DEVELOPMENT OF CONTROL MONITORING FOR THE PURPOSES OF INTEGRATED WATER RESOURCE MANAGEMENT OF THE VITOSHA NATURAL PARK

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Abstract

The "Development of water and water resource system balance for the territory of the Vitosha Natural Park" is the first comprehensive study of its kind on the water resources of the Vitosha Mt. and on the possibilities of using them for the purposes of the integrated management of the park. The project is developed by experts of the National Institute of Meteorology and Hydrology (NIMH), the Geological Institute (GI) of the Bulgarian Academy of Sciences and the University of Architecture, Civil Engineering and Geodesy as part of the "Implementation of the priority activities of the Management Plan of the Vitosha Natural Park – Phase 2" (funded by Operational Programme "Environment 2007 – 2013"). A new methodological approach has been applied to the assessment of the water and water resource system balance for the purposes of the Management Plan and the main trends and risks, the impact of climate change and extreme phenomena (floods and drought) are evaluated. Recommendations are given for the park management in view of the requirements of the water protection zones, according to the regime of permits and adaptation measures. In this context the necessity is considered for the development of control monitoring on the park territory, which is treated as a system. Its sub-system of water resources needs observations on runoff, runoff disturbances and wastewater.

The development of a pilot project has been substantiated with the aim of launching the construction of a modern monitoring system for the water resources of the Vitosha Natural Park, affording the possibility of realistic assessment of the water balance in its region. The results of this work are directly related to the water supply of the settlements in the area, ensuring the ecological runoff and integrated management of water and forest resources.

Key words: *water and water resource system balance, integrated management, adaptation measures, climate change, ecological runoff, hydrometry, control monitoring, water meter devices*

1. INTRODUCTION

The "Development of water and water resource system balance for the territory of the Vitosha Natural Park" is the first comprehensive study of its kind on the water resources of the Vitosha Mountain and on the possibilities of using them for the purposes of integrated management of the park. The project is developed by experts of the National Institute of Meteorology and Hydrology (NIMH), the Geological Institute (GI) of the Bulgarian Academy of Sciences (BAS) and the University of Architecture, Civil Engineering and Geodesy (UACEG) as part of the "Implementation of the priority activities of the Management Plan of the Vitosha Natural Park – Phase 2". The project is financed by the European Regional Development Fund and the state budget of the Republic of Bulgaria through the Operational Programme Environment 2007 – 2013. A new methodological approach has been applied to the assessment of the water and water resource system (WRS) balance and an integrated analysis is realized for all elements (precipitation, temperature, evapotranspiration, land and soil cover, hydrogeology, water abstraction and water use, water transfer, etc.) (Benderev et al., 2014; Ilcheva et al., 2014; Ilcheva et al., 2015). An assessment is made for the main trends and risks, impact of climate change and extreme phenomena (floods and drought) for the purposes of the management plan. Some critical issues and sections are identified and recommendations are given for the park management in accordance with water protection zones and reserves, as well as with regime of permits. Recommendations are given for management under conditions of climate change, drought and floods. The elaborated strategy for integrated management of the water supply systems and the water

protective forests indicates the necessity of developing the control monitoring on the park territory (Ilcheva et al., 2015; Marinov et al., 2014; Mitigation vulnerability…, 2014).

The Vitosha Natural Park (NP) is included in the protected areas of the European ecological network Natura 2000 under BG0000113 code with the name of Vitosha. In addition, it is the first natural park on the Balkan Peninsula with special status declared as early as in 1934. The stringent regulatory requirements for its protection and maintenance are due not only to the observed rare biological species with habitats on its territory but also to its utmost importance for the formation of the main elements of the environment in the vast region of the metropolitan city.

A very substantial part of the measures to be included in updating the management plan for the park is the need to conduct observations on the runoff of the numerous rivers taking their sources from the Vitosha Park. The Management Plan of the Vitosha Natural Park for the period 2005 – 2014 contains many important inferences concerning the hydrological knowledge about the area. Briefly, they can be summarized as follows:

1. The runoff of the Vitosha rivers has not been studied in sufficient detail.
2. The internal annual runoff distribution of the Vitosha rivers has not been investigated well enough.
3. The minimum runoff of the Vitosha Mt. has not been investigated.
4. The river runoff in the places of the small number of hydrometric stations is disturbed.

In this context, the following has been envisaged in the Terms of Reference for Updating the Management Plan of the Vitosha Natural Park – Plan 2 from 2015 **(quotation-excerpt)**:

1.1.1. Hydrology and hydrography. Hydrographic network – rivers, springs, lakes

To update, refine and supplement the text of Plan`1 by submitting basic hydrological and hydrographic characteristics, including: rivers, formed at the park territory; density of river network; watershed basins and their area; lakes; **annual runoff of the single rivers and total runoff for the park – monthly and annual runoff distribution, phase distribution, assessment of the water resources in the phases.**

To study and analyze the available monitoring, reference literature and other data and to describe in a concise text in Plan`2 the following hydrographic parameters essentially and in tabular form in Proceedings of Abiotic Factors:

- Annual runoff – to provide methodology for annual runoff calculation, to provide a table with the natural water resources according to altitude belts, to provide a table with the runoff distribution of the major rivers on the territory of the Vitosha NP (if such information is available) and tables with the monthly and annual runoff distribution. Phase distribution of river runoff. Typology of the phase regime.
- Minimum runoff – historical data. Table of the guaranteed water resources in the Vitosha Mt. according to altitude belts. Table with the physical geographic and hydrological characteristics of the rivers in the area. **(end of quotation)**

The Terms of Reference for Updating the Management Plan state these tasks rather cautiously in view of the almost missing observation base. However, their performance by using indirect methodologies and imitation mathematical models would not lead to usable results if there are no real observations in an appropriately selected network of monitoring stations. The known in hydrology analogy methods need reliable “analogues” and modern mathematical modeling of hydrological processes require verification of the models and additional adaptation to the local conditions. So, without the realization of some of the steps proposed in this attitude, the good intentions of the new management plan will be implemented but without the desired actual effect on the hydrological knowledge on the Vitosha Mt.

The provisions in the Terms of Reference for a new management plan are undoubtedly correct and represent significant progress in the vision for preserving the ecological balance in this valuable

territory. Our opinion is not aimed at opposing to their idea, but at indicating the necessary prerequisites for their effective implementation.

The Vitosha Natural Park is a complex system, composed by numerous sub-systems. Its management obeys the fundamental principles of the system management theory, according to which the management is reduced to the following:

1. The current state of the system is determined by observation (measurement) of basic characterizing parameters.
2. If it does not coincide with our requirement to the system, called "terms of reference", a management "impact" is developed and applied to the system.
3. The system reacts in a certain manner to this impact, which is called the "system response".
4. Observation (measurement) of the basic parameters is conducted again and if the system "response" does not coincide with the "terms of reference", a new managing impact is developed and applied again.
5. This series of actions is repeatedly carried out in the same sequence until the state of the system falls within the desired limits. Then the observations continue and only in case that the system deviates from the "terms of reference" it will be subjected to a new managing impact.

The principle is simple enough and universally applicable to any kind of systems.

It follows from the above scheme that the basic activity in the management is "observation" or "measurement" of the characteristic parameters of the system since a given system cannot be managed if not known quantitatively.

If a sub-system of the Vitosha Natural Park is considered as an example, provisionally called "Water resources" (comprising river runoff, domestic and business use, as well as wastewater generation), it becomes clear that the knowledge on its characteristic parameters is almost zero. Till now it has been possible to evaluate them only by means of indirect and roughly approximate methods. This is not enough for the optimal management of the system, where "managing" impacts of particular type and dimension are required. The inference that at the present stage this system is not known to the sufficient degree provides the ground to focus our attention on the monitoring of its quantitative parameters. The above mentioned research work "Development of water and water resource system balance for the territory of the Vitosha Natural Park" represents a serious progress in the study of the "water resource" system and provides the necessary prerequisites for the logically following steps towards the creation of direct quantitative monitoring network for operative management. The aim of these steps is to substantiate the necessity of developing a next project with a task for initial building of a specialized monitoring network for the water resources in the park.

2. NECESSARY MEASURES FOR MONITORING OF THE WATER RESOURCE SUB-SYSTEM IN THE VITOSHA NATURAL PARK

As already pointed out above, the ecological system of the Vitosha Natural Park is a complex of different sub-systems – components of the environment. The name "Water Resources" is adopted here quite provisionally and serves at this stage to designate only the river runoff and its use for various purposes. Groundwater is also water resource but for the present its unknown contribution will be evaluated within the frame of the formed runoff in the river network of the mountain.

In this context of consideration, the following regime varieties of this resource fall within the scope of the necessary observations:

- River runoff in the territory and along the periphery of the mountain.
- Caught water at the intakes for domestic and business use.
- Reversible and waste water in the water intakes on the territory of the mountain.

The monitoring of this water is an obligatory activity both in composing the actual water balances and in the management decisions for impact on their regime of distribution.

It is obvious that the full coverage with water observations is an extremely ambitious task, which is impossible in the current economic situation. However, to outline this as a scheme of the "ideal monitoring" is an important step for elucidating the volume of the measures needed and their planned priority execution in long-term respect. The near prospects are to acquire the necessary minimum of direct information to achieve the set management objectives.

2.1 River runoff monitoring

A characteristic feature of the park is that it is with an almost round shape and it is located entirely in a mountain landscape. The main watershed between the major basins in Bulgaria – the Danube and the Aegean, between the basins of the Iskar and Struma Rivers in particular, passes across the park area.

The high-mountainous character of the territory determines the formation of a large number of rivers, flowing in almost radial direction and leaving freely the area outlines. It is practically impossible to cover them with observations. And in view of the uniform regional conditions of runoff formation in whole groups, the individual monitoring is inexpedient.

The more significant rivers with well-shaped riverbeds leaving freely the park territory are: Struma, Rudarshtitsa, Vladayska, Boyanska, Dragalevska, Bistritsa, Zheleznishka and Palakaria. These rivers together with their numerous small tributaries drain the entire territory of the park. With the exception of the Struma River they all belong to the Iskar River catchment. After leaving the park territory some of them merge together, forming the Sofia Perlovska and Slatinska Rivers.

The organization of hydrometric stations at each of these rivers would contribute much to the study of the water regime in the mountain. However, having in mind the practical difficulties for the investment and institutional service of observations, restrictions and rationalization of the monitoring network have to be realized. The objective of this optimization is to reach maximum effect for the study of the runoff regime with a minimum number of hydrometric stations.

The long-year experience from the hydrological explorations in Bulgaria proves that the following considerations have to be taken into account, when realizing this optimization:

1. In regions with restricted area (as in the case with the Vitosha Park) the climatic factors for runoff formation are quite similar, depending to the greatest extent on the exposition of the catchment areas and their average altitude.
2. The mountainous regions are characterized by very well pronounced dependences of the runoff modulus and its annual variation on the average altitude of the basins.
3. Economical solutions are achieved with the maximum use of the existing technical infrastructure for the purposes of monitoring.

Based on the above considerations grouping can be proposed of the rivers with respect to slope exposition, with carrying out the monitoring for one of them – a "river-analogue". In this way the number of the monitored rivers on the park territory is reduced to four, one per each slope – western, northern, eastern and southern. To clarify the runoff distribution with altitude it is expedient to organize two observation points for each river, located at different elevations. So a sufficiently reliable database would be obtained for the runoff from Vitosha, since the data from the existing hydrometric stations of the national reference network at the Vladayska River near Knyazhevo (HMS No 18420) and at the Palakaria River near the Relyovo village (HMS No 18370) can be also used in the analyses. The service information for the tributary from the Struma River to the Studena dam, obtained on the base of the water balances of the reservoir, can be used for the same purposes. The reference HMS No 51650 at the Struma River near Pernik can be used as an additional control hydrometric station.

Before starting a project for constructing a monitoring network in the Vitosha Natural Park for the river runoff regime it is necessary to select and justify its scheme. The first approximation of such a scheme is given here, which will launch the systematic study of runoff by direct measurements.

a) Western slope of the Vitosha Mt.

River – analogue: Vladayska

Hydrometric stations:

- existing HMS No 18420 near Knyazhevo at an elevation of about 700 m.
- new station near Zlatni Mostove at an elevation of about 1400 m.

b) Northern slope of the Vitosha Mt.

River – analogue: Boyanska

Hydrometric stations:

- new station in the Boyana quarter at an elevation of about 600 m.
- new station in the area of the Tintyava chalet at an elevation of about 1600 m.

c) Eastern slope of the Vitosha Mt.

River – analogue: Velena (Zheleznishka)

- new station at the siphon of the Rila water pipeline, elevation about 750 m.
- new station above the Zheleznitsa village at an elevation of about 1000 m.

d) Southern slope of the Vitosha Mt.

River – analogues: Struma and Palakaria

Hydrometric stations:

- existing monitoring on the runoff from the Struma River to the Studena dam at an elevation of about 850 m.
- existing HMS No 18370 at the Palakaria River near the Relyovo village at an elevation of about 895 m.
- new station at the Palakaria River near the Yarlovo village at an elevation of about 1100 m.

The above scheme is considered to be good enough to monitor the runoff formation in the park area. It envisages observations in 9 points, 3 of them existing and 6 new ones.

The realization of such a project needs the relevant stages, which is specially treated in item 3 of the present concept.

The exact determination of the places of the new hydrometric stations is subject to specifying and this activity requires more detailed study. It has to be taken into account that the design of the hydrometric networks should meet certain technical and organizational requirements.

2.2 Monitoring of natural runoff disturbances

The river runoff disturbance implies any human interference, leading to diversion of water from its natural course for different domestic and economic purposes.

The above cited work “Development of the water balance for the territory of the Vitosha Natural Park” from 2014 contains the whole necessary information about the points on the park territory, where the violations take place. Direct measurements have to be organized for the most significant ones in order to establish their regime characteristics.

The most essential runoff disturbances are observed in the two collecting channels – Vladaya and Palakaria, which except the local runoff disturbances transfer large water volumes from the Iskar to the Struma River basin. In our view the primary task is to organize observations through direct measurements of the water quantities taken by these two derivations.

a) Vladaya collecting channel

The channel is about 13.4 km long, its initial intake being at the Vladayska River at an elevation of 1050 m and its mouth – in the Kladnishka River bed at an elevation of 1010 m, from where the water runs to the Studena dam. With the other 6 water intakes built along its length the channel collects water from the Vladayska, Bistrata (a tributary of the Vladayska River), Marchaevska (a tributary of the Rudarshtitsa River), Rudarshtitsa and other three small tributaries, which dry out in summer. The channel is dimensioned to conduct up to 2 m^3/s, a significant capacity for the scale of the local rivers.

A consistent solution would be obtained if there is a measuring device at each of these intakes for the water influx in the derivation. At the present stage there is no reliable information whether such measuring devices function and whether the quality of such information is satisfactory.

b) Palakaria collecting channel

The channel is about 8.8 km long, its initial intake being at a drying tributary of the Palakaria River at an elevation of about 1344 m and its mouth is in the Struma River at an elevation of 1318 m. Other 6 water intakes are built along the length of the Palakaria River and other of its drying tributaries. The channel is built with a capacity of 0.9 m^3/s. There is no information whether the water intakes are equipped with measuring devices.

Except via these two relatively large collecting channels, the disturbances of the natural runoff in the mountain are also realized through numerous small water intakes and captures, included in individual or group water conduit networks for drinking water supply of the neighboring villages, chalets, tourist centers and other sites. Their high dispersion and the small size of the water quantities caught characterize them as minor runoff disturbances. Moreover, most of them are operated by the Sofia Water AD company and the water consumption should be measured, at least by the individual water meters of consumers. It may be considered that this information is available for use.

With this formulation of the problem, the task is outlined to study the water intakes along the two collecting channels with respect to existing measuring devices or conditions for the installation of new ones. As far as the rest small but numerous consumers are concerned, the possibilities for access to information about the realized water consumption should be explored.

2.3 Wastewater monitoring

Wastewater is a major source of anthropogenic pollution of the water bodies in the park. It can be stated with certainty that so far no observations have been carried out of its quantity. Unfortunately, the lack of a centralized sewage system in the park makes the overall monitoring and control impossible.

The task in this context will be limited to the construction of measuring facilities only at the existing local treatment plants or in the main collectors of the group sewage systems.

3. DEVELOPMENT OF A PILOT PROJECT ON BUILDING A MONITORING SYSTEM FOR THE WATER RESOURCES IN THE VITOSHA NATURAL PARK

The development of pilot projects is an acknowledged global practice, when the problem to be solved is complex and some of the factors determining it need additional long-term studies. This is the case with this concept since the launching of systematic observations on water resources cannot be postponed and their institutional setup encounters problems that have yet to be solved. At the same time the infrastructure of the water resource system is with threatening propagation in the park, without making any quantitative verification concerning the ecosystem tolerance towards this impact.

It is typical for such projects that on the base of an overall assessment of the scale of the necessary measures, their implementation has to be started in stages, their initial phase being the object of the pilot project. It has a dual objective – to launch the measures envisaged and verify the adequacy of solutions and effectiveness of the technical tools used.

Main reasons for the project assignment

The following key inferences can be made based on the explorations conducted so far on the water regime of the Vitosha Natural Park:

- The park falls within the Natura 2000 European Ecological Network of protected areas. Its unique natural settings were evaluated as early as in 1934, when it acquired a special statute of state protection by proclaiming it a Natural Park.
- Since the beginning of the last century the park has been used for tourism and recreation with the construction only of chalets and lodges that are with picturesque incorporation in the landscape. The incompatible quality of the natural water was used for the water supply of Sofia at that time, its population not exceeding 300 000 inhabitants till 1950. According to data of the International Water Supply Association water with such high quality is not available in any of the other European metropolitan cities!
- The vigorous development of the capital city since the middle of the last century has led also to the invasion of urban infrastructure in the park territory and the construction of water supply facilities has been expanded to critical dimensions, without having the necessary vision for the adverse ecological consequences. According to data from the official census in 2011 about 1.3 million inhabitants live in the metropolitan city but according to unofficial information about 2 million people reside daily in the city.
- At the background of this irresistible anthropogenic pressure on the park territory no visible attempts are noticed to perform systematic control on its water resources that are constantly exhausted.

Aim of the project

The aim of the project is to launch the construction of a monitoring system for the water resources in the Vitosha Natural Park of a modern type, with the possibility for realistic assessment of the water balance on its territory.

Scope of the project

The scope of this system in its complete form is significant. Furthermore, there are a number of unsolved administrative and organization problems related to financing, operation and maintenance of this system. Therefore it is expedient to address them by reasonably planned stages, the pilot project covering only the initial phase of this activity. This restriction is required by the objective conditions of the existing ambiguity related to the property of terrains and facilities, as well as by the ensuing thereof institutional obligations for monitoring. For this reason the executive team will also undertake the obligation to conduct the runoff observations during the pilot project and to submit the obtained database to the contracting authority.

The following monitoring points will be explored, built and commissioned within the frames of the pilot project:

1. a hydrometric station on a river – analogue for the rivers at the northern slopes of the Vitosha Mt. It is desirable to built the station at the Boyanska River but its location may be changed after the exploration phase of the project because at that stage a section should be selected, which does not require additional construction works.
2. a hydrometric station at the mouth of the Vladayski collecting channel in the Kladnishka River, from where the water is discharged in the Studena dam.
3. a hydrometric station at the mouth of the Palakaria collecting channel in the Struma River above the Studena dam.
4. a hydrometric device for wastewater in an additionally indicated by the contracting authority group collector or after an existing Wastewater Treatment Plant (WWTP) on the park territory.

After completing the installation of the hydrometric stations, it is envisaged in the project to conduct author monitoring in the course of one year. It is assumed that by this term the administrative-legal relationships between the interested institutions concerning the property and obligations to conduct the monitoring in the coming years will become clear.

Quality of the measuring equipment

The installation of fully automated electronic equipment is envisaged with continuous data recording during the observation period and with optional possibilities for transfer of the stored information by conventional telecommunication means to the main dispatching computer.

4. CONCLUSION

The proposed project for the development of water resource monitoring in the Vitosha Natural Park, which is a site of national importance and an element of the European ecological network Natura 2000, indicates the necessary technical measures, by means of which such an effectively functioning system can be constructed. To this end the will of all institutions possessing legal ownership rights in the park territory is necessary, their understanding about the importance of such a system being beyond any doubt. Efforts should be applied to coordinate the activities under unified research-methodological guidance. In Bulgaria there is a rich scientific experience on the problems of water resources and a very old tradition in their observation, updated by the recent advances in measuring technique and metrology.

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APPENDIX: Illustration examples for the proposed solutions, applied at other sites



Examples of hydrometric facilities in derivation channels



Installation of a hydrometric device in a channel



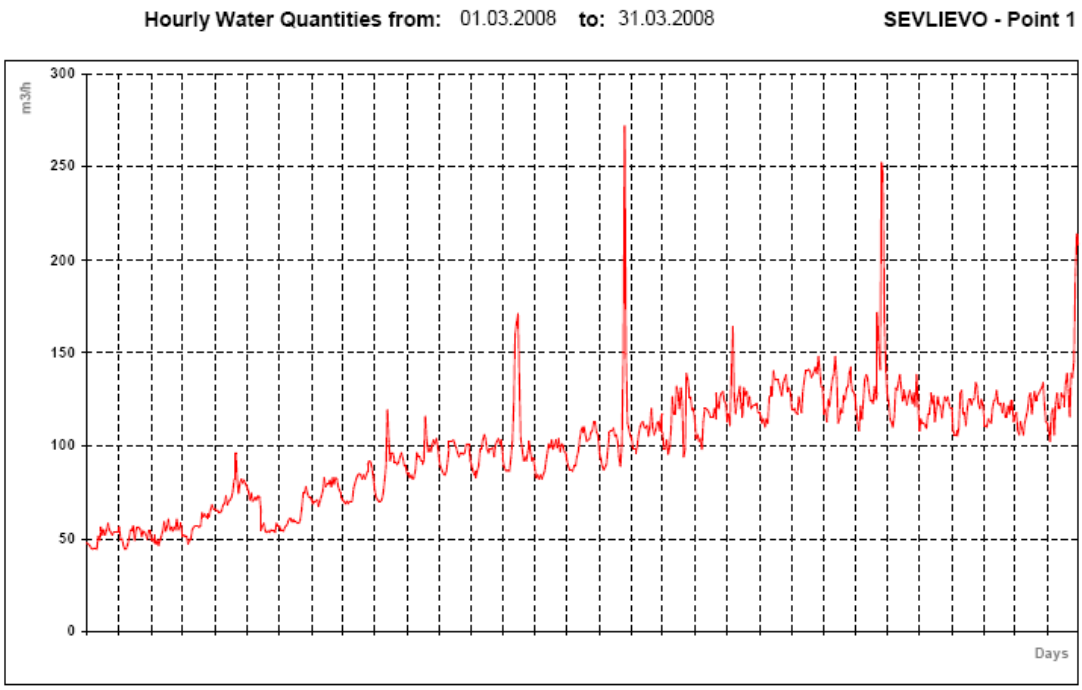
Examples for the position of the panel with recording equipment

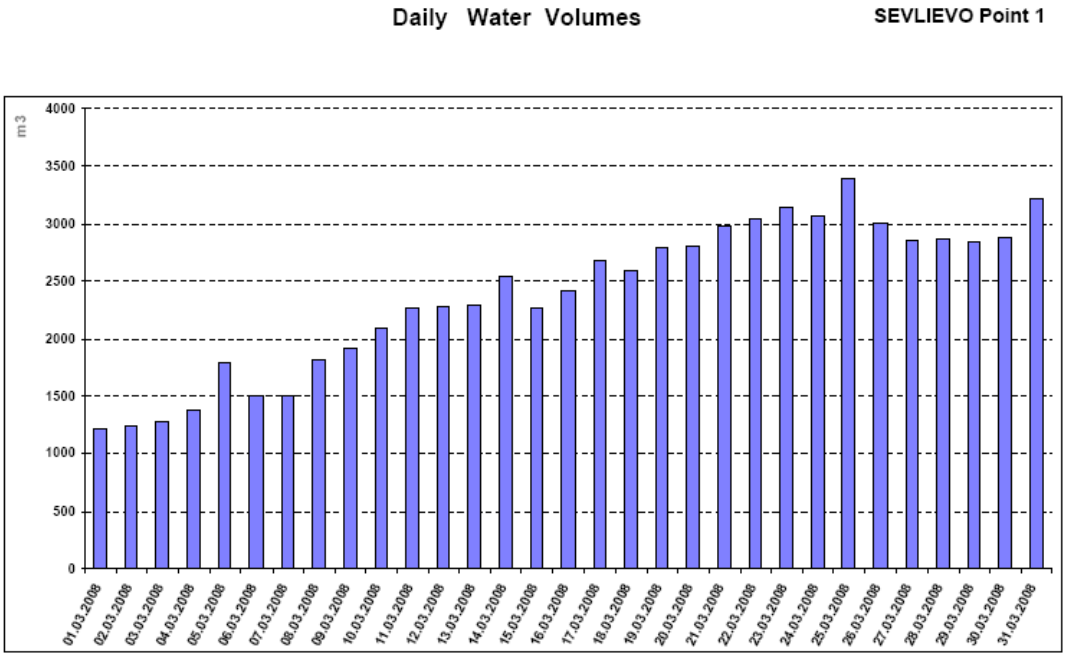


Calibration measurements with a hydrometric propeller



Calibration measurements with hydrometric robot





Example diagrams of the measured flow rates and water volumes by the recording equipment