Environmental Rehabilitation of Volga-Akhtuba Floodplain

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Abstract. The research considers the water bodies of the Volga-Akhtuba floodplain requiring an optimal hydrological regime, aimed at preserving floodplain oak groves, soil fertility, spawning sites and at the development of the territory agricultural potential. New solutions are presented, aimed at complex approach to floodplain territory rehabilitation, at minimization of floodplain degradation and at its restoration, instead of traditional hydro-mechanized work on cleaning tracts, eiks and lakes of the floodplain. A phased restoration of the floodplain natural state and creation of balanced ecosystem with an operating self-purification mechanism are planned as a result of the proposed measures being implemented. These measures enable to increase the acreage of irrigated lands for vegetable crops by accumulating spring flood waters in the water bodies of Volga-Akhtuba floodplain.

1. Introduction

The Volga-Akhtuba floodplain within the Volgograd region has a high biological and landscape diversity. It contains numerous water bodies: the river Akhtuba, stretching for 90 km within Volgograd region; Krasnoslobodsky tract (33 km long); Kashirinsky tract (99.3 km); 8 backwaters; 6 large ducts; 173 eiks, over 200 large lakes (unique accumulators of liquid and solid river runoff) and 2 marshes. The total area amounts to 206.8 ha [1].

In total, within the Volgograd region the Volga-Akhtuba floodplain has over 400 water bodies and valuable natural complexes: wetlands; spawning grounds of valuable commercial fish, including sturgeon; places of wetland birds density, including globally rare species, nesting of the white-tailed eagle; floodplain oak groves of a pedunculate oak special ecotype (an outpost of oak in the extreme southeast of Russia); habitats of relict plants (ferns); a unique combination of wetlands with gallery oak groves.

Today, being a specially protected natural area the Volga-Akhtuba floodplain requires an optimal hydrological regime. It is aimed both at preserving floodplain oak groves, soil fertility, spawning sites and at developing the agricultural potential of the territory.

The environmental parameters of water bodies are affected by the artificial regulation of the hydrological regime of the floodplain, as well as by the expansion of residential areas. Thus, they are transformed and lose numerous ecosystem properties that are significant for humans. Intense and unregulated anthropogenic impacts result in violations of the natural physicochemical parameters of water bodies, loss of biodiversity, degradation of the structure and functions of biological communities. It causes reduction in the range of potential ecosystem services - the benefits “that people get from ecosystems”. The restoration of the lost properties of aquatic ecosystems is a key
factor in increasing the sustainability of developed landscapes, creating comfortable conditions for living and managing the population [2].

The main factor that has caused the need for rehabilitation of the Volga-Akhtuba floodplain eriks and lakes is the change in the hydrological and environmental situation. The situation resulted from changes in the hydrological regime by regulating the river Volga flow after the construction of the Volzhskaya hydroelectric power plant.

Eriks are one of the main waterways of the Volga-Akhtuba floodplain. Numerous sub-parameters of floodplain water bodies depend on their water content. In this regard, of practical importance is work aimed at improving the state of water supply to degraded water bodies. The degradation of water bodies can include siltation, overgrowth of alien shrub and woody vegetation, overlapping by unauthorized enclosures that result in losing most of ecosystem functions. The hydrological regime of floodplain ecological systems depends on the functioning of the main elements of natural water bodies.

An important part optimizing the hydrological regime of the network of tracts, eriks and floodplain lakes is played by both the volume of special release and the duration of maximum discharge through the Volgograd hydroelectric complex. The optimal flooding of the floodplain territory is achieved at maximum flow rates – 27,000 cu m/s, its duration being 14 days at least [3, 4].

The State Program of the Volgograd Region "The use and protection of water bodies, prevention of negative impact of water on the territory of the Volgograd Region for 2014-2020", approved by the Government of the Volgograd Region dated August 30, 2013 No. 453-п, provides for the implementation of environmental rehabilitation of the Volga-Akhtuba floodplain.

2. Materials and Methods

In order to minimize the degradation of the floodplain, and also to restore it, a fundamentally new solution was adopted instead of the traditional hydro mechanized works on clearing tracts, eriks and lakes of the Volga-Akhtuba floodplain. It is aimed at a comprehensive approach to the rehabilitation of floodplain territories proper, namely: clearing water bodies from reed vegetation and the removal of alien species of woody-shrubby vegetation that oppress the local floodplain flora; the formation of a complex bottom topography with the necessary depths and shallow waters, planting of trees and shrubs of a typical floodplain flora; formation of recreational qualities of the coastline.

In order to achieve the goals set in the framework of cooperation with Volgograd Regional Committee of Natural Resources, Forestry and Ecology, the functioning of water bodies located in the Volga-Akhtuba floodplain against the background of environmental protection measures was reviewed and analyzed.

Sites for cleaning water bodies were chosen based on route and topographic surveys. Areas with noticeable rifts and tree blockages constricting the watercourse were visually identified. Based on the materials of topographic surveys, shallow areas of lakes and areas requiring an increase in the cross section of the rivers and channels were determined.

3. Ecological rehabilitation of water bodies in Volga-Akhtuba floodplain

Dredging and clearing of water bodies have a negative impact on biocenoses, since there is a direct destruction of tree-shrub and grass vegetation in the work area, storage of soil, and placement of construction sites. Without active recovery, plant complexes are either restored for decades, or are not restored at all. In the clearing zone, perennials are almost completely replaced by ruderal annuals. Alien (invasive) plant species easily naturalize disturbed habitats. They occupy habitats typical for the floodplain of black poplar stands, willows and osier beds, changing the properties and functions of natural ecosystems. It results in the change in forest-forming species. Studies show that the restoration of the normal functioning of aquatic ecosystems in a natural way without disturbing the bottom surface takes place in the second or the third year. Studies conducted in 2013 on the Krasnoslobodsky water tract, where large-scale dredging was carried out, showed that the biocenoses restoration processes are very slow. After the hydraulic works, the riverbed was a ditch filled with water. They
completely destroyed coastline biotopes which are characterized by the highest rates of species richness and species diversity in the water body were overgrown with macrophytes. The restoration of this biotope and overgrown biocenosis was not observed even a year after the work completion. The species composition of the bottom fauna was characterized by extremely low rates. In cleared areas, only 7 zoobenthos species were detected [5].

So, on the Krasnoslobodsky waterway, measures were taken to rehabilitate the eriks Degtyarny, Dudarev, Nareznoy and Zhernova — more than 16 km long, and erik Averkin — 4.8 km long.

In 2019, the environmental rehabilitation measures of erik Sudomoyka, Sakharny and Lake Zapornoye were started. More than 5,500 trees and shrubs are planned to plant on the area of more than 57 hectares.

On the Kashirinsky waterway, measures were taken to rehabilitate erik Kashirin and duct from erik Kashirin to Lake Proklyatoe, over the area of 29 hectares.

![Figure 1. Riverbed woody vegetation of the erik Sudomoyka](image1)

In 2019 rehabilitation measures the eriks Chaika, Old Kashirin, the lakes Proklyatoe, Kamyhistoe and Kruzhnoe started: more than 13,000 trees and shrubs were planted on the area of over 68 hectares; rehabilitation of 19 km long erik Shumrovaty: planting over 10,000 trees and shrubs on the area of 220 hectares; and rehabilitation of Lake Shirokogorloye: planting over 5,100 trees and shrubs on the area of 128 hectares.

As a result of implementing these measures, it is planned to restore gradually the natural state of the floodplain territories, to create a balanced ecosystem with an effective self-cleaning mechanism, which will increase the area of irrigated land for vegetable crops by accumulating spring flood waters in the previously created reservoirs of water bodies of the Volga-Akhtuba floodplain.

![Figure 2. Lake Malaya Nevidimka](image2)  ![Figure 3. Lake Bolshaya Nevidimka](image3)
Based on the materials of visual route surveys of sites with the probe bottom examination in certain sections of water bodies, the need for the following activities is considered:

- clearing the channels of eriks, the ducts and lakes with dredging;
- clearing trees fallen into water bodies;
- clearing the bottom of household waste in areas adjacent to settlements.

The formation of hydraulic parameters that increase the throughput and capacity within one water body, without going beyond the boundaries of coastlines, enables to improve the sanitary condition of water bodies in the low-water period.

Technical rehabilitation is carried out on the formed, stable (in the lay-out) channel without cutoff.

These measures contribute to improving the throughput capacity of water bodies, both during the period of maximum discharges and during the phase of the flood rise and fall, besides, the network of existing eriks and the channels provides hydraulic connection to numerous lakes of the Volga-Akhtuba floodplain.

Currently, the water bodies of the Volga-Akhtuba floodplain are mainly a typical example of natural systems degradation due to high anthropogenic impact: water bodies are located close to highways, surrounded by villages, dammed up to ensure the safety of settlements in floods; lands adjacent to water bodies are used for agriculture. The built-up area increasing and highways being constructed, lakes and rivers lost their flowage.

In this regard, there is a justified need for a comprehensive cleaning and deepening of water bodies of the Volga-Akhtuba floodplain as of flood water receivers.

General parameters and dynamics of the model territory (landscape), including the lake Zapornoe:

- The total area of the model plot is 101.5 sq km;
- The build-up area (%): 1940 - 6.298%; 1984 - 9.271%; 2012 - 16.157%. Thus, in the period from 1940-2012 the build-up area increased by 156.5%;
- The population size at the model plot in 2010 amounted to 21601 people;
- Density of population 213 people/sq km;
- Density of road and path network (km/sq km): 1940 - 0.835; 1984 - 0.834; 2012 - 2.089.

Figure 4. Comparison of the residential area near the lake Zapornoye in 1940, 1984 and 2012: the state of building-up and of the road-path network (based on data from topographic maps of 1940, 1984 and a space photograph of 2012 near the lake Zapornoye)
Flood scale and duration decreasing, siltation processes accelerate, eriks and lakes are quickly overgrown with air-water plants. Overgrowth accelerates the siltation of shallow waters and enhances waterlogging, slows down the water flow during floods, and contributes to a decrease in flora and fauna diversity both in shallow water and in adjacent meadows. Due to the multiple mechanical dredging of the water bodies beds, the hydrobiont fauna and the aquatic flora, which should maintain water quality, are depleted. Fish productivity is steadily declining. Ground vegetation is highly transformed as a result of high anthropogenic impact. The animal population corresponds to the parameters of the anthropogenically disturbed landscape. Habitats of aquatic plants, of bottom invertebrates, as well as nursery grounds for hatchlings were lost. Thus, the water bodies have almost completely lost most of their ecosystem functions and need to be restored through the implementation of special rehabilitation measures [6].

Figure 5. Common reed thickets on the lake Zapornoye

Having analyzed the state of water bodies, we believe, that environmental rehabilitation of the Volga-Akhtuba floodplain should be based on ecosystem restoration measures. They include increasing water availability in the discharge flow of the Volgograd hydroelectric complex, provided for by the operation regulations (at the level of 25000-27000 cu m/s, duration 5-7 days); maintaining the design levels after the flood decline, restoring typical biodiversity groups in the formed habitats (tree-shrub and grassy vegetation) and improving water quality [7].

Bed formation in eriks and ducts enables to increase throughput both during the peak of the flood and during the phases of ups and downs. This measure enables the lakes to be filled in the flood for 5-7 days to the marks of the normal headwater elevation (hereinafter NWL). Improving the quality of water, maintaining design levels after the flood decline and the formation of recreational qualities of the coastline are achieved by removing thickets of aquatic vegetation. It is done in a part of the area between the boundaries of the water surface at the NWL and the top of dead storage (TDS). Besides, the bottom of the lakes is cleared of household clogging garbage, abandoned nets and other ownerless fishing gear. Works are also underway in the water protection area of the channels to the lakes; alien trees being eliminated and local trees being planted.

Ecological rehabilitation of water bodies is an environmental protection measure aimed at optimizing the hydraulic regime and restoring the normal functioning of the main elements of the ecological systems of water bodies.

Considering the above provisions the ecological rehabilitation of the water bodies is carried out in 2 steps:

- Technical phase:
  - littoral formation with depths 0.2 to 0.7 m at least 20% of the lake area, and with depths 0.8 to 1.5 m 20% at least.
- the formation of a pelagic zone with depths of 1.6 to 2.0 m at least 20% of the lake and with depths of 2.1 to 3.0 m at least 10% of the lake.

- Biological phase:
  - According to the ecological conditions of the landscape under rehabilitation, primarily, the level of water flooding, it is essential to restore tree-shrub vegetation, meadow floodplain communities, submerged littoral vegetation and to reconstruct of the helophyte community.

Considering the real conditions, based on the specific local conditions on the area to be cleared (mainly on the depths, the width of the clearing and the type of soil), clearing can be carried out by two types of mechanisms: an excavator and a dredger.

Clearing and dredging of water bodies on cramped and built-up plots of the coast are supposed to be done by the dredger. In the areas where excavation equipment and vehicles are accessible, excavation is carried out.

The channels are cleared by an excavator up to the design level with the subsequent loading of soil onto vehicles and transportation to the permanent dump for the allocated places for their placement.

Water availability and cross section dimensions determine channel formation works with the dredger. This eliminates the need to remove trees and shrubs along the banks of water bodies.

When clearing water bodies with a dredger, the extracted soil is transported via floating and onshore soil pipelines to the alluvium map. It is washed in a non-cascading manner into the alluvial map with a ring levee. The pulp is supplied through a welded main pulp line. Soil on the map is laid by slip-joint pipes or quick-disconnect pipes. The clear water is discharged from the map through the discharge chandler well to erik over the discharge pipeline through the local treatment plant.

Before the works start, the fertile soil layer is removed from the surface of the designed alluvial maps and the base of the map dipping dams for subsequent reclamation of alluvial maps.

Fallen trees during the clearing of water bodies of the Volga-Akhtuba floodplain are removed either manually or from a motorboat by sawing and towing to the point of extraction to the shore. Trunks are subject to sawing and transferring to the population as firewood, unwanted branches are transported to a household waste dump.

The implementation of these measures results in the gradual restoration of the natural state of the floodplain area, the creation of a balanced ecosystem with an operating self-cleaning mechanism. Besides, after the spring flood, it will enable to ensure the use of previously created storage tanks of water bodies to increase the irrigated areas during the cultivation of vegetable crops.

However, the close location of the Volga-Akhtuba floodplain to Volgograd and Volzhsky, as well as the historical features of the floodplain territory use, namely the development of housing construction, recreation, agriculture, leave their imprint on the preservation of the unique and typical natural complexes of the floodplain.
4. Conclusions

Studies on the ecological rehabilitation of floodplain water bodies provide for an increase in the receiving capacity of lake basins, water availability, flow rate and depth of water bodies. Rehabilitation will enable to increase the filling rate Zapornoye lake with water and, accordingly, to reduce the introduction of sediment deposits from fields and meadows. Therefore, the effects of Volga flood regulation will be mitigated.

Water quality as a result of ecological rehabilitation will be improved due to restoration of aquatic vegetation developing in the littoral zone of lakes. There is a large amount of scientific data indicating the existence of a close relationship between the vegetation of higher aquatic plants, self-cleaning of water bodies, the circulation of substances and the processes of formation of water quality in them.

- higher aquatic plants, due to their morphological (stem structure, location of organs, etc.) and environmental (density of thickets, etc.) features, can serve as a biological filter when suspended and poorly soluble contaminants enter the water body [9];
- higher aquatic plants can serve in a water body not only as mechanical suspension filterers, they are also able to absorb and accumulate mineral and organic substances, to exhibit a certain activity in the processing of suspensions using them in the course of metabolism, thereby they affect the quality of water, being the main factor in regulating water quality [10];
- ions absorbed by higher aquatic plants are removed from substances cycle in a water body not for a short period of time, as is the case with the development of phytoplankton, but for a longer period - 5 to 6 months;
- biogenic elements and organic compounds obtained by plants do not remain ballast, but are used by them to maintain functional activity aimed at the formation of biomass containing a significant amount of proteins, amino acids, carbohydrates, etc. and can be used for business purposes [11];
- coastal-aquatic plants inhibit the development of phytoplankton and “blooming of water” with a biomass of 1.5 kg / sq m [9].

An important direction in planning and implementing environmental rehabilitation of disturbed landscapes is the restoration of a typical vegetation cover, since it is plants that form the habitat structure for various groups of animals on a landscape basis [12].

The restoration of full-fledged bottom community’s characteristic of the floodplain should be expected after the formation of thickets biocenosis. In this case, the restoration of zoobenthos, in the presence of nearby non-drying water bodies, a kind of refugiums, occurs quite quickly. This is facilitated by the high adaptation of the taxonomic and ecological complex of benthic fauna of the floodplain to habitat in stressful situations. Species richness and biodiversity of the bottom fauna of
the cleared channel to Proklyatoye lake will be restored. Erik Kashirinis the refugial water body from which hydrobionts will penetrate and populate.

The process of fish fauna restoration in disturbed areas is determined by the characteristics of the water bodies of the northern part of the Volga-Akhtuba floodplain. During floods, floodplain water bodies, as well as the Volga and Akhtuba for a period form a single water system. Fish are given the opportunity to move within it, and they actively use it. Thus, during high water there is a redistribution of fish between floodplain water bodies, the Volga and the Akhtuba [4]. The increase in depth in some parts of the water body to 2.5 - 3 m creates more favorable conditions for fish wintering. In addition, the extraction of excess bottom sediments saturated with detritus from water bodies improves the hydro-chemical regime, thus reducing the possibility of clogging phenomena.

To maintain the desired structure of natural complexes in the landscape, it is necessary to formulate these parameters and requirements and to use management tools to maintain the described structure or to change it in the direction desired.

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