

An aerial photograph showing a flooded village. The water is dark and murky, covering most of the area. Several buildings with corrugated metal roofs are partially submerged. A large pile of debris, including wood, metal, and other household items, is visible in the center. A large green tree stands in the water, its reflection visible. Power lines and poles are also visible, some partially submerged.

A Preliminary Environmental Risk Assessment of the Kakhovka Dam Flooding

ENVIRONMENT AND CONFLICT ALERT UKRAINE

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Introduction

On June 6, 2023, between 2:30 and 3:00 A.M., the dam at the Kakhovka Hydroelectric Power Plant in southern Ukraine collapsed as a highly likely result of an [explosion](#). This caused catastrophic flooding that submerged [hundreds](#) of square kilometers of land and over [80 settlements](#) in the Kherson and Mykolaiv regions within days.

Built in the 1950s, the 30 meters high dam was the last in a system of six Soviet-era dams on the Dnipro River, holding water in an immense water basin of Kakhovka Reservoir with a capacity of 18 cubic kilometers and an area of over 2 100 square kilometers. The reservoir had been used to provide drinking and irrigation water to parts of Ukraine's southern districts of Kherson, Zaporizhzhia, and Dnipropetrovsk, as well as to Crimea, through two long channels. It is also a [protected](#) nature site as part of the Emerald Network under international conventions due to its unique flora, fauna, and natural habitats. The dam also served as an energy facility, producing electricity to balance the power system of Ukraine.

Available evidence [points](#) to the deliberate destruction of the dam by the Russian forces, which were in control of the hydropower plant since the early days of Russia's full-scale invasion of Ukraine in February 2022. Previously, the dam faced shelling early on in the conflict and was damaged after Russian troops retreated from Kherson in November 2022.

Ukrainian and international environmental experts have [assessed the](#) destruction of the Kakhovka Hydroelectric Power Plant as the [largest environmental catastrophe](#) in Europe since the Chernobyl disaster in 1986, with a growing number of voices in political and legal circles calling for its recognition as an 'ecocide'. Immediate consequences of the flooding were disastrous: entire villages and towns were destroyed, thousands of homes and farms were flooded, thousands of animals drowned, and up to 4 000 residents of the Kherson region [had to evacuate](#) from the affected areas in the Ukraine-controlled territory, as people were left without homes, access to water, and power supplies. The situation is [believed](#) to be even more dramatic in the Russian-occupied parts of the Kherson region on the left bank of the Dnipro River. This side constituted the majority of the flooded areas, but there is little information about the developments there. It is already clear that the consequences of the destruction of the dam and hydropower plant will be generational due to its far-reaching impacts on entire ecosystems, livelihoods, and environmental health.

This **Environment & Conflict Alert** looks into the key issues stemming from the Kakhovka dam destruction and maps the most acute environmental risks, which could lead to severe public health problems. The findings build upon existing research on past massive flooding incidents and their impacts on the environment, as well as on the analysis of disaster data from non-governmental humanitarian organizations and the United Nations, including open-source mapping of potentially hazardous facilities, Russian military positions, nature reserves, etc.

Mapping the Main Areas of Concern

To illustrate the environmental dimensions of the hydropower plant's destruction, the visualization shows five key areas of concern regarding direct environmental disasters with highly probable long-term impacts on ecosystems, livelihoods, and health. This list is however not exclusive.

Potentially hazardous facilities: Downstream of the dam are a large number of industrial areas, [petrol stations](#), workshops, and factories that are known to process or store a range of hazardous materials or toxic substances that have likely washed away. The Kherson oil depot, a shipyard, a brick production factory, and fish farms have been affected, with the [potential release](#) of different fuels, solvents, cleaning agents, pesticides, and antibiotics. The [Flash Environmental Assessment Tool](#) (FEAT) can provide helpful guidance in understanding the risks linked with the different types of industrial activities.

Military positions: Russian armed forces have been [constructing](#) miles of trenches and hundreds of fortified positions south of the Dnipro River, while also mining the riverbanks and lands. The flood water resulted in the [washing](#) away of different types of mines, munition, and weapons systems. These pose additional explosive risks to civilians as well as possible long-term impacts from the large amount of military energetic materials in munitions that can affect soil and water sources.

Landfills: The downstream area has several formal and informal landfills with solid waste. Existing [research](#) shows how floods can result in the widespread dispersal of solid waste downstream, leaving trails of (micro)plastics, heavy metal pollution, and the spread of organic materials that can affect water sources, clog pipelines and impact flora and fauna. Before the war, the Ukrainian government was attempting to address the large number of illegal waste dumps and developed a [public reporting system](#). Two official landfills have been directly flooded, and seven others are likely affected, while informal and illegal waste dumps are expected to further add to the spread of solid waste.

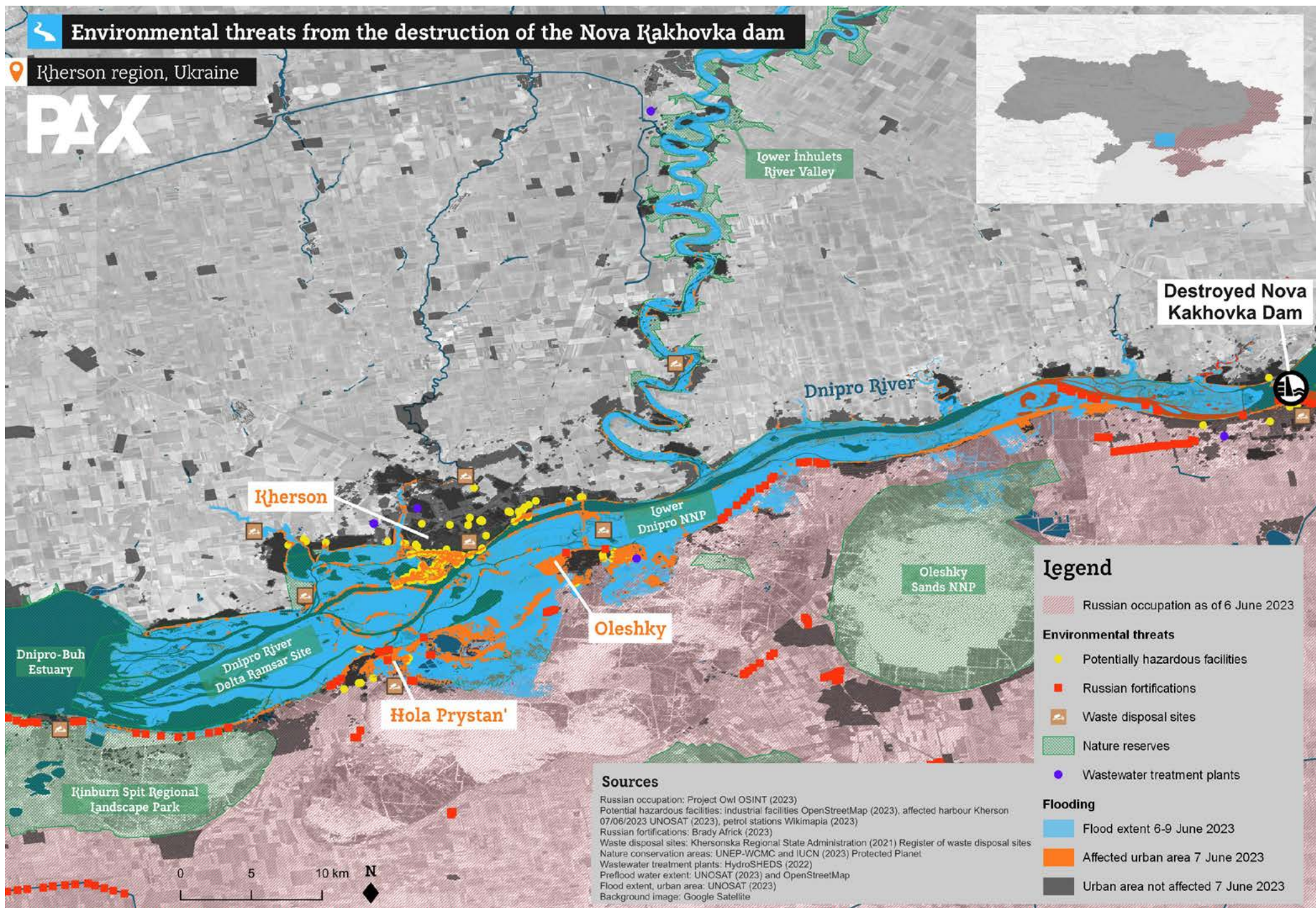
Nature reserves: The south of Ukraine hosts [numerous protected nature reserves](#) with unique ecosystems that have been directly affected or are at risk from the flood event. Downstream protected areas are experiencing a massive flow of debris and pollutants, while the upstream nature parks are under threat due to the progressive shallowing and draining of the reservoir. According to an [analysis by the](#) Ukrainian Nature Conservation Group, the affected area can extend to at least 5 000 square kilometers, including the flooded and dried-up zones.

Water security: The flood has affected both the provision of drinking water access and agricultural irrigation. Downstream, damaged water intakes and clogged pipelines limit the operations of water treatment facilities. One plant has been completely flooded and four are dangerously close to the flooded areas. Upstream, the rapidly dropping water levels [reduce](#) or even stop the flow of water into irrigation canals that farmers in southern Kherson and Crimea depend on for agriculture.

Environmental threats from the destruction of the Nova Kakhovka dam

Kherson region, Ukraine

PAX



Environmental and Humanitarian Risks

The destruction of the Kakhovka Hydroelectric Power Plant has already resulted in an environmental catastrophe, provoking a humanitarian crisis and economic losses with long-term consequences for Ukrainian citizens and likely transboundary effects. The main humanitarian risk from the Kakhovka dam breach is the disrupted access to water for drinking and technological purposes.

The [UN stated](#) an unprecedented impact on the 700 000 people that are now experiencing a dire shortage of drinking water in the affected areas. The World Health Organization has issued a [warning](#) for cholera outbreaks and botulism due to limited access to clean water. The ongoing and possible consequences are presented below according to the different types of impacts, divided into two zones: downstream and upstream from the dam breach location.

Downstream Zone: Risks due to flooding

Water resources: According to the Ministry of Environmental Protection and Nature Resources of Ukraine, more than 80% or 14.5 cubic kilometers of water [has already been lost](#) from the Kakhovka Reservoir, which indicates a massive decrease in the water level. The biggest concern is the damage to drinking water intakes in the affected settlements. Moreover, the breach of the dam [has resulted](#) in the release of approximately 150 tons of oil products from the hydropower plant, and according to Ukrainian officials, another 300 tons were at risk of leaking. REACH [states](#) that 456.000 tons of transformer oil have already spread. Also, there is a high risk of surface water and groundwater pollution by organic substances from decomposed bodies of animals, plants, and food products, as well as by chemicals from hazardous facilities damaged in affected areas, including industrial facilities, gas stations, warehouses with chemicals, wastewater infrastructure, industrial waste deposits, and landfills. At least 54 oil [locations](#) have been affected, with an estimated total of 134 hazardous facilities. This impacts the Dnipro River basin, its smaller tributary rivers, its river mouth and estuaries, and the Black Sea.

Agricultural lands: Southern Ukraine is an agricultural region that is now facing losses of arable lands with long-term consequences for food security in Ukraine and beyond. The upper layer of fertile soil has likely washed away. On the one hand, this intense erosion process destroys the productive of topsoil; on the other hand, it contaminates the flooded lands downstream with agricultural and other soil-bound pollutants. Recent [estimates](#) by the UN in collaboration with the Ukrainian government also warn of contaminated sediments that have accumulated on the bottom of the reservoir and are washed downstream.

Debris accumulation: After the dam destruction, a strong flow of water has destroyed and swept downstream a large amount of debris, potentially containing [hazardous materials](#) of the damaged buildings, including [asbestos](#), infrastructural objects, industrial facilities, and household and natural waste. Satellite imagery analysis by [REACH](#) and social media footage [shows](#) the large stream of sediments into the Black Sea, and different types of waste washing up on the shores around Odesa city.

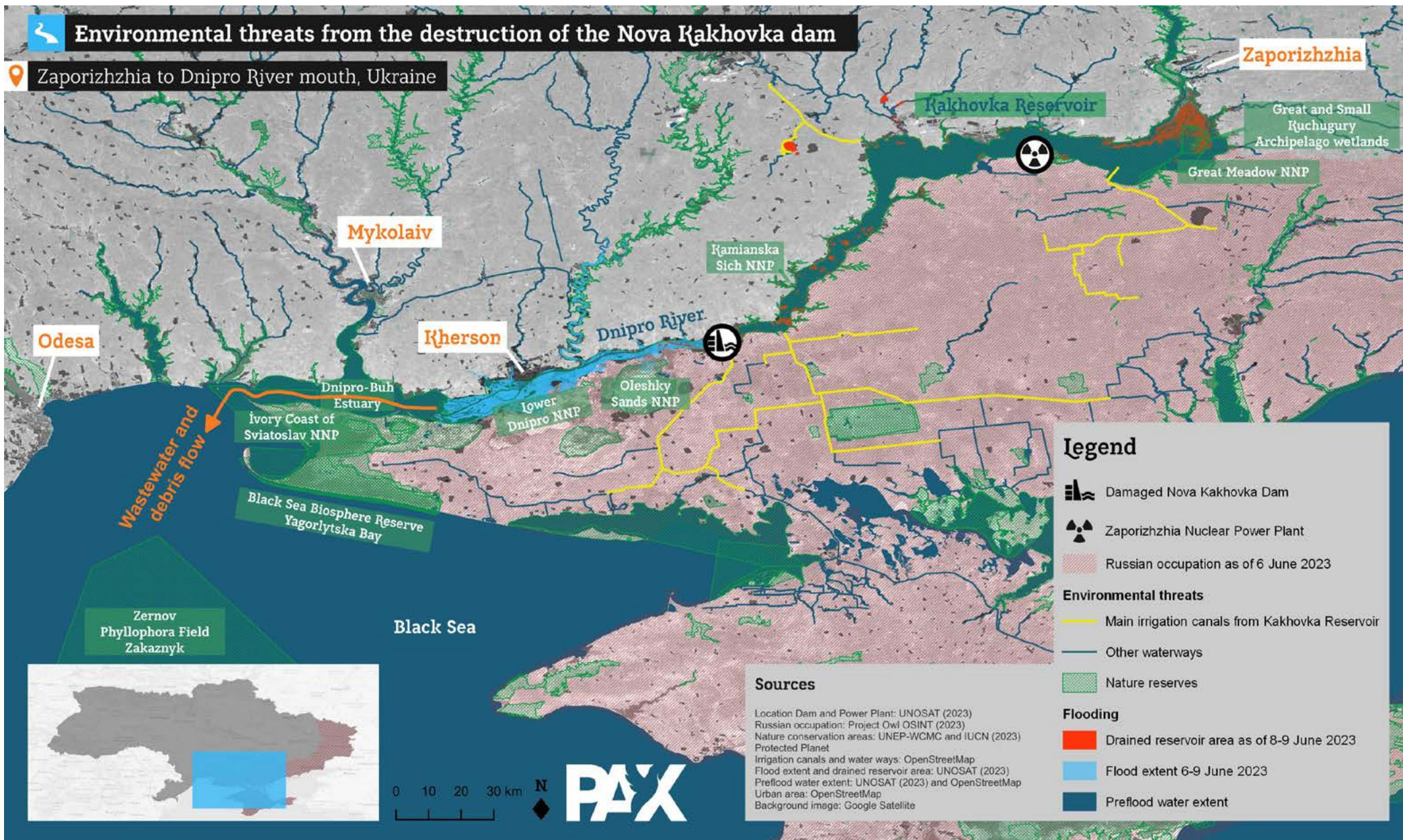
Explosives: Another danger caused by the flood is the washing out of the [minefields](#), battlefields, and military positions, containing mines, munition, and unexploded ordnances. Beyond the [explosive](#) risks, the [accumulation](#) of different types of explosives and munitions and their large number could lead to the pollution of water and land resources. At the same time, there is a high probability of mines being deposited in silt deposits at the bottom of the river, which will complicate mine clearance work in this area.

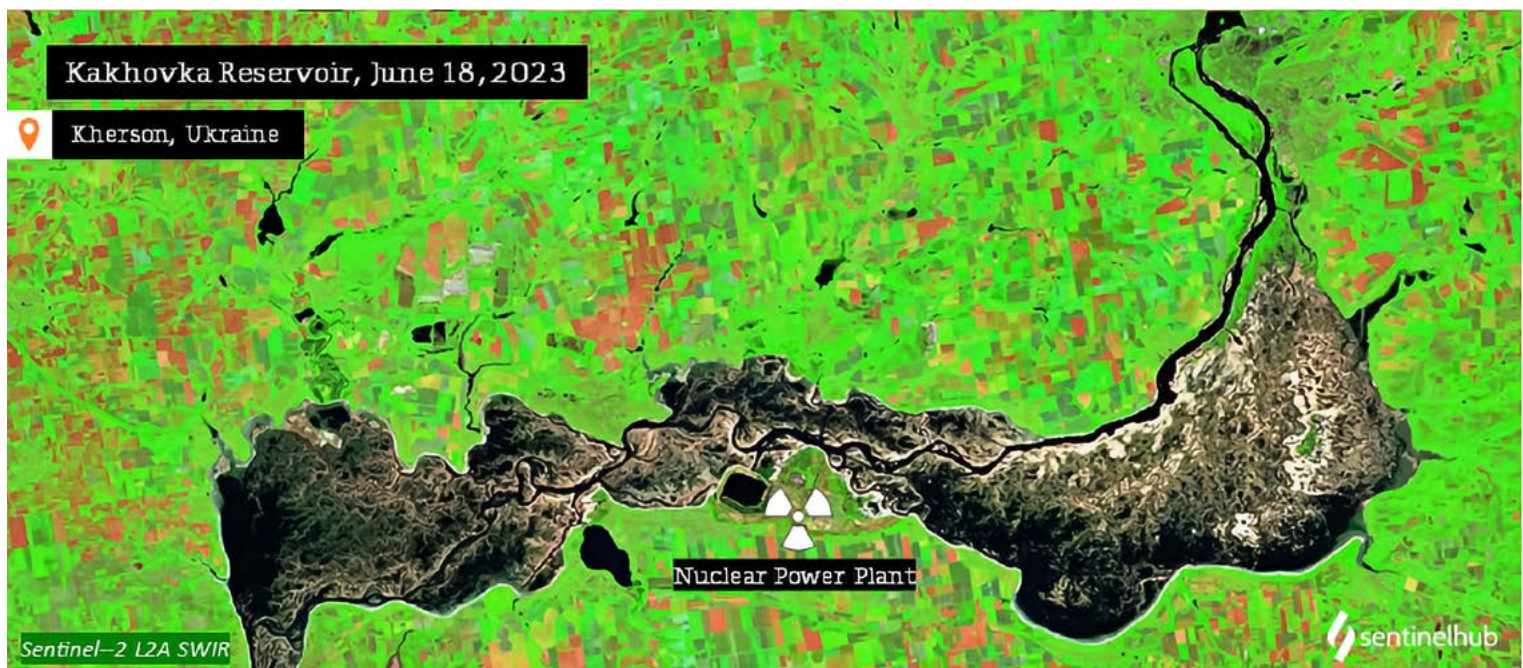
National protected areas: There are three main national nature parks (NNP) in the affected areas below the Kakhovka Hydroelectric Power Plant: “Lower Dnipro”, “Oleshky Sands”, and “Ivory Coast of Sviatoslav”, which belong to [the nature reserve fund](#). The whole area of the largest nature park “Lower Dnipro”, extending over 80 000 hectares of nature conservation lands, has been flooded, which destroyed the habitats of 1 016 species of flora and 1 140 species of fauna, some of which are on the verge of extinction and are listed in the Red Book of Ukraine for protection. In NNP “Oleshky Sands”, the flood threatened the habitats of 164 species of birds and 156 species of mammals. Over the entire downstream area, approximately [55 000 hectares of forests were flooded](#), of which 47 000 hectares are located in the occupied territories on the left bank of the Dnipro. Among those, young pine trees up to 10 years old are expected not to survive the inundation by the floodwaters. Despite that the floodwaters have gradually retreated from the 9th of June onward, many ecosystems of these nature parks are very likely lost forever due to the flood’s damage to living organisms and vegetation. The washout from the flooding, including contaminated waters and debris, will likely also affect the marine and coastal environment around the Kinburn Spit NNP in the Black Sea, a [protected](#) area in the southern Mykolaiv region that hosts a wide range of unique species of birds and fish and a rich ecosystem.

Upstream Zone: Risks due to Draining and Shallowing

The area upstream of the destroyed dam is gradually being drained, as most of the 18 cubic kilometers of water has disappeared from the reservoir. This directly affects the nuclear safety of the Zaporizhzhia Nuclear Power Plant, water availability in irrigation canals, and the state of ecosystems. Consequently, the lack of water will deteriorate livelihoods in the wide region depending on the reservoir, including for electricity and agricultural production.

Water resources and agriculture: As a result of the draining of the reservoir, significant water shortages will interrupt the operation of the **canal-based irrigation system**. According to [NASA Harvest’s satellite-based analysis](#) as of June 12, 2023, three of the four major canals intended for farm irrigation are already disconnected from water sources, with the fourth under the same risk in the coming days. It is estimated that 94% of [irrigation systems](#) in the Kherson region, 74% in the Zaporizhzhia region, and 30% in the Dnipropetrovsk region remain without a source of water. The limited access to water will create **pressure on small rivers** – the tributaries of the Dnipro River – as the upstream areas become dependent on them for drinking water, technological needs, and agriculture. Additionally, the reservoir drainage, interruption of irrigation, and continued water demand will most likely lead to a **decreased groundwater level**. The dehydration of the soil will lead to the loss of vegetation and an increase in harmful toxic substances in the soil. All these factors will lead to soil salinization, a decrease in soil productivity, and the degradation of arable lands, putting harsh limits on the capacity for farming in the region. Moreover, [damage to the fishing industry](#) is already being reported, more explicitly meaning the death of fish. The spawning period has just ended, and due to the drop in the water level, the spawn will dry out.





Pollution: Industrial pollution that settled in the sediments of the lake forms an additional risk. The bottom silt deposits of the reservoir accumulated for decades and contain hazardous substances associated with various regional industries such as agrarian or metallurgy sectors. The now-drained reservoir bottom will spread with the wind and is a source of toxic dust. For reference, a similar scenario [occurred](#) in Salt Lake City, where the drying up of the lake [created](#) a 'toxic dust' bowl.

Nuclear safety: Draining of the Kakhovka Reservoir endangers the operation of the Zaporizhzhya Nuclear Power Plant, located upstream of the destroyed dam, which relied on water from the reservoir for the cooling process and other safety purposes. The current water level has dropped significantly, leaving the reservoir almost empty. Though most of the nuclear reactors are shut

down, cooling water is still needed for the remaining two reactors, which will be a serious issue in the upcoming months, [warns](#) the International Atomic Energy Agency.

National protected areas: The affected area upstream contains [two national nature parks](#) - “Great Meadow” (16 755 hectares) and “Kamianska Sich” (12 261 hectares). It is [predicted](#) that the water-covered area of these parks will be reduced to almost half of their current size: with more than 7 000 hectares for the NNP “Great Meadow”, and 5 500 hectares for the NNP “Kamianska Sich” due to the emptying of the Kakhovka Reservoir and shallowing of the Dnipro River. The NNP “Great Meadow” is home to 54 species of fish and 156 species of birds. For the large majority of those, the reservoir emptying is expected to lead to their loss of life. Also, two wetlands of international significance - “Great and Small Kuchugury Archipelago” (7 740 hectares) and “Sim Mayakiv Floodplain Archipelago” (2 140 hectares), situated on the territory of the occupied NNP “Great Meadow”, will be heavily impacted by the drop in water levels.

Flooded Kherson Ports and Industrial Areas



Conclusion

The dam collapse of the Kakhovka Hydroelectric Power Plant is causing major direct and indirect environmental degradation, both upstream and downstream. A massive number and diversity of living organisms, wildlife, and their habitats have been destroyed, such as wetlands, forests, coastal ecosystems, grasslands, estuaries, archipelago systems, etc. which is especially dramatic for the many protected nature reserves in the region. This will lead to a profound **loss of biodiversity and ecosystem services** in the affected region. The emptying of the reservoir is leaving irrigation canals dry, as well as the agricultural lands of the wider regions of Kherson, Zaporizhzhia, and Dnipropetrovsk. Mapping of the facilities with hazardous materials affected by the flood demonstrates that **significant pollution of water resources** is highly probable. Subsequently, there is an increased risk of both chemical and bacteriological contamination. A lack of clean water can cause outbreaks of infectious diseases.

Urgent response measures are required to prevent further pollution and subsequent cleanup of affected water sources from debris, toxic substances, and unexploded ordinances, where the security situation allows. In this regard, the lack of access to the affected areas constitutes an acute problem, because the left-bank part of this territory, including the Kakhovka Hydroelectric Power Plant, is under Russian occupation, while the Ukraine-controlled right bank of the Dnipro River is regularly under fire from Russian troops. This precludes the provision of humanitarian support and in-field assessments of the scale of environmental consequences, necessary for the planning and implementation of response measures to reduce the long-term civilian and ecological harm from this environmental disaster.



Ukrainian citizens and supporters attend 'Stop The Ecocide In Ukraine' demonstration at the Main Square in Krakow, Poland on June 11, 2023
Credit in photo: © Beata Zawrzel/ZUMA Press Wire

Harm Mitigation and Accountability

Along with an urgent need for humanitarian aid to the affected civilians, the environmental harm should be mitigated and reduced by all the available means, including the following:

- ◆ detailed identification and analysis of the most hazardous facilities that could be damaged in affected areas, based on the preliminary desk-based risk mapping as provided, among others, by this report, with extra attention for toxic industrial facilities, warehouses with chemicals, industrial waste deposits, landfills, military fortifications, cemeteries, mass burials, cattle burial grounds etc.;
- ◆ establishment of an appropriate working platform involving national and international experts to unite the international efforts in response to this environmental catastrophe;
- ◆ development and implementation of the emergency response plan with measures to prevent, mitigate and reduce environmental damage caused by the consequences of the dam's destruction, with urgent attention to issues of water and soil contamination, and with a special focus on environmental rehabilitation of the affected areas of the nature reserve fund of Ukraine;
- ◆ development and implementation of a long-term water, food, and livelihoods security plan for the regions impacted by the drying up of irrigation infrastructure dependent on the Kakhovka Reservoir;
- ◆ inclusion of the destruction of the dam as part of a wider international assessment to hold Russia accountable for the environmental damages caused by its invasion of Ukraine. This act could be a relevant stepping stone to recognise 'ecocide' as an international crime to be prosecuted by the International Criminal Court.

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Cover photo: An aerial view shows a flooded area with oil on the water after the Nova Kakhovka dam breached, amid Russia's attack on Ukraine, in Kherson, Ukraine June 10, 2023. REUTERS/Inna Varenysia

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