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Managing Hydrological Risk in the Urbanized Territories in the Framework of Implementing the Concept of Smart Cities Territories

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Abstract

The article deals with the tasks of risk assessment and prevention of damages from dangerous hydrological processes (rainfalls, floods, marsh floods, mudflows, etc.) in the aspect of implementing the concept of the Smart City. Natural and anthropogenic flood factors, risk assessment and risk management methods are discussed. flooded areas. The issues of predictability of hazardous hydrological processes and damage assessment are discussed. The example of the Kuban River basin assesses the adequacy and effectiveness of decisions taken in the field of minimizing the negative impact of water, the sufficiency of forces and resources to ensure the safety of the population and economic objects.

Keywords: smart city, hydrological risks, emergency situations, modeling and forecasting, causes and factors of hydrological risks

1. INTRODUCTION

In Russia, up to 2025, within the framework of the Digital Economy of Russia program, 50 smart cities are planned to be created. It would be provided by through the introduction of the modern information technologies. The Hardware and Software Complex "Safe City" is the important part of the Smart City for protection of the population against threats of natural and man-made nature. "Safe City" unites various information systems: informing the population, emergency notification, emergency call system - 112.

New modern technological as Bloch chain, Big Data and others provides fundamentally new opportunities for the development of distributed databases needed to assess and manage the hydrological risks of urbanized areas. At the same time, the using of the most modern technologies relies on adequate modeling and forecasting of hydrological processes. Hydrological forecasting has to consider climate changes and the poorly predicted long-term meteorological events.

The development of the General Plans for settlements are as examples of such activitie. In this Plan is demonstrated the zoning of the built up area is considered according to the degree of dangerous processes. The monitoring of dangerous processes is proposed to implement the methods of engineering protection. At the same time, a certain standard level of reliability is provided. But the risks, damages, consequences for ecosystems that arise, are rarely considered enough.

The concept of the Smart City through the using of information systems, high-tech hardware and software systems for modeling and forecasting hydrological risks, including GIS technology, is designed to fill this gap. In this article, this problem is considered in the case of floods.

The task of assessment of the influence of urbanization processes on the critical infrastructure of a city, the city's ecosystem, on its social environment, etc. requires the implementation of a systematic, complex approach to manage of the urban environment.

The conception of the "Smart city" provides the transition from existing purely "reliability" solutions to a comprehensive assessment of the urban environment risk at a new level in the development of information and analytical support for management tasks, including the use of Geo Information System (GIS).

The social and material losses in floods is a consequence of the significant variability and poor predictability of the development of dangerous hydrometeorological processes and which are affected by poorly organized economic activity. It is impossible to completely eliminate the threat of floods due to the natural features of the functioning of the climate system and the probabilistic nature of dangerous hydrological events. At the same time, the organization and conduct of preventive, protection and evacuation measures significantly reduce the risks of losses for the economy of the country and the population and this is a fully realizable task.

In accordance with the Federal Law "On Technical Regulation" [1], "risk" is defined as "the probability of causing harm to the life or health of citizens, property of individuals or legal entities, to state or municipal property surrounding environment, life or health of animals and plants, taking into account the severity of this harm. Disaster risk arises when hydrometeorological, geological and other hazards interact with factors of vulnerability of a physical, social, economic and ecological nature. Therefore, the issues of risk managment are require interdisciplinary and the pooling of efforts of various departments and organizations.

2. MATERIALS AND METHODS

2.1. Natural and anthropogenic factors of hydrological risks of urbanized territories and the main causes of negative consequences in floods.

Global urbanization processes and unauthorized development of hydrologically unfavorable territories increase the risks of emergencies related to flooding

The main dangerous hydrological processes in most of the territory of the Russian Federation are floods. The spring high water caused by the melting of the snow cover accumulated during the winter period. The danger is also presented by floods as a result of the passage of the heavy rains, typhoons and monsoons. In addition to these reasons, floods can be formed during the break of lakes, formed as a result of rubble of river valleys, floods and glutton formation.

A serious problem is man-made floods, among which the most severe consequences are caused by the destruction of dams, and are accompanied by the propagation of a breakthrough wave, whose height can reach tens of meters.

The inductive impact of floods includes:

1) direct flooding of territories;

2) the dynamic impact of water with consequent damage; 3) impacts of synergistic dangerous processes (channel deformations, flooding, processing of beaches, loss of stability of slopes, deterioration of sanitary and epidemiological conditions).

Emergency situation forecasting is an anticipatory assumption about the probability of emergence and development of an emergency situation on the basis of an analysis of the causes of its occurrence and its sources in the past and the present, predicting the consequences of emergencies [3]. The goals and objectives of hydrological disaster prediction are:

- early receipt of qualitative and quantitative information about a possible emergency caused by dangerous hydrological phenomena:
- planning of the necessary forces and means for carrying out protective measures and emergency response measures;
- assessment of possible socio-economic consequences of emergencies.

There are main causes of man-made floods (i.e. flooding of river valleys or coastal areas), associated with the construction of hydraulic structures) include:

- breakthrough of the pressure front of structures and the pouring of the reservoir into the river valley;
- complete opening of the spillway gate structures and resetting the downstream hydroelectric water flow exceeding the capacity of the riverbed;
- irrational management of reservoir mode (or cascade) during periods of high floods;
- tightness of the river valley of protective dams insufficient height and reliability and their breakthrough during the passage of the river maximum water flow, or lack of drainage systems (culverts, pumping stations, etc.), leading to flooding spaces that took place in Kuban in 2002 in elevated discharges into the downstream hydroelectric periods in the formation or destruction of the ice cover.

Within the framework of the Smart City concept and ensuring the safety of the population and territories against hydrological threats, it is necessary to further improve the methods of processing available statistical information of the parameters of emergencies related to floods (number, scale of emergencies, number of victims, damages) and development of forecasting methods for rare events. it is possible to formulate the main causes of significant negative consequences in floods, based on practical experience, as well as an analysis of the existing scientific and methodological base:

1. In forecasting emergencies, the anomalous nature of hydrometeorological phenomena, including due to anthropogenic impacts on the catchment and river bed, and climate change, is not sufficiently taken into account. In the long-term and medium term, the uncertainty of the forecast of climate change and its consequences for

elements of the hydrological cycle, including extreme characteristics.

2. There are mistakes in engineering-geological and hydrological surveys, engineering calculations and design due to insufficient means, limited hydrological and meteorological monitoring data, lack of required qualification of specialists for interpretation of monitoring results and fulfillment of forecast calculations.
3. There is a poor quality of construction of buildings, engineering structures, as well as in the creation of engineering protection systems in the flooded zone.
4. There are unauthorized or unregulated regimes of operational control of the hydraulic structures, inadequacy of necessary repair work at the facilities.
5. Violation of land use conditions in the lower reaches, including unauthorized construction of flooded areas on the shores of lakes, rivers and reservoirs.
6. Insufficient awareness of the population about the possible consequences of the hazardous effects of water in general and the passage of a specific hazardous flood in particular.
7. There are forces and means at extreme floods for the organization of timely reaction to the extreme situations.

All of these factors exacerbate the negative effects of flooding in urbanized areas.

2.2 Normative and legal and methodological support for the management of hydrological risks.

Analysis of the problem area associated with the risk of flood emergency situations shows that it is necessary to implement a risk-based approach to the management of disaster warning systems and to improve applied methods for the analysis and management of disaster risks in floods. To solve this problem, it is necessary to develop the scientific and regulatory framework of the risk-based approach in the flood risk management system, taking into account the integrated solution of monitoring, forecasting and warning of emergencies, timely detection of threats and response to hazards.

It is necessary to solve the following tasks at the state level for the construction of Smart city:

a) territorial planning, urban zoning, maintenance of natural and technical supervision, etc.);
b) the strengthening of control over the prevention of construction in zones prone to floods, flooding, to introduce mandatory life and property insurance programs for people, who live in the prone of floods zones [4].

The amount of individual risk in Russian Federation is the indicator of protection of the population from hazards. The numerical values of this value for the subjects of the Russian Federation are determined by the ratio of the number of deaths during the implementation of hazards to the population of the subjects [1]. The Order of the Federal Agency for Technical Regulation and Metrology of June 29, 2016 No. 274 approved and introduced the National Standard of the Russian Federation GOST R 22.10.02-2016 "Safety in emergency situations [2]. This standard defines for Russian Federation the acceptable risk of natural, man-made and biologically-social emergencies.

The EMERCOM of Russia carries out activities in the field of disaster risk reduction, incl. negative impact of water. This activity is realized in the form of laws, regulations and practice recommendations [4]. The main methodological problem is typing (or classification) of the causes and scenarios associated with dangerous hydrological phenomena.

The task of forecasting and assessing the risk of hydrological emergencies includes an assessment of the negative impact of water in the implementation of scenarios of three types:

1) scenario of a catastrophic event;
2) the most likely scenario, i.e. events of acceptable risk;
3) an optimal scenario, accompanied by the implementation of the necessary preventive measures and operational actions.

As a scenario of a catastrophic event, an extreme, very rare hydrological event of low probability is taken, for example, the historical extremum of the maximum water discharge. In some cases, in the practice of designing hydraulic structures, one speaks of a "backward" mode of operation of a technical system (built-up area, etc.) [5]. As an event of a likely scenario (or an event of acceptable risk), a situation is considered that corresponds to the normative level of security, i. scenario of flood occurrence 1% of the security for which the master plan of the city is projected (flood, the probability of occurrence of which is considered once in a hundred years). For hydraulic systems - is the reliability of building structures, which is set by building codes for each class of hydraulic facilities. The range of security levels is very wide and varies from 1 event in 10,000 years to 1 time in 10 to 20 years [6, 7].

The optimal scenario is considered when taking additional measures of engineering protection, carrying out preventive measures related to population resettlement from zones prone to floods, based on the results of forecasting of a dangerous situation, combating congestion, cleaning and widening of riverbeds, etc. The optimal scenario is developed on the basis of rational measures, when the estimates of the prevented damage and the evaluation of the spent funds for the organization of anti-spree activities, organizational and technical works, etc. are known. The economic efficiency of measures is one of the main criteria in developing measures that form the optimal scenario.

The activities to protect the population and territories from natural and man-made threats are prescribed in the law on local self-government and are specified in Federal Law No. 68-FZ [8]. It is necessary to update the available estimates of possible flooding areas, taking into account extreme weather events, taking into account climate change in each specific municipal entity subject to flood risks. Each municipal entity has a previously completed assessment of the flooding of critical infrastructure facilities, economic objects, residential buildings located in flood zones i.e. for different scenarios of emergencies.

Each Russian municipal entity has a security passport of the urban territory (which is regularly updated) and also has the necessary emergencies reserves. Local government solve the protection tasks from floods and other dangerous processes.

2.3 The proposed approach - index for risk management.

The proposed approach is based on the methodology of the risk-oriented method INFORM (index for risk management). The integrated INFORM index of risk includes about 50 different indicators for measuring the dangers and impact on them, vulnerability indicators and determining the necessary resources for stopping hazards and is defined as the geometric mean by the formula[1]:

$$R = \sqrt[3]{H \times V \times L} \qquad (1)$$

where H - indicator of danger and threats;

V - the indicator of vulnerability;

L - an indicator of the insufficiency of the potential for counteraction of danger.

In accordance with the proposed structure of the integrated risk index, the indicators are divided into three dimensions (hazard, vulnerability and inadequate capacity to counteract hazards and threats), in each of the three dimensions, the corresponding indicator is assessed on a 10-point interval scale. To obtain the integral risk index, the "counteraction potential" index is used instead of the index - the "lack of counteraction potential" index.

This method allows using in the calculations of the integral risk index both averaged formulas (geometric mean, arithmetic mean, etc.) and linear combinations.

The indicators and specific indicators are described in more detail in the monograph [4]. All indicators are normalized and take values from 0 to 10. The closer the value of the indicator to zero, the more favorable the situation in the area that is measured by the corresponding indicator.

The flood hazard index is calculated by the formula:

$$I_1 = \alpha_1 \frac{S^*}{S} + \alpha_2 \frac{N^*}{N} \qquad (2)$$

α_1, α_2, weighting factors, $\sum_{i=1}^{2} \alpha_i = 1$; $\alpha_i > 0$; $\alpha_1 = 0{,}3$; $\alpha_2 = 0{,}7$.

S^* – the area with 1% security, the area subject to flooding, km^2;

S – total area of the territory of the municipalities, km2;

N * - the population affected by the flood, thousand people.

The vulnerability index of the population is calculated on the basis of information on the population (age composition, mobility), the deterioration of critical infrastructure, the deterioration of housing stock and the presence of dilapidated housing. The index of the counteraction potential shows the presence of the forces and facilities of the Ministry of Emergency Situations for informing, alerting the population, as well as the availability of necessary equipment for responding to emergencies and evacuating the population. The system of indicators for the formation of each of the three components of the integral risk index is formed taking into account the indicators indicated in the order of the Ministry of Emergency Measures of Russia from 25.10.2004 № 484 [10]. In addition to these indicators, the integral index uses indicators that characterize the socio-economic development of the entity and municipalities.

Calculations made on the basis of formula (2) made it possible to rank the municipal formations of the Krasnodar Territory in terms of the risk of occurrence of emergencies related to floods and to determine which municipalities need priority measures to prevent flood risks and respond to them.

3. RESULTS

Evaluation of sufficiency and efficiency of decisions taken on the example of the Kuban basin.

As an example, consider the decisions taken to prevent floods in urban areas using the example of the Kuban River Basin (Krasnodar Territory).

a) *The most likely scenario of emergency situations in floods.*

Assessment of acceptable risk areas in relation to the threat of floods is presented based on the materials of the Scheme for the integrated use and protection of water bodies in the basins of the Kuban and the Black Sea, developed by the Kubanvodproject Institute [9]. Territories within the flood zone floods 1% of the supply for the Kuban basin are called floodwaters. Floodwaters were identified on the basis of an actual survey of the Kuban basin territory, an analysis of past floods and the most powerful in recent years of the security to 1% security in 2002 year. Distribution of floodwaters in the basin of the river. Kuban is given in Tables 1 [9].

Table 1. Floodwaters in the passage of floods 1% of the supply of the rivers of the Kuban basin

№ п\п	River basins	Total lands, ha	Including	
			farmland	populated items
1				
2	Krasnodar region	81224	22667	3928
3	Republic of Adygea	40609	17084	1218
4	Stavropol region	6842	3538	291
5	Karachay-Cherkess Republic	10615	2721	587
6	TOTAL for the pool	139290	46010	6024

[1] [1]www.inform-index.org

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To develop emergency prevention measures for floods, it is advisable to use a risk-based approach, in which it is important to take into account not only the hazards (hazard index), but also vulnerability (vulnerability index) and counteraction potential (counteraction potential index) [4].

To determine the hazard index, the data obtained in Table 1 are used. In determining the area that is affected by floods in the most likely scenario and in the worst case scenario. Further, the population of the potential flooding zone (taking into account the safety passports of the territories of municipalities) is calculated.

b) *Emergency situations during the passage of catastrophic floods and floods.*

Catastrophic hydrological events are rarely observed on rivers and other water bodies, have a low probability of exceeding, but are accompanied by huge economic losses and human casualties. An example of such an event was rain rains on the river Adagum in 2012, accompanied by a lot of number of human casualties. A catastrophic situation of this kind significantly changes our understanding of possible risks. Figure 1 shows the flooding areas of the city of Krymsk flooded with 1% of the supply, estimated before the event in 2012, and taking into account the information on the 2012 flood [11]. The results of the comparison show that the risks of the negative impact of water significantly increase during the passage of catastrophic events.

To account for catastrophic events and formulate appropriate catastrophic disaster scenarios, it is possible either to use hydrometeorological scenarios that led to an outstanding flood, or to attract events of a more rare (small) probability. In Fig. 2 shows the result of calculating the flood zone of the city of Krymsk during the flood with a period of recurrence once in a thousand years (0.1%) [11]. In general, for the region as a catastrophic one, it is possible to propose a consideration of the scenario of occurrence of an emergency with an increase in the area of flooding three times, which roughly corresponds to the extreme event in Krymsk.

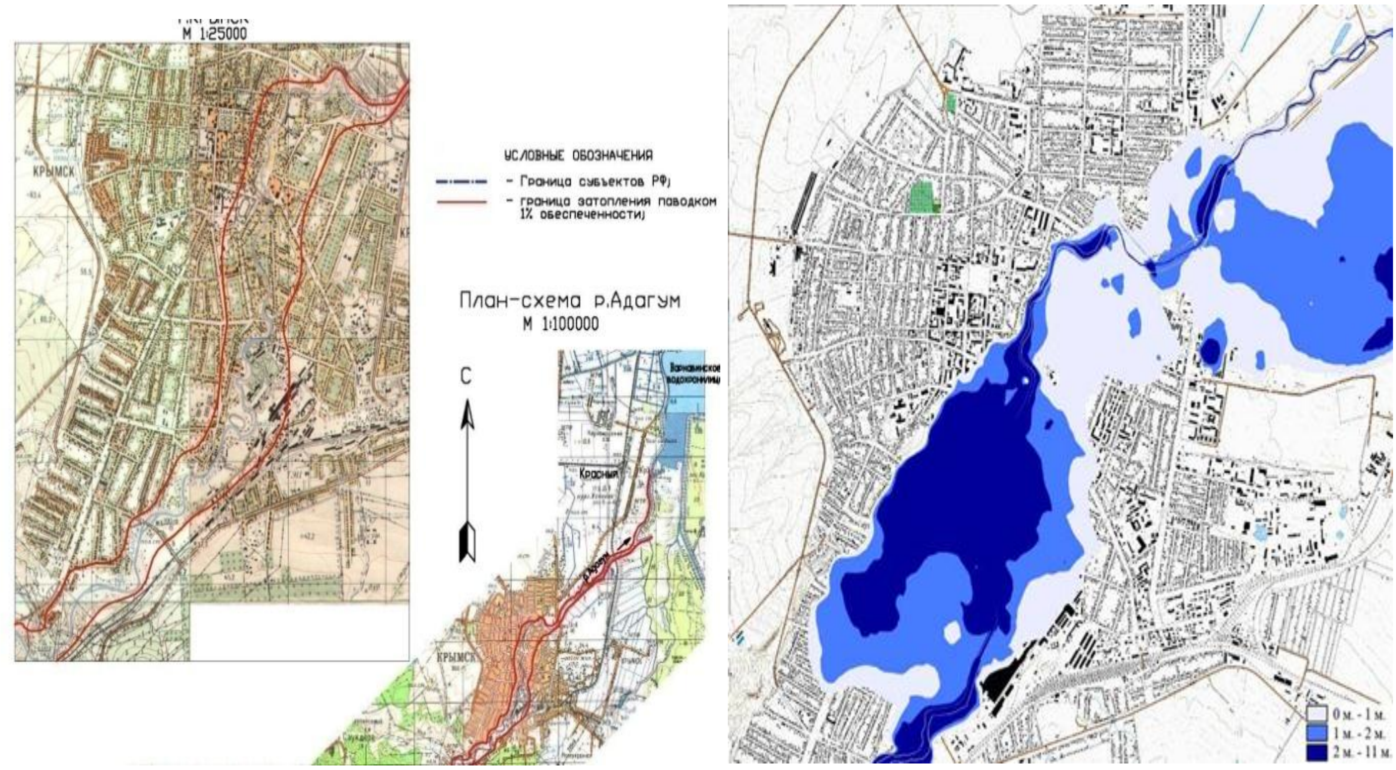

Fig.1. The boundaries of the flooded areas of the city of Krymsk. Zones of flooding in 1% flooded flood, calculated on the basis of data prior to the passage of the catastrophic high water 06 - 07/07/2012 (materials of SKIOVO of the Kuban basin [9]) (a) and the flood zone of the city of Krymsk at a flood of 1% hydrodynamic modeling taking into account the occurred catastrophic event of 2012 (b).

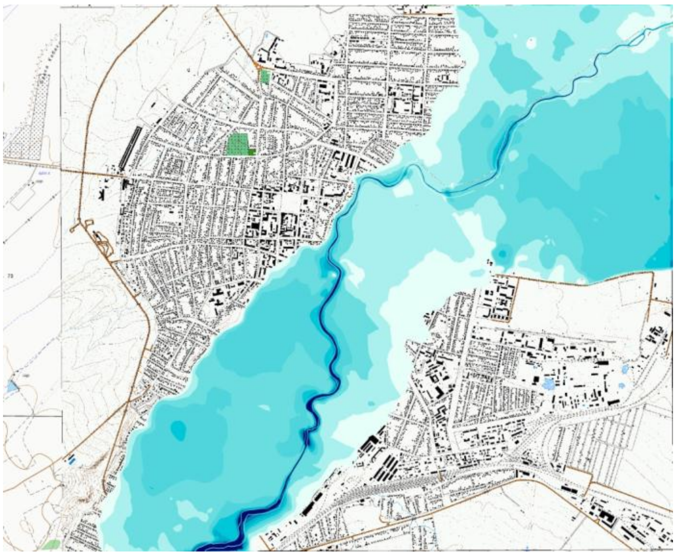

Fig. 2. Zones of flooding of the city of Krymsk during the passage of a flood of 0.1% of the supply [11].

c) *Optimal scenario of emergencies in the passage of floods and floods*

The optimal scenario for the development of emergency situations involves consideration of the negative impact of water, taking into account the implementation of additional measures of engineering protection of the population and organizational and technical measures to protect the economy and the territory from flooding, the implementation of measures to predict emergencies and prevention of the population.

4. DISCUSSIONS

The additional risk of occurrence of ES in this region is related to the following factors:

- the level of technical safety of almost all reservoirs is lower than permissible, which threatens the emergence of accidents with disastrous consequences for the population and the economy of the region;
- the missed flow rate below the Krasnodar Reservoir is more than 1200 m3 / s is associated with the risk of breakthrough of the Kuban dumping dams and the Protocols due to their poor technical condition;
- the danger of flooding of areas increases due to a decrease in the capacity of the canals to transfer flow as a result of their overgrowing and silting.

Based on the materials of SKIOVO [9], it can be concluded that the flood protection system of the river. Kuban does not meet the requirements of operational reliability and does not provide guaranteed protection from floods of the entire population of the region living in the flooded areas.

The measures ensuring the optimal forecast scenario of the territory functioning with the possible development of negative hydrological processes should be aimed at improving the technical state of protective structures, bringing their status (design characteristics) to the normative level.

5. THE CONCLUSION

The results of the research showed that the current state of the methodological support regulating emergency management associated with hydrological hazards requires further development of the basic provisions in the direction of improving and broadly implementing the risk-oriented approach and performing monitoring activities.

The proposed methods of analyzing the risk of emergencies and recommendations for engineering protection can significantly reduce the damage caused by floods.

To implement the conceptual provisions of the Smart City in the field of hydrological safety, it is necessary to introduce a risk-based approach, use GIS technologies, interface scenario hydrological modeling with the AIC "Safe City". It is necessary to further improve the regulatory and methodological support, generalize the proposed approaches to risk assessment in the framework of the proposed emergency scenarios for all flood hazard areas of the Russian Federation, and develop and improve methods for assessing the risks of catastrophic floods and other extreme hydrological events [11 - 15].

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