A complexly method of GIS technologies and models used in the development of environmentally modes of hydraulic and hydropower facilities in Uzbekistan

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Abstract. In this article we consider the results of studying the problems and prospects of using information technologies to ensure the introduction of new innovative approaches in hydroecology and hydropower, the creation of GIS (GIS- geographic information systems) for hydroecological and hydro-technical monitoring, and also as a visual material for students studying the use of information systems in the development of environmentally acceptable modes of operation of hydraulic structures. The article was devoted to an actual theme - GIS-systems creation for hydro ecological monitoring as tool for support the information systems of the Aral Sea basin and optimisation models at development of ecologically applicable modes of exploitation of hydro technical buildings. It is possible and useful to use association of outputs from various scientific researches in one GIS-database as universal tool for modeling. As example of such approach can be consider as one interconnected system which combination results of work:
- System of water-salt balances in all rivers of Uzbekistan.
- System of digital maps and schemes that can be used in the development of environmentally acceptable modes of operation of hydraulic and hydropower facilities in Uzbekistan.
- The Aral Sea basin monitoring systems (ASBMS) as a digital system of hydroecological monitoring of quality of surface waters on basis ArcView.

Keywords: Information technologies and education, hydraulic and hydropower facilities, hydroecological and hydrotechnical monitoring,

1. Introduction

Under the control of the «Uzgosvodkhozkontrol» inspection, there are 273 large and especially important hydraulic engineering facilities. Of these: 50 - reservoirs, 35 - pumping stations, 31 - hydroelectric power stations, 60 - main canals, 24 - main collectors, 64 - hydroelectric facilities. To ensure irrigated agriculture in Uzbekistan, there are 46,668 inter-farm and 175,000 on-farm hydraulic structures. Water resources management and their use for various purposes is carried out through hydraulic structures, hydroelectric power stations and pumping stations, the effectiveness and reliability of which depend largely on the quality of project development. For successful project development, it is necessary to analyze the initial data (topography, geology, hydrology, etc.), know the structures of the structures, the possibilities of their application and the technology of their construction, master the methods of calculating the selected structures, and predict the consequences caused by their construction and operation. Considering the specifics (agricultural orientation in the development of the economy) and the peculiarity of the geographical location, where there is an acute shortage of water resources, the priority areas in the development of this sector of the national economy are the use of water and energy-saving technologies and the efficient use of hydraulic structures, hydroelectric power stations and pumping stations. Therefore, the use of geographic information systems and technologies will help designers in the reconstruction and construction of new hydropower plants, hydroelectric power stations and pumping stations. The operation of hydraulic structures should be considered inextricably linked with the operation of all structures included in the
hydraulic unit. The operation of the hydraulic structures of the reservoir units at the local drain solves two main problems: - to ensure the supply of water from the reservoir in accordance with the established consumption schedule; - to support the construction of the site in working condition. These tasks should be considered as a single set of operational measures, due to which the unit of structures is operated for fish farming, water supply, irrigation, hydropower, etc. In addition, at present, the efforts of many countries and organizations are aimed at addressing improvement issues for the operation modes of hydraulic structures in Uzbekistan, special attention is drawn to hydroelectric power stations, since the energy component of the country's economic development is of paramount importance. Due to the fact that in Uzbekistan there is a large water management complex, knowledge of the specifics of the formation of operating modes of hydropower plants and hydropower plants and pumping stations, assessment of the hydraulic, hydrological and hydrochemical status at a given time is a very important component for planning future work A dense network of canals requires systematic hydroecological monitoring, since it depends on the quantity and quality of water how hydroelectric power stations and pumping stations will work.

2. Purposes and research tasks

This work is devoted to solving the following issues [1-9]:
1. Development and application of computerized databases, geographic information systems and integrated models for assessing the various possibilities of environmentally acceptable operating modes of hydropower plants and pumping stations.
2. The potential and ongoing use of models in the planning and management of water resources.
   From risk management to sustainability management, the creation of decision support systems. The experience of using GIS technologies will be used in the development of criteria for the safe operation of hydraulic power stations, hydroelectric power stations, pumping stations, as well as the development of hydrometric support.
   The following work plan is envisioned: 1. We intend to investigate the distribution and levels of contamination in the drainage of municipal and industrial sewage for the administrative districts of both rivers (MONITORING). 2. We shall reveal peculiarities of the pollution and analyze the dissolved minerals in the water to highlight the hydroecological situation of the Aral Sea basin (MODELLING). 3. We intend to apply methods, theories and technical means of western science and combine them with our program of hydroecological monitoring taking into account all anthropogenous and physico-geographic factors (DECISION SUPPORT).
   In the 2000s, the basics of an integrated methodology were developed in detail (Fig. 1-2) [10-13], in subsequent years the methodology was supplemented and many blocks were uncovered and investigated [14-19]
   The operational experience of hydraulic structures shows that any deformations, including emergency ones, do not occur unexpectedly. They are preceded by the accumulation of a number of reasons that, by observing the state of the structure, can be identified in advance. Therefore, almost any deformation can be prevented by operational measures or, as a last resort, limited to dimensions that are not harmful to the stability of the entire structure. Subsequently, such deformations are easily eliminated and the structures are again brought into a stable state. But for this it is necessary to know the reasons leading to a decrease in the stability of the structure, and how to eliminate them.
Components of a hydroecological monitoring system in the Aral Sea basin.

Anthropogenic factors
- Agricultural waste waters
- Industrial waste waters
- Household waste waters
- Socio-demographic factors

Hydrotechnical and hydromeliorative measures
- Regulation of waste waters, watering, irrigation and drying
- Building of canals, collectors and water reservoirs

Physiogeographic factors
- Geological structure
- Hydrography and landscape
- Vegetation
- Underground basin structure
- Climate rain and snow temperature, evaporation

Factors influencing pollution
- Fluctuation of waters flowing into the Aral Sea
- Modelining

Figure 1. Major monitoring categories in the Aral Sea basin monitoring systems (ASBMS)

Predictive modeling of types in the Aral Sea basin pollution
1. Deterministic models
2. Stochastic models
3. Synthetic modeling types are envisioned

Identification of control means and points

3. Cartography ArcView GIS
2. Statistical method and model, regresional and correlational analysis, trend-analysis

Hydrotechnical and irrigation and drainage measures
- Construction and operation of water dams and reservoirs
  1. land reclamation and irrigation
  2. energy purposes
  3. integrated applications

Construction and operation of canals
1. Agricultural
2. Derivational

Pumping stations - construction and operation

1. Hydroecological analysis (negative impact on the environment)
2. Economic analysis (depreciation, depreciation)
3. Technical analysis (possibility of reconstruction and modernization)

Figure 2. Input and output components of an Aral Sea basin model.

Figure 3. Block – Hydrotechnical and irrigation and drainage facilities
3. Results

Over the past twenty-five years, the author has developed geographic information systems based on GIS for various research purposes [10–15]. When carrying out projects, the authors used the methods and experience of leading foreign specialists from the Institute for the Study of Environmental Systems of the University of Osnabrück (Germany) and the International Technology Centers (Yokaiichi and Tsukuba, Japan), in which the author improved his skills. At that time, a large project existed at the German Institute for the study of the hydroecological situation of the Elbe River, where the focus is on the use of GIS technology (http://elise.bafg.de). Experience in the European project Intas “Restoration and management options for water and tugai ecosystems of the northern delta of the Amu Darya River” project was used (project Intas Aral Sea Project Call 00-1039 Ecosystems on the Northern Amudarya Delta Region: http://www.usf.uos.de/projects/aral/ The two priority areas most concerned with the issue of water conservation of the Amudarya river resources are monitoring of hydraulic structures and water quality.

A series of GIS maps with different parameters of hydraulic structures of Uzbekistan were developed, a system of recommendations and practical measures aimed at using the criteria for the safe operation of hydraulic structures of the Republic of Uzbekistan was compiled.

![Figure 4. a - example of the use of GIS (ArcView system.) For hydroecological monitoring of the Aral Sea delta. By clicking on this point located on our card, we get access to the database. Information can be obtained in two ways: 1) in the form of histograms; 2) in the form of tabular data, such as dBASE format files. b - Example of System of support of decision-making.](image)

Into structure and a format of details of system of decision-making enters: 1) the Text information (the annotated reports, instructions on using; 2) the digital information (statistics, tables); 3) the graphic information (diagram’s, schemes, cards); 4) the vector information (the user layers thematic and topographic maps); 5) hyperlinks on files containing in information bases. The target given systems: 1) the image; 2) schedules; 3) texts.

Key parameters: 1) system of coordinates; 2) filling of layers of electronic maps, raster and vector objects; 3) Creation of files of a databank; 4) Graphic display of investigated objects on technology GIS. The position of the monitoring posts is shown on the map; most of the posts are entered into the interactive map in the form of tables and figures.
Figure 5. An example of use GIS for studying of hydraulic engineering constructions, at cursor prompting on a water basin, it is possible to receive at once a space picture where it is in details possible to learn a water basin configuration.

A methodology was developed and definitions of criteria for the limiting state (Table 1) under which the design is recognized as hazardous to the environment, as well as criteria for hydroecological tension [16-18]. When creating digital maps for areas of research, in which the most and most dangerous zones were identified during the operation of these structures [19-20].

Table 1 The list of criteria for hydroecological tension

| Indicator name | Formula | Indicator value for the Amudarya river basin |
|----------------|---------|---------------------------------------------|
| Drain coefficient | $K_i = \frac{W_{wi}}{W_{wr}}$ | Surkhandarya region - 1.24 |
| The full chemical composition at the closing gauges, taking into account polluting ingredients. (Uzhydromet standards http://lex.uz) | The number of ingredients in excess of the MPC, the degree of their excess | Termez 6 (1,1-4) Nukus 8 (1,2-4) |
| Integral index of water pollution by average MPC | Termez 4,9 and 2,4 Nukus 3,8 and 2,7 |
| $S_j$ - is the coefficient of the hydrochemical load of the territory caused by the municipal sewage | $S_j = LH_d.s.$ |

According to the technique of relief plastics on the landscapes of adjacent territories, the most mudflow hazardous and avalanche hazardous areas were identified that must be taken into account for
the design and repair of hydraulic structures. According to the technical data obtained for specific hydropower and irrigation facilities, various models can be obtained, for example, to study the flow rate of water in the gates of hydropower and irrigation facilities and other parameters. The authors conducted an analysis based on the results of the monograph “Genesis, formation and regime of surface waters of Uzbekistan and their influence on salinization and pollution of agrolandscapes (on the example of the Amudarya river basin)” [23], which describes in detail the effect of various factors on the hydrological and hydrochemical regime of large rivers of Uzbekistan. When analyzing changes in the water regime of the Amudarya river in time and along the length of the river, the following characteristics are considered: a) change in the average monthly water discharge for different years: 1997-2000; 2001-2005; 2006-2012; b) the dependence of the averaged average monthly water discharge on the averaged average monthly water levels; c) the dependence of the average monthly discharge of water of the lower sections on the average monthly discharge of water of the upper sections. Schedules of intra-annual water consumption for various periods of years were compiled, including the current state (Fig. 6).

**Figure 6.** An example of an analysis of the water discharge of the Amudarya basin by years:

a) Intra-annual changes in water discharges for different years of the Amudarya-Atamurat river (Kerky city)
b) Dependence of average monthly average water discharges on the average daily water levels of the Amu Darya river / city Atamyrat (Kerki city) for May-August 2008-2009 years

It can be seen from (Fig. 6) that the lowest water discharge is observed in the July-November month, their slight increase occurs in February, from March to June, the maximum water discharge is observed. Thus, there is a slight shift in the flood from the summer to the end of spring, due to the influence of climatic factors. For the authors' studies, the above methodology is used for the Chirchik-Bozsu basin, where the hydraulic structures of the Lower Chirchik cascade of hydropower plants are located. Also in the technique, studies the features of construction of pumped storage hydroelectric power plants (PSHPPs) in Uzbekistan with consideration for the possibility of using them to cover the drops and peaks of loading, as well as the features of using the water resources in Uzbekistan—the priority provision of agricultural needs. The efficiency of creating pumped storage power plants at local waterways. One of the features of hydropower is the ability to be used for efficient storage on both a small and large scale by creating pumped storage hydroelectric power plants (PSHPPs). The special features of hydropower resources in Uzbekistan include their seasonality and the priority provision of agricultural needs. The goal of this study is to consider the issues of creating PSHPPs in Uzbekistan with consideration for the features of hydropower resources and the regulatory tasks facing them. Fig. 2, which show the daily electricity generation schedule for the power system of Uzbekistan for July 23, 2017, which was presented by the Uzbekenergo JSC. On the schedule, we have marked out the zone of operation of pump stations of the PSHPP in the energy consumption mode during the period of mini-other maneuverable power plants that can cover only peak loads, PSHPPs,
apart from working in the peak part of the schedule, can also work in the pumping (loading) mode in drop of the load schedule, providing a more favorable baseline mode for TPPs as well as contributing to the interstation power flows. In addition to the above advantages, PSHPPs may have the so-called fuel effect, which is achieved owing to the difference in fuel consumption in TPPs during the periods of energy storage and generation of peak power. During the periods of reduced load, the PSHPP is charged at the specific consumption of reference fuel by baseload power plants $G_r = 0.25–0.27$ kg/(kWh). In the generating mode, the PSHPP replaces the loads of the thermal power plants at peak conditions with the specific consumption of reference fuel $G_g = 0.5$ kg/(kWh). If the efficiency of the PSHPP is $\eta = 0.70–0.75$, then the specific fuel saving $\Delta G = \frac{(G_g - G_r)}{\eta}$ is $0.1–0.14$ kg/(kWh), i.e., approximately 20%.

![Figure 7. Schedule of daily electricity production by the power system of Uzbekistan [24].](image)

4. Conclusions

Based on the joint use of GIS technologies and optimization models when developing environmentally applicable operating modes for hydraulic structures and hydropower facilities, the following tasks can be solved:
- Establish the laws and characteristics of the development of hydrological and hydrochemical processes in the basin of the Amu Darya and Syr Darya rivers and the impact on hydraulic structures;
- Determine the role of hydroecological monitoring of water quality as a generalized integrated assessment of the whole complex of anthropogenic and physical-geographical factors affecting the formation of water quality;
- Develop a hydroecological classification that takes into account various factors: socio-demographic, economic, hydrochemical and other features affecting the hydroecological situation;
- Propose a number of new methods of hydroecological mapping using GIS technologies.
- Develop mathematical hydraulic and hydrological models that reflect the possibility of improving the operating mode of hydraulic structures;
- Develop on its basis a decision support system;
- Preparation of practical recommendations for solving various scientific and applied problems for environmental purposes and assessment of natural resources.

It is proposed in the systems of reservoirs also to provide for the construction of hydropower facilities - low-capacity hydraulic power plants (PSPPs). This is especially advisable in reservoir systems such as Kaparas, Sultansanzhar and the Tuyamuyun hydroelectric channel, as well as the Talimarjan and Arnasai hydraulic structures and they should be considered as a
single system that solves the tasks of both maneuvering and storage of the energy of renewable energy sources. The capacity of such a PSHPP will obviously be determined in many respects by the water discharge of a local waterway; i.e., a scheme with the use of ground-water is possible.

To sum up, we can draw the following conclusions:
1. The establishment of PSHPPs in Uzbekistan is necessary to reduce the share of the capacity of TPPs that are used to regulate drops and peaks of electrical load.
2. Given that the main purpose of water resources is irrigation, it is necessary to develop the existing schemes of PSHPPs, in particular, to construct them at local waterways

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