

Landscape-hydrological basis for water resources protection and development of the Baikal territory

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Abstract. Landscape-hydrological research in the Lake Baikal catchment area has identified individual hydrological properties of landscapes. We analysed physico-geographical conditions, ecological and socioeconomic features of the territory and identified the areas responsible for the formation of qualitative and quantitative characteristics of natural waters, determined areas with significant loads on the aquatic environment, revealed areas with different resistance to anthropogenic influences. Functional zoning of the territory provides the basis for the schemes of water resources use and protection as well as recommendations for the development of the Baikal Natural Territory in relation to the water factor. Our experience in the practical implementation of the landscape-hydrological approach for the water resources management within the Lake Baikal catchment area is represented in the projects of ecological justification of economic activity, water protection zoning of natural and residential areas. Assessing opportunities for the development of the territory based on the water factor rooted in the analysis of water and ecological natural potential, in the stability of hydrological functions of landscapes to natural and anthropogenic changes we examined using the example of zoning the southern shore of Lake Baikal for the recreational purposes. The conception of moisture transformation mechanisms in landscapes as it moves to the draining water body is taken as a basis of water protection zoning.

1. Introduction

Water resources management based on water utilization measures does not fully ensure the reproduction and preservation of natural waters of high quality, since they are aimed only at preventing and eliminating negative water-ecological situations. The objectives of a preventive focus are important as they take into account the consequences of possible natural and climatic changes and anthropogenic impacts on water bodies and their catchment areas. The research experience here shows that basin management should be based on knowledge of the formation and transformation patterns of natural waters in terms of possible changes. Such studies are expedient on the basis of the landscape-hydrological approach, concerning landscape as a spatially localized territory, with certain water-balance relationships. Within the Lake Baikal catchment area we, being guided by landscape-hydrological principles, carried out various projects aimed at optimizing the use and protection of water resources [1].



2. Theory and methods

The landscape-hydrological analysis of the territory is a research of the process water yield from a unit of area with an individual physical and geographical structure that determines the formation of hydrological characteristics within the natural complex.

The key-notes of the landscape-hydrological approach are as follows.

1. Landscape is a single object with specific internal connections which determine the transformation of precipitation into surface and underground runoff, i.e. possessing individual hydrological functions.

2. The process of watershed yield from landscape is caused by its physical and geographical parameters, especially by steepness of slopes, type of soils and vegetation, composition of soils, geomorphological features, etc.

3. The quantitative measure of the hydrological function of a landscape is the overland runoff, that shows the rate of water yield from a local area for a certain period of time and can be calculated on the basis of the model equation: $\sum q_{ij} f_{ij} = Q_j$, where Q_j is the river runoff at the main stream station from the m -th catchment; q_i is the overland runoff of i -th landscape; f_{ij} is the area of the i -th landscape within the boundaries of the m -th catchment [2].

Differences in the hydrological functions of landscapes and spatial differentiation of hydrological characteristics in terms of magnitude and character in the intra-annual section determine the landscape-hydrological organization of the territory, which is the basis for solving practical issues related to water and environmental issues, as well as to water protection and management of the territory. The specific nature of natural water formation and transformation in a specific landscape represents a landscape-hydrological basis for assessing the water-ecological status of the territory and determining the functional hydrological changes resulting from the transformation of nature [3].

Spatial differentiation of runoff values from the landscapes of the Lake Baikal catchment area evaluates the water-resource and water-ecological potential of the catchment area and enables zoning the territory in accordance with these factors [4]. The individual hydrological functions of each landscape determine the quantitative and qualitative characteristics of water supply from the catchment to the draining water body, determine the floods and high water areas formation, as well the areas of low moisture and water-ecological tension, and other hydrological characteristics of the catchment area [5].

3. Results and discussion

Combination of physico-geographical settings of the catchment area is determined by the individual hydrological regime and the water-ecological potential of the landscapes. Water-ecological potential due to the flow control mechanisms within the natural complex characterizes the sustainability of landscapes to external impact, the ability to stabilize the water regime, regulate the quantitative and qualitative characteristics of natural waters [6]. The level of water-ecological potential determines different degree of landscapes stability to anthropogenic impact and the possibility of economic development of the territory without compromising the quality of water resources.

Zoning the Lake Baikal catchment area according to the level of water-ecological potential shows areas with various parameters of inland landscape runoff regulation and natural complex resiliency to natural and anthropogenic changes [7]. Low level of water and ecological potential is characteristic for high-mountainous and steppe landscapes with a low-power soil and vegetation cover, where precipitation forms an increased surface run-off, causing erosion processes and possible rapid arrival of pollutants into water bodies.

Dark coniferous landscapes on watersheds, gentle slopes with moss-grassy soil cover, meadow-marsh and floodplain-valley complexes on foothill plains and lowlands a high water-ecological capacity. Significant filtration and accumulating properties of these communities cause slow water loss, providing a high level of self-purification, water protection and environmental protection capabilities of the territory, including significant resistance of landscapes to changes (figure 1).

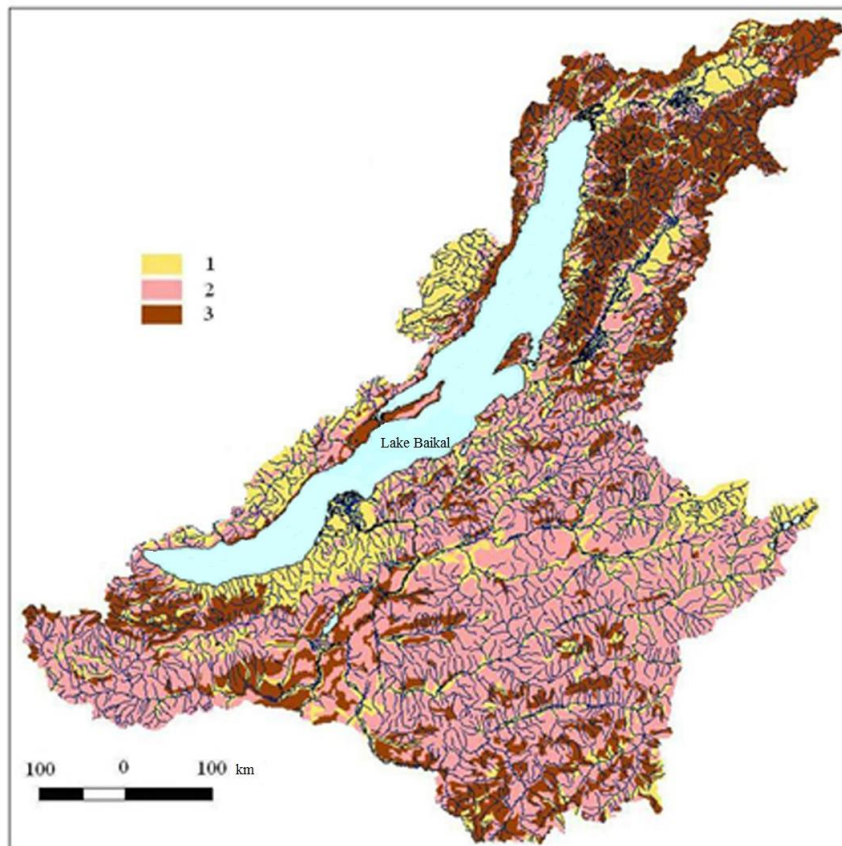


Figure 1. Water-ecological capacity of landscapes of the Lake Baikal catchment area. (within the borders of the Russian Federation): 1 - high, 2 - medium, 3 - low.

Based on this analysis, it is possible to assess the development of the territory with respect to the water factor, to develop schemes for utilization and protection of water resources of the Baikal Natural Territory [7]. In accordance with these principles, the rationale for the recreational development of the Lake Baikal shore within the boundaries of the Irkutsk region and a project of the water protection zone of Lake Baikal have been carried out.

Complex analysis of structural landscape elements, geomorphological and hydrological features of the shores, mechanisms of landscape planning of the territory [8] identify areas preferable for recreational activities and areas prohibited for economic use with regard to the environmental protection. The zone of current state preservation is an area with landscapes which determine the formation of quantitative and qualitative parameters of water resources. In these areas it is necessary to preserve the existing landscape structure and it is advisable to prohibit all types of economic activities, including recreation areas, placement of permanent camps and tourist bases, economic infrastructure that contribute to the violation of vegetation and soil cover.

The zone of possible adjusted development includes natural complexes that do not have the environment forming and water protection role, which have an average sensitivity and resistance to external influences. The low level of water and ecological capacity of these sites assumes possible recreational development of the territory subject to the implementation of environmental measures aimed at preventing surface disturbance of soil and vegetation cover and the entry of pollutants into surface waters and subterranean horizons.

Intensive development of recreation is possible in areas with low hydrological functions, but optionally high or medium level of resistance to external impact. Anthropogenically transformed

residential and agricultural territories are also included in this zone. The main water-ecological patterns of nature management are the self-restoration of natural hydrological properties, the observance of water protection measures and the prevention of the receipt of pollutants into water bodies and on the terrain (figure 2).

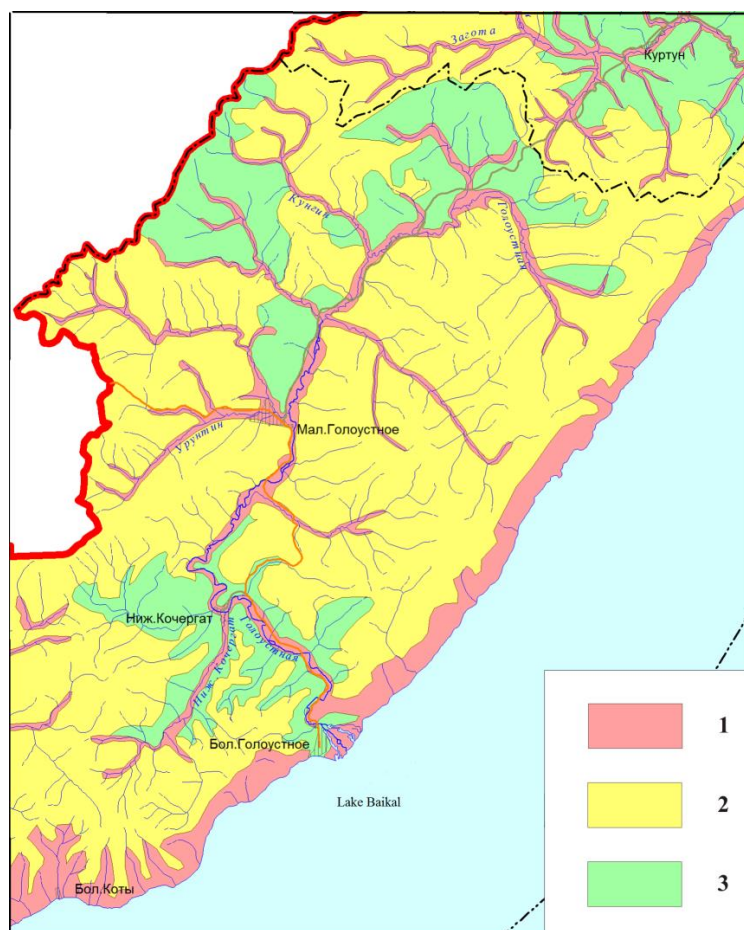


Figure 2. Landscape-hydrological zoning for the purposes of recreational development of the Central ecological zone of the Baikal Natural Territory. Zones: 1 - preservation of the current state; 2 - regulated use; 3 - development.

Recreation development on the Lake Baikal shore should not contribute to reducing the quantitative and qualitative characteristics of surface and groundwater entering the lake reservoir. The task is especially urgent up-to-date, under a significant deterioration of the environment within the lake and coastal area.

One of the conservation tools for Lake Baikal and its shore is the water protection zone, the project of which is scientifically based and developed in accordance with landscape and hydrological principles and assumes elements of additional internal functional differentiation for the economically developed areas at the shore [9]. Namely the hydrological functions of landscapes are the main factors that determine the quantitative and qualitative characteristics of surface and groundwater entering the lake and, hence, are the parameters that determine the size and configuration of the water protection zone of the water body.

The individual project of the water protection zone of Lake Baikal presupposes prevention of water pollution and water quality and coastal ecosystem preservation. The dimensions of the water protection zone should ensure the protection of the lake from the receipt of pollutants through the

realization of the natural properties of self-cleaning of surface and ground runoff in landscape elements, and also minimize the consequences of dangerous hydrological and geomorphological processes and anthropogenic impact on the water body.

In accordance with the landscape-hydrological principles, the water protection zone limits the territory which drains directly into the lake. The water protection zone includes coastal areas occupied by landscapes with high water and ecological capacity, as well as areas adjacent to the reservoir and characterized by low resistance to natural and anthropogenic changes. The frame of the water protection zone of Lake Baikal is composed of dark coniferous landscapes on gentle slopes, humidified estuary areas of tributaries and wetlands on the shores, which act as a natural filter on the way of pollutants entering the lake. To limit the anthropogenic transformation of certain coastal areas, the landscapes subject to exogenous processes and the potential threat of technogenic emergency situations are included into the water protection zone.

On the natural territory of the Baikal mountain fringe the boundary of the water protection zone is drawn along the points of inflection of the relief, the mountain ledges and the peaks of the first watershed, including all areas of direct flow of slope flow into the lake. The expansion of the water protection zone beyond the first watershed is carried out in areas of high exogenous activity (floods, mudflows, collapses, debris flows, etc.). The water protection zone includes basins of small elementary watercourses that directly flow into the lake, wetlands of lowland and meadow-marsh complexes of the coastal, mouth areas of tributaries. In coastal areas with slopes of 3-7 °, the boundary is drawn along the contour of landscapes, the structural components of which have a high water conservation capacity (figure 3).

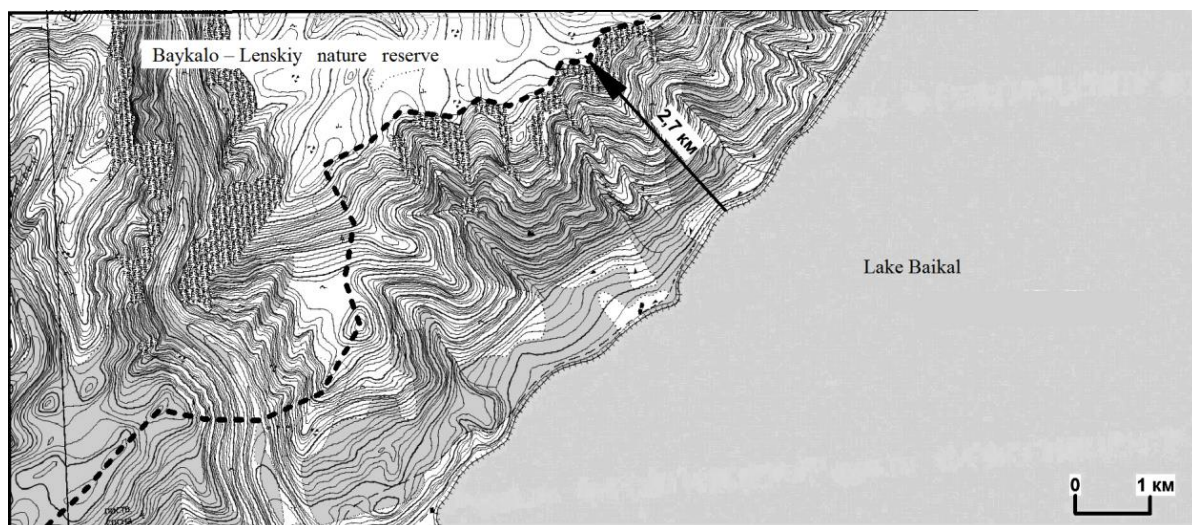


Figure 3. The boundary of the water protection zone of Lake Baikal

Using landscape-hydrological principles in combination with landscape planning tools, we developed the methods for water protection zoning of settlements [10]. In urbanized areas, as well as on natural ones, the priority criterion for justifying the size of the water protection zone is the possibility of natural self-purification of natural waters. Settlement areas requires an assessment of current state of natural complex and analysis of anthropogenic transformations of its components, which makes it possible to carry out functional zoning of the urbanized area according to the water factor. This zoning implies the establishment of different restriction levels within the zones in order to prevent the entry of pollutants into Lake Baikal and to minimize the negative anthropogenic impact on the ecosystem of the reservoir, taking into account the economic development opportunities for the areas [11].

4. Conclusion

The landscape-hydrological approach enables to consider the landscape as a single object with a set of cause-effect relationships and a specific water-balance structure that determine the mechanism of precipitation transformation into surface and underground runoff with specific quantitative and qualitative characteristics.

Changes in the structure of landscapes as a result of fires, logging, and economic use of the territory result in transformation of properties and all hydrological characteristics of the territory. Analysis of disturbances in natural conditions allows predicting changes in the quantity and quality of the basin's water resources.

Landscape-hydrological zoning is the basis for developing targets for different territories from the standpoint of preserving the hydrological functions of landscapes and developing schemes for the utilization and protection of natural waters.

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