Evaluation of Flooding Risk and Engineering Protection Against Floods for Ulan-Ude

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Abstract: The report presents the results of the study on analysis and risk assessment in relation to floods for Ulan-Ude and provides the developed recommendations of the activities for engineering protection of the population and economic installations. The current situation is reviewed and the results of the site survey are shown to identify the challenges and areas of negative water influence along with the existing security system. The report presents a summary of floods and index risk assessment. The articles describes the scope of eventual flooding, underflooding and enumerates the economic installations inside the urban areas’ research-based zones of flooding at the rated levels of water to identify the likeliness of exceedance. The assessment of damage from flood equal to 1% is shown.

Keywords: risk assessment, scope, dam bordering, dredging, clearance, cost-effectiveness.

1. Introduction

Ensuring Russia’s national security is a priority of state policy. Recently, sustained steadily increasing trend of natural disasters and combined natural and man-made disasters is a source of concern and the identifying ways to address problems, aimed at reducing risks of natural hazards. Clearly, the report draws attention consideration of the most densely populated territory with a high concentration of strategic assets.

Ulan-Ude is major, industrial and transport center, the capital of Buryatia with a population of about 400000 people, representing about 40 per cent of the total republic. The geographical location of Ulan-Ude is in the lower Selenga River at the confluence of Uda. Selenga within the boundaries of the city has a well-developed sharply asymmetric valley with an extensive left-bank floodplain 4-5 km wide. Uda is one of its main tributaries, the floodplain of the river is developed fragmentarily. Floodplain areas of the city are well developed and inhabited. One of the most significant natural hazards for the territory of Ulan-Ude are floods. It poses a serious threat flooding and underflooding in the part of the city with huge damages. An analysis of archival and literary sources has indicated to periodic floods in the city. The earliest references back to 1751. According to description for the last 3000 years catastrophic floods were recorded in 1751, 1752, 1785, 1830, 1867, 1869, 1897, 1908, 1932, 1936, 1940, 1971, 1973 and 1990. Historical records also indicate that Verkhneudinsk (Now Ulan-Ude) was almost completely flooded. “Soil water was overflowing and flooded the courtyards, so that the back of the city, adjoining the high sand bordering the city from the north-east was flooded earlier than approached water from Selenga ... "[1]. To date, a rather serious situation has developed...
for Ulan-Ude and the surrounding suburban areas. On the one hand, this is an intensive development of the private sector along the rivers without taking into account the flooding in the former agricultural lands, also the spontaneous settlement of citizens with a permanent residence on the sites of most horticultural associations entering the city's borders, but located in hazardous areas. On the other hand, despite the fact that for many years the complex of various activities has been carried out against the negative impact of water, however, the city is not fully protected from this dangerous occurrence. Now the city is in urgent need of protection against flooding.

Thus, the purpose of this article is a comprehensive analysis of the causes and features of flood development in the city, an assessment of their negative consequences and proposals for possible protection.

2. Background information and research methods

The initial information for the study was the long-term data of the level regime in dynamics since 1936, the maximum expenditure, the intensity of the rise and fall, and the duration of standing of high marks. The data on hydrological stations were used for work, reference materials were used on the location of industrial and household objects, the population numbers specified in the administrations, as well as general information and facts about the floods. The cartographic base was a topographic basis of scale 1:2000, high resolution satellite images, thematic cartographic materials. In the process of work, statistical methods of processing hydrological information, mapping and GIS technologies were applied.

The damage assessment was carried out according to the Methodology of Estimation of Probabilistic Damage from the Harmful Impact of Waters and Evaluation of the Effectiveness of the Implementation of Preventive Water Management Measures [2].

Recommendations for the implementation of measures for engineering protection against the negative impact of water are developed in accordance with the provisions of the Water Code, state standards of norms and rules for engineering protection of areas from flooding and flooding and on hydraulic structures. [3-7].

3. A brief description of the floods

The increase of the level and water’s consumption in the rivers Selenga and Uda (in the district of the city) are recorded during the spring season at breakup on rivers and in the second half of summer due to the cyclonic fronts’ passing. Repeatability calculations for the genesis of formation on rivers confirm that there are the prevalence of flood waters, rarely deep floodwater, which are more specific for the river Uda. There are possible congestion in areas of natural and anthropogenic narrowing of the Selenga’s riverbed. According to the data for the last 100 years the frequency of floods in the city is 24-40%, whereas in the upper of rivers it reaches 80-90%. Out of the most catastrophic floods (large for the entire Selenga basin) occur 8-12% [1,8,9].

Congestion floods are local and registered in the area of road and rail bridge within the city. Their length is usually small, 2-6 days, the largest flood is usually inferior. Besides, nowadays they rather successfully traced and warned.

The most dangerous and poorly predictable flooding. The excess water level above the critical level (output of water on the floodplain) reaches 2-3 m. Thus, for the Selenga river in 1936 year it was 246 cm., 1940 – 245 cm., 1973 – 207 cm.; for the river Uda in 1985 year – 248 cm., 1991 – 266 cm., etc. [10]. Mountain rivers provide a fast discharge of water, therefore the intensity of the rise is considerable and reaches up to 1.3 m./day. The decrease of the water is slower – 0.4-0.5 m./day. Duration of standing high marks largely depends on the climatic conditions of this time: for the river Selenga it can reach up to 38 days (1936), but the average is 20-25 days and for the river Uda in the range of 15-20 days.

Features of passing of the floods on the rivers Selenga and Uda are in the rare coincidence of their time. On the Selenga rain floods come low tide and observed throughout the summer. The entire process can take up to 6-8 floodwaves. The maxima of rain floods predominate above the highs of
floods as absolute value, as the number of them. Flood peaks are observed from mid-July which regularly lead to flooding of coastal areas. Some other level regime is formed on the river Uda. There are the floods which usually superimposed on the decrease of floods. Maxima are often observed in early summer, much earlier than on the Selenga. The comparison of floods showed: for the river Selenga security is 1-5% and the security levels made 6-32% for Uda in the same dates [1,8,9].

Thus, there are three possible scenarios for the passage of floods in the city. Areas subject to the flooding only by waters of Selenga river or Uda. But the most catastrophic version of their joint sequential effects: in the case when the beginning of the flood observed on the river Uda and then continues on the Selenga river (1936).

The evaluation of risk from flooding for the city

The definition of flood zones is made with the help of geoinformation modeling ArcGIS with the calculated water levels given probability of the exceedance. The boundary of the flooding obtained in a GIS-package from the raster format converted to vector (Figure 1) [11-17].

Figure 1. The modeling of the flood zone of Ulan-Ude.

Mapping allowed us to estimate the extent of adverse impact of waters and to identify the list of objects. So, when flooding of 1% availability in the Selenga river the area of flooding is 38.2 sq. km., of which 2209.4 ha. under economic object: houses and objects of infrastructure – 88.04 ha.; industrial enterprises and production facilities – 69.61 ha.; communications, engineering structures 82.2 ha.; warehouses, storage companies and other production facilities – 51.514 ha.; gardens – 486.4 ha.; agricultural land – 1431.636 ha.; roads – 32.2 km.; power line – 17.2 km.; communications line – 5 km. In dangerous areas live about 40 thousand people. Among the flooded buildings included the socially important facilities: 4 schools, 4 kindergartens, 1 boarding school, 1 elementary school-garden, the Central stadium of the Republic of Buryatia [18].
In the assessment of damages used the normative enlarged specific of damage’s costs caused by flooding to homes, infrastructure, industries, communications and various industrial and agricultural objects and facilities, as well as arable land, gardens, orchards and other agricultural lands. In accordance with the methodology in the calculation the territorial coefficient is applied, taking into account the climatic conditions. Overall, the total damage reaches up to 27.3 billion rubles, which is about 70 % of the total amount of damages for settlements in the floods in the Selenga river [2].

4. Engineering protection of the city against floods
To protect the city from harmful impact of waters with the 60-ies of the last century a number of activities were conducted. However, today, existing structures are only a partial protection. Dam right Bank of the Selenga river diking is provided for flood protection areas wastewater treatment plant and section of the Central part of Ulan-Ude. Parts of bank protection are made along the site of a city water intake, the site of a glassworks, the Island “Komsomolsky”, near the road bridge. Some of them require repair or reconstruction. In addition, the protection for the primary zone of flooding – the left-Bank part of the city, as well as the low areas (the Uda) is not available.

To minimize risks engineering measures for the protection of the city are made. They are made in accordance with the provisions of the Aquatic code, relevant rules and regulations. The most vulnerable area of the city is the left-Bank part. Two alternative options were considered: the resettlement of the people living there or building a long dam. The first option is unlikely to be implemented due to the difficult economic situation and high cost, also high cost of urban land and the current active development. Therefore, for the effective protection of the left Bank of the city appropriate is the construction of a dam embankment with a length of over 22 km. from the shore about 10 km. Based on the topographic conditions and contours of the river banks, the dam provides continuous, planned location was determined. Based on the selected location of the route, maidenbower distances and heights of dams are evaluated [4-7,19]. The height of the dam is determined from the calculation of the level of the water in terms of tightness and varies in the range of 4.1 to 7.3 m. For two segments of the maximum narrowing of the channel, where the design height of the dam is more than 6.5-7.0 m. provides for the dredging of 1.5-2.0 m. Also for a partial redirection of the river flow recommended the execution of works on clearing the right Bank of the ducts. Total length of these works is approximately 11 km. In addition, an overhaul of the existing right Bank dams and shore protection structures are carried (Figure 2) [19-21].

The cost calculations of a set of measures of engineering protection of the city are made according to the method [2]. In general, the cost of the recommended actions will amount to 3.85 billion rubles. The non-approved damage is more than 23 billion rubles.

The main criterion of profitability in the design of prevention and mitigation of negative impact of water is a measure of economic efficiency. For Ulan-Ude it is 7.6, thus measures on engineering protection are assessed as highly cost-effective [2].

5. Conclusions
Thus, on the basis of detailed analysis and calculation of risk indicators, a simulation of flood zones with the calculated water levels with given probability of exceeding, which identified the extent of adverse impact of waters, and to identify the list of objects within the city and to evaluate the probabilistic damage. Only direct damages to the Republic of Buryatia is estimated at about 27.3 billion rubles. To minimize risks the two options considered: proposed and developed a complex of measures of the population’s protection from floods in Ulan-Ude. To protect the population and economic objects of the city the option is justified as the feasibility of the construction of left-Bank dams of the embankment with protection. Quantitative assessments, maps of flood zones, risk are an objective basis for effective management in the functional organization of the territory and to ensure the constitutional right to the necessary degree of safety and security of the population of the city from flooding.
Figure 2. The projected dams from flooding of Ulan-Ude.

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