

ABSTRACT

of the doctoral thesis by Alzhigitova Manat Meiramovna «Research of hydrogeodynamic processes of the Alakol depression under the influence of increasing antropogenic load (using the example of intensive development of the territories of the Akshi settlement)», submitted for the degree of Doctor of Philosophy (PhD) in the specialisation 6D075500 – ‘Hydrogeology and Engineering Geology’

Relevance of the research. The Alakol depression is a unique natural system in Eastern Kazakhstan, characterised by a complex hydrogeological structure and intense interaction between surface and groundwater. In recent decades, anthropogenic impact has intensified within the basin, linked to the development of recreational infrastructure, water abstraction, irrigation and the economic development of adjacent areas. These factors lead to changes in the natural hydrogeodynamic regime, fluctuations in lake levels and the intensification of geomorphological processes.

When designing, constructing and operating buildings and structures in coastal zones, a serious problem arises regarding the engineering protection of shores and slopes from hazardous geological processes, which include shoreline abrasion, flooding of areas, slope erosion, gravity (slope) processes, including the intensification of landslides, and others. Such processes often result in significant economic damage associated with the irreversible loss of valuable coastal areas, deformation of buildings and structures, and damage to and destruction of transport and engineering infrastructure. In this regard, studying advanced international experience in the engineering protection of coastal areas and assessing the feasibility of applying such methods is a pressing scientific and technical task. The coastal zone of Lake Alakol is of particular concern, where processes of erosion and the collapse of coastal cliffs are observed. These processes not only alter the morphology of the shoreline but also affect the stability of engineering structures, the tourism infrastructure and the ecological condition of the water body.

This factor is particularly relevant given that, to date, the shoreline has come very close to major recreational areas and tourist infrastructure facilities. Their location directly within the zone of potential deformation places an additional load on the soil mass and increases the risk of adverse engineering-geological processes developing.

Changes in hydrogeodynamic conditions under the influence of anthropogenic factors can lead to an imbalance between groundwater and surface water, an intensification of erosion processes, and the degradation of coastal ecosystems.

In this regard, the study of hydrogeodynamic processes and their impact on the stability of the shores of Lake Alakol is a pressing scientific task aimed at assessing the current state of natural and technical systems, forecasting future changes, and developing measures for the sustainable use of water resources in the Alakol depression.

The relevance of the study lies in the fact that the shoreline of Lake Alakol is subject to hazardous geological processes (scouring, shoreline collapse, landslides, erosion), which are exacerbated by natural and anthropogenic factors. These processes threaten the stability of engineering structures and tourism infrastructure, as well as the ecological condition of the water body; they also lead to economic losses and the loss of valuable coastal areas. Consequently, a scientific assessment and the development of methods for coastal protection are necessary to ensure the safe and rational use of the territory and to prevent destruction and damage.

The subject of the research is the coastal zone of Lake Alakol, which is subject to hydrogeodynamic processes and anthropogenic pressure.

The subject of the research is the impact of hydrogeodynamic processes on the stability of the shores, engineering structures and tourism infrastructure.

To achieve this objective, the following tasks were addressed in the study:

- to analyse the current state and long-term trends of hydrogeodynamic processes in the Alakol Basin, including the village of Akshi, and to determine the main characteristics and impact of anthropogenic pressure.

- to develop a geofiltration model of the coastal zone of the village of Akshi to determine the groundwater level and the characteristics of the geofiltration regime in the coastal strip of Lake Alakol;

- To assess the stability of the shoreline using the phi-c reduction method based on the PLAXIS 2D software package;

- engineering-geological recommendations are proposed to ensure the stability of the lakeshore zone of Lake Alakol and to mitigate the impact of hazardous geological processes; these recommendations can be utilised in the planning of coastal development and tourism infrastructure within the Alakol depression.

Research methods. The study utilised research methods including: GIS analysis, hydrogeodynamic and geomorphological observations, assessment of anthropogenic load, and numerical modelling of shoreline stability in PLAXIS 2D.

The scientific novelty of the study lies in the following:

The scientific novelty of the study lies in the application of a comprehensive approach, including the analysis of changes in hydrogeodynamic conditions, the integration of remote sensing data, the use of GIS technologies, and the development of predictive models, providing a new level of understanding of water exchange processes and their anthropogenic transformation in the Alakol Basin. This study is the first to focus on changes in the hydrogeodynamic processes of the Alakol Basin under the influence of increasing anthropogenic pressure.

For the first time, a geofiltration model of the littoral zone has been developed and tested using the Modflow 6 software package, taking into account both natural and anthropogenic influencing factors, which allows for more accurate prediction of changes in groundwater levels and the filtration regime.

The application of the phi-c reduction method in the coastal zone of Lake Alakol has revealed the stability characteristics of the geological massif under anthropogenic loading, which had not previously been investigated in this region.

The development of a geofiltration model of the shoreline zone based on the Modflow software package and phi-c reduction methods for predicting changes in hydrogeodynamic processes under the influence of anthropogenic factors has not previously been studied in this region and constitutes an innovative part of the research.

Main conclusions to be defended:

1. Using the MODFLOW software package, a geofiltration model of the coastal zone of the village of Akshi has been developed. This model makes it possible to determine the groundwater level responsible for soil waterlogging and the nature of the filtration regime, which forms the basis for predicting the stability of the hydrogeodynamic system as the area is further developed.

2. Using the PLAXIS 2D software package and the phi-c reduction method, critical sections of the Alakol Lake shoreline zone prone to deformation have been identified, which will require the development of engineering measures for its reinforcement.

3. The proposed recommendations for ensuring the stability of the shoreline of Lake Alakol and mitigating the impact of hazardous geological processes can be utilised in planning the development of coastal areas and tourism infrastructure within the Alakol Basin.

The practical significance of this work lies in:

its applicability to the development of effective methods for planning and regulating economic activities in the village of Akshi and adjacent areas, particularly regarding the siting of tourism infrastructure.

An assessment of the stability of the coastal zone enables the development of engineering measures to reinforce the shores and reduce the risk of damage, which is of direct importance for the preservation of tourist facilities and recreational areas. Furthermore, the developed geofiltration model of the coastal zone section in the village of Akshi serves as a tool for forecasting changes in groundwater levels and preventing negative consequences (flooding, shoreline degradation, and reduced slope stability).

The proposed recommendations for the sustainable management of water resources in the Alakol Basin can be incorporated into regional programmes for environmental protection and sustainable natural resource use, as well as utilised in the development of strategies for the sustainable development of the region's tourism sector; they will also be useful for local authorities, environmentalists and other stakeholders to ensure environmental sustainability and the conservation of natural resources in the region.

This work may serve as a basis for further scientific research in the fields of hydrogeology, engineering geology and ecology in the studied region and in other similar regions of Kazakhstan.

The author's personal contribution lies in conducting field research involving the photographic documentation of shorelines and slopes, the collection, systematisation and analysis of data, as well as the processing, interpretation and mapping of the results. The author studied and analysed the literature, developed

research methods and formulated the aims and objectives of the work. The results obtained are presented in scientific articles and the main provisions of the thesis to be defended.

Reflection of research results in publications

The scientific propositions and conclusions of the work have been tested in expert discussions at national and international scientific conferences, and published in 8 articles, including 2 articles in an international journal indexed in the Scopus database, 4 articles in a national specialist publication recommended by the Committee for Control in the Sphere of Education and Science of the Ministry of National Education and Science of the Republic of Kazakhstan, 1 article published in a journal; 1 abstract published in the proceedings of an international conference.

Brief description of the main content of the thesis.

The thesis consists of an introduction, four main sections, a conclusion and a list of references. Well-founded conclusions and results are presented at the end of each chapter. The thesis is a complete, independent piece of research aimed at studying the hydrogeodynamic processes and assessing the stability of the coastal zone of Lake Alakol, with the development of recommendations for their engineering protection and the rational use of coastal areas.

The introduction justifies the relevance of the research, formulates the aim and objectives of the work, defines the object and subject of the study, and highlights the scientific novelty and practical significance of the results obtained.

The first chapter provides an analytical review of studies of the Alakol Basin and the Lake Alakol shoreline, demonstrates the extent to which the natural conditions have been studied, and identifies gaps in the study of hydrogeodynamic processes and the stability of the coastal zone. The analytical review established that the Alakol Basin and the coastal zone of Lake Alakol are characterised by a significant degree of study in terms of natural conditions, including geological structure, climatic features and hydrological regime. At the same time, it was found that issues related to the comprehensive analysis of hydrogeodynamic processes and their impact on the stability of the coastal zone under conditions of increasing anthropogenic pressure have not been sufficiently addressed. An analysis of domestic and international studies has shown that modern methods of geoinformation analysis, remote sensing and numerical modelling (including geofiltration and geomechanical modelling) are widely used in global practice, enabling the assessment of shoreline stability and the prediction of the development of hazardous geological processes. The need to adapt and implement these approaches to the conditions of Lake Alakol has been established, which determined the choice of methods and directions for this study.

The second chapter establishes that the formation of the hydrogeological and engineering-geological conditions of the Alakol Basin is determined by the complex interaction of natural and anthropogenic factors. Key natural factors include hydrometeorological conditions, wind-wave regime, geomorphological features of the coastal zone, geological and tectonic structure, hydrogeological conditions and glacial processes, which together determine the current dynamics of the shoreline and the conditions for the development of exogenic processes. It has been found that

wind-wave activity plays a decisive role in the formation of abrasion and coastal reshaping processes, whilst the geomorphological structure and lithological composition of rocks determine varying degrees of slope stability. It has been shown that anthropogenic factors, including the development of tourism infrastructure, the irrational siting of facilities in the coastal zone, water abstraction, irrigation and land development, significantly alter the natural hydrogeodynamic regime. This manifests itself in fluctuations in groundwater and surface water levels, changes in the filtration regime, and the intensification of hazardous geological processes, such as flooding, erosion, abrasion and landslides. It has been established that, under modern conditions, it is precisely the combined impact of natural and anthropogenic factors that determines the trends of coastal zone degradation.

In the third chapter, a geofiltration model of the coastal zone of the village of Akshi was developed using the Modflow 6 software package, which enabled the influence of both natural and anthropogenic factors on the formation of the hydrogeodynamic regime to be taken into account. The modelling results provided quantitative assessments of changes in groundwater levels, the directions of filtration flows and their discharge areas, which enabled the identification of areas of potential flooding and zones of increased filtration activity. It was established that anthropogenic loading contributes to the redistribution of groundwater flows and changes in their regime. The stability of the Alakol Lake shoreline was assessed using the PLAXIS 2D software package and the phi-c reduction method. The calculations determined the slope stability factors, identified the most vulnerable sections of the shoreline, and established the conditions under which stability is lost.

Chapter 4 presents recommendations for stabilising engineering-geological processes and protecting the shoreline of Lake Alakol. The proposed measures are aimed at reducing the intensity of hazardous processes, increasing the stability of the shoreline, and ensuring the safe development of tourism infrastructure.

The thesis comprises 102 pages and consists of an introduction, four chapters, a conclusion, a bibliography (94 references), Appendices A and B, seven tables and 48 figures.

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