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Original article

METHOD OF PROTECTION OF COASTAL LANDS OF THE KUDEPSTA RIVER IN CASE OF EMERGENCIES

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Abstract

Background. Long-term hydrological observations of the Kudepsta River formed the basis for a comprehensive study of the water body. Application of modern geoinformation technologies and statistical analysis method, large-scale field surveys of river channel processes allowed to justify the method of flood protection of the Kudepsta River coastal lands. As a result of the survey of the Kudepsta River channel section in the area of Kudepsta settlement and calculations of shoreline displacement, it was proposed to apply a flexible gabion structure to strengthen the right bank part of the river. This design demonstrates high efficiency of protective measures against erosion and waterlogging of the coastal strip. The estimation of economic efficiency of the method of bank protection is carried out, as a result the coefficient of economic efficiency is equal to 1.77, which is economically favorable. The payback period of construction will be 1 year. Practical experience in the implementation of such engineering solutions can be widely used in the implementation of bank protection works on mountain rivers in various subjects of the Russian Federation.

Purpose. Objective of the study to investigate the method of protection of the coastal lands of the Kudepsta River in case of emergency situations.

Materials and methods. The study area is located on the right bank of the Kudepsta River, its length is 358 meters. The site is located in the mouth of the Kudepsta River valley – it is a right bank section of the river, which is represented by a terrace with an overflow exposed ledge with a height of 2 to 5 meters. It is characterized by degradation associated with landslide processes occurring in the riverbed

Results. To prevent flooding of the adjacent territory and erosion of the banks of the Kudepsta River in the study area it is necessary to build a retaining wall 5.0 m high, 358 m long from gabion structures. Bottom reinforcement of the channel bottom is provided taking into account the possibility of its erosion and in order to protect the erosion funnel.

Conclusion. Based on the survey of the Kudepsta River channel section and shoreline displacement calculations, flexible gabion structures should be used to reinforce the right bank part of the river. This design demonstrates high efficiency of protective measures against erosion and waterlogging of the coastal strip. A method of coastal protection to prevent flooding of the adjacent territory and erosion of the banks of the Kudepsta River at the research site by means of a retaining wall 5.0 m high, 358 m long made of soft gabion structures is proposed.

Keywords: flood; bank stabilization; gabion structures; water flow; channel deformations; scouring

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Научная статья

СПОСОБ ЗАЩИТЫ ПРИБРЕЖНЫХ ЗЕМЕЛЬ РЕКИ КУДЕПСТА ПРИ ВОЗНИКНОВЕНИИ ЧРЕЗВЫЧАЙНЫХ СИТУАЦИЙ

Л.В. Кравченко, А.Е. Хаджиди, Д.С. Колмычек

Аннотация

Обоснование. Многолетние гидрологические наблюдения на реке Кудепста легли в основу комплексного исследования водного объекта. Применение современных геоинформационных технологий и метода статистического анализа, масштабные натурные обследования русловых процессов реки позволили обосновать способ защиты от наводнений прибрежных земель реки Кудепста. В результате обследования участка русла р. Кудепста в районе поселка Кудепста и расчетов смещения береговой линии предложено применить гибкую габионную конструкцию при укреплении правобережной части реки. Данная конструкция демонстрирует высокую результативность защитных мероприятий против размыва и подтопления береговой полосы. Выполнена оценка экономической эффективности способа берегозащиты, в результате получен коэффициент экономической эффективности равен 1,77, что является экономически выгодным. Срок окупаемости строительства составит 1 год. Практический опыт реализации подобных инженерных решений может найти широкое применение при выполнении берегозащитных работ на горных реках в различных субъектах Российской Федерации.

Цель. Цель исследования – изучить способ защиты прибрежных земель реки Кудепста при возникновения чрезвычайных ситуаций

Материалы и методы. Исследуемый участок находится на правом берегу реки Кудепста, его протяжённость 358 метров. Участок расположен в устьевой части долины реки Кудепста – это правобережный участок реки, который представлен террасой с надпойменным обнажённым уступом высотой от 2 до 5 метров. Характеризуется деградацией, связанной с оползневыми процессами, происходящими в русле реки

Результаты. Для предотвращения подтопления прилегающей территории и размыва берегов реки Кудепста на участке исследований необходимо устройство подпорной стены высотой 5,0 м, протяженностью 358 м из габионных конструкций. Низовое укрепление дна русла предусматривается с учетом возможности его размыва и из условия защиты воронки размыва.

Заключение. Исходя из обследования участка русла р. Кудепста и расчетов смещения береговой линии необходимо применение гибких габионных конструкций при укреплении правобережной части реки. Данная конструкция демонстрирует высокую результативность защитных мероприятий против размыва и подтопления береговой полосы. Предложен способ защиты прибрежных территорий для предотвращения подтопления прилегающей территории и размыва берегов реки Кудепста на участке исследований, путем устройства подпорной стены высотой 5,0 м, протяженностью 358 м из мягких габионных конструкций.

Ключевые слова: паводок; берегоукрепление; габионные конструкции; водоток; русловые деформации; размыв

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Introduction

The channel process is closely linked to sediment transport and can be seen as its external manifestation. The degree to which the channel influences the flow and the flow influences the channel depends on channel stability and flow velocities. The interaction between flow and channel produces channel forms that are most appropriate to the nature of the flow, velocities and gradients. The flow tends to smooth out all sharp breaks in the channel, which leads to a reduction in local resistance, movement and scour rate, i.e., increased channel stability. However, the dynamic equilibrium that characterizes rivers in their natural state can be disrupted by artificial changes in water and sediment flow regimes. Siltation of the river bed together with anthropogenic interference in natural water balance processes leads to a significant reduction in the channel capacity, resulting in a critical rise in water levels during the flood period.

Rational and safe management of water resources in mountain rivers requires the construction of bank protection structures, as well as the installation of automated water level control systems. The environmental aspect of flood control measures takes into account the preservation of biological diversity of riparian areas. The Kudepsta River is a mountainous river in the North Caucasus. Its source is located on the southern slopes of the Alek Range at Mount Efrem near the village of Vorontsovka. It flows into the Black Sea within the limits of the village of Kudepsta in the Khostinsky district of Sochi, a southern resort of the Krasnodar Territory. The Kudepsta River is characterized by frequent floods occurring at any time of the year, during which the adjacent floodplain is flooded. For the safe living of the inhabitants of the settlement and guests coming for vacation, it is necessary to develop protective measures to prevent flooding. Therefore, the purpose of the work is to justify the method of protection of coastal lands and settlements by means of bank reinforcement of the Kudepsa River section on the basis of studies of the right river bank erosion.

Materials and methods

The study area is located on the right bank of the Kudepsta River, its length is 358 meters. The site is located in the mouth of the Kudepsta River valley – it is a right bank section of the river, which is represented by a terrace with an overflow exposed ledge with a height of 2 to 5 meters. It is characterized by degradation associated with landslide processes occurring in the riverbed (Fig. 1).

The valley of the Kudepsta River, floodplain part, is made by alluvial-deluvial and alluvial-liman sediments. The width of the modern floodplain on the survey area is 50-60 meters In geological terms, the site of works at a studied depth of 9.0 m is composed of Quaternary sediments (QIII-IV), it takes part alluvial-deluvial and alluvial-liman deposits. According to the type of channel process of the Kudepsta River belongs to the side channel type with elements of limited meandering and mountain-doline wandering.

Fig. 1. Landslide on the right bank of the Kudepsta River

The side-bank type is widespread in mountainous-predmont rivers composed of sediments of any size and is characterized by the presence of large staggered shoals in the channel, which occupy a large part of the channel width during the low-water period. During floods the sidebanks are covered with water and the channel takes on a more rectilinear appearance; when the sidebanks dry out during low water, the river channel takes on a meandering appearance. Between side-banks there are rolls, and the river channel is located at concave banks.

Depths here are 0.2-0.3 m on the rolls, up to 1.5 m on the shoulders, current velocity is 1.0 and 0.5 m/s respectively. The bottom of the river is uneven and cluttered with boulders and karches. The left bank merges with the valley slope, the right bank is steep, up to 3-5 m high (along the right bank terrace), steep in the tops of bends, composed of pebble and gravel material with loamy filler, deformable.

The right bank of the river in the study area is steep with a height of (3.19-6.40) m, subject to deformation, the left bank is represented by an undrained slope of the valley, banks overgrown with woody and shrub vegetation.

The right bank is eroded, the bank collapses to expose the root system of woody vegetation, as a result trees and loamy sediments end up in the river channel part, partially carried away by the river water flow downstream. All this reduces channel capacity and contributes to the formation of karst and debris.

Planned deformations in the study area are mainly confined to channel bends and are observed during floods. The studies were carried out at the sites (Nos. 1-6) and are shown in Fig. 2.

Figure 2 shows that there is a constant meandering of the river flow and channel shifting in the study area. Thus, as a result of the flood emergency in 2022, the village of Kudepsta was partially flooded.

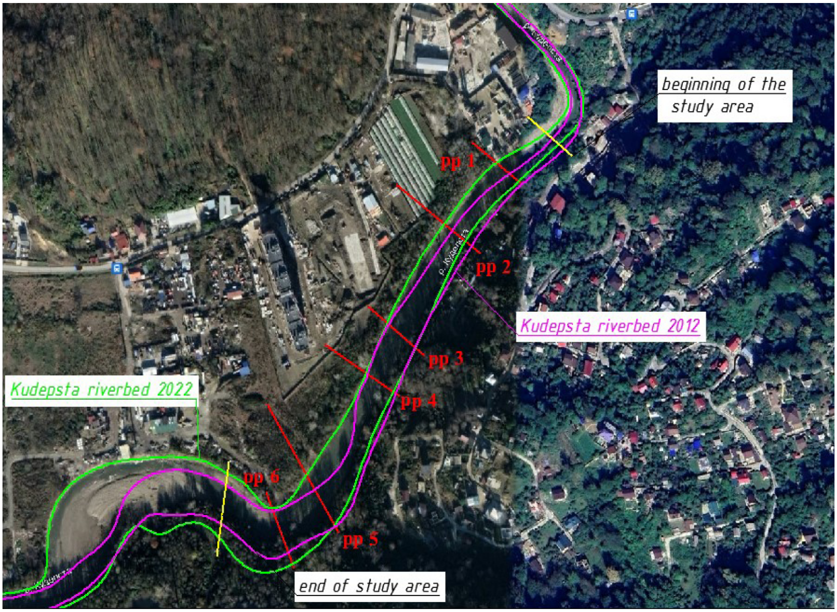

Fig. 2. Study area on the Kudepsta River with boundaries of direction and intensity of bank erosion using Google Earth Pro satellite images for 2012 and 2022.

To determine the method of bank reinforcement and technical parameters of the structure, the calculation of the shoreline displacement was performed. Displacement of the shoreline (boundary of the water body) of the river. Kudepsta is determined by the formula:

$$L_{\mathrm{b}} = C_{\mathrm{m}} \cdot k_{\mathrm{iz}} \cdot T_{\mathrm{pr}} \cdot \frac{H_{max} - H_0}{H_{\mathrm{pl}} - H_0} \tag{1}$$

where L_b – displacement of the mean channel line or concave bank line at a given cross-section, m;

C_m – the highest rate of planned deformations, m/year;

k_{iz} – coefficient of the bend development rate;

T_{pr} – number of years of the forecast period, year;

H_{max} – the greatest depth at the design site, m;

H_{pl} – the greatest depth of the reaches of the given bend, m;

H_0 – average depth of 2 rolls adjacent to the bend, m.

Calculation data of displacement of the right bank of the Kudepsta River in the study area is given in Table 1.

Table 1.

Right shoreline displacement calculation data

Watercourse-well	Highest rate of planned deformations, Sm (m/year)	Coefficient of velocity of radiation development, k of	Number of forecasting years, Tpr (year)	The greatest depth of the shoulder of the given bend, Np (m)	Maximum depth at the pop. profile site, Hm (m)	Average depth of 2 adjacent bends, H0 (m)	Offset of concave bank centerline, Lb (m)
r. Kudepsa – pp №1	0.25	0.82	33	0.57	0.57	0.45	6.77
r. Kudepsa – pp №2	1.64	0.04	33	0.10	0.10	0.09	2.16
r. Kudepsa – pp №3	1.30	0.10	33	0.12	0.10	0.09	1.43
r. Kudepsa – pp №4	1.47	0.10	33	0.12	0.11	0.10	2.43
r. Kudepsa – pp №5	2.30	0.75	33	0.94	0.10	0.07	1.96
r. Kudepsa – pp №6 2,63 km from estuary	0.05	0.75	33	0.92	0.92	0.20	1.24

From the data in Table 1 it is clear that the value of displacement of the right bank line of the Kudepsta River at the embankment development site in Kudepsta settlement during 33 years will be (1.24 - 6.77) meters.

Results

To prevent flooding of the adjacent territory and erosion of the banks of the Kudepsta River in the study area it is necessary to build a retaining wall 5.0 m high, 358 m long from gabion structures (Fig. 2).

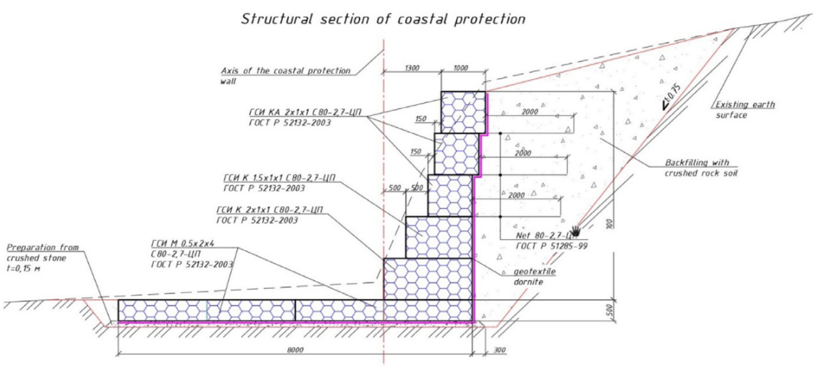

Fig. 2. Coastal protection structure design

Bottom reinforcement of the channel bottom is provided taking into account the possibility of its erosion and in order to protect the erosion funnel.

The retaining wall is installed from gabions of GSI K-2,0x1,0x1,0x1,0-C80-2,7-CP GOST 52132-2003, laid perpendicular to the wall axis on the base of mattress-tufa gabion. Then there is a row of gabions GSI K-1,5x1,0x1,0x1,0-C80-2,7-CP GOST 52132-2003, also laid perpendicular to the axis of the bank protection wall. The next three rows are box gabions with reinforcing panel GSI KA-2,0x1,0x1,0x1,0x1,0x2.0-C80-2,7-CP GOST52132-2003 (length of reinforcing panel 2 m), installed on top of each other with a 0.15 m overhang towards the bank slope with joint dressing. The "overhang" of the upper gabions over the lower ones on the back edge of the structure is 0.15 m.

Mesh size 8x10 cm made of wire with diameter d=2.7 mm, densely coated with zinc and polymer with service life up to 75 years. Laying is carried out long lengthwise on geotextile Dornit 300.

All gabion structures are connected by wire.

The 6.0 m mattress gabion extends from under the row of box gabions to the design river bottom.

The installation of geotextile is intended to prevent washout of the slope soil and backfill through the gabion structures, i.e. a back filter is installed along the contact surface.

In order to prevent scour zones at the interface of the bank protection structure with the bedrock bank, the end section of the bank protection structure is embedded in the bedrock bank. The interface is designed as a combination of a gabion wall and a rock fill made of stone with a diameter of D=0.15-0.25 meters.

The backfill behind the face of the gabion retaining wall is a gravel-sand mixture. The angle of internal friction of the gravel-sand mixture is not less than 28^{o}. Then backfilling with soil from the excavation of the gabion excavation is performed. The backfill soil is placed and compacted in layers not exceeding 0.5 meters. The standard compaction factor is 0.95.

Filling of mattresses and gabions is made of natural stone (average density of stone not less than 2.3 t/m^3, strength reduction index not less than 0.8).

Works in the riverbed are carried out only at low water levels in the river. It is forbidden to carry out works in the river bed during the fish spawning period. During the spawning period works on the shore (territory planning, procurement of construction materials and products, etc.) are carried out.

Conclusion

As a result of research on the Kudepsta River section in the area of Kudepsta settlement, it was established that the right bank of the river in the study area - steep with a height from 3.19 to 6.40 m, is subject to deformation, the left bank is represented by an undrained slope of the valley, banks overgrown with woody and shrub vegetation. The calculation method determined the amount of displacement of the right bank line of the Kudepsta River at the site of embankment development in the settlement of Kudepsta during 33 years, which will be from 1.24 to 6.77 meters.

Based on the survey of the Kudepsta River channel section and shoreline displacement calculations, flexible gabion structures should be used to reinforce the right bank part of the river. This design demonstrates high efficiency of protective measures against erosion and waterlogging of the coastal strip. A method of coastal protection to prevent flooding of the adjacent territory and erosion of the banks of the Kudepsta River at the research site by means of a retaining wall 5.0 m high, 358 m long made of soft gabion structures is proposed.

To assess the economic efficiency of the bank protection method, the prevented damage (losses, damages, costs) minus operating costs for maintenance and servicing of the facility (net profit) to the capital investment providing this result was calculated. The economic effect of preventing damage from flooding is 296.29 million rubles. The cost of bank reinforcement construction is 160.68 million rubles. The coefficient of economic efficiency is 1.77, which is economically favorable. The payback period of construction will be 1 year.

Conflict of interest information. The authors declare that they have no conflict of interest.

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ВКЛАД АВТОРОВ

Все авторы сделали эквивалентный вклад в подготовку статьи для публикации.

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