Non-destructive testing as an element of monitoring the operational reliability of rice systems for the rational use of water resources

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Abstract. This article presents the results of monitoring the operational reliability of structures of an on-farm network of rice systems for the rational use of water resources. At present, the state of the water basin of the Kuban River is characterized by a high level of economic and integrated development. The amount of irretrievable withdrawal of water resources in the Lower Kuban exceeds the maximum permissible withdrawal limit by 3.5 times. Thus, the Kuban River has virtually no free water resources in the lower reaches after the Krasnodar reservoir, for further development. Studies conducted on the on-farm network facilities have shown that closed structures on rice systems are in a worse position than open ones. The drainage structure in the form of a pipe was examined in detail, since the structure is exposed and accessible for inspection and measurements. However, part of the structure that was under water during operation got serious damage; the pipeline was destroyed along the entire length from the junction to the water intake well. The use of monitoring the operational reliability of the structures of rice systems has shown the opportunity to improve the quality of the control effects of technical operation, reduce repair costs and obtain the expected economic effect, and also allows to solve the technical problems of long-term operation, classification and determination of damage volumes of the examined structures to improve the calculation of the residual reserve of capacity and establishment the duration of their continued functioning. The use of non-destructive testing methods allows you to scientifically substantiate the costs of maintenance and overhaul, to clarify the rules for operating on-farm network facilities.

1. Introduction
Currently, in the Krasnodar Territory and the Republic of Adygea there is a rapid revival of the rice industry, for example, in 2015, the areas allocated for rice cultivation amounted to more than 170 thousand hectares. The plans for 2020 are to sow 180.8 thousand hectares, which is almost 10 thousand more than last year, the Krasnodar Territory alone grows more than 78% of rice cereal in Russia. At the end of the 19th century, in the floodplain of the Kuban River, drainage of drains was carried out, it was here that they decided to start the first cultivation of rice [1].

At present, the state of the water basin of the Kuban River is characterized by a high level of economic and integrated development. The value of irretrievable withdrawal of water resources in the Lower Kuban exceeds the maximum permissible withdrawal limit by 3.5 times [2]. At the same time, at present, the reimbursement of water resources is not provided, especially during the period of low water. There is also non-compliance with sanitary and environmental releases at a sufficient level.
Thus, the Kuban River has virtually no free water resources for further development in the lower reaches after the Krasnodar reservoir.

All these unresolved problems indicate that it is necessary to justify methods for improving the operational reliability of structures of the on-farm network of rice systems for their further use in the water management complex in southern Russia (Figure 1) [3].

![Figure 1](image1.png)

**Figure 1.** The total volume of water supply to rice systems, billion m$^3$ by years

Currently, rice cultivation in the Krasnodar Territory and the Republic of Adygea is experiencing technical unresolved problems [4], because Rice systems have already worked out their technical resources for the period of long-term operation. When cultivating rice, the on-farm network covers various areas of irrigated land with different agrometeorological and irrigation and drainage conditions, which imposes an additional operational load on it (Figure 2) [5].

![Figure 2](image2.png)

**Figure 2.** Dynamics of changes in sown areas in the Krasnodar Territory and the Republic of Adygea for the production of rice groats for 7 years, the area of thousand hectares, by years

It is necessary to develop a monitoring technique for the rational use of water resources and to increase reliability during the long-term operation of on-farm networks of rice systems. It is also necessary to carry out the technical justification of the plan for various experimental studies of long-running facilities of the on-farm network of rice systems with non-destructive control devices using the example of the Lower Kuban [6].

Implementation of monitoring the operational reliability of structures of on-farm networks of rice systems consists in the implementation of engineering and land reclamation measures for sustainable and effective water conservation, rational use and development of the water management using the example of the Lower Kuban [7].

2. **Materials and methods**

In recent years, more and more attention has been paid to the research of various technology options
for monitoring the land flooding of rice systems.

The research methodology was determined after a visual examination [8] of butt joints and flat and volume reinforced concrete and concrete elements of open and tubular structures of the on-farm network of the Zakubansky reclamation-water massif of the Krasnodar Territory. It is recommended to use when determining the strength of concrete structures with non-destructive methods. The ultrasonic method with through sounding or the mechanical methods of non-destructive testing can also be used for that purpose. For a non-destructive testing of pressure and non-pressure pipes, the average strength of concrete of a structure is taken as a single value calculated as the arithmetic average of the concrete strength of the controlled sections of a structure (Figure 3) [9].

![Monitoring of structures of the on-farm network of rice systems: a – georadar (GPR) sounding; b - total station survey.](image)

Figure 3. Monitoring of structures of the on-farm network of rice systems: a – georadar (GPR) sounding; b - total station survey.

3. Results

As a result of the reconnaissance survey, the methods for performing topographic surveys were clarified and the boundary of the experimental section of the subject to topographic survey was determined. To determine the coordinates of the points of the satellite geodetic network in MSK-23 and the heights in BSV-77 [10], the points of the state geodetic network were used.

During the tacheometric survey [11], the authors determine the boundaries of the site subject to leaching of the soil and the location of the georadar sounding of the structures. The main consequences of erosion of an on-farm network of rice systems characteristic of southern Russia include siltation by products of erosion of structures of an on-farm network of rice systems with slopes up to 0.0005 - 0.0019, which necessitates their periodic cleaning. The decrease in the values of the humus horizon and the formation of a hollow relief of the irrigated area. We observe pollution and siltation of rivers, ponds and lakes everywhere [12]. Gully formation and emergency state of the on-farm network of rice systems.

Studies conducted on the on-farm network facilities have shown that closed structures on rice systems are in a worse position than open ones. The drainage structure in the form of a pipe was examined in most detail, since the structure is exposed and accessible for inspection and measurements [13]. However, part of the structure that was under water during operation received serious damage, the pipeline was destroyed along the entire length from the junction to the water intake well. The peeling of concrete occurred to a depth of 10-15 cm, in the places of peeling, the reinforcement was exposed and severely corroded: the rods with a diameter of up to 20 mm were completely rotted, and with a diameter of up to 50 mm - by 50-70%.

One of the characteristic defects, shown in Figure 4, is the destruction of the joints between the rings; the traces of the repairs made by the previously operating organization to eliminate filtration through the structure are also visible [14].
Figure 4. GPR sounding of a pipeline with defects on the on-farm network of the rice irrigation network: a - pipeline; b - profile fragment across the structure at the junction between the rings.

The destruction of concrete occurred due to the fact that the concrete in this place is in the most adverse conditions and leads to the accumulation of defects and the destruction of concrete. The presence of these defects after a long life of the structure is due to the imperfect technology for the production of reinforced concrete, its low frost resistance, and the imperfection of installation works [15]. When cleaning closed waterworks from congestion with metal hooks, there is a violation of the butt joints and the inner surface of the pipe.

During the GPR sounding of the water-lifting structure [16], the voids under the ring and to the left of it, as well as the longitudinal crack formed to the right and to the left of the ring, the profile fragment across facilities (Figure 5 b). Sealing of butt joints was broken [17], and water seeped into the soil of the base of the pipe, which is why the heterogeneity of the underlying soil is visible on the radarogram. When wet soil acts on concrete, an oxidizing reaction occurs, and therefore caverns and depressions have formed on the surface of the lower part of the structure, shown in figure 5.

Figure 5. GPR sounding of a water supply structure with defects on the on-farm network of the Azov rice irrigation network: a - water supply structure; b - profile fragment across the structure.
In the study of the water-lifting structure, it was recorded that the concrete along the surveyed structure has a porous structure, different color. It was noted that on the concrete surface there is a deep trace left by the chisel, compared with structures that have been in operation for less than 20 years [18]. A large number of cracks were found on the rings at the beginning and at the end, which expose the reinforcement throughout the structure. There are cracks that are directed parallel to the bottom of the wall and also damaged the side faces of the wall.

The joint of the rings of the 1st and 2nd sections was severely destroyed, longitudinal cracks with an opening of up to 15-20 mm, indicating the delamination of concrete, which leads to exposure of the reinforcement and to the destruction of the concrete body of the structure. Cracks in concrete are also on the vertical faces of the sides of the well, inclined, almost horizontal cracks completely cut through the section of the rings of the 2nd compartment. The crack opening reaches 0.5-1.8 mm, the horizontal displacement of the edges of the cracks is 0.7-1.1 mm, and the upper edge of the well is offset 22˚ relative to the vertical axis. Concrete of the sides and the bottom of the well are in a state of complete water saturation [19], the examined areas are torn apart by tearing cracks (crack widths 0.4, 0.9, 0.2 and 1.2 mm), one above the south side (5.2 mm). In the 2nd compartment - three on the north side (0.2, 0.2 and 0.8 mm wide), two on the south (1.4 and 1.2 mm wide). There are seven cracks in the 3rd compartment of the structure, the location of which could not be tied to other factors. In the subsequent compartments, one or two cracks were found in the middle part. All cracks completely cut through the section of the structure, so each crack of the western side corresponds to a crack of the eastern side, located opposite the first. This clearly indicates the presence of a crack in the bottom concrete, which connects the opposite cracks in the sides of the well. The thickness of the protective layers is not always respected. During the construction of the concrete, class B 50 concrete was used [20].

4. Conclusion

Based on the results of a technical assessment and analysis of the reliability of the on-farm network of rice systems structures with non-destructive testing methods, the need for improving the methodology of experimental studies during technical inspection of both structures and individual elements is determined and given.

The use of monitoring the operational reliability of structures of the on-farm network of rice systems has shown the opportunity to improve the quality of the control effects of technical operation, reduce repair costs and obtain the expected economic effect, and also allows to solve the technical problems of long-term operation, classification and determination of damage volumes of building elements to improve the calculation of residual capacity and establishing the duration of their future operations Nia.

The use of non-destructive testing methods makes it possible to scientifically substantiate the costs of maintenance and overhaul, to clarify the rules for operating the on-farm network of rice systems. An important component that made economic use of intensification of water resources possible during the operation of the on-farm network facilities is the ability to prevent damage from the unexpected failure of the on-farm network of rice irrigation systems affected by defects during the irrigation period.

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