Mon25-182

Geoinformation and cartographic support of water resources management on the example of the Tysa River basin

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SUMMARY

The Tysa automated information and measurement system is an important tool for managing the water resources of the Tysa River basin. It allows for effective monitoring, forecasting and management of floods by integrating data from various sources, including geographic information systems (GIS) and ADCP. Operational data of the Tysa AIMS are key for making informed decisions by regional and district executive structures. Implementation of GIS technologies allows optimizing water resources management and developing strategies to minimize flood risks, which ensures sustainable development of the region and rational use of water resources. The system also facilitates cross-border cooperation by participating in international projects and supports the modern GSM data transmission mode.

The analyzed stock materials and the results of the work of the Tysa River Basin Water Resources Administration and its individual structural units allow us to assert the crucial role of geoinformation and cartographic support for the work of water management structures, the State Emergency Service, local governments, environmental and non-profit structures and organizations, as well as scientists in the development and implementation of water management plans for the Tysa River Basin within the Transcarpathian region of Ukraine. Significant changes relate to the algorithms and timing of data collection, processing and presentation, and the adoption of relevant management and project decisions.

Introduction. Water resources management in the Tysa River basin is an important task for ensuring sustainable development of the region, minimizing flood risks and ensuring rational use of water resources. Geographic information systems (GIS) and automated information and measurement systems (AIMS) play an important role in this process, allowing for monitoring of the hydrological state, forecasting changes, and developing management strategies.

One of the key tools in managing the water resources of the Tysa River basin is the Tysa Automated Information and Measurement System (hereinafter referred to as AIMS Tysa), which is operated by the Tysa Automated Information and Measurement System Operation Department (AIMS-Tysa) and Geographic Information Systems (GIS). Implementation of GIS technologies allows to integrate various spatial data for comprehensive analysis and effective management decisions.

Materials and research methods. The study is based on the analysis of the stock materials of the Tysa River Basin Water Resources Administration and its structural units, including hydrological monitoring data, mapping materials, and GIS modeling. The main methods are: retrospective method (analysis of available collection materials to determine dependencies and relationships); cartographic method (study and analysis of collection mapping materials of the Tysa River BWRA); geographic information analysis (use and analysis of digital maps and satellite data).

Results. The Tysa River Basin Water Resources Administration is a budgetary non-profit organization that is managed by the State Agency of Water Resources of Ukraine. The main purpose of the Tysa River Basin Water Resources Administration is to monitor, manage, use and restore surface water resources in the Tysa River basin. The main tasks and activities of the Tysa BWRA:

- monitoring of water resources: The water monitoring laboratory regularly controls the quality of surface water;
- operation of the automated information and measurement system (AIMS Tysa). This system is constantly being improved to increase the efficiency of hydrometeorological and environmental monitoring, which is important for timely response to floods;
- cross-border cooperation: The Tysa River BWRA participates in international projects and cooperates with border countries to improve water management in the Tysa River Basin. (FloodUZH, TACIS, INTERREG/TACIS, AdaptWater, SAFETISZA).

Transcarpathian region is characterized by a dense hydrological network. Over the past decade, two catastrophic floods have occurred on its territory (1998, 2001). Automated hydrometeorological measuring stations were built to monitor flood situations. To ensure the smooth operation and maintenance of the stations, a new department was created within the Tysa River BWRA - *The Department of Automated Information and Measurement System (AIMS-Tysa) and Geographic Information Systems (GIS) Operation* (established in June 2005). The department's activities are divided into 4 main areas:

- operation of automated measuring stations;
- information and technical support of the Tysa River BWRA activities;
- providing radio communication between the Tysa River BWRA and the Interdistrict Water Management Department;
- provision of wired communication for Tysa River BWRA.

Currently, there are 50 automated measuring stations in the Tysa River basin, including 30 hydrometeorological, 13 meteorological, 1 for water quality control, 4 for monitoring the operation of pumping stations, and 2 for monitoring the operation of locks. All of these stations are part of the unified Ukrainian-Hungarian leash monitoring system AIMS Tysa, which also includes hydrometeorological and meteorological stations located in Hungary. Future plans include connecting stations in Romania and Slovakia to this system.

The AIMS Tysa system has an international certificate of ISO 9001:2008. All automatic measuring stations have been switched to the modern GSM data transmission mode, which covers almost the entire territory of the Transcarpathian region.

Evaluation of the effectiveness of AIMS Tysa. The automated monitoring system allows to obtain data on water level, precipitation and other parameters in a timely manner, which contributes to timely response to flood situations (Fig. 1). The information from the stations is automatically transmitted online at five-minute intervals to Ukrainian and Hungarian water authorities for management decision-making. The data obtained from the Tysa AIMS is used to build digital models of flood zones, analyze changes in river channels, predict potential damage, etc. The operation of the automated information and measuring system has made it possible to reduce the time for making management decisions during floods by four times and is in line with modern approaches to integrated water resources management.

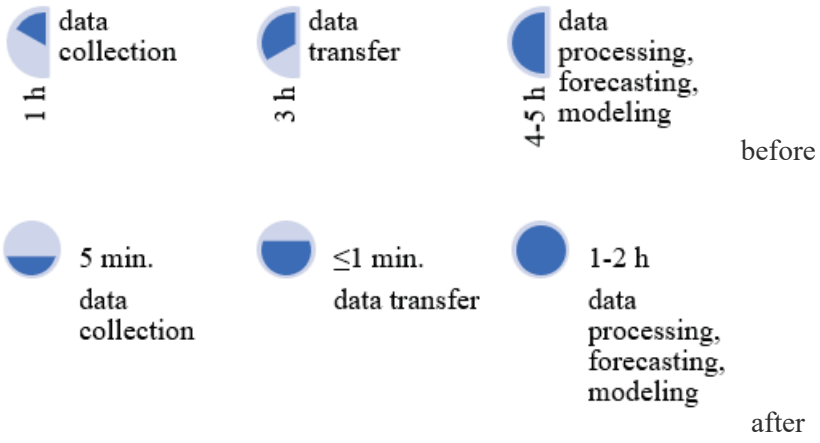

Figure 1. *Block diagram of management decision-making (before and after the implementation of the Tysa automated information and measurement system)*

The advantages of implementing AIMS Tysa in the system of management decision-making on the water management complex of the Transcarpathian region are listed below:

- obtaining accurate and timely information on water levels from automated gauging stations to assess the current state of the hydrological situation and to make forecasts;
- modeling and forecasting of possible scenarios of flood situations in order to assess their possible consequence;
- identification of high-risk flood zones to optimize the costs of preventive measures;
- informing the public about the level of danger and dangerous areas that may occur during floods.

GIS application in water management. As part of its activities, the Tysa River BWRA actively uses geographic information technologies, in particular software products: ArcGIS (ESRI), Panorama, Mapinfo, MS Access to integrate data on water bodies, land use and hydrological conditions of the Tysa catchment area and develop thematic maps showing flood hazard levels and potential threats to water resources. Using data from the Tysa automated information and measurement system (AIMS) and ADCP measurements, the DIWA HFMS model predicts the development of flood situations on the rivers of Transcarpathia. This model covers the catchment area of three countries: Ukraine, Hungary and Romania. It operates automatically and provides hydrological forecasts every hour. During floods, the system's operational data is an effective tool for making informed and coordinated decisions by local executive structures, such as regional and district state administrations, the State Emergency Service, water and road services, the agricultural sector, and local communities.

Functions and areas of application of GIS and geoinformation technologies in the work of the Tysa River BWRA. Employees of the Tysa River BWRA are actively using geographic information technologies not only for applied purposes. For example, *the information and reference function* is provided by creating and maintaining spatially coordinated information databases, including a series of digital maps for the Draft Tysa River Basin Management Plan, creating and maintaining databases of surface water monitoring systems in Transcarpathian region, etc (Khilchevskyi et al., 2022). *The function of automated mapping* is provided by the structural units of the Tysa River BWRA by accessing the display of thematic data layers of the Tysa AIMS in free access on the Google Maps base map. *The function of spatial analysis and modeling* is based on the capabilities of ArcGIS analytical blocks, which are used by the Tysa Automated Information and Measurement System AIMS Tysa and Geographic Information Systems (GIS) Operation Department for applied water management tasks within the Tysa River basin.

The process *modeling function* is implemented in modeling hydrological processes, predicting the consequences of catastrophic floods (1% probability), as well as in solving scientific and applied problems, including those related to the conservation, restoration and rational use of water resources in the Tysa basin. One of the most important functions of the Tysa River BWRA is to *provide geographic information support for decision-making* in compliance with current legislation, norms, rules and standards in planning and designing transboundary cooperation programs within the Tysa sub-basins and water management in the region (Cabinet of Ministers of Ukraine, 2018; Leta et al., 2022).

At the same time, geographic information technologies are widely used for scientific purposes, in particular when considering methodological aspects of GIS analysis in water resources management. development of approaches to integrate GIS data and monitoring indicators in the activities of the Tysa River BWRA, including to ensure international norms and standards of monitoring, ecology and water resources management, goals of balanced development of territories, as well as integration into the European space (Directive, 2000; Directive, 2013; Khilchevskyi et al., 2019).

Conclusions.

Geoinformation and mapping support for water resources management in the Tysa River basin is an important tool for making informed decisions on water conservation, protection, restoration, and management. It is worth noting that operational reports, scientific forecasts and recommendations for local governments and relevant services are based on mapping models.

The analysis of the effectiveness of the Tysa AIMS and the implementation of GIS technologies shows a significant improvement in water resources monitoring and flood risk management. Prospects for further implementation and expansion of the use of GIS data and technologies include: improving flood forecasting models using artificial intelligence and machine learning; using satellite data for a more accurate assessment of the state of water resources; integrating GIS data with other information systems to improve the efficiency of water management at the regional and international level.

Acknowledgements

We would like to thank to the Tysa River Basin Water Resources Administration, (T.R.B.W.R.A.) (Uzhhorod, Ukraine) for the provided data. We would also like to thank all those who have offered or will offer suggestions for the improvement of the present paper.

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