RADIAL WATER INTAKES AS A TOOL FOR ENHANCING THE RESILIENCE OF WATER SUPPLY SYSTEMS IN UKRAINE

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The full-scale war in Ukraine has exposed the critical vulnerability of traditional riverbed water intakes to physical destruction and environmental terrorism. The destruction of dams, fluctuations in reservoir levels, and the risks of transboundary river pollution (in particular within the Dnipro and Desna river basins) threaten the water security of millions of citizens [1, 2].

In this context, radial water intakes serve as a strategic instrument for enhancing the resilience of critical infrastructure. By applying the method of bank filtration, they ensure stable water abstraction even during significant shallowing of water bodies and create a natural barrier against surface contamination [3]. Research into their implementation is essential for developing a protected water supply system under wartime threats and during post-war recovery in accordance with the “Build Back Better” principle [4].

The use of radial water intakes in Ukraine provides a qualitatively new level of resilience of critical infrastructure through the combination of the natural protective properties of soil and the structural features of the facility:

• **Natural barrier filtration as protection against ecocide.** The use of thick layers of alluvial deposits (sand, gravel, and pebbles) transforms the soil mass into a highly efficient purification system. As water passes through the soil strata toward the underground radial collectors, natural sorption of suspended solids, petroleum products, and bacteriological contaminants occurs. This ensures the supply of high-quality water even in cases of catastrophic river pollution (for example, discharge of toxic substances or detonation products of munitions), since the soil mass acts as a reliable, cost-free filter that does not require complex chemical reagents.

• **Hydraulic independence from artificial shallowing.** Traditional surface water intakes are critically dependent on the stability of the water level in the reservoir. Radial collectors are installed deep within the aquifer, enabling them to abstract groundwater recharged by infiltration from a remote river channel. Thus, the water intake continues to operate steadily even in the event of a sharp drop in water level caused by dam destruction, sabotage, or seasonal low-water periods.

• **Physical protection and "natural armor".** From a military security perspective, radial water intakes represent one of the most protected types of hydraulic structures. The main functional elements – horizontal filtration collectors – are located beneath a soil layer at depths of 10 to 30 meters. Such burial creates a powerful natural shield that reliably protects the underground infrastructure from the kinetic energy of artillery shells, fragmentation damage, and blast waves from missile strikes. Destruction of the above-ground pavilion does not result in the loss of functionality of the well itself, allowing for rapid restoration of water supply.

• **Camouflage and capacity concentration.** Unlike extensive water intake complexes or well fields consisting of dozens of separate wells, a radial water intake occupies minimal surface area (only the head of the central shaft). This significantly simplifies concealment from aerial reconnaissance and reduces the costs associated with fortification or air defense protection.

• **Energy independence during power shortages.** Concentrating a large discharge (water yield) within a single shaft makes it possible to optimize the energy supply system. Maintaining the operation of such a unit requires only one high-capacity diesel generator or a local renewable energy station [5]. This significantly increases the autonomy of the facility during blackouts compared to the need to power dozens of dispersed wells or open-reservoir intakes.

The implementation of radial water intakes within Ukraine's post-war reconstruction framework aligns with the international "Build Back Better" principle, as it provides not only technical advantages but also significant economic efficiency [6, 7]:

• **Optimization of capital expenditures.** Construction of a single high-capacity radial water intake directly within the city or in the nearest coastal zone is considerably more cost-effective than major rehabilitation or the installation of new multi-kilometer trunk water mains from remote sources. Concentrating capacity at one point eliminates the need for numerous booster pumping stations and complex communication networks, which are the most vulnerable to damage.

• **Reduction of operational costs.** The concentration of large water volumes in a single shaft well enables the use of highly efficient energy-saving equipment. This substantially reduces the energy consumption per cubic meter of lifted water compared to operating a large number of separate vertical wells. In addition, reagent costs for water treatment are significantly reduced, since the primary purification function is performed by the free natural filter—the alluvial soil layer.

• **Durability and investment attractiveness.** Due to the large filtration area and low groundwater velocities, radial water intakes have a unique life cycle exceeding 50 years. This is 2–3 times longer than the service life of traditional vertical wells, which quickly fail due to clogging (colmation). Such performance indicators make radial systems attractive for international investment and grant funding aimed at restoring critical infrastructure.

• **Strategic autonomy.** In the long term, the economic benefit lies in minimizing losses from potential emergencies. The availability of an autonomous and protected

water source helps avoid significant costs associated with water delivery by tanker trucks and with mitigating the consequences of industrial shutdowns in the event of failures in trunk surface water supply systems.

The implementation of radial water intakes in Ukraine represents a strategic step toward strengthening the resilience and viability of critical infrastructure under wartime conditions. Owing to the deep placement of filters and the use of the natural purification potential of soil, these structures provide reliable protection against missile strikes, transboundary river pollution, and critical shallowing of water bodies. The concentration of high capacity within a single compact facility enables easy organization of autonomous power supply and camouflage, while their long service life makes them an economically sound foundation for post-war reconstruction in accordance with the “Build Back Better” principle.

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