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Boundaries of sanitary protection zones for "Elizavetinsky" and "Novo-zapadny" water intakes

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Abstract. The Elizavetinsky water intake is the primary source of water for the city of Krasnodar, responsible for its extraction and purification. The system consists of several wells located in the microdistrict of Elizavetinskaya Sloboda. The water from the wells is purified in a system that filters it, removes harmful impurities, and disinfects it. We will develop and implement a set of measures to reconstruct this water intake. The reconstruction will include the construction of new facilities and the repair of existing ones to provide for future development in the area of the Western Bypass. This article presents a definitive approach to determining sanitary protection zones using the "circle" formula. This is the simplest method of calculation. The second method is the analytical method of sanitary protection zone calculation. This is the most accurate method because it takes into account the water flow. It is essential to comply with environmental protection measures to ensure the environmentally friendly operation of the water intake during the extraction of water from artesian wells. These measures are regulated by the norms of sanitary regulations and standards. It was therefore decided that regular inspections and testing of wells for leaks or other problems were necessary. If unsafe wells are found, they must be abandoned or rehabilitated immediately, in accordance with environmental safety requirements. To prevent new groundwater problems from occurring, new wells must be closely monitored and all groundwater safety and protection regulations and requirements must be strictly enforced. Facility planning and design will prevent potential threats to aquifers. Zones 2 and 3 were defined by clearly delineating the sanitary protection zone boundaries using both volumetric and analytical methods. We developed a remediation plan that includes protective measures to eliminate and prevent the possibility of groundwater contamination.

1 Introduction

Elizavetinsky water intake is an important infrastructure facility of the Krasnodar city. Elizavetinsky water intake is located in the city of Krasnodar, located in the Southern Federal District of Russia. It occupies a territory in the north-western part of the city, near

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the Kuban River and the microdistrict of Elizavetinskaya station. The exact location of the water intake on the map of Krasnodar city is as follows (Fig. 1):

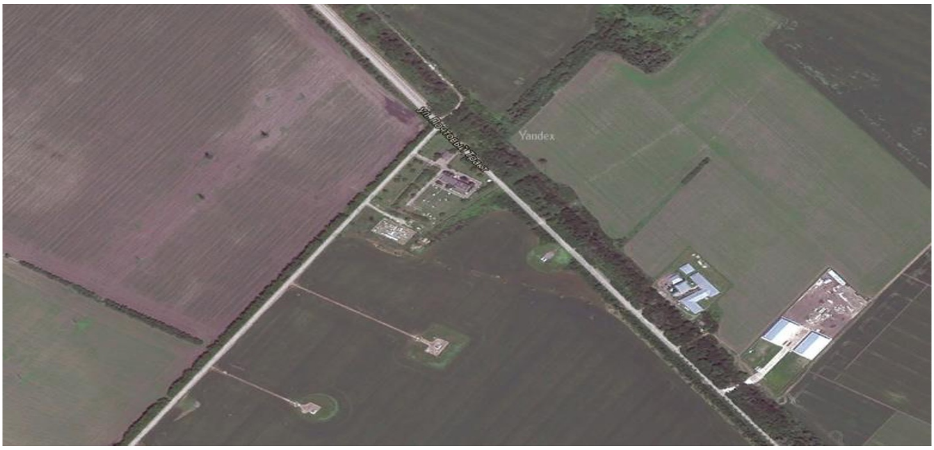

Fig. 1. Location of the water intake "Elizavetinsky".

The water intake is located in close proximity to a major transportation artery, the Western Bypass, which provides convenient access to the facility for maintenance and repair work.

Elizavetinsky water intake is engaged in water extraction and treatment for the needs of the city of Krasnodar. It consists of several wells located in the Elizavetinskaya Sloboda microdistrict. Water from the wells passes through a purification system, where it is subjected to filtration, removal of harmful impurities and disinfection. The purified water is then supplied to the city's water supply network.

The capacity of the water intake is 42 400 m^3/day. There are 50 artesian wells at the water intake, of which 21 operate the "Apsheron aquifer complex" (the best in terms of water quality) and 29 operate the "Quaternary aquifer complex" (high iron and manganese content prevails). The water supply pumping station (WSP) of the 2nd lift is not operated.

At present, the water intake operation mode provides for the supply of raw, untreated water, bypassing VFW and VNS, through two conduits to the Novo-Zapadniy water intake in the amount of 30 000 m^3/day.

To date, the investment program of LLC "Krasnodar Vodokanal" for the construction, reconstruction and modernization of the centralized cold water supply and wastewater facilities of the municipal formation of the city of Krasnodar for 2014-2025, approved by the decision of the City Duma of Krasnodar from 11.12.2013 № 58 p. 15, developed and implemented a number of measures to reconstruct this water intake, consisting of two stages. The first stage involves the launch of the clear-water reservoir and the 2nd lift water intake and water supply through one of the two water pipelines to provide water supply for new subscribers. This stage includes:

- Modernization of the 2nd booster pumping station (replacement of pump units, shut-off and control valves, engineering communications, installation of automated process control and monitoring equipment, and instrumentation and control systems), with an increase in capacity to 22 000 m^3/day;

- Construction of an electrolysis unit to produce sodium hypochlorite with a capacity of 300 kg/day of active chlorine to meet the requirements of the Sanitary Regulations 2.1.4.1074-01 Drinking water [1, 2];

- Modernization of clear-water reservoir of 3000 m3 in terms of ventilation system reconstruction and installation of modern instrumentation and control equipment.

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After the implementation of the first stage, the Elizavetinsky water intake will be able to meet the demand of up to 22,000 m^3/d of new subscribers in the area of the Western Bypass in a regular mode.

The second phase involves the construction of new facilities and reconstruction of existing facilities to accommodate future development in the Western Bypass area, as follows:

- Expansion of the boundaries of the land plot of the Elizavetinsky water intake headworks for construction of two clear-water reservoirs and a deferrization station;
- Construction of two clear-water reservoirs of 10 000 m^3 with installation of engineering communications and instrumentation equipment;
- Construction of a deferrization station with a capacity of 30,000 m^3/day, with installation of utilities;
- Construction of two water pipelines from artesian wells to the headworks of the Elizavetinsky water intake to separate the "Quaternary" and "Apsheronsky" operational complexes.

Implementation of the second stage of reconstruction (modernization) of water intake "Elizavetinsky" will allow to provide water supply (44 400 m^3/day) corresponding to the Sanitary Regulations 2.1.4.1074-01 Drinking water in the area of prospective development of the Western Bypass and Elizavetinskaya station [2, 3].

2 Materials

Elizavetinskaya village is located on the Predkubanskaya plain with a relief height of 23-38 meters above sea level. The presence of small drops and elevations is due to the location of the village in close proximity to the Kuban River. The relief slope prevails in the north-western and western direction.

Water is extracted from artesian wells at the Elizavetinsky water intake. On the territory of the water intake there are 29 well clusters extracting water from the Apsheronsky and Quaternary aquifers.

Artesian wells are usually drilled to the pressurized groundwater table. Drilling wells disrupts the integrity of soil layers, which can lead to groundwater leakage and contamination of soil and groundwater. Chemicals may also be used during water extraction, which can enter and contaminate the environment.

Water extraction from artesian wells can lead to changes in the hydrological regime of the territory, which can affect the state of aquatic ecosystems and biodiversity. Changes in groundwater levels can lead to drying or waterlogging of territories, as well as to changes in the composition of aquatic organisms [4-6].

Since the water produced at the Elizavetinsky water intake undergoes additional treatment rather than just standing in a clean water tank, such water can have a negative impact on human health, as untreated water contains a large amount of salts.

3 Research methods

Volumetric method. To determine the sanitary protection zone using the volumetric method, the "circle" formula is used. The name of the formula is related to the resulting shape of the sanitary protection zone in plan. This method of calculation is the simplest.

The circle formula:

$$r = \sqrt{\frac{Q \cdot t}{n \cdot \pi \cdot m}}$$

Where Q - well water flow rate, m^3/day;
t – water intake operation time, day;
n – active porosity of soils, m^3/ m^3;
m – thickness of aquifer from which water is extracted, m;
r – radius of the sanitary protection zone (since the resulting shape of the sanitary protection zone is a circle, the length and width of the sanitary protection zone are equal), m.

To ensure water consumption of prospective connection objects in the area of the Western Bypass, it is necessary to drill artesian well No. 18 with a depth of 215 meters at the water intake "Elizavetinsky" with a flow rate of 54 m3/hour (1296 m^3/day) to replace the well No. 40896/18, which is out of operation.

For the 2nd belt:

$$R_2 = \sqrt{\frac{1296 \cdot 365}{0.15 \cdot 3.14 \cdot 9}} = 334\ m$$

For the 3rd belt:

$$R_2 = \sqrt{\frac{1296 \cdot 9125}{0.15 \cdot 3.14 \cdot 9}} = 1670\ m$$

The length of the 2nd and 3rd sanitary protection zone (2R) for the calculated well will be 668 m and 3340 m, respectively.

4 Analytical method

The analytical method of calculating sanitary protection zone is the most accurate, as this method takes into account the water flow.

Let us determine the size of sanitary protection zones of the 2nd and 3rd zones of the above mentioned well by the formulas:

$$Y_L = \frac{Q}{klm}$$

$$X_L = \frac{Q}{2\pi klm}$$

$$t = \left[\frac{R}{X_L} - \ln\left(1 + \frac{R}{X_L}\right)\right]\frac{nX_L}{kl}$$

$$t = -\left[\ln\left(1 - \frac{r}{X_L}\right)\right]\frac{nX_L}{kl}$$

$$L = R + r$$

$$d = \frac{2Qr}{\pi mnL}$$

1) Let us determine the position of the stagnation point (X_L) by the equation.

$$X_L = \frac{1296}{2 \cdot 3.14 \cdot 25 \cdot 0.001 \cdot 9} = 916.73$$

2) Initial data: Q = 1296 m^3/day, m = 9 m, n = 0.15, k = 25 m/day; I = 0.001 m/m, t = 365 and 9125 days for the 2nd and 3rd belt of the sanitary protection zones respectively.

$$t = \left[\frac{R}{916.73} - \ln\left(1 + \frac{R}{916.73}\right)\right]\frac{0.15 \cdot 916.73}{25 \cdot 0.001}$$

$$t = -\left[\ln\left(1 - \frac{r}{916.73}\right) + \frac{r}{916.73}\right]\frac{0,15 \cdot 916.73}{25 \cdot 0.001}$$

For the 2nd belt:
L_2 = 375.5+294.8 = 670.3 m
For the 3rd belt:
L_3 = 2805.5+847.51 = 3653.01 m
For the 2nd belt:

$$d_2 = \frac{2 \cdot 1296 \cdot 365}{3.14 \cdot 9 \cdot 0.15 \cdot 670.3} = 332.6;\ 2d_2 = 665.2\ m$$

For the 3rd belt (Table 1):

$$d_3 = \frac{2 \cdot 1296 \cdot 9125}{3.14 \cdot 9 \cdot 0.15 \cdot 3653.01} = 1527.5;\ 2d_2 = 3055\ m$$

Table 1. Calculation results.

Type of belt sanitary protection zones	Time, days	Radius upstream (R), m	Downstream radius (r), m	Length (L=R+r), m	Width (2d), m
2nd belt	365	375.5	294.8	670.3	665.2
3rd belt	9125	2805.5	847.51	3653.01	3055

5 Results

To ensure environmentally safe operation of water intake during water production from artesian wells, it is necessary to comply with environmental protection measures, which are regulated by sanitary regulations and standards and other legislative acts [7, 8].

One of the primary objectives is to identify and eliminate all inactive, old, defective, or improperly operated wells that may pose a risk of aquifer contamination. This requires regular inspections and testing of wells for leaks or other problems. If unsafe wells are found, immediate action should be taken to abandon or rehabilitate them in an environmentally safe manner.

To prevent new groundwater problems from occurring, the drilling of new wells and any new construction must be closely monitored. It is important to ensure that all regulations and requirements regarding groundwater safety and protection are met. Proper planning and design of new facilities can help avoid potential threats to aquifers [9, 10].

Another important aspect is the prohibition of undesirable practices that may adversely affect groundwater quality. This includes the prohibition of injection of waste water into groundwater aquifers, underground storage of solid waste and subsoil mining. It is also necessary to timely implement sanitary protection measures for surface watercourses and reservoirs to prevent pollution of aquifers. To ensure the safety of groundwater, it is necessary to prohibit the placement of industrial effluent storage, sludge storage, fuel and lubricants, pesticides and mineral fertilizers, as well as other facilities that pose a risk of chemical pollution of groundwater. This requires strict control by regulatory authorities and compliance with relevant regulations [11, 12].

Strict sanitary supervision over the use of pesticides and biological means of controlling plant pests and diseases is established in the territory of the third belt; the use of highly toxic, persistent in soil and cumulative substances is also not allowed.

6 Conclusions

The Elizavetinsky water intake, located in the north-western part of the city of Krasnodar, is a large-scale complex of hydraulic structures designed to extract and purify water for the needs of the city of Krasnodar. Currently, the operating organization of this water intake OOO "Krasnodar Vodokanal", develops and implements measures to reconstruct and modernize this water intake to provide water of the required quality to existing and prospective subscribers [13].

There are 3 zones of sanitary protection at the water intake. Each Sanitary Protection Zone has its own set of rules and restrictions. The size of the sanitary protection zone of the 2nd belt of artesian wells is about 300 meters, 600 meters for the 2nd belt and 3000 meters for the 3rd belt of Sanitary Protection Zone.

After specifying the Sanitary Protection Zone by volumetric and analytical methods, it was determined that the length and width of the 2nd and 3rd Sanitary Protection Zone belts are 668 meters and 3340 meters, respectively (volumetric method), the length of the 2nd and 3rd Sanitary Protection Zone belts are 670.3 meters and 3653.01 meters, respectively, and the width of the 2nd and 3rd Sanitary Protection Zone belts are 665.2 meters and 3055 meters, respectively (analytical method).

To ensure environmentally safe operation of water intake "Elizavetinsky" and bringing the quality of extracted water from underground sources to the quality standards reflected in SanPiN 2.1.4.1074-01, an action plan has been developed, including sanitary and protective measures aimed at eliminating and preventing the possibility of groundwater pollution. These measures are planned specific for each Sanitary Protection Zone belt.

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