Forming a sustainable ecological environment of the coastal areas of urban water bodies

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Abstract. Green embankments are one of the topical themes in modern urbanism and the most valuable urban resource, mainly determining the image and state of the city’s environment. Russia’s historic cities are redeveloping the coastal space. The historic image of the city’s water features is essential in many ways. The waterways of the urban system originally were and are city-forming objects. Improvement, renovation, and restoration of coastal areas is an urgent task, requiring integrated approaches to realize the sustainable development of urban areas.

1 Introduction

Water bodies are structural elements of the natural-ecological framework of urban districts. The presence of water bodies caused the emergence of historic cities and a set of advantages in their development: provision of drinking water; trade links; strengthening of defensive functions; increased opportunities to fight fires; allowed citizens to engage in various crafts and industries; use of water energy in water mills; fishing and much more. The presence of urban water bodies contributed to creating a harmonious spatial structure of interaction between the urban environment and natural landscapes [1-3].

Historical experience in the development of coastal spaces of urban water bodies needs to be better studied, which makes it difficult to further the formation of theoretical and practical experience in architecture and urban planning at the present stage of development.

The article deals with the creative approach and aspiration of the 18th-century architect P.R. Nikitin to better utilize the natural conditions and local features of the cities of Kaluga province, the interrelation of the architectural and planning structure of urban areas, strict regular compositions softened by fanciful river bends, view embankments, squares of cathedral and city churches.

In landscaping the coastal areas of urban water bodies integrated into the urban structure, the goals of ecological recovery and increasing the attractiveness of the territories through the organization of green embankments with the use of natural technologies of self-purifying the water body by plants are considered.

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The origins of the study of coastal aquatic plants were connected with the development of fish farming in Europe in the 18th century, then in Russia, where the study of flora and fauna of water bodies was connected with the organization of some hydrobiological stations for the effective exploitation of natural resources of water bodies. However, this experience is only applied to the ecological rehabilitation of water bodies integrated into the urban environment.

The final part of the article analyzes the experience of applying bioengineering technologies and green embankments and gives an objective assessment of the possibility of more extensive application of these technologies in forming a sustainable ecological environment of coastal areas of urban water bodies.

2 Materials and methods

In the urbanized environment, urban water bodies are undergoing anthropogenic pressures, accelerating coastal landscape development rates, and increasing population recreational needs, to which climate change is added. The search for new scientific knowledge in maintaining and landscaping urban water bodies is required.

The actual direction of this research topic is landscaping and preserving the architectural and landscape environment of coastal areas of urban water bodies, introducing innovative ecological technologies of coastal area organization, and preserving and improving the biological diversity of ecosystems of urban water bodies.

The goals of Sustainable Development and Forming a Sustainable Ecological Environment are a guideline for the development and improvement of the organization of landscaping of urban water bodies, aimed at supporting the ecological and historical-cultural balance of the territories. This direction defines the following tasks:

1. The study of historical conditions of formation and evolution of the development of urban water bodies and coastal areas on the example of plans of county towns of Kaluga province by P.R. Nikitin;
2. Study of the main urban-environmental problems of urban water bodies
3. Analysis of experience and practice of landscape and urban development of coastal areas of urban water bodies. Identification of the main techniques for organizing green embankments.

The research methodology is based on a systematic approach to conducting complex research. It includes the study of literary, archival, and reference sources, cartographic and photographic materials, involvement of Internet sites with cartographic data of the studied territories, the study of official state documents, scientific and analytical developments, project materials, and scientific publications, as well as other sources.

3 Results

The urban development management system in Russia began to emerge in the 18th century. The decrees of Peter I on “red lines”, fire protection decompaction of buildings, development of stone construction, orders on comprehensive application of green spaces, and construction of embankments played the role of building rules for the erected St. Petersburg [4].

The foundations of spatial planning and development of the urban environment laid by Peter the Great on the example of St. Petersburg and its environs were applied on a grandiose scale to provincial cities during the reign of Catherine II.

To strengthen the centralization of state administration, Empress Catherine II, on November 7 (18), 1775, issued the “Establishment for the administration of the provinces of the Russian Empire” [5], following which, in 1775-1785, a cardinal reform of the
The administrative-territorial division of the Russian Empire was carried out. The provincial reform of Catherine the Great prompted the emergence of a large number of new towns and increased the administrative status of the former ones, and, as a consequence, the introduction of the principles of regularity in the layout and further development of provincial centers. According to the Empress’s decree, “On making all cities, their buildings and streets special plans for each province especially”, the task of developing general plans for almost 500 cities was set [6].

Changes in urban space concerning the regular plans of provincial and county towns, the formation and inclusion of historical and cultural landscapes, as well as their preservation in modern urban planning conditions require detailed consideration. According to the new city plans, integrating the natural environment of coastal areas into the development was essential in the urban architectural and spatial structure. Engaging in this respect are the plans of provincial and district towns of Kaluga province, created under the direction of architect Pyotr Romanovich Nikitin at the end of the 18th century.

Kaluga province was established on August 24, 1776, by a nominal decree of Catherine II with 12 counties and the appointment of Mikhail Nikitich Krechetnikov as governor. Kaluga province became a benchmark for the implementation of the new administrative reform. It was in Kaluga province that, for the first time in history, all the counties and their central cities received their coats of arms, which was unique for that time and emphasized the status of this territory. In addition, the plans for the development of provincial and county centers and the system of organization of administrative, residential, and religious areas of the cities of the entire province in the shortest possible time almost simultaneously were carried out for the first time in Kaluga province. The great merit in this process belongs to the outstanding architect of that time – Pyotr Romanovich Nikitin. Pyotr Romanovich arrived in Kaluga in 1776 at the invitation of Governor-General Mikhail Nikitich Krechetnikov and worked in the city for 6 years. He left behind an indelible legacy – he reformatted an Old Russian settlement into an imperial city and immortalized himself directly in the architectural buildings and the regular plan of Kaluga and the plans of the district towns of Kaluga province.

One of the first instructions of the new architect was to draw up a detailed plan of the city of Kaluga with settlements, which was carried out by a team of military topographers. Special “Commission on stone construction”, which worked in St. Petersburg, did not accept the project, sending it for revision because Nikitin did not indicate stone buildings in the drawing already built at that time in the city. In the end, the architect had to adjust the plan twice. In the final version, the regular plan was approved by Viceroy Krechetnikov himself already in 1785-1786. A new architect finalized this variant – Ivan Denisovich Yasnygin, as Pyotr Nikitin died in 1784 [7].

There is no doubt that P.R. Nikitin conceived the basic scheme for the city redevelopment, determining the location of squares and the grid of streets. In the final version of the project, the city received the outline of a regular trapezoid, to which, on the sides, from the side of the Moscow and Tula outposts, adjoined the “rectangles” of the Yamskie settlements.

Architect P.R. Nikitin cared a lot about the landscaping of Kaluga. For example, the city magistrate, on the initiative of Pyotr Romanovich, decided to move to the outskirts of the city, all the industries that were dangerous in terms of fire or unsanitary.

When P.R. Nikitin drew up the city layout, he showed great concern for clean air for the citizens. Most of Kaluga’s streets face the steep bank of the Oka River and the equally steep slope leading to the Yachenka River: thanks to this, no matter where the wind blows from, it always quickly penetrates the street space. The city is constantly easily ventilated, as the avenues intersect at right angles to each other. Numerous underground springs in the bowels
of Kaluga were enclosed in wooden pine tarred pipes. Drainage was carried out by water pipes in ceramic pipes in the form of conical couplings.

Kaluga’s unique natural and historical landscape was considered in the city plan and skillfully linked to the complex topography. According to the plan, streets parallel to the Oka River were connected to the ancient radial-ring layout, which provided an opportunity to preserve the historic environment and historical monuments in combination with new construction sites. The plan successfully combined the techniques of radial, fan, and rectangular compositions. The development of the Catherine time, with few exceptions, has survived to the present day. Kaluga’s 18th-century general plan became the historical framework for modern Kaluga.

The creative activity of P.R. Nikitin went far beyond the city of Kaluga. In parallel with the solution of the plan of the city of Kaluga, Nikitin was engaged in the plans of district towns. The compilation of each plan was preceded by surveying, measuring, and bounding the towns. Analysis of the general outlays of the county towns draws attention to P.R. Nikitin’s constant striving to utilize better the landscape conditions and local historical features of each town.

Characteristic of P.R. Nikitin’s work: parade-like construction of city centers with perspective views of the best parts of the surrounding landscape. The regular compositions contrast with the picturesque river bends towards which the city center opens up.

The formation and development of architectural and planning structure and functional purpose of riverside territories co-occurred with the growth of cities, influenced by changing cultural features and traditions, political and socio-economic conditions [8].

In general, the 18th century brought many innovative edicts in urban planning, in addition to the beginning of gardening and landscaping of streets and roads. The arrangement of boulevards as far back as in the Peter the Great times developed into broad measures for the greening of cities. St. Petersburg was surrounded by two green belts along the Fontanka and Moika rivers, and since the Peterhof Road connected the capital with the imperial country residences, Peter had the idea of turning it into a continuous ribbon of seaside parks. This is how the world’s most excellent park system was created, stretching for almost 40 km [9]. Thus, the ideas of continuity of the water-green framework in urban conditions have been successfully addressed and realized in the historical period. Studying the accumulated experience will help to avoid the repetition of innovative “mistakes” and unjustified search for solutions to architectural problems.

Modern cities with water bodies have an undeniable advantage. However, the intensive development of coastal areas has caused several problems. In a number of cities, transportation highways have effectively “cut off” the coastal strip from the urban area. In larger cities, the shores of water bodies are framed with artificial (concrete, granite) materials and structures, and the natural coastal boundary is broken. In some small towns, the water’s edge is inaccessible due to litter and weedy vegetation, and conditions for staying in such coastal areas are uncomfortable and environmentally unsafe. Coastal areas have lost their scenery character and spatial continuity between city centers and areas of modern residential development due to the enclosed spaces of industrial, agricultural, and warehouse complexes. Often such sites are degraded and aesthetically unappealing.

The main urban-environmental problems of coastal areas of urban water bodies can be distinguished:

- unbalanced territorial-planning and architectural structure of coastal areas;
- lack of clear recreational zoning with access to water bodies;
- pollution of surface and groundwater;
- need for a developed natural framework.

This range of problems makes it difficult to use coastal areas for recreational purposes and disturbs the ecological balance of urban districts.
4 Discussion

Forming a qualitatively new level of healthy urban environment implies large-scale greening of territories and the search for new spaces and existing park green zones to create a unified natural framework. Greened coastal areas are required as a link for individual parks, squares, boulevards, and so on. The choice of coastal area organization requires an integrated approach and considering local conditions. Traditionally, the banks of rivers and other water bodies in cities, especially densely built-up ones, were reinforced with monolithic stone or concrete embankments. The creation and preservation of concrete frames and other capital construction on the banks is justified where the waterfront serves as a wharf and transportation routes. However, water bound by concrete and stone does not contribute to the development of aquatic ecosystems. As a result, populations of aquatic plants, insects, fish, and birds are declining.

In many cases, concrete embankments can be dispensed with by replacing them with bioengineering techniques such as using natural materials and planting specific types of trees on the slopes of water bodies. The benefits of natural embankments include city protection from river overflows, provided that the width of the embankment matches the maximum level of seasonal overflow; increased biodiversity, improved water quality; improved urban microclimate; air purification; and improved quality of life for city dwellers. Increasing the amount of green space in the city positively impacts people’s physical and mental health.

Russia has accumulated extensive experience in studying the role of vegetation in water purification and using macrophytes. It has been proven that vegetation is the “green” shield of living water. The coastal belt of reeds, rushes, cattails, and sedges is a biochemical barrier. The positive role of aquatic vegetation is seen in protecting the banks from erosion and scour; in the reed barrier, wave impacts do not reach the banks. In hydraulic engineering, the method of bank protection by planting reeds and bulrushes is known; the robust root system of these plants intertwines, spreads, and strengthens the ground against rupture. The sanitary role of the vegetation barrier is now also recognized. Mineral and organic matter, suspended solids, and various pollutants carried by water runoff primarily encounter the vegetation belt. Reed thickets have the unique property of destroying oil pollution, “neutralizing” phenols and toxic chemicals, and even purifying water from heavy metals. Various aquatic vegetation is essential to inhibit the growth of blue-green algae. The combined activity of bacteria, algae, and higher aquatic plants, various invertebrate animals inhabiting water bodies ensures biological equilibrium and promotes self-purification of water bodies.

The options for green embankments are varied. In some cities of our country, interesting projects of green embankments using natural technologies of self-purifying water bodies by plants have been successfully realized or are under development.

One of the brightest and freshest examples of the Russian practice of organizing modern green coastal space is the famous Elastic Strip project implemented in Kazan. The project creates a continuous ribbon of landscapes along the coastal areas of the Lower, Middle, and Upper Kaban lakes, linked into a single system: an ecological strip, a cultural strip, and a transportation strip. The main idea is to create a new public and green space and radically clean the lakes, based on the biological principle of water purification in the city – at the expense of plants and soil.

The water cascade is one of the waterfront attractions. It consists of seven mini-ponds with filtering layers of sand and gravel and, most importantly, carefully selected plant species that promote purification and self-regeneration of the lakes. Water from the lake is pumped from the lake to the first reservoir, from there to the second, to the third, and so on. The first reservoir is planted with Eichhornia (water hyacinth), the purification is due to the
roots of the plant, which reach a length of about a meter. Microorganisms live on the roots, which filter all the water that passes through them. In the second reservoir – marsh aire, then reed, turfgrass, narrow-leaved hornwort, Glyceria – plants, each performs its water purification functions at different stages. Relatively clean water flows into the seventh cascade with water lilies, which do not grow in dirty water, which is a criterion of water purity [10].

It is known that the landscape organization of the coastal strip, taking into account the architectural heritage, emphasizes the originality and specificity of the city. A project to reconstruct the embankment of the Oka River is being implemented in Kaluga as part of the federal project “Forming a Comfortable Urban Environment”. The strategy for the development of the urban area includes the idea of creating a unified historical-tourist-recreational complex, including the embankment of the Oka River, Volkov Square, the banks of the Yachenskoe Reservoir, and Gorodskoy Bor. The project envisages slopes landscaping and restoration of comfortable slopes to the Oka River. Specialists suggested using embankment hills, flat meshes filled with stones, and phytobotanical sites. It is proposed to plant aquatic plants, which is partially already addressed in the project.

5 Conclusion

The history of Russian urban planning shows that most coastal cities have their characteristic image of coastal area. Visual and compositional “interaction” of coastal areas and the city should reveal the uniqueness of urban areas. Riverfronts are of great functional and cultural importance. Aquatic ecosystems improve quality of life. Various green embankment options are required for environmental and recreational purposes to create a sustainable and comfortable urban environment: managing self-purification in urban water bodies, maintaining clean water, and directing improvements in their design and operation.

Realization of the significant natural and historical-cultural potential of coastal areas of urban water bodies and the formation of the infrastructure of coastal areas of urban water bodies has a positive impact on the development of the recreational sector, on the environmental friendliness of urban complexes, activating the processes of formation of comfortable urban environment and development of public spaces.

Each urban water body is unique, and the choice of shore protection and coastal area landscaping technology depends entirely on local climatic and urban planning conditions. It is not feasible to create a single model project. The prospects for developing this direction lie in the integrated approach of studying the conditions and main parameters of the environmental situation and characteristics of different groups of urban water bodies. Considering these parameters, it is possible to create fundamental models of natural waterfront development for certain climatic and environmental conditions.

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References
4. M.V. Ponomareva, The system of architectural and construction coordination and control in Russia in the XVIII-XIX centuries (Architect and profession, St. Petersburg, 1999)
5. Institution for the administration of the provinces of the Russian Empire in 1775 (Pechatano pri Senate, Moscow, 1775) Russian legislation of the X–XX centuries, O.I. Chistyakov (ed), vol.5 (Legal Literature, Moscow, 1987) ISBN 5-7260-0154-0
6. The complete collection of laws of the Russian Empire 16(11883), 319 (St. Petersburg, 1830)
8. D.V. Bobryshev, S.E. Vershinina, IrSTU Bul. 12(95), 103-107 (2014) УДК 711.4; 712