

Viktor A. Volosukhin, Mikhail M. Mordvintsev

Academy of Hydraulic Structures Safety, Novocherkassk, Russia, email: mail@academy-gts.ru

Lockage of the Lower Don: history, problems, purposes

Abstract: This paper presents the physical and geographical characteristics of the Lower Don as well as the history of its lockage. During the low water levels in the upper and lower reaches of the Volga and on the Don River below the Tsimlyansk water-engineering system, ship companies are experiencing difficulties with vessels being loaded at full load because of insufficient depth. The use of flexible impounding dams is proposed, which during low-water seasons induce the water level rise in navigable rivers and during flooding, they are arranged in the apron of the channel.

Keywords: navigable rivers, internal waterways, water-engineering system, river regulation, dredging, locks, flexible water-filled dams.

1. Introduction

The Russian waterways were a powerful factor influencing the development of complex social and economic processes in the second half of the 18th century and the early 19th century. Research on riverways as the most important element of the transportation network has been necessary to analyse different types and forms of economic activity and the natural and geographical environment of Russia.

Studies conducted by the Ministry of Communication Lines were important due to a large number of water bodies covered by this works. Beginning from 1901, «Materials related to the Russian rivers and the history of improving their navigation conditions» have been regularly published. Along with research on large rivers, lakes and watersheds used for transportation purposes, the Ministry of Agriculture and State Property carried out extensive investigations into water bodies in the territory of Russia with the purpose of irrigation and drainage of lands. This series of 65 issues (1901–1915) became a major event in the history of hydrographic development. Each of these issues was a monograph on a particular river or basin.

The issue of the Don River improvement for navigation has been raised a long time ago by the Ministry of Communication Lines. Works on crossover regulation were carried out. As for the major improvement of rivers aimed at creating new conditions for navigation of fully laden ships (with a large draft), particular attention to this problem was paid when a report of N. P. Puzyrevsky's research team was published in 1910. The Don River research report (Puzyrevsky, 1910) provides information on the navigation conditions of the Don and measures to improve its navigability, as well as technical and economic information on the Don and its basin. The author of the report also tried to determine freight regions for the Don and although those findings required further studies and testing. Therefore, they gave a very clear idea about the importance of the Don after improvement of its navigability. In conclusion, the report presents a project to improve the Don using a lockage and a schedule of expenditures. The Don River map with locks (Fig. 1) and a shortened longitudinal profile of the Lower Don are enclosed.

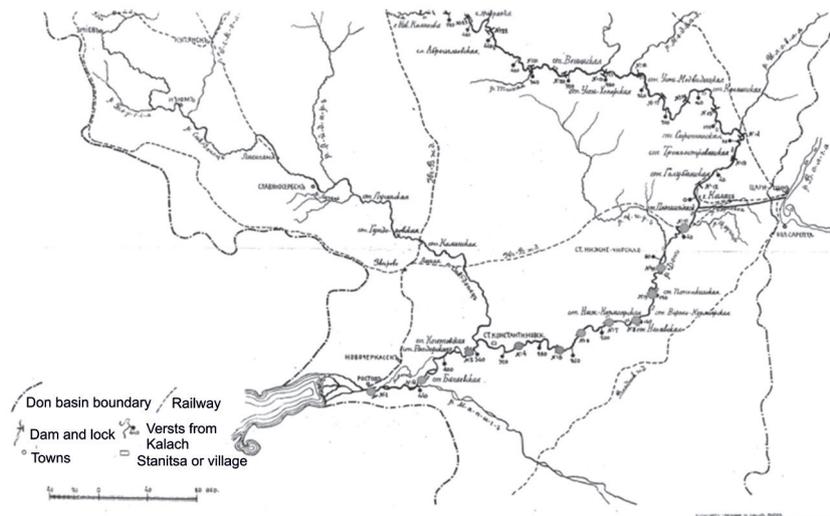


Figure 1. Map of lock location on the Don River (Puzyrevskiy, 1910)

2. Results

The total length of the Don is 1,984 km (1,860 versts, which is an obsolete Russian unit of distance equal to 3,500 feet or 1.6 km), while together with tributaries – 9,122 km (8,551 versts). Based on the outflow conditions, the Don River can be divided into 3 sections: the upper reaches from the river head to the mouth of the Voronezh River, the middle reaches – from the Voronezh River to the town of Kalach-on-Don and the lower reaches – from the town of Kalach-on-Don to the estuary (at present – from hydraulic works of the Tsimlyansk reservoir to the river mouth).

According to the data from N.P. Puzyrevsky's report, the upper reaches are 432 versts (461 km) long; the banks of the river head are low-lying and sloping, their width is small, sometimes below 1 sazhen (a unit of length equal to 2.13 m), but it gradually increases and reaches 20 sazhen (~ 43 m) in the Tuskaya province. Before entering the Voronezh province, the river width is 30–40 sazhen (64–85 m) and banks are up to 25 sazhen (~ 53 m) high.

When entering the Voronezh province, the width of the river valley increases to 3 versts (3.2 km) and more; the right bank here is higher than the left one. The channel width usually varies from 50 to 100 sazhen (~ 107–213 m), but in some places it increases to 100–200 sazhen (213–427 m). The depth does not exceed 0.5 sazhen (~ 1 m) in the river head. In the further section of the river's course, cov-

ering the Voronezh province, the bottom has depressions with a depth varying from 0.1 to 4.9 sazhen (~ 0.2–10.5 m). The average slope in this section of the river is 0.000165.

The middle reaches of the Don with a length of 863 versts (~ 910 km) have steep banks; the river valley is rather narrow here. The banks are eroded by the river, which often results in the supplying of the load. The right bank within this section is high and steep, similarly to the previous section, and the left bank is more sloping and sandy. The river valley here is covered with meadows, and there are many lakes and former riverbeds on the river floodplain. The river width is 100–200 sazhen (213–427 m); the number of bars and shallows is relatively large (about 200), many of them have a depth of less than 8 verzhok (0.36 m). The depth of pools in this section is close to 8 sazhen (17 m), slopes on bars vary within the range of 0.0029–0.00028.

The lower section of the river, from Kalach to the estuary, is 575 versts (613 km). The elevation of the right bank decreases and the river forms a floodplain, the width of which is often more than 10 versts (10.7 km). In some places, the channel approaches the hills and then the right bank becomes steep and high. The height of banks is 30 sazhen (64 m) or more above the Don water level. According to N.P. Puzyrevsky, the banks were covered with vineyards, gardens and melon fields. The left bank is low-lying, sloping and covered with grass-rich steppes.

The width of the river along this section is 100–200 sazhen (213–640 m). The number of shallows and bars is large (35); the depth at some bars is nearly 16 vershoks (0.7 m) or even less within a large shoal (before the Don flow regulation by the Tsimlyansky reservoir). The slope of the Don lower reaches is rather small, 0.02‰ on the average.

The Don estuary forms a delta occupying up to 300 square versts (according to modern estimates – 340 square km); the delta is crossed by numerous river channels.

N.P. Puzyrevsky (1910) reported that there were 270 bars on the Don River, based on the data of the studies carried out in different years starting from 1892 as well as report sheets of river bars formation. According to N.P. Puzyrevsky, the large differences in the length of bars can be explained by the fluctuations of these values for the considered period (1900–1908): «[...] those give some notion about the Don River only at the moment of the carried out study and thus they cannot serve as judgements about changes in the length of bars in time and the width of their fairways».

Considering the length of bars during the period of 1900–1908, one can see that the depths did not exceed 0.7–0.8 m in a low-water period of the year. During a spring flood, water levels were considerably higher than the levels in a low-water season: «[...] the largest rise reaches up to 6 sazhen (12.8 m) near the town of Pavlovsk and more than 6 sazhen near Kachalinskaya stanitsa, but in low-water years, the water level increases no more than 1.5 sazhen (3.2 m). Near the Rostov the water-level rises in spring are slightly smaller but the waters inundate the floodplain on the left bank over a distance of 10 versts» (Fig. 2).

The spring break-up usually took place in late March or early April and during the period of 1894–1908 – on average between 8 March and 1 April. In the report by N.P. Puzyrevsky, some data on water discharges determined in different places of the Don River are given in chronological order. Noteworthy are diagrams of water discharge curves for the monitored river sections. It appears that the largest changes in the water level were observed near the town of Kalach-on-Don. The observations were carried out there in two periods: in 1895–1896 and in 1907. The observations in the later

period did not reveal such large variations as in the former. N.P. Puzyrevsky notes that «[...] the curves of discharges and velocities determined in these two periods coincide with low water levels quite accurately. For high water levels, the discharges determined in the latter period are relatively larger and this indicates certain changes in the river channel, its slopes and can be explained by intensive dredging works conducted in the period of 1896–1907».



Figure 2. Spring floods of the Don River near Rostov (after N.P. Puzyrevsky, 1910).

The Lower Don is relatively well researched regarding the geology. It is important to note the rather large depth of erosion in the valley (more than 25 m) and filling with sandy and clayey sediments.

The beginning of navigation on the Don dates back to the 14th century when the town of Azov was founded in the Don estuary. The Don navigation had another impetus in the 16th century under the influence of intense relations with Tsargrad. At that time, an interesting attempt was made by Sultan Selim to dig a canal between the Volga and the Don in the vicinity of the Ilovlya and Kamyshanka rivers. N.P. Puzyrevsky writes «Turkey's project was not successful due to major technical difficulties at that time, however, this excellent idea has not died to this day [...]». This idea was implemented only in the middle of the 20th century by Russian engineers who constructed the Volga-Don navigation canal.

In the 15th century, towns providing observation and stanitsa services gradually emerged, which had a major impact on the further development of the Don navigation. At the end of the 17th century, the Don territory became very active owing to Peter the Great, who concentrated his activities here while organising the navy against Turkey. From the first half of the 17th century, shipping activity could develop

in regular conditions, parallel to the growth of commercial and industrial activity.

The beginning of the cultural development of Don Army Oblast dates back to the second half of the 19th century, when schools were created and the manufacturing industry developed. All this with the simultaneous development of farming was conducive to the shipping business development on the Don.

In the early 20th century, navigation on the Don was organised from stanitsa Liski of the South-Eastern Railway to Kalach only in spring (2 months) and from Kalach to the Don estuary during the whole navigation season. By 1906, there were 195 steam vessels and 471 non-steam vessels (Puzyrevsky, 1910).

During this period, the navigation depth on the Lower Don was maintained by dredging; there were 7 dredgers, 4 of which belonged to the Don River committee that was established in 1894 to improve the navigation conditions of the Don and consisted of merchant and shipping representatives.

The Don lockage project drawn up by N.P. Puzyrevsky on the basis of investigations conducted in 1906-1909 aimed at improving the navigation conditions of the Don from Kalach to Rostov along a distance of 500 vests (~ 533

km). The objective of the Don lockage project by N.P. Puzyrevsky was to reach navigation depths through the construction of temporary dams blocking the river. Furthermore, it was proposed to construct chamber locks for vessels to move from one bay to another. The target maximum draft of vessels after the completion of improvement works on the Don was 2.75 m (9 feet). For the river fleet of that time, the project provided the following dimensions of vessels: an effective length – 120 sazhen (~256 m), the light width – 15 sazhen (~ 32 m).

In 1913, the construction of the Don lockage system began. Primarily the Kochetovsky hydroelectric complex was built (№3 according to N.P. Puzyrevsky). It was extremely necessary for the regular functioning of the North-Donetsk water system (№1). The history of its construction and the stages of its reconstruction are described in detail in the book published in 2009 by the Publishing House of «Transportation Bulletin» Journal. The title of the book is *Structure №1 on the Don. New life of the Kochetovsky hydroelectric complex* (Lendov, 2009). The main stages starting from its construction to the last reconstruction and the installation of a new lock chamber in this hydroscheme are shown in Fig. 3.

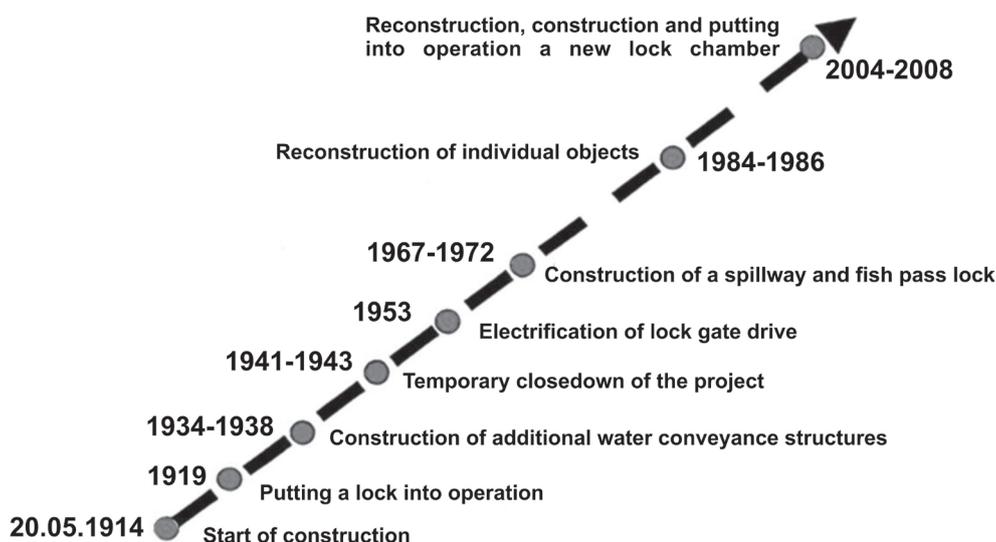


Figure 3. Main stages of Kochetovsky hydroelectric complex reconstruction (Lendov, 2009)

Obviously one can argue about favourable or unfavourable choice of location for the hydroelectric complex but as R.P. Stepanov, GIP Gipprochtrans said “There is no one right type of construction design for a river” (Lendov,

2009) and one can find many advantages and disadvantages in each gage line.

Already in the 1950s and 1960s, after the launch of the Volga-Don canal and due to the increased size of new vessels, the old Kochetovsky lock required reconstruction. Its

overall dimensions became a serious obstacle for navigation as new generation ships with a length of 130-140 m did not fit in the lock chamber. In the mid-1950s, large-scale works began, following the design by «Giprorechtrans». They were completed in 1969. As a result, the lock was fully adjusted to the overall dimensions of the similar structures located on the Volga-Don canal. At the same time, a three-span weir with a fish-pass erected at the location of an additional opening was incorporated into the Kochetovsky hydroelectric complex of structures. The upper and lower wharf guides were constructed, machinery buildings with the control panel were erected, and the replacement of the lock electromechanical equipment was carried out.

By the 1990s, the Kochetovsky hydroelectric project became outdated again. Further increasing of the overall dimensions of the old lock chamber was considered irrational. It was more profitable to construct a new modern lock with the standard overall dimensions near the old chamber so that the new lock would take over the main traffic of large ships. In April 2008, the first freight ship went through the new lock.

In 1974, a hydroelectric project with a lock was constructed next to stanitsa Nikolayevskaya. When referring this hydroscheme to the project by N.P. Puzyrevsky (1910), its number corresponds to approximately №5. Its construction was necessary to secure the navigation along the section from the exit of the lower inlet canal of lock №15 to the gage line of the Nikolayevsky hydroelectric project. The hydroelectric complex includes: navigation lock №1, fish-pass lock №2, a removable («navigation») dam, a spillway dam, an earth dam, a spawning and fish-pass canal with a regulator. The removable dam (Pouare farms) allows for the regulation of backup values and provide flood passing without a backup of the Don water level.

The Konstantinovsky hydroelectric project (the hydroscheme by N.P. Puzyrevsky №4, the construction has been unfinished in the 1910s) was launched in 1982 and began to secure the navigation at a distance of 43 km from the Nikolayevsky hydroelectric project to the Konstantinovsky hydroscheme gage line. The hydroscheme includes: a navigation lock, a lock for high-speed ships, fish-pass lock №1,

fish-pass lock №2, a spillway dam with a spillway regulator, an earth dam, a spawning and fish-pass canal with a regulator.

A special feature of this water engineering system (compared with the Kochetovsky and the Nikolayevsky hydroschemes) is the production of a year-long (constant) backwater. Reclamation experts of Yuzhgiprovodkhoz (now YUZH Vodoproekt), who constructed the drainage system over an area of 30,000 ha in the Kagalnitsky section of the floodplain indicated the impossibility of preventing the groundwater flow from the upper bay of the Konstantinovsky hydroelectric complex and consequently preventing the saltation and inclination of the floodplain; the most productive land was flooded by unprofitable fish breeding pools. The same can be expected in the influence zone of the future Bagayevsky hydroscheme if the backwater level is not withdrawn at least during the autumn-winter low-water season.

The Lower Don reaches from the Kochetovsky hydroelectric complex to the estuary is in a largely unregulated and characterized by changed hydrological regime. Along the 164 km long section, 45 bars are located. Despite extensive dredging works, some bars preserved their typical bed forms, due to the limited width of the navigation path and steep turns of the channel, this section is difficult to navigate.

The design and construction of the project «Development and implementation of the integrated reconstruction project for the Azov-Don basin, the third stage (Bagayevsky hydroelectric project)» is carried out in accordance with the RF Government directive of 29 February, 2016, №327-p Strategy of the RF inland water transport for the period till 2030. The Bagayevsky hydroelectric project will be located on 3089 km of a shipway near khutor Arpachin (by N.P. Puzyrevsky's scheme – gage line №2, the location of which is slightly higher than the designed OPK «TransGidroProject»).

The future of navigation companies, ports, and the Russian river transport industry as a whole are primarily determined by the conditions of inland waterways. The further survival and development of the industry is connected with the construction of new shallow-draft ships (A.D. Redkin, vice-president of the «Association of ports and ship owners of the

river transport» (APSORT) presented his view on the conditions and prospects of the river transport in the perspective of inland waterways, 2008).

The Bagayevsky hydraulic project is a water transport project that provides navigation depth control during the navigation season. The water transport project includes: structures designed to increase the water level, navigation passes, fish passes securing favourable conditions for fish to pass from one pool of the hydraulic project to another.

In terms of the construction design, the Bagayevsky hydraulic project largely mirrors the Konstantinovskiy hydroelectric complex that has been operating on the Don since 1982. The maximum design head of the hydro-scheme (difference between the normal water level NWL and the minimum downstream level MDL with P-99%) is 3.8 m, on average the value of backwater level does not exceed 2.0 m.

According to the opinion of designers, at the initial stage of the project, the Bagayevskiy hydroscheme in the version of the gage line near khutor Arpachin completely solves the problem of securing depths on the Lower Don. Below this gage only 4 bars are located, that requiring minimum dredging works in this section. A disadvantage of this gage line is flooding of riverside lands, because the Don River banks was higher before stanitsa Bagayevskaya construction. However, this problem is solved by engineering protection of lands.

Incidentally, it was noted in the preliminary design that in the inter-navigation (winter)

3. Conclusion

Most representatives of the public fear that the Bagayevskiy hydroscheme construction results in considerable changes in the hydrological regime of the Lower Don and its tributaries: the area exposed to floods will increase, abrasive processes along the banks will be activated, the floodplain flooding will increase, the landscape below the hydroelectric complex will change. According to V.A. Krivoshey, the Don River will eventually turn into a canalized water-transport system. Citizens of the Rostov Region will be able to assess the consequences

of this solution at the beginning of the hydro-scheme construction (Krivoshey, 2013). In the field of hydraulic engineering, there are different ways to increase the minimum depth. These are: riverbed deepening by dredging, removal of sills in some sections of the channel, a river channel straightening using the adjustable structures (longitudinal jetties, wing and retaining dams, overflow dikes, spurs in the river bank etc.), and a river lockage. Taking into account a variety of conditions determining the character of particular river reaches, one should consider some versions of solutions

period, the head is not maintained on the hydro-scheme, all the spillway openings are opened, gates on the controlled spillway are lifted, gates of the spillway dam are removed from grooves and are stored in the warehouse of gates. Hence the outflow through the spillway is not regulated. Elevation of the upper part of the spillway guarantees their normal operation under any discharges in the winter period when the ice thickness is up to 70 cm. Such solution is also a positive aspect of the project. There are different opinions about the Bagayevskiy hydroelectric complex construction – whether it is necessary in general or it is possible to avoid negative results of its construction.

V.A. Krivoshey, president of the National Centre of Water Problems notes that global and local trends in the field of river shipment not give reasons for the Bagayevskiy hydroscheme construction. In his opinion, it is necessary to adapt the ships to waterways and ensure their attractiveness for cargo carriers rather than to construct new hydraulic complexes. In this respect, there are large reserves, not only for the Don River but also for inland waterways as a whole (Krivoshey, 2013).

However, one should note that regulating operation for the Tsymlyansk reservoir can lead to increasing the depth below the Kochetovskiy hydroelectric project. Nowadays, the influence of the last mentioned reservoir is limited according to the prolonged low water level of the Don, related to the rules of using the water resources in Bagayevskiy hydroelectric complex.

of this solution at the beginning of the hydro-scheme construction (Krivoshey, 2013).

including those listed above when analysing the designs of navigation depth increase.

The overall dimensions for the Russian navigation can be secured only by the backwater (river lockage), but the backwater structures during flooding should pass discharges under the minimum drop of water levels in pools and

these levels should not exceed the minimum household values. Thus, the dam gates should be dismantled or laid on the apron. A possibility to use flexible elements to create the backwater as a mean to decrease costs of the hydraulic complex construction should not be rejected.

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