DEVELOPMENT OF THE INTEGRATED APPROACH OF THE FLOOD RISK MANAGEMENT: THE UKRAINIAN EXPERIENCE

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Abstracts. The paper deals with the experience in designing and operating the Early Flood Warning and Decision Support System (EFWDSS). The existing conception of separate development of each component of system was reconsidered, and the integrated approach "From sensors to decision-making" was proposed. According to this approach, the flood risk management is based on a use of the comprehensive end-to-end service delivery which includes many stakeholders. EFWDSS includes the technical and management parts. The advantages and problems of the practical operation of system are considered. The experience of development of EFWDSS can be used in developing other similar systems.

Introduction

The river floods of different origin and inundations connected with them cause more economic damage in Ukraine than any other natural disaster. A large part of the country's territory, especially located in the Carpathians mountains region, suffer from floods, practically, every year. Annually river inundations cause damage to the national economy estimated to be equal to tens of millions of US dollars. The cost of inundations sometimes includes the loss of human life. Taking into account this fact, the issue of development of comprehensive flood management measures is of great significance for Ukraine. But, the experience of floods of the last years indicated a number of problems in the flood management policy and showed that the existing flood risk management system does not meet the increased requirements of different categories of users regarding the accuracy and timeliness of warnings as well as the quantitative estimation of socio-economic vulnerability to floods. This paper deals with the experience in designing and operating the Early Flood Warning and Decision Support System (EFWDSS) as the essential informational component of the national system for the natural hazards risk management.

Methodology and materials

The study is based on:

- the results of the National Program of Protection from Technogenic and Natural Emergencies;
- the Strategy of Development of Hydrometeorological Service of Ukraine (author was among the developers of these Program and Strategy);
- the new information technologies which are used in the hydrometeorology and the hazards risk management.

Besides, the recommendations of the Directive 2007/60/EC on Assessment and Management of Flood Risks as well as the recommendations of publications of the World Meteorological Organization regarding the development of warning systems for hydrometeorological hazards were used.

Results and Discussion

General information

The significant damage to the population and the economy of Ukraine are caused by waters disasters. The river floods of different origin and related inundations are common for the majority of rivers in Ukraine. The spring floods are the most characteristic phase of hydrological regime of plain rivers. The snow-rainfall floods occur in the Carpathians mountain rivers during the winter-spring period. The rain floods are typical hydrological events for the Carpathians mountain rivers from April to October. Due to this reason, surface waters can be regarded as a restricting factor for social development in the most regions of Ukraine.

About one-third of the Ukraine's population are affected by floods. The frequency and intensity of floods as well as the magnitude of damage caused have increased in many regions of Ukraine during the past decades. The researches of the scientists from The Ukrainian Hydrometeorological Institute have shown that the global and regional climate changes are the principal reason of this. The studies also show that there is a significant chance of strengthening risks of the disastrous floods in the next 20-30 years.

Flood disasters

In Ukraine flood disasters are categorized as small, large, very large and catastrophic, depending on the size of the area inundated and on the value of damage done (*Manukalo,* 1998). Small flood disasters lead to the insignificant damage in some settlements. They occur on each river about once in 2-5 years. Large flood disasters lead to flooding of significant stretches of a river valley and disturb the normal economy within the large areas. The frequency of these disasters is about once in 20-25 years. The very large flood disasters involve a large river system with a number of cities. The economic activity is paralyzed by them and population and property should to be evacuated. The frequency of these flood disasters is about once in 50-100 years. The catastrophic flood disasters occur in a number of river systems and many cities. The economic objects, and engineering communications are flooded. The human victims also accompany these flood disasters. The frequency of catastrophic flood disasters is about once in 100-200 years. The catastrophic flood disasters during last 100 years occurred; in springs of 1931 and 1970 - on the Dnipro river and its the largest tributaries – the Prypyat' and Desna rivers; in 1969 and 2008 - on the Dniester river; in 1998 and 2001 – on the Tisza river.

Vulnerability to floods

Unfortunately, in Ukraine the issue of quantitative estimation of socio-economic vulnerability to floods has been studied not enough. In this paper the assessment of vulnerability to floods is based on the methodology which was elaborated by the State Service of Ukraine of Emergencies. According to this methodology the following indicators of vulnerability are analyzed: hazards to human life and health; a loss of city’s lands; a shortage of water supply for different needs; a destruction of city’s infrastructure (residential and industrial buildings, power and communication

networks); environmental pollution. The magnitude and scope of impacts have been used as criteria for this evaluation. Three levels of impact (high, medium and low) have been proposed for evaluation of vulnerability. These criteria are expressed in relative units (points) and they does not fully consider the damage in monetary terms. The vulnerability of major areas to floods is given in Table. In general, it adequately shows a distribution of vulnerability to floods in areas located in different natural regions of Ukraine.

*Table***.** Vulnerability of Ukrainian territory to river floods

Vulnerability levels	Areas
High	Carpatians region: (Tisza, Prut, Dniester river basins); Prypiat' lowland (Prypiat river basin)
Medium	Dnypro and Volyn' upland (Dnipro, Desna, Southern Bug river basins)
Low	Steppe zone (Siverskyi Donets river basin, Black sea river basins)

Flood warning: present state and new challenges

The integrated flood management includes a number of structural and non-structural measures. Among non-structural measures it is necessary to note an importance of the effective Early Flood Warning System which enhances all (structural and non-structural) flood management measures.

Ukraine has a long experience in the flood management. The national activities in this field are coordinated by the Central Government of Ukraine. The number of governmental bodies are involved in this activity. In particular: a) the State Agency of Water Resources is responsible for general flood management, development of new engineering structures of flood management; b) the State Service of Emergency is responsible for flood control combats, organization of the preventive protection, evacuation of population, properties and livestock, search and rescue, recovery and reconstruction; c) the Hydrometeorological Service (HMS) is responsible for providing economic sectors, governmental bodies and general population with meteorological and hydrological information, forecasts and warnings. It can be arqued that information and forecasting of the Hydrometeorological Service are the core of the Flood Warning System.

The flood forecasts are based on the meteorological and hydrological forecasts. The flood forecasts and warnings are special forms of flood prevention, in fact the most efficient ways in terms of costs and benefits. They provide decision-making bodies with information to enable them to produce the most efficient flood management strategy. During a year HMS makes more than 1300 hydrological long-term forecasts and more than 8000 short-term forecasts. More than 3000 forecasts concern floods. The hydrological forecasts are released for all urban areas located on rivers. The water regime characteristics (maximum water levels and it's temporal distribution, dates of maximum water levels and discharges, runoff volume) are forecasted with different degrees of detail. The length of forecast period depends on hydrological characteristics and sizes of river basis, and ranges from a few hours (flash floods on

mountains rivers) up to 30-90 days (spring flows characteristics for large plain rivers).

The hydrometeorological forecasts and warnings are the component (subsystem) of the National Early Warning System for the hazards risk management which is operated by the Ukrainian Government. It includes facilities to get forecasts, to analyze a current hydrometeorological situation, to make a flood risk assessment and to disseminate warnings using communication facilities. The central, regional and municipal Governments, the Civil Defence and Mass Media are recipients of flood warnings.

The recent experience of floods in Ukraine indicated a number of problems in the flood management and showed that the existing flood warning system does not meet increased requirements of different categories of users regarding the accuracy and timeliness of hydrological forecasts and warnings.

In response to these challenges the Early Flood Warning and Decision Support System, as the essential informational component of the national system for the natural hazards risk management, was developed by the Ukrainian Hydrometeorological Institute in the cooperation with the State Service of Ukraine of Emergencies in the frames of: a) the National Program of Protection of Population from Technogenic and Natural Emergencies; b) the Strategy of Development of Hydrometeorological Activities in Ukraine till 2020. The Hyogo Framework for Action (ISDR 2005), which was adopted by the World Conference on Disaster Reduction (Hyogo, Japan, 2005), as well as the Directive 2007/60/EC on Assessment and Management of Flood Risks were also taken into account at designing the EFWDSS.

These documents identify priority areas in this issue: a) ensuring disaster risk reduction as a national and local priority with a strong institution basis for implementation; b) identifying, assessing and monitoring disaster risks and enhancing early warning; c) better knowledge management for building a culture of safety; d) reducing the underlying risk factors; and e) enhancing preparedness for an effective response

The existing conception of separate development of each component of EFWDSS was reconsidered, and the new integrated approach "From sensors to decision-making" was proposed. According to this approach, the flood risk management is based on a use of the comprehensive end-to-end service delivery which includes many stakeholders. EFWDSS has aimed at increasing a lead-time of flood forecasting and warnings, that is very important for a creation of the effective Early Warning System. This approach is based on using the modern information technologies which were developed in the areas of hydrometeorology and civil protection.

EFWDSS includes two principal large parts: the technological part and the management one (Fig). The technological part consists of the following elements: a) hydrometeorological measurement network, data storage and real-time transmission; b) GIS database which is coupled with electronic maps for a hazard's risk assessment; c) forecasting and warning; d) hazard risk assessment on different

temporal and spatial scales; e) multi-hazards database; f) submitting information and warnings to the users on the national, regional and local levels.

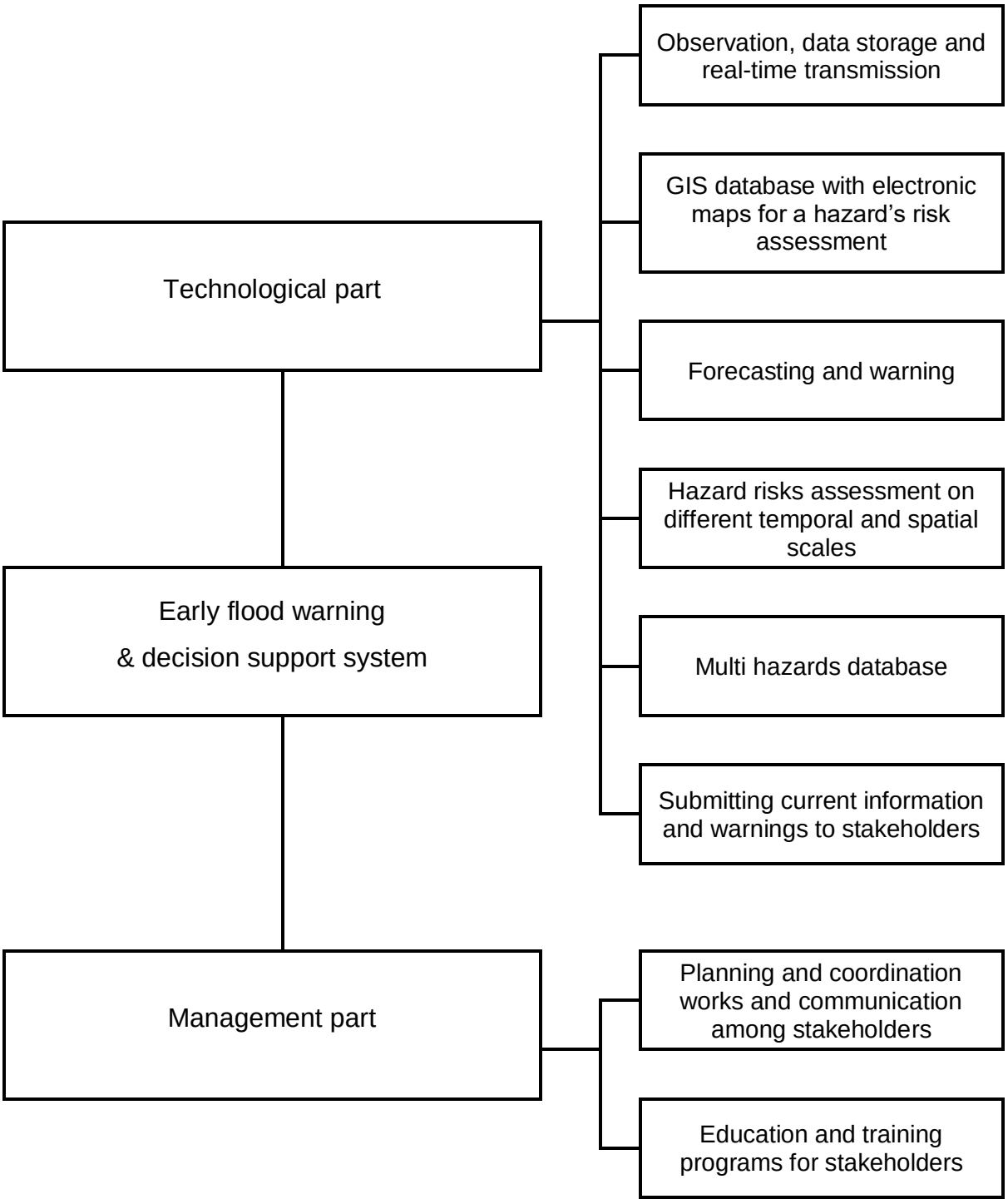

Figure. Block diagram of the Early Flood Warning and Decision Support System

The management part includes: a) planning, coordination and control of works and communication among stakeholders; b) education and training programs for staff of different agencies involved in EFWDSS and for general public.

Efficient functioning of each element and the system as a whole requires support by governance, coordination mechanisms from national to regional and local levels, and by appropriate infrastructure and financing. Practically, there are direct and return linkages there are between all components of the system. These links need to be coordinated across many authorities at national, regional and community levels to ensure the system's work. Failure in one component or lack of coordination across the stakeholders can lead to the failure of the whole system.

In 2018 EFWDSS should be put in the working operation. In order to test the system, the trial of the system's prototype was conducted in 2015. In general, the practice of the flood risk management confirmed the effectiveness of EFWDSS. This system helped the hazard risk management authorities to: a) identify the hazard risk level, including, the possible social, economic and environmental damages; b) determine the best protection measures on the basis of continuous monitoring, forecasting and warning of extreme weather-related events.
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On the other hand, a number of shortcomings in the operation of this system's components were identified. The problematic issues, current capabilities and needs of the Hydrometeorological Service to ensure the successful implementation of tasks provided for each component of EFWDSS will be considered below.

The hydrometeorological measurement network, data storage and real-time transmission

The primary factors which influence the accuracy and lead - time of hydrological forecasts are the accuracy, speed and reliability with the real-time values of collected hydrological and meteorological variables. The hydrometeorological observation system includes 187 points of meteorological observation and more than 400 points of hydrological observation located on surface water bodies - rivers, lakes and reservoirs.

But, the density of the ground network for hydrometeorological observation (especially for precipitation measuring in mountain parts of the Carpathians river basins) is comparatively low, its distribution in the river basins is unfavourable. This density of observation points does not allow to forecast flash floods in mountain river basins, especially, distribution of flow in time, with the essential accuracy.

Taking into account the unsatisfactory density of hydrometeorological network, the Hydrometeorological Service has elaborated the Plan of increasing the number of points of hydrometric and precipitation observation for period of 2016 – 2018. The first stage of this plan is to putt in operation 20 points of hydrometric and 35 points of precipitation observations in mountain parts of the Tisza, Prut and Dniester rivers.

There are a lot of technological problems in hydrometeorological observations. Mostly old types of hydrometric instruments are used in the Hydrometeorological Service for measuring water levels and discharges. The automated hydrological stations are installed only at 5% of points of hydrological observations. A number of Doppler flow velocity meters in the Hydrometeorological Service is extremely limited.

The automation of precipitation measurement and an installation of meteorological Doppler radars are also the priority for the Hydrometeorological Service.

GIS database with electronic maps for a hazard's risk assessment

This component of the system is ready for using only about by 35%. Works in this direction are carried out in the framework of preparation for implementation the Directive 2007/60/EC on Assessment and Management of Flood Risks in Ukraine. The main difficulty is to create detailed digital maps of river basins as this work requires considerable financial resources. The Ukrainian side hopes to receive the financial and technical assistance from the European Union to complete this work.

Forecasting and warning

The flood forecasts which are based on meteorological and hydrological forecasting are the core of the EFWDDS. The forecasting of hydrological events in Ukraine started in 1930s. At present the water regime characteristics (water levels and discharges, their temporal distribution, dates of maximum water levels and discharges, runoff volume) are forecasted with different degrees of detail. The length of forecast periods depends on hydrological characteristics and size of river basis. Periods range from a few hours (rain floods on mountain rivers) up to 30-90 days (spring runoff volume and water inflow to reservoirs in plain river basins). The methods of forecasting are based on mathematical modeling of process that take place in river basins and determine the conditions of flood formation: precipitation types, soil moisture and soil freezing, geomorphologic characteristics of river basins. Developing the forecasting methods which are based on GIS-technologies and are integrated with data of observations of automatic stations is a priority for the nearest period.

Hazard risks assessment by different time and spatial scales

The methodology, which now is used for the assessment of vulnerability of the society to flood disasters does not meet the demand of flood risk management. The improved methodology is being elaborated now by the experts from the Hydrometeorological Service, the State Service of Emergencies and the State Agency of Water Resources. It will be based on the approaches of assessment of damages from natural disasters which were developed by the State Service of Emergencies and on the recommendations of experts from European countries who has an experience in the implementation of the Directive 2007/60/EC on Assessment and Management of Flood Risks. This methodology will take into account the frequency and level of flood hazards for different natural zones of the country and for different seasons of the year. Data on flood hazards for a long period will be consolidated in a database, which will be the segment of national multi - hazards database.

Submitting current information and warnings to stakeholders

Obviously, warnings must reach all stakeholders: people at risk of flood hazards and authorities responsible for the hazards management. The information in warnings should be timely, clear and address the specific needs of end-users. Means of

communication at national and local levels should be pre-identified and the order of sending the warning messages should be established. The procedure for warnings should be implemented in the form of working schemes and plans which are defined for every year.

Planning and coordination works and communication among stakeholders

This component of the management part is critical to the successful operation of the entire system at both phases: the pre-disaster activity and the post-disaster activity. The effective governance of flood management and protection can only be achieved by coordination and integration of work of multiple government agencies as well as local communities. The lack of proper coordination and communication between stakeholders will minimize the efficiency of hydrometeorological forecasts and warnings.

The test operation of EFWDSS showed the following shortcomings in this component of the system: a) the absence of coordination in planning and, in some cases, the presence duplication of activities in the flood risk management by the different agencies involved in the flood management; b) the problems with understanding and effective using the information and warnings from the Hydrometeorological Service by the staff of agencies; c) the scarcity of budget funds for providing the sustainable activity in the flood risk management

Education and training programs for stakeholders

In general, the education system in Ukraine guarantees training of skilled professionals. However, introducing the new methods and technologies in the hydrometeorology and flood management require additional training for practicing professionals and revision of the curricula in tertiary education institutions.

Besides, it is needed to strength the capacity-building of experts from the agencies responsible for the flood risk management in order to improve a skills of using the hydrometeorological information and services through the relevant training programs.

In order to solve this problem, the Hydrometeorological Service should develop the training program of skills upgrading for professionals from its organizations and for managers working in agencies which are responsible for flood management and protection.

Conclusions and recommendations

Floods are inevitable, but their impacts can be reduced through the adequate planning of mitigation and prevention measures, including establishment of adequate preparedness systems to increase the effectiveness of the emergency response triggered by early warnings and emergency operation. In spite of economical problems Ukraine is developing its floods management policy. A lot of attention is given to development of the Early Flood Warning and Decision Support System as one of component of the National System of Protection from Hazards of Natural and Technogenic Origin. The hydrometeorological information, forecasts and warnings

of the Hydrometeorological Service are extremely valuable to ensure the effective flood risk management.

At present, the analysis of results of test operation of EFWDSS have been completed by the experts from the Hydrometeorological Service and the State Service of Emergencies. The recommendations for the Ukrainian Government regarding the legislative, organizational, technical and financial issues to be resolved before the introduction of EFWDSS in operation are preparing now on the basis of this analysis. Putting the system in the working exploitation is expected in 2018.

References

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