SECTION: GEOGRAPHY AND NATURAL SCIENCE

DOI 10.70286/ISU-22.10.2025.003

DAMS IMPACT ON ENVIRONMENT: 55 YEARS FOR KAPCHAGAI RESERVOIR IN KAZAKHSTAN

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Abstract. The purposes of reservoir construction and the reasons for the failure of reservoirs at various points in history are briefly examined. The environmental consequences of reservoir construction are analyzed as a reason for active public resistance to river flow regulation. The example of the largest Kapchagai reservoir on the Ili River, built in 1970, shows a set of environmental protection measures that were not implemented during the period of its filling. Particular attention is paid to the most acute processes of the entire natural environment degradation in the Ili River delta in the first decade of the reservoir's filling.

To build or not to build dams on rivers? The heated, often irreconcilable, debate is stirring up people, including politicians, energy specialists, water management experts, and the general public. And there are significant reasons for this. On the one hand, there is a growing need to provide high-quality water to the population, utilities, energy, industry, agriculture, and other sectors of life [1, 2]. And the thousand-year history of mankind shows that it has not yet been possible to manage without regulating river flows with dams. After all, water resources on Earth are distributed unevenly both in space and time. True, at different stages, different sectors of human activity dominated. Accordingly, the need for various dams and reservoirs prevailed – from small dams and earthen dams for water supply of ancient settlements to numerous, but still small, ponds for water mills, and then for nascent factories and plants.

However, this era is long gone, and such dams have largely been removed. This was followed in the 19th and 20th centuries by an aggressive phase of dam construction for hydroelectric power. Hydroelectric power plants were built everywhere—on lowland and foothill rivers, where flooding and loss of natural resources were enormous. Therefore, new dams were subsequently built primarily in the mountains, where the loss of natural resources was less. he dams themselves grew larger and larger, reaching gigantic proportions. Outdated small and medium-sized dams began to be gradually demolished, riverbeds were cleared, and free river flows were restored. And this trend continues. But giant dams in the upper reaches of rivers have become monopolies of water resources, and intense competition for water within river basins is emerging on transboundary rivers. The most dramatic situation is developing in the lower reaches and deltas of transboundary rivers, for example, in Central Asia [7; 9 - 11]. Moreover, the Central Asian states have begun actively constructing small hydroelectric power plants in mountainous regions to quickly overcome the acute shortage of energy and water for irrigation and water supply. In this situation, they postpone the solution to obvious environmental consequences for the future.

The largest number of reservoirs in the world are built for irrigation purposes. The lifespan of small reservoirs is about a century, depending on the rate of sedimentation. Therefore, their elimination presents no difficulties. The situation is significantly more complex for large irrigation reservoirs, which are built in conjunction with hydroelectric power plants and also serve water supply, water transport, fish farming, and other functions. Often such reservoirs are part of entire cascades, such as the cascade of Dnieper reservoirs in Ukraine. The elimination of such reservoirs, even given the enormous negative impacts on nature and on human life in such regions, is a complex task. Overall, the question of whether or not to build new reservoirs has no clear answer. Often, the vital need to solve pressing energy and water problems forces their construction. An important task is to minimize the negative consequences of such decisions, provide for necessary and possible compensatory measures, and also seek new technological solutions to the problems that arise in the future. In this regard, the aggressive activities of some environmentalists who groundlessly oppose the construction of new dams or unjustifiably demand the destruction of existing ones do not inspire confidence.

Environmental issues of the Kapchagai Reservoir. Heated debates surrounding the construction and operation of reservoirs are driven by a number of negative consequences for nature and society. These consequences have been well studied in many scientific publications, including a number of ours [1; 2; 6; 8; etc.]. But it is precisely this balance of interests that is taken into account when deciding on the construction of reservoirs at every historical moment. This was the case during the construction of the Kapchagay Reservoir (Fig. 1) and the hydroelectric power station. What negative consequences of the creation of this largest reservoir in the intermountain Ili Valley were critically perceived on the eve of the damming of the river in the distant 1970? Naturally, attention was drawn to the flooding of huge areas of land (about 147 thousand hectares at a normal sea level of 485 m) and the possible flooding of the southern gently sloping coast (about 90-100 thousand hectares). It should be noted that the reservoir's design capacity of 28.1 km3 was subsequently reduced to 18 km3, and the flooded area did not exceed 100 thousand hectares.

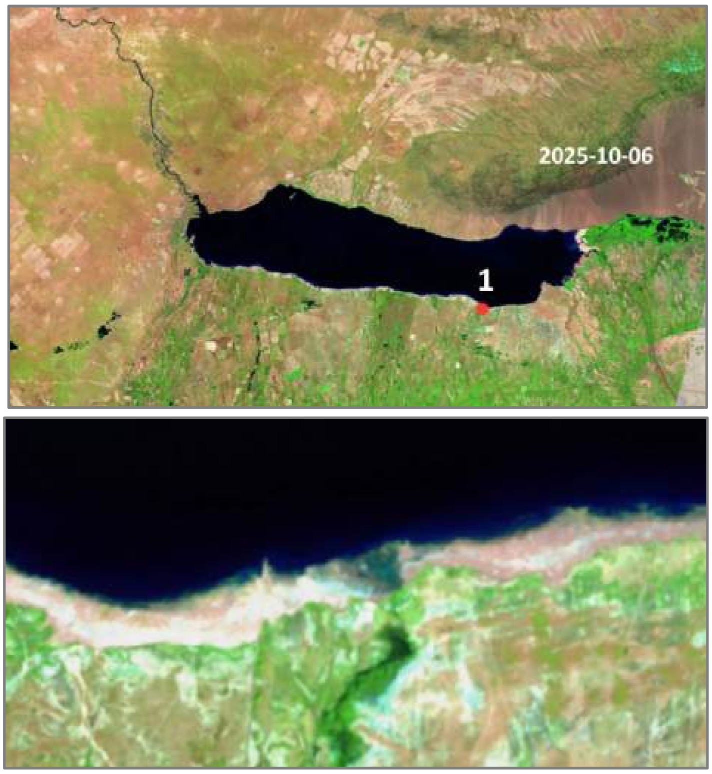

Fig. 1. Kapchagay Reservoir: top – general view and research point (1); bottom – fragment of the coast during the period of reservoir drawdown (ESA: Sentinel-2, 06-10-2025).

However, the most vigorous criticism of the project was directed at the potential damage to the uniquely rich Ili River delta and Lake Balkhash. After all, the existing experience of regulating the flow of other rivers in Central Asia has already shown what severe degradation processes this can lead to. True, environmental protection measures were taken into account when designing this hydroelectric complex. This includes a counter-regulator in the lower reaches of the Ili River, lake systems for managing delta flooding, and the so-called "bridge" in the Uzunaral region of Lake Balkhash (a regulator of water flow between the freshwater western part and the salty eastern part of the lake). However, due to financial constraints and some administrative decisions, these environmental measures were not implemented. As a result, already in the first decade of the rapid filling of the reservoir, which coincided with the low water levels of the 70s, deep degradation processes occurred in the delta, which the eldest (in age) of the authors of this note had the opportunity to study [5; 7; 10; 11].

The rapid desertification and salinization of the delta's once-rich landscapes has literally shocked the scientific community and sharply intensified discussions around the project's fate. Decisions were made to slow down the filling of the reservoir, reduce the maximum filling level of the reservoir, rationally manage environmental water releases into the delta, and take other measures. There were even some, in our opinion, biased predictions about the flooding of huge areas of the southern coast of the reservoir [3], calling into question the very existence of the project. However it was our position that was taken into account, namely that the width of the zone of severe flooding would not exceed 2-3 km from the water's edge due to the peculiarities of the groundwater regime in the intermountain valley. And long-term remote sensing by Landsat (NASA) and Sentinel (ESA) satellites confirmed our forecast.

However, the unique nature of the processes of interaction between fresh surface waters and saline soils and mineralized groundwater in the eastern part of the reservoir southern coast the still attracts attention. This is why we undertook a route survey of this part of the coast and are showing the results in the form of photographs (Fig. 2-4).

Fig. 2. The salt-filled, deserted shore of the reservoir, 400-500 meters wide, during a decline in water level. The fishing brigade area near the village of Teskensu (photo by Dariga Koroleva and Maxim Leman, October 6, 2025).

Fig. 3. Width of the drying zone from the water's edge to the flood-free coast when the reservoir is drowdowned in 2025 (photo by D. Koroleva and M. Leman, 10/06/2025)

Fig. 4. Highly saline coastal soils in the reservoir waterlogged zone (photo by D. Koroleva and M. Leman, 10/06/2025)

These photographs show the severe salinization processes occurring in the eastern part of the southern coast of the Kapchagai Reservoir. In particular, it is confirmed that annually in the “drying” zone up to 400-500 m wide, with seasonal fluctuations in the reservoir level, restoration of soil salinity occurs. And these salts, during the next flooding of the coast, become an additional source of increased mineralization of surface waters [4; 5]. In the zone of severe waterlogging by a reservoir 2-3 km wide, “solonchak soils” (salt marshes) are formed with a thick layer of salts on the surface (up to 10-15 cm) and the amount of salts in a meter-thick layer of at least 200-300 t/ha. During strong winds, these salts are partially transported to adjacent areas. However, in the western part of the reservoir's southern shore and along the entire northern shore, no salinization processes have been observed or predicted.

Subjective recommendations. Overall, the environmental situation in the Kapchagai Reservoir area has now stabilized. It continues to serve as a strategic water and energy reserve for southeastern Kazakhstan. However, the issue of constructing a counter-regulator (in the Kerbulak area) to control flooding in the Ili River delta has not yet been resolved. After all, the consequences of the huge fires in the delta in 2021-2022 have not yet been fully overcome. And manipulation of water releases from the Kapchagai Reservoir is unlikely to be promising, despite pressure from environmental organizations. The problem of managing the flow of water between the western and eastern parts of Lake Balkhash to maintain water quality in its freshwater western part also remains unresolved. In our subjective opinion, this problem can be partially solved by constructing a bridge crossing in the Uzunaral region to connect the northern and southern Balkhash regions. This will facilitate the economic development of the southern Balkhash region and also create an opportunity to monitor the water flow between these parts of the lake and assess the prospects for managing this process.

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