/Ministry of Rural Development and Food (MiRDeF) and supported by Directorate of Land Reclamation/Prefecture of Kavala, have been providing water quality information, the only available till now. According to this, within the territory of Kavala prefecture, monthly scheduled samplings from surface irrigation water bodies are made. Samples are sent to Laboratory of Soil-hydrology and Geology/MiRDeF, where they are analysed for physical (electrical conductivity, pH), chemical (Cl^-, Ca^{+2}, Mg^{+2}, Na^+, alkalinity), irrigational (vestigial Na_2CO_3, dissolved Na and Mg, S.A.R., $CaCO_3$) and environmental (dissolved O_2, NO_3^-, dissolved Cd) parameters. The monitoring programme has been providing a long time series of data that contributed to the understanding of major pollution mechanisms of surface and underground irrigation water systems. On the other hand, it is obvious that a monthly sampling step, acts like a "low-pass filter" to hydrology systems condition. Additional high frequency information could conceal other potential threats, while real-time information could also drive to immediate actions.

The Water Framework Directive (WFD) 2000/60/EC (Council of the European Union, 2000), represents the European Union policy for all kind of inland water and the actions that all Member States should take are mentioned. Among others, guidelines for systematic water quality monitoring are described. Greek legislation was harmonized to WFD, with Law 3199/2003 (Hellenic Republic, 2003) and water quality monitoring, for public administration, was put on a new footing.

This paper presents the work of design and operation of a telemetry network for real-time monitoring of irrigation water in Kavala. It was part of the project: "Integrated system for water quality management and olive trees optimization, using Geographical Information Systems in Prefecture of Kavala", supervised by Directorate of Land Reclamation and Directorate of Planning and Programming/Prefecture of Kavala and carried out from November 2007 to November 2008, with consortium of contractors: DRAXIS S.A.-I.M.C. S.A. The project was 80% co-founded by the European Regional Development Fund, under the Framework of the Operational Program: Information Society (IS), Priority Axe: Action Line 2 - Citizens and Quality of Life, Measure 2.4 - Regional Geographical Information Systems and Innovative Actions. The aim of this Measure was to formulate a strategy and an action plan for the IS in all regions, to encourage innovative pilot activities related to the development of IS applications at regional and local levels and to establish and support geographical and environmental mapping and administrative systems at a central, regional and local level.

2. Objectives of monitoring

It is important to define the objectives of monitoring, before proceeding to network design. The legislative framework is given by WFD, while guidelines and issues concerning water quality monitoring are listed in literature (EEA, 1996; 1997; Chilton, & Milne, 1994; Zacharioudakis et al., 2001; Wagner et al., 2001). The local-prefectorial and real-time character of the system focusing on specific agricultural needs of each area, and the parallel existence of the monthly step sampling programme, were incorporated. These specifications formed the particular frame within which the objectives of the whole attempt had to:

— Be oriented to irrigation needs.
— Incorporate innovative technology.
— Combine system reliability to operational autonomy.
— Provide high frequency data.
— Contribute to the understanding of the influence of agricultural activities to surface and underground water systems.
— Create a database with minimum human intervention and easy access to interested parties.
— Give immediate warnings in case of water quality alteration.
— Help to optimise local irrigation schedules.
— Lead to a rational management of water resources.
— Reduce bureaucracy in public administration.
— Follow the guidance of the relative legislation.

— Operate complementary to national irrigation water quality programme (MiRDeF) and to forthcoming national water quality monitoring programme (Supervised by Directorate of Water/Eastern Macedonia and Thrace Region Authorities).

3. Network design

Design criteria had to satisfy the objectives mentioned above and intend to incorporate economic, technical and social aspects, ensuring a cost effective operation. Scientific criteria, applied according to design theory for water quality monitoring (EEA, 1996; 1997; Wagner et al., 2001). Area catchments were scanned and appropriate monitoring points were searched out. The aim was the hydrological and hydrogeological characteristics of each water system, to be examined. These would reflect the flow mechanisms, the interaction of ground water to precipitation and surface water, the residence time of physicochemical contaminants, the geochemical characteristics of aquifers and the consequences of agricultural activities. Economic and social aspects concerned the "specific weight" of each water body according to its contribution to prefectorial agricultural product and gross income. Emphasis was given to land, highly contributed to local rural economy but also sensitive to potential danger of pollution. Technical aspects had to do with system sustainability and vulnerability to nature and human factors. Points, protected from extreme weather phenomena, floating objects, flood, passing animals, human "curiosity" and, if possible, with easy access to power supply, were searched out. According to these criteria, three areas of interest were defined: Area A, eastwards, comprised by Nestos river basin, Area B, westwards, comprised by Pieria basin and Area C, at the north part of the island of Thassos.

Area A belongs to catchment area of Nestos river. More than 35% of the total cultivated land of Kavala is there and it is covered by an extensive surface irrigation network. Surface water comes from Nestos to more than 160.000 stremmas of cultivated land, consisting mainly of bread crop and secondly green fallow, asparagus, rice and kiwi trees. More than 150.000.000 m^3 of river water is diverted every year to West Adducent Canal (WAC), with a flow up to 22 m^3/h. WAC is branched off to five smaller canals that irrigate the valley through canalets. Gravity and subterranean drainage is accomplished by four drainage ditches (T1-T4), that discharge into the sea. Part of water in T 's is pumped back to refill canals. Nestos valley is the most productive agricultural area in Kavala, with the most extensive irrigated land.

Area B lies between Paggaeo mountain at the north and Symvolo mountain southward and is known as Pieria basin. There are more than 30.000 stremmas of cultivated land, mainly bread crops and intensive cultivations. About 20.000 stremmas are irrigated by a pipeline network, supplied by 70 main public boreholes, 120-200 m deep and some tens of swallow, private ones. Precipitates and Paggaeo mountain water bodies are the main sources of Area's B underground aquifers. Although there is also considerable arable land along the west coasts of Kavala, local economy has been gradually turning to tourist activities and this was the reason that this area was exempted from monitoring.

North part of island of Thassos was selected as Area C. There are about 80.000 stremmas of cultivated land, all over the island, covered by olive trees are irrigated by pipeline local networks supplied by public boreholes, 80-150 m deep. Southern part has been more rapidly developed due to increasing tourist interest, while northern part's economy, leans up more on agricultural production.

In the defined Areas A, B and C, according to MiRDeF monitoring programme, monthly samplings have been carried out in two sites, in both, rivers Nestos and Marmaras. Also, during summer period, three more samplings (at the beginning, middle and end of summer) are added to the schedule,

Fig. 1: The telemetry network for monitoring quality of irrigation water in prefecture of Kavala consists of four stations: STATIONS 1 and 2 in Area A (Nestos river basin), STATION 3 in Area B (Pieria basin) and STATION 4 in Area C (NW of Thassos island).

in six more sites for surface and five sites for underground irrigation water: In surface water of drainage ditches T1-T4 (six points), and in underground water of Thassos island (five wells in N-NW coasts). The results from analysed samples, have been showed that in the system of Area A, the quality of "output" water that discharge from T's ditches into the sea, is downgraded compared to the "input" water that enters WAC,. In Area C, the overpumping boreholes, during summer, have been causing phenomena of water salinization along the N-NW coastal aquifers of the island. In Area B, there is lack of data about quality of underground water. This general view acted as background knowledge for the forthcoming additional data and as a guide for the final selection of monitoring points.

4. Network set out

In order design criteria and cost efficiency to be achieved, four stations were decided to set: Two stations in Area A, one station in Area B and one in Area C (Fig. 1).

One station at the beginning and one at the end of the surface irrigation network, in Area A, could bring valuable information: Examining the input and output "signal" of the system, its characteristics could be identified. The existing irrigation network infrastructure offered two points that seemed to be ideal: A lodge, acting as "control room" for the water watchman that controls the floodgates and the flow of water from WAC to the valley, according to everyday water needs. It is the check point for input "signal" and STATION 1 was set there (Fig. 2). The second point had to be somewhere at the end of drainage ditches, in order system "response" to be checked. STATION 2 was put

Fig. 2: STATION 1 was put at the beginning of irrigation network of Nestos river basin, in a floodgate room in WAC. A plastic case was plunged into WAC and the sensors were put inside the case to be protected.

Fig. 3: STATION 2 was put at the end of irrigation network of Nestos river basin, in T2 drainage ditch. A plastic case to protect the sensors was used.

in T2 ditch, nearby a lodge with pumping equipment for refilling canals with the water of T2, which is partly reused before discharges into the sea, 2.5 km further down (Fig. 3).

STATION 3, in Area B, was tried to be set inside an existing pumped borehole of Pieria basin. Since this was impossible, because inside all boreholes pumping equipment was placed and moreover the adjacent piezometers were not wide enough, the idea of a “by pass” branch was adopted. The pumped borehole would drive part of underground water into a branch pipe, specially manufactured for the case. Sensors were put inside this “flow cell”, and circuitous water was driven back to underground aquifer, through the piezometer (Fig. 4).

The same procedure followed in Area C, except that “by pass” system was not necessary. The adjacent piezometer of an existing borehole located on the N-NW coasts of Thassos island, was wide enough for sensors to be plunged and STATION 4 was placed there (Fig. 5).

Maximum protection for all the four stations was achieved, using the existing infrastructure (lodges for data and communication units, canal “nest” for surface and piezometers for underground sensors)

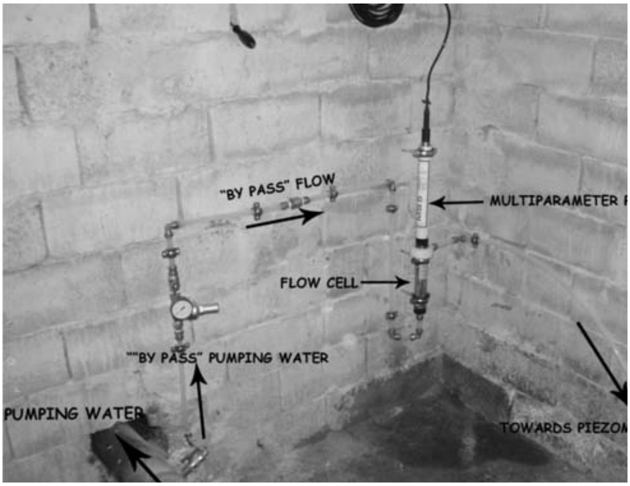

Fig. 4: In Area B (Pieria basin) STATION 3 was put in a borehole lodge. A "by pass" system was designed to drive the pumping water into a flow cell where the sensors were put and circuit back the water underground, through the adjacent piezometer.

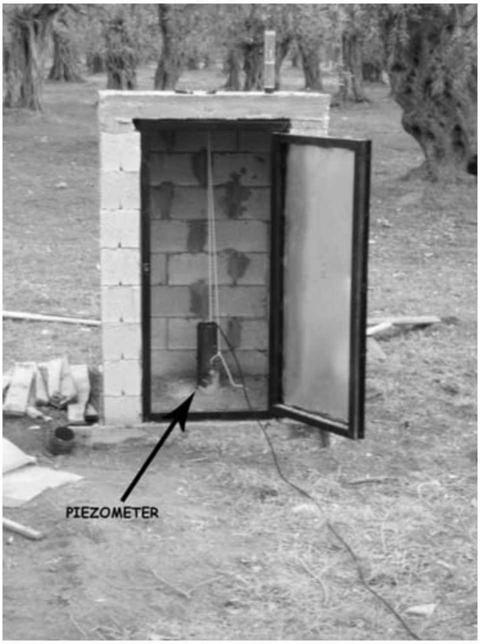

Fig. 5: In Area C (Thassos island), STATION 4 was plunged in the piezometer of an existing borehole and a small lodge to protect the sensors was constructed.

and manufacturing extra more when this was not enough (plastic cases for surface water sensors, underground pipes for power supply and communication cables etc.).

5. Operation

5.1 Measurement issues

Guided from the background information described in section 3 and budget limitations, the monitoring of physicochemical parameters of temperature, pH, electrical conductivity, dissolved oxygen, turbidity and water level was considered, at first phase, as adequate.

Fig. 6: The equipment of “OTT Messtechnik GmbH & Co. KG” was used in each station.

The choice of the appropriate measurement cycle, demanded a clear picture of the hydrological-hydrogeological conditions and mechanisms of potential pollution in each monitoring site and definition of monitoring objectives. The latter, as mentioned in section 2, was oriented to high frequency-real-time monitoring, while the former was still under investigation: Generally, surface water (like this in Area A) is specified by fast flows and underground water (like this in Areas B and C) by slower flows. This dictated more frequent measurements for STATION 1 and 2, than that for STATIONS 3 and 4. On the other hand, the examination of influence of continuous borehole pumping, in underground aquifers, requires high frequency monitoring. It was considered that setting a beginning rate of one measurement per hour, could be adequate.

5.2 Equipment

A success operation of a water quality telemetry network is finally ruled by the management of data acquisition, maintenance, transmission, processing and reporting. The accuracy, protection, continuity, and easiness of these procedures had to be ensured by the use of robust hardware and sophisticated software. The equipment of “OTT Messtechnik GmbH & Co. KG” was considered to meet the requirements. Specifically, each station was equipped with the following devices: (Fig. 6)

- OTT Hydrolab Minisonde 5. A multiparameter probe carrying temperature, pH, conductivity, dissolved oxygen (luminescence-LDO), turbidity (self cleaning) and depth sensors.
- OTT Duosens standard. A data logger with display and operating button (“jog-shuttle”) for entering observer values and for offset settings.
- OTT additional equipment: Wavecom M1306B, GSM/GPRS 900/1800 MHz modem, charger and battery as buffer, overload protection system.

Data are transmitted via GPRS and stored to a web server on Prefecture of Kavala‘s data room. Software packages OTT Hydras 3 and Hydras RX, are used, for communication management in the measuring network, equipment configuration, data reading, data management from measuring sites to measuring network, data processing and storage and data evaluation.

Data accessibility and report policy for the interested parties have been considering. SMS and e-mail alarms for each measured parameter in each station have been planning to warn when a measured parameter excesses the specified limit value. By this way, critical information will be instantly received and immediate actions will be enabled.

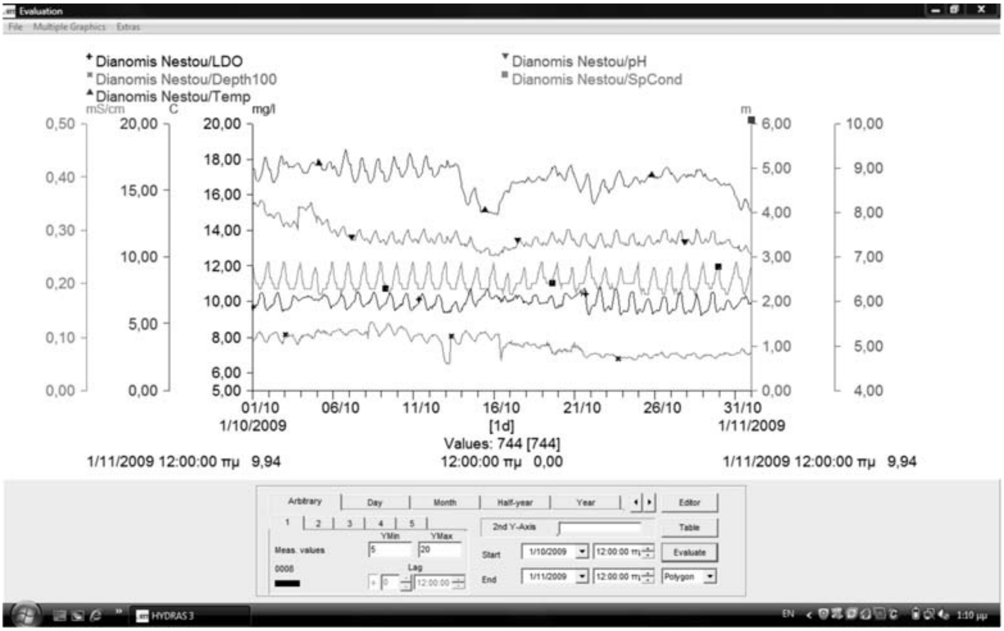

Fig. 7: Data (dissolved oxygen, water level, temperature, pH, electric conductivity) recorded on STATION 1, on October 2009 and plotted with OTT "Hydras 3" software package.

In Fig. 7, a timeseries of data, hourly measured on STATION 1 (Dianomis Nestou-WAC) on October 2009 is illustrated. The raw data set consists of temperature, pH, electrical conductivity, dissolved oxygen (LDO) and water level measurements and is plotted with OTT "Hydras 3" software package. The good physicochemical quality of the river water is obvious from the range of the parameters values. The presumable dependence of these parameters upon the daily variation of temperature is clearly indicated. The main disturbance which is observed between the 13th and 16th of October, is attributed to a rainfall. The water level data are not directly correlated to the above, since the water flow in WAC is controlled.

6. Conclusions

The rational management of water resources has been dictated from the increasing need for good quality water and the new legislation in force. A telemetry network for real-time water quality monitoring was set, supervised by Directorate of Land Reclamation/Prefecture of Kavala. It is comprised of four stations, placed on selected sites in irrigation canals and boreholes within prefecture of Kavala. Objectives, design criteria and operation issues are presented. The attempt is an innovative action for local authorities' administration. It aims to supplement water quality databases, with the missing high frequency information. The operation of such a network can eliminate time between a pollution event and actions to take and become a reliable tool for local bureaus and scientists.

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