# Economic Assessment of Damage Caused By Fluctuations in the Level of Lake Baikal

Olga V. Gagarinova[1*], Gerelma B. Dugarova[1], Tatyana I. Zabortseva[1], and Viktor N. Bogdanov[1]

[1] V.B. Sochava Institute of Geography Siberian Branch Russian Academy of Sciences, Irkutsk, Russia

*Corresponding author: whydro@irigs.irk.ru

**Abstract.** The problem of regulating Lake Baikal and the negative impact of water has been discussed since the time when the Irkutsk hydroelectric power station was built (1950). This becomes especially important during periods of prolonged low or high water, because it affects all human activities and changes in the ecosystem of the coastal territory, causing processes of soil and vegetation cover degradation, structural changes in landscapes, and the loss of the unique natural properties of the shore as a whole. Losses and damages caused both by the influence of water and transformations of natural shore complexes are observed in the socio-economic system of the shore areas. An analysis of the current natural and socio-economic situations in the adjacent territories revealed a set of possible consequences and damages for the territory from the influence of fluctuations in the level of Lake Baikal. Losses of land, forest and hunting resources, a reduction in tourist and recreational activities, a change in the socio-economic infrastructure, and a decrease in the economic development of the shore areas as a whole are possible as a result of flooding and abrasion destruction of the shore. The article presents the specific results of our research: an economic assessment of damage in case of possible flooding of shore areas due to the rise in the level of Lake Baikal; a detailed description of capital facilities caught in the flood zone; key areas with detailed and comprehensive characteristics. We have calculated the direct and indirect damages from flooding. Some recommendations and suggestions are given to minimize the negative impact of the waters of Lake Baikal.

**Keywords:** economic damage, environmental consequences, flooding, recreational system.

## 1 Introduction

Attention to the problem of regulation and fluctuations in the level of Lake Baikal has continued since the construction of the Irkutsk hydroelectric power station (since the late 1950s). This problem remains relevant now, especially during periods of prolonged low or high water, which, with varying intensity, affect the change in the ecosystem as well as all spheres of human life. In such conditions, the assessment of socio-economic damage is of particular importance as one of the most urgent tasks for ensuring the safety of the population and the sustainable development of territories.



O. Batdelger et al. (eds.), *Proceedings of the Fourth International Conference on Environmental Science and Technology (EST 2023)*, Advances in Engineering Research 224,
https://doi.org/10.2991/978-94-6463-278-1_14

Such interest in this problem is not accidental since it concerns a unique natural object: Lake Baikal. Long-term studies on Baikal identified low water (1976–1982 and 1996–2015) and high water (1930–1942; 1983–1995; and 2020–2021) periods that have significant consequences and damage [1, 2]. [1] and [3] paid special attention to this process in the middle of the last century.

Therefore, there was a need for a comprehensive research to substantiate the principles for regulating the level of Lake Baikal, taking into account modern environmental, socio-economic and water management requirements.

However, it should be noted that in foreign and domestic literature, the issues of changing the water level in reservoirs are mostly considered from the standpoint of high water (flooding and flash flood), which bring significant consequences for the environmental and damage to the population and the natural and economic complex. Society pays more attention to this problem, and the negative effects of floods are more often considered in legal documents. At the same time, a dry period brings no less problems and consequences than a flood (drainage, violation of water supply, disruption of energy and water management systems, etc.). In addition, material damage from flooding and drainage is accompanied by severe moral, psychological, and social consequences, which are still difficult to assess in terms of value [4, 5].

In general, the economic and environmental approaches to assessing damage from negative water impacts (flood and drainage) and methods for assessing damage are insufficiently developed and limited to the assessment of damage from flooding.

We have focused in detail the theoretical and methodological aspects of flood damage assessment in our previous articles [6, 7].

Therefore, this article based on many years of research presents the specific results of study on the economic damage assessment in the case of possible flooding of shore areas because of raising the level of Lake Baikal to provide the recommendations and proposals to minimize the negative impact of the waters of Lake Baikal.

The object of the study is the shore Baikal territories of the Irkutsk region (Slyudyanskii, Irkutskii, and Olkhonskii districts), located in the zone of potential flooding.

## 2 Materials and methods

Basic materials for the study were obtained from the open public data of the Unified State Register of Real Estate, official responses to inquiries to the territorial authorities, and the results of expeditionary observations. Numerous large-scale cartographic materials and remote sensing (Earth Remote Sensing) data were used. Difficult issues on individual facilities, linear structures (including power transmission lines, and sections of the heating network), transport and communication facilities (including piers, mooring facilities, etc.) were resolved jointly with the services of architects of the Slyudyanskii and Olkhonskii districts, specialized specialists, managers and heads of municipalities of the first and second levels (Slyudyanskii, Olkhonskii and Irkutskii regions). Materials were also received from various organizations and federal departments (the East Siberian Railway, a branch of Russian Railways, the East Siberian River Shipping Company, the Yenisei Basin Water Administration of the

Federal Agency for Water Resources; the Baikal National Park of the Preserved Baikal Region; etc.).
In the course of a comprehensive study and assessment of economic damage, a large amount of factual material was obtained, which serves as the main basis for developing recommendations and proposals to minimize the negative impact of the waters of the lake. Baikal.
In this work, we used general geographical research methods and methods of geoinformation mapping. It is worth mentioning that nowadays there is no universal comprehensive methodological toolkit for assessing environmental and socio-economic damages under the negative effects of fluctuations in the level of water bodies [7]. However, there are a number of individual methodological developments and recommendations, because of which the damage assessment was carried out. Many of these methods affect only the socio-economic consequences, such as, for example, the [8-10].

## 3 Result and Discussion

In the framework of this study, one of the main purposes was the socio-economic assessment of damages when changing the level of Lake Baikal and discharge of the Irkutsk Hydropower Plant. It includes the assessment of environmental losses (cost estimation of land, forest, hunting and fishing resources losses) and the assessment of damage for transport, communications, industry, energy, agriculture, social and housing objects.
The damage assessment was based on GIS modeling of the Baikal coast in the range of 455.54 – 457.85 meters (in every 10 cm) with allocation and description of key areas.
In this article, we conducted a cost assessment of land, forest and hunting resources and we completed damage assessment for transport, industry, energy, agriculture, social facilities and households. For other natural factors (for example, soils, archaeological sites), we provided a qualitative assessment of consequences.
We also have presented an analysis of objects by socio-economic activities (Table. 1), a detailed description of the key areas in the flooding zone.
More than 200 capital facilities are located on the territory of Irkutsk Oblast within the zone of potential flooding (Table 1). Most of the capital construction objects are situated in the Irkutsk district (114 objects). However, Olkhonsky district is the leader in the amount of damage, because recreational facilities are mainly located here.
Several buildings in the mixed use area, concentrate only in the Slyudyanskii district within the zone of potential flooding are classified as *industrial facilities*. Several housing and communal facilities are noted in the area, including a sewage pumping station, a sewage treatment plant, a water pumping station and a sewerage network in Slyudyanka. In two other administrative districts (Irkutskii and Olkhonskii) there are no objects of the specified block in the flood zone.
*Transport objects*. Within Irkutsk Oblast, 10,442 m of linear road network objects turned out to be in the potential flood zone at the shore, including roads of urban settlements 1.3%, the predominant part being roads of settlements and villages (mainly with a dirt surface - 98.7%). A very small part of them is included in the USRN (Unified

State Register of Real Estate) and amounts only 3.4% of all potentially flooded specified objects.

**Table 1.** The number of capital facilities in the negative influence zone of waters

| Municipalities | Number of objects, units | Number of land plots, units | Square, sq m |
|---|---|---|---|
| **Slyudyansky district** | | | |
| Industrial and infrastructure facilities | 41 | 120 | 407963,91 |
| Households and homesteads | 17 | 56 | 43026,88 |
| Social facilities | | 1 | 1083,16 |
| Recreational facilities | 10 | 42 | 1756175,75 |
| Total | 68 | 219 | 2208249,7 |
| **Olkhonsky district** | | | |
| Industrial and infrastructure facilities | 3 | 16 | 36319,42 |
| Households and homesteads | 6 | 20 | 21623,95 |
| Social facilities | 7 | 1 | 19317,72 |
| Recreational facilities | 29 | 25 | 76507,19 |
| Total | 45 | 62 | 153768,28 |
| **Irkutsk district** | | | |
| Industrial and infrastructure facilities | 37 | 54 | 36136,84 |
| Households and homesteads | 57 | 216 | 41014,36 |
| Social facilities | | 1 | 572,78 |
| Recreational facilities | 20 | 84 | 171035,91 |
| Total | 114,00 | 355,00 | 248759,89 |
| **Irkutsk** | | | |
| Industrial and infrastructure facilities | 6 | 9 | 2907 |
| Households and homesteads | | | |
| Social facilities | | | |
| Recreational facilities | 2 | 7 | 27588,054 |
| Total | 8 | 16 | 30495,054 |

*Energy objects*. Data on energy facilities were obtained based on cartographic and expeditionary materials. These include power lines, the supports of which were in the zone of possible flooding.

61 objects are assigned to the *recreational sphere*. In the context of administrative districts, recreational facilities are distributed as follows: Slyudyanskii district - 16.39%, Olkhonskii district - 47.54% and Irkutskii - 36.07%. Parts of the territories of well-known tourist centers on Baikal, such as Ulirba, Togot, Mandarkhan-City, Sagan-Nuge 2, Bayar (Olkhonskii district), fall into the zone of potential flooding.

*Households and other outbuildings*. During the study, 80 household objects turned out to be in the flood zone, most of them belong to outbuildings. Most of the affected households are noted in the Irkutskii district (71.25%), in the Slyudyanskii district (21.25%), and Olkhonskii district (7.5%).

*Objects of cultural heritage*. In the shore area of Lake Baikal, within the boundaries of the regions of Irkutsk Oblast, there are objects of cultural heritage, represented by architectural and archaeological monuments (the latter are not considered within the framework of this paper). A significant number of cultural heritage monuments are part of the object of federal importance "Complex of the Circum-Baikal Railway". Studies have shown that the main part of the monuments included in the Circum-Baikal Railway complex is located outside the zone of potential influence of Lake Baikal level fluctuations. Separate engineering structures located in areas of possible flooding are stone bank protection structures erected in the 19th century, which have not been destroyed by fluctuations in the water level of Lake Baikal for more than a century.
Thus, after all calculations, we got the direct and indirect damages from flooding (Table. 2). The direct damage includes damages to capital facilities, land, forest and hunting resources.
As for indirect damage, it is 3.6 % of the direct damage [11].

**Table 2.** The total amount of direct and indirect damages in Irkutsk oblast

| Name | Amount of damage, rubles |
|---|---|
| The amount of damage to capital facilities | 212,751,650 |
| **Cost estimation of losses** | |
| Forest resources | 25,715,130 |
| Hunting resources (including Red List ) | 50,690,430 |
| Land resources | 1,516,978,190 |
| **Total of direct damage** | 1,806,135,410 |
| **Total of indirect damage** | 65,020,874 |

The numerous studies have produced some important findings in identification of the most vulnerable flooding areas of the shore area of Lake Baikal within the borders of Irkutsk Oblast. Thus, based on the factual material obtained for certain key areas that are most vulnerable to fluctuations in the water level of Lake Baikal, we have formulated a number of specific proposals. For example,

*The village of Utulik, Slyudyanskii district* (see Fig. 1). When the water level of Lake Baikal rises, recreational areas and households may be flooded, which will lead to significant damage. Taking into account the peculiarities of the relief and the nature of the shore of Lake Baikal, we can recommend property insurance as measures to minimize the consequences of flooding, with subsequent regulatory and legal changes in the Rules for Land Use and Development of the Settlement.

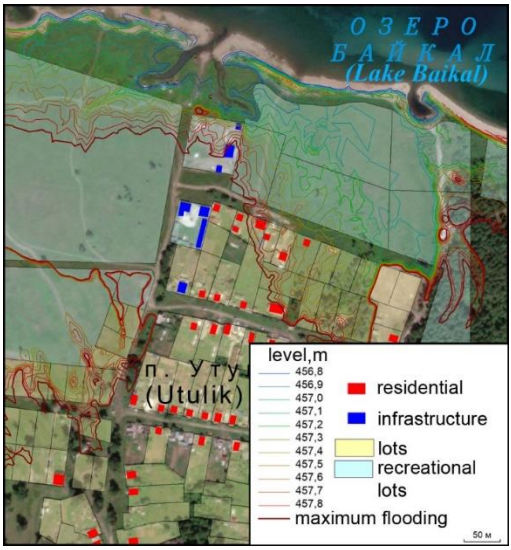


**Fig. 1.** The zone of potential flooding in Utulik (Slyudyansky district, Irkutsk region)

*The village of Bolshoe Goloustnoye, Irkutskii district* (see Fig. 2). The shore of Lake Baikal in the village is subject to intense abrasion, which will intensify with rising water levels. For this section of the shore of Lake Baikal, it is necessary to create shore protection structures in order to reduce large-scale abrasion, protect household plots and objects located on the shore, and preserve the mooring infrastructure and beach spaces.

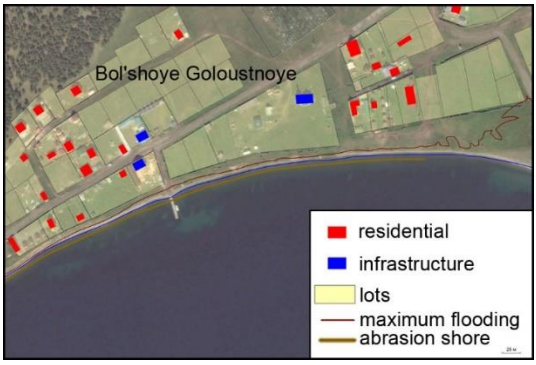


**Fig. 2.** The zone of potential flooding in Bolshoe Goloustnoe (Irkutsk district, Irkutsk region)

*The village of Listvyanka, Irkutskii district* (see Fig. 3). In the village of Listvyanka, when the level of Lake Baikal rises, floodig the coast in the mouth zone of the Krestovka River can be expected. As a measure to reduce the negative impact of water, it is advisable to recommend the transfer of economic facilities from the impact zone. Such recommendations are also substantiated by the facts of the flooding of sites located in the valley of the Krestovka River by the river and groundwater during floods and heavy rainfall.

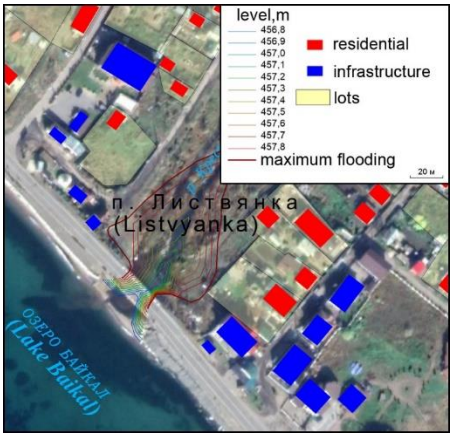


**Fig. 3.** The zone of potential flooding in Listvyanka (Irkutsk district, Irkutsk region)

Based on the results of the study performed on the impact of fluctuations in the water level of Lake Baikal on the shore, preventive proposals were formulated to reduce the negative impact of the lake.

1. To identify zones with special conditions for the use of territories that are subject to the potential negative impact of the waters of Lake Baikal, with the subsequent introduction of amendments and additions to the current regional legal acts regulating the activities and residence of the population within the boundaries of these zones.
2. To provide access and mandatory familiarization of citizens living and carrying out economic activities in the shore areas with information about the zones of negative impact of water, the possible consequences of flooding or shore destruction, and activities to minimize damage.
3. To organize compulsory insurance (state or commercial) of property risks for citizens and organizations, located and living in the zones of negative impact of the waters of Lake Baikal.
4. To organize the transfer of objects and/or the creation of shore protection structures in areas most vulnerable to the negative impact of water.
5. To create a monitoring system (annual expert assessment) of the negative impact of water on objects of economic, housing, recreational, and transport infrastructure on the shore of Lake Baikal, regardless of departmental affiliation (East Siberian Railway PJSC Russian Railways, East Siberian River Shipping Company, municipalities, etc.).

## 4 Conclusions

Thus, the economic damage assessment and the development of constructive proposals and recommendations for mitigation of the negative impact of waters on the socio-economic system of the shore of Lake Baikal are the relevant results of our studies aimed at improving legal documentation at various levels and developing management decisions. Our study is an important interdisciplinary comprehensive study with specific results to substantiate the principles of lake management.

Now we have calculated the direct and indirect damages from flooding.

Based on the results of the study, some recommendations and proposals are given for key areas on mitigation of the negative water impact of Lake Baikal, as well as for preventive measures.

## 5 Acknowledgments

This work was funded by RFBR and MECSS, project number No. *20-55-44023* and research work No. *FWEW-2021-0009.*

## References

1. Afanasiev, A.N.. Water resources and water balance of the Baikal basin. Novosibirsk. Science, 238 p. (in Russian) (1976)
2. Nikitin, V.M., Abasov, N.V., Berezhnykh, T.V., Osipchuk E.N.: Risks of low-water and high-water periods for Lake Baikal. Geography and Natural Resources, 5:29–38. (in Russian) (2016)
3. Afanasiev, A.N.: Water balance of Lake Baikal. Proceedings of the Baikal Limnological. Stations of the Academy of Sciences of the USSR, XVIII: 155-241. (in Russian) (1960)
4. Surzhikov, V,I.: On the issue of assessing the economic and social damage from floods. Geographical and Geoecological Research in the Far East, 1:191-197. (in Russian) (2019)
5. Win, Shelly, Win, Win Zin & Kawasaki, Akiyuki.: Establishment of flood damage function models: A case study in the Bago River Basin, Myanmar. International Journal of Disaster Risk Reduction, 28: 688-700 (2018). https://doi.org/10.1016/j.ijdrr.2018.01.030
6. Dugarova G,B.: Analysis and the consequences assessment of flooding in Tulun (Irkutsk region). ECO, 1:130-150. (in Russian) (2021)
7. Dugarova, G,B., Zabortseva, T,I.: Methodological bases for assessing damage when changing the level regime of a reservoir (on the example of Lake Baikal). Geography and Natural Resources, 5:179-186 (in Russian) (2022). https://doi.org/10.15372/GIPR20220519
8. Methodology for assessing the probable damage from the harmful effects of water and assessing the effectiveness of the implementation of preventive water management measures. VIEMS. -. - 153 p. (in Russian) (2006)
9. Methodology for determining the amount of harm that may be caused to the life, health of individuals, property of individuals and legal entities as a result of an accident of a hydraulic structure (with the exception of shipping and port hydraulic structures) dated 12/10/2020. No. 516. (in Russian) (2020)
10. GOST R 22.8.09-2014. Safety in emergencies: Requirements to safety, risk and damage levels at underflooding of urban and industrial areas. (2015)
11. Methodology for assessing damage from emergencies of the Ministry of Emergency Situations of 09/01, N 631. (in Russian) (2020)