Use of Pumping Stations and Reservoirs for Water Supply in Rural Areas of Central Yakutia

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Abstract. The peculiarity of the design, construction and operation of water supply and sanitation systems in the Far North is directly related to the permafrost-climatic and economic factors. This should take into account factors such as the high cost and shortage of electricity, types and nature of production, natural conditions and conditions of water disposal, capacity and features of the regime of water sources. In the early 1990s, the construction of the main water supply system, which consisted of pumping stations, pipelines, reservoirs and canals, began in rural areas of Central Yakutia in order to provide the population with drinking and technical water. This system consists of three branches of main water pipelines: 1 – Lena-Tuora Kuel-Tatta, 2 – Bedeme-Tungulu and 3 – Lena-Muru. The object of study is the main conduit Lena – the Muru. The article presents the results of the study of the main water pipeline «Lena – Muru» for 2014 – 2016 years, compiled schedules of water supply pumping stations in the reservoir, power consumption of electricity and financial costs for it. In addition, the mode of operation of pumping stations of the main water pipeline for the period 2014 – 2017 is analyzed and the ratio of the volume of water supply, electricity consumption and financial costs are shown.

1. Introduction

The first and most important thing that a person can't do without is air, the second most important thing is water, but not just water, namely drinking water. Fresh water in the world is not only in lakes and rivers, a significant amount of it is concentrated in glaciers and reservoirs located deep in the earth, under the thickness of sea waters. Getting access to these resources is quite difficult. Water covers more than 70% of our planet's territory, but only about 3% is fresh water. Most of the fresh water on Earth is in the form of ice and only 1 % is available for consumption.

Around the world, providing people with quality drinking water is one of the main challenges today. In Russia, this problem, as in other countries, is equated to the main state tasks. It has become particularly relevant due to the almost universal deterioration of the overall environmental situation, for example, excessive pollution of water bodies and water supply sources. In this regard, the safety of drinking water supply has become one of the main components of the environmental safety of the Russian population-this is confirmed by the Federal target program Drinking water adopted by the government of the Russian Federation, which is now underway and will continue (Federal program "Clean water" no. 1092/2010).

Today, there is a big problem with drinking water in the cities and towns of Yakutia. For example, in Yakutsk, due to physical wear and tear of the city's water supply networks, water from the tap, which must be drinking according to Federal environmental rules, becomes dark in the summer after an ice.
drift, i.e. contaminated. Another problem is the seasonal water supply of agricultural areas in Yakutia. The territory of Yakutia is located in the region of permafrost influence and therefore water supply is carried out only in the warm period of the year - this is the end of spring, summer and early autumn. In addition, due to the influence of permafrost and extremely cold climate on the pipeline system, its use is not completely unprofitable. Therefore, today we use methods for designing, building and operating small lakes-reservoirs.

2. Material and methods

2.1. Study area

In Central Yakutia, a system of main water supply is operated, which consists of pump stations [1-7], pipelines, reservoirs and channels [8-10]. This system consists of three branches of penstocks: 1) the Lena river – the village of Tuora Kuel and channel p. Tuora Kuel – Tatta river, 2) reservoir village Bedime – lake village Tungulu, together with a pumping station, which pumps water through the pipeline into the reservoir of Nal in village Tungulu and 3) the Lena river – lake Muru (Borogontsy) (Fig. 1).

Agricultural areas of Central Yakutia are in dire need of water. This need arose due to the extremely low rainfall (250...300 mm per year) and drying up of lakes. The first diversion of water from the Lena river was made in August and September 1993, Lenskaya water was first filed with the head of the pump station to the reservoir Bakyam (Tumul). Trunk main Lena river – lake The Muru is located in the Central Yakutia: Ust-Aldan ulus (district) of Sakha Republic (Yakutia). The water conduit was put into operation on October 30, 1998 [11].

The conduit uses head advancement, two intermediate reservoirs (Batyam, Bulgunnyahtah) and four finite reservoir (Kuosagas 1, Kuosagas 2, Horo, Maygas) [12]. All water bodies are filled with river water every year [13-14].

Reservoir Bakyam, Kuosagas 1, Kuosagas 2, Maygas provided by the water supply of settlements Tumul, Borogontsy, p. Mandaba, Charan, Nosovka, Borogontsy, p. Mandaba, Charan, Nosovka, Maygas with a population of about 8 500 people. Working year old water pipes in Mandaba, Charan, Nosovka, Maygas. Ends the main conduit Lena-Muru the Muru alas. It has three stationary and one floating pump station with a total installed capacity of 2050 kW [15]. The length of the pipeline with diameter of 530...630 mm – 73.2 km. Pipeline laid on a recumbent and anchor poles.

2.2. Methods

As the primary methods, the work is based on empirical methods based on the use of methods and techniques of experimental research, which allows obtaining actual information. A special place among them is occupied by basic methods, which are relatively often used in practical research activities. These include: the observation method of collecting information, based on registration and fixation of primary data about the object; the study of primary documents, based on research documented information about the object and measurement method determine the actual numerical values of properties of the studied object, by means of appropriate measuring units, e.g. watts, amps, cubic meters, rubles, normo-hours. Graphical research methods often involve the use of various charts, graphs, and histograms as a tool for studying phenomena. For example, when determining the volume of reservoirs in main pipelines and presenting the results of data processing in the form of a Pareto diagram. Also, the graphs displayed by the polyline are usually used when studying the nature of changes in the studied object from time to time.

In addition, the work used simple methods: collection, processing, generalization and analysis of literary and stock materials, field expedition research, field research on water intakes and water bodies, theoretical provisions and recommendations developed in Geocology, hydrology and Geology, computer methods of data processing, economic and statistical, ecological and economic.
Figure 1. Study area and photos of research objects
3. Results and discussions
The purpose of the work is to conduct research for the period 2014 – 2017 years, as well as to analyze the operation mode of pumping stations and show the ratio of water supply, power consumption and financial costs.

The technological scheme of water supply district is as follows (Fig. 2). Water intake is carried out by floating pump station From the Lena river (1) near the village sottintsy (vegetable Gardens). This pumping station is rearranged depending on the depth of the river. Next, the water enters the main pumping station of water pipeline Lena – Muru named after a well-deserved reclamation expert of Russia Anatoly Petrovich Protopopov (2). Then the water is discharged into the reservoir Bakyam in the village Tumul (3). From the reservoir Bakyam Tumul pumping station (4) water is pumped further into the village Syrdakh in the reservoir Bulgunnyahtah (5). Then the water Syrdakh pumping station (6) is supplied via line d = 650 mm in the group of reservoirs in the Borogontsy – Summer Water Kuosagas (SWK) (7), which created lake Muru. Lake Muru, consists of a group of small reservoirs: Kuosagas 1, Kuosagas 2, Horo, Maygas [11].

![Figure 2. Technological scheme of the water pipeline Lena – Muru](image)

1) Water Intake is a floating pumping station (FPS). 2) Head pumping station (HPS). 3) Reservoir Bakyam in v. Tumul. 4) Tumul pumping station (TPS). 5) Reservoir Bulgunnyahtah in v. Syrdakh. 6) Syrdakh pumping station (SPS). 7) The Muru Reservoir (Kuosagas 1, Kuosagas 2, Horo, Maygas in the Borogontsy) - Summer Water Kuosagas (SWK)

As a result of the conducted research for 2014 – 2016 years at the facilities of the main water conduit Lena – Muru were made histograms of water supply pumping stations in the reservoir (Fig. 3), graphs of electricity consumption (Fig. 4) and financial costs for energy consumption (Fig. 5). Also in 2016, water losses were identified during transportation through the main water pipeline – 20 thousand m$^3$, for population consumption – 150000 liters/day, for livestock watering – 4350 liters/day.
The following results were revealed during the daily monitoring of the pumping stations operation mode. In figures 6 – 9 shows the results as histograms of the volume of water (m$^3$) supplied pumping stations of the water main Lena – Muru from surface waters (river, lake, reservoir) to water reservoirs of settlements.

Tumul pumping station no. 2 (v. Tumul). Figure 6 shows the results as histograms of flow (pumping) of water pumping stations 2 from the reservoir Bakyam (v. Tumul) by pipeline to reservoir Bulgunnyahtah (v. Syrdakh) in 2014, total water volume for July amounted to 152800 m$^3$.

![Figure 6](image)

**Figure 6.** The histogram of pumping water, pumping station no. 2 from the reservoir Bakyam (v. Tumul) by pipeline to reservoir Bulgunnyahtah (v. Syrdakh) in 2014

Figure 7 shows the results in form of histograms pumping water, the pumping station no. 2 (v. Tumul) in May – June – July 2015, from the reservoir Bakyam (v. Tumul) by pipeline to reservoir Bulgunnyahtah (v. Syrdakh), the total volume of water made up 407200 m$^3$.

![Figure 7](image)

**Figure 7.** The histogram of pumping water, the pumping station № 2 from the reservoir Bakyam (v. Tumul) by pipeline to reservoir Bulgunnyahtah (v. Syrdakh) in 2015

Figure 8 shows the results in form of histograms pumping water, the pumping station no. 2 (v. Tumul) in May – June – July 2016, from the reservoir Bakyam (v. Tumul) by pipeline to reservoir Bulgunnyahtah (v. Syrdakh), the total volume of water made up 657600 m$^3$.

![Figure 8](image)

**Figure 8.** The histogram of pumping water, the pumping station № 2 from the reservoir Bakyam (v. Tumul) by pipeline to reservoir Bulgunnyahtah (v. Syrdakh) in 2016
Figure 9 shows the results in form of histograms pumping water, the pumping station no. 2 (v. Tumul) in May – June – July – August 2017, from the reservoir Bakyam (v. Tumul) by pipeline to reservoir Bulgunnyahtah (v. Syrdakh), the total volume of water was 167200 m$^3$.

As a result of the conducted researches the operating modes of pump station no. 2 for the period 2014 – 2017 are calculated and analyzed. Therefore, we can conclude that the most was pumped in 2016 – this is due to the fact that there were 2 pump units, and the least was pumped in 2014 and 2017, due to problems with pumps and power outages.

In addition, table 1 shows the ratio of the volume of water flow, electricity consumption and financial costs in 2014 and 2017 pumping stations of the water main Lena – Muru.

| Name of pumping stations | Water supply Volume for 2014/2017 (thous. m$^3$) | Electricity Consumption for 2014/2017 kWh | Rub |
|--------------------------|-----------------------------------------------|----------------------------------------|-----|
| (FPS) Floating pump station | 389/400 | 68640/62857 | 456813/224248 |
| (HPS) Head pump station | 805/600 | 438480/302400 | 2918172/2431132 |
| (TPS) Tumulskaya pumping station | 615/530 | 345600/240000 | 1341688/2208000 |
| (SPS) Serduchka pumping station | 360/350 | 201600/150000 | 2473073/1380000 |
| (SWK) Summer water sup. Kuosasgas | 18/20 | 10800/12240 | 71876/88360 |
| Total: | 2187/1900 | 1091120/688233 | 7261622/6331740 |

4. Conclusion
After a study of the mode of operation of the pumping stations for the period 2014 – 2016 it was revealed that most water supply was carried out in 2014, the Head pumping station (HPS) – 805 thousand m3, in 2015 – at Tumul pumping stations (TPS) – 577 thousand m3, in 2016, the Head pumping station (HPS) – 733 thousand m3. Electricity consumption in 2014, in 2015 and 2016, respectively, 438480, 219046 and 353770 kWh. Financial costs for energy consumption in 2014, 2015 and 2016 respectively 2918172, 2783454, 2826623 rubles.
After analyzing the mode of operation of the pump station no. 2 for the period 2014 – 2017 years revealed that most of the water was pumped in 2015 and 2016 – this is due to the operation of 2 pumps, and the least was in 2014 and 2017, due to problems with pumps and power outages.

Shows the ratio of the amount of water flow, electricity consumption and financial costs for the 2014 and 2017 pumping stations of the water main Lena – Muru. At the same time, it was revealed that in 2014 all indicators were higher than in 2017, although it should be the opposite.

5. References
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