GENEVA WATER HUB

Integrating Foreseeable Indirect Effects of Water Services Damage and Pollution of Freshwater on Civilians and the Environment into Military Operations

Workshop Report

Geneva, 26-27 November 2025

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The Geneva Water Hub extends its sincere thanks to all participants for the openness, expertise and thoughtful contributions they brought to the workshop. Their collective input greatly enriched the discussions and this report, while individual contributions remain unattributed in accordance with the Chatham House Rule.

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oating sludge at final effluent.Photo by Cpt212 on Istock.

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Workshop Report

1 INTRODUCTION

On 26–27 November 2025, the Geneva Water Hub (GWH), in partnership with the Ministry of Foreign and European Affairs of Slovenia, and with the support of Switzerland, convened a workshop entitled "*Integrating Foreseeable Indirect Effects of Water Services Damage and Pollution of Freshwater on Civilians and the Environment into Military Operations*" The event brought together military practitioners alongside representatives of international organizations, humanitarian NGOs, and academia. Over two intensive days, participants explored practical tools, operational experiences, and emerging good practices to strengthen the integration of predictive analysis of collateral damage to water services and freshwater ecosystems into military planning and decision-making. Participants were encouraged to engage both creatively and pragmatically, with the aim of generating concrete, actionable recommendations.

Freshwater ecosystems and associated infrastructure are civilian objects frequently affected by military operations. Their protection is not only a legal obligation under International Humanitarian Law (IHL), but also a matter of operational foresight and risk mitigation.

The principles of distinction, proportionality, and precautions must be applied throughout the targeting cycle. IHL prohibits attacks expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated.[1] While collateral damage assessments have traditionally focused on direct and immediate harm, IHL also requires consideration of reasonably foreseeable indirect effects, including reverberating effects and cumulative impacts, particularly where these may foreseeably cause civilian death, injury, or destruction, as reflected in State positions and military doctrine.[2] The obligations to take constant care to spare civilians and civilian objects in the conduct of military operations and to take all feasible precautions to avoid and in any event minimize incidental civilian harm extend to the choice of means and methods of warfare, as well as to decisions regarding the timing, location, and manner of attack.[3]

[1] See Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts, 8 June 1977 (AP I), Arts 51 (5) (b); and ICRC Customary Law Study, Rule 14.

[2] See ICRC, "International Humanitarian Law and the Challenges of Contemporary Armed Conflicts: Building a Culture of Compliance for IHL to Protect Humanity in Today's and Future Conflicts", September 2024, pp.41 & 44; and Principle 9, "The Geneva List of principles on the protection of water infrastructure", Geneva Water Hub (2019), (hereinafter - GWH, Geneva List).

[3] See Isabel Robinson and Ellen Nohle, "Proportionality and precautions in attack: The reverberating effects of using explosive weapons in populated areas", *International Review of the Red Cross*, *98*(1), 2016, 107–145; Geoffrey S. Corn and Tyler R. Smotherman, "Improving Compliance with International Humanitarian Law in an Era of Maneuver War and Mission Command", *SMU Law Review*, *78*(1) 2025, 33-39.

Water infrastructure and freshwater ecosystems are, in principle, protected as civilian objects under IHL. However, water infrastructure may become a military objective when it is simultaneously used for civilian and military purposes or otherwise makes an effective contribution to military action, including when integrated into national security systems. This creates complex legal and operational challenges for the application of the principles of distinction and proportionality. Addressing these challenges is essential because damage to water infrastructure can have severe and long-term consequences for civilians, including through disruption of access to water and related essential services. It also requires closer examination of the legal and technical implications of integrating water networks into national security systems while ensuring the continued protection of civilians and civilian objects.

Damage to water systems or pollution of freshwater ecosystems can trigger cascading consequences: outbreaks of waterborne diseases, disruption of livelihoods, displacement, environmental degradation, and even indirect blowback affecting force protection and post-conflict stabilization efforts. These reverberating effects may far exceed the immediate harm caused by the initial strike.

The water system comprises all elements that are needed to supply water to the local population and other end users (e.g., agriculture, industry). Next to water-related infrastructure, this includes water resources themselves, the staff operating water facilities, and different agencies and utilities involved in service provision and water governance. The functionality of the overall water system can depend on many different factors, such as access to requisite materials and consumables, financial resources to operate facilities and pay staff, or the institutional capacity of oversight agencies to uphold water quality standards.[4]

Yet, while kinetic and cyber effects of warfare, such as casualties from airstrikes, are often documented and publicized, the indirect harm resulting from degraded water services tends to remain less visible. This relative "invisibility" can undermine operational performance and mission success, as long-term civilian suffering and environmental damage may generate strategic, public, and political repercussions.

At the same time, integrating foreseeable indirect effects into military decision-making remains challenging, particularly in fast-moving operational environments characterized by limited time and incomplete information. Estimating cascading impacts across interconnected water systems requires both legal interpretation and technical expertise.

The workshop therefore sought to bridge legal doctrine with practical planning tools and operational realities. By equipping commanders, planners, and legal advisors with a more holistic understanding of water systems' vulnerabilities and their long-term civilian and environmental consequences, the discussions aimed to enhance situational awareness, inform target engagement decisions, and ensure compliance with IHL without compromising combat effectiveness.

[4] See Juliane Schillinger, Gül Özerol and Michiel Heldeweg, "A social-ecological systems perspective on the impacts of armed conflict on water resources management", Geoforum, 131, 2022, 101-116.

2 LEGAL FRAMEWORKS GOVERNING THE PROTECTION OF WATER INFRASTRUCTURE

Under IHL, the principles of distinction, proportionality, and precautions require that reasonably foreseeable direct and indirect civilian harm be taken into account in the conduct of hostilities. Water infrastructure is protected as a civilian object unless and for such time as it becomes a military objective. Even where water networks serve both civilians and militaries, and become military objectives, any attack must comply with the requirements of proportionality and precautions (both active and passive). [5]

DUAL-USE INFRASTRUCTURE AND STRUCTURAL COMPLEXITY

Water systems increasingly intersect with energy systems, industrial production, and broader national security infrastructure. Where they serve military functions or are integrated into military-industrial complexes, they are more likely to fulfil the definition of military objectives.[6] For example, a municipal water treatment plant may provide water to an active military base as well as to a nearby city. In some cases, such as Yemen, water reservoirs may be located within a military base, supplying water to military personnel while also serving an adjacent civilian neighbourhood. In such instances, such water systems may become the object of an attack if they meet both cumulative criteria for classifying them as military objectives. It must be noted that some water infrastructures, benefiting from special protection regimes, have immunity against attacks even when they serve military purposes.

This creates complex challenges for the application of distinction and proportionality, particularly where essential civilian needs remain dependent on the same infrastructure.

Addressing these structural realities is critical for two reasons. First, the potential characterisation of water infrastructure serving both civilian and military purposes as dual-use objects may complicate compliance with the special protections afforded to such infrastructure indispensable to the survival of the civilian population. Second, legal and technical analysis of how water systems are embedded in national security architectures is necessary to ensure sustained protection of civilians. The mere military use of water and related infrastructure does not negate obligations to avoid or a least minimize foreseeable harm to civilian populations.

[5] See AP I, Arts 51 (5) (b), 57 and 58; and the corresponding ICRC Customary Law Study, Rules 14, 15-21, and 22-24, respectively.

[6] AP I, Art. 52 (2); ICRC Customary Law Study, Rule 8. See also Principles 6 & 8 of the GWH, Geneva List.

SPECIAL PROTECTION REGIMES

In addition to the general rules governing conduct of hostilities, specific protective regimes apply in the water context:

- **Works and installations containing dangerous forces**, such as dams and dykes, may only be targeted under exceptionally strict conditions.[7]
- **Objects indispensable to civilian survival**, including water infrastructure and related energy systems required for water purification and distribution, are protected against attack and other hostile acts.[8]
- **The natural environment** benefits from protection as a civilian object and from prohibitions against methods or means of warfare expected to cause widespread, long-term, and severe environmental damage.[9]
- **Water service and relief personnel** must be respected and protected, and granted access necessary to carry out emergency repairs and maintain essential civilian services.[10]

Legal protection of water has evolved progressively, increasingly informed by developments in human rights law and international environmental law. This evolution reflects growing recognition of the systemic and long-term consequences of water infrastructure degradation.

FORESEEABILITY AND THE STANDARD OF CARE

A central issue concerns the scope of foreseeability in military planning. The concepts of "reasonable," "foreseeable," and "excessive" must be interpreted in light of operational context, available resources, and the type of conflict. At the same time, foreseeability possesses an objective dimension. The humanitarian consequences of targeting and damaging water purification facilities, treatment plants, or interconnected energy systems are well documented, technically understood and foreseeable. [11] The obligation to take all feasible precautions to avoid and in any event minimize incidental civilian harm includes identifying the location of infrastructure critical for the delivery of essential services, including underground systems, prior to attack. This requirement applies irrespective of the conflict's geographic or political context.

The "standard of care", inherent in the obligation to take constant care to spare the civilian population, civilians and civilian objects during military operations, rises because of increased, accumulated knowledge on the interdependency of essential services. Foreseeable reverberating effects must therefore be incorporated into proportionality assessments and operational planning.

COMPLIANCE CHALLENGES IN ASYMMETRIC CONTEXTS

In contemporary armed conflicts, non-state armed groups may exploit the protected status of water infrastructure by operating within, or, in close proximity to, civilian facilities (for example, ISIS controlling dams). Such conduct creates significant operational

[7] See AP I, Art. 56; Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of Non-International Armed Conflicts, 8 June 1977 (AP II), Art. 15; ICRC Customary Law Study, Rule 42: https://ihl-databases.icrc.org/en/customary-ihl/v1/rule42. See also Principle 13 of the GWH, Geneva List.

[8] See AP I, Art. 54; AP II, Art. 14; ICRC Customary Law Study, Rule 54: https://ihl-databases.icrc.org/en/customary-ihl/v1/rule54. See also Principle 12 of the GWH, Geneva List.

[9] See AP I, Art. 55; ICRC Customary Law Study, Rule 43-45: https://ihl-databases.icrc.org/en/customary-ihl/v1/rule43, ICRC, Guidelines on the Protection of the Natural Environment in Armed Conflict, 2020. See also Principle 15 of the GWH, Geneva List.

[10] See AP I, Arts 70-71 and 60-67; ICRC Customary Law Study, Rules 31-32 and 55-56. See also UNSC Resolution 2417 (2018) and Resolution 2730 (2024); and Principles 7 and 17 of the GWH, Geneva List.

[11] See ICRC, "War in Cities: Preventing and Addressing the Humanitarian Consequences for Civilians", Geneva, 2023; Protection of Civilians in Armed Conflict: Report of the Secretary-General, UN Doc. S/2025/271, 15 May 2025, paras 61–65; David Kaelin, Caroline Pellaton and Tadesse Kebebew, "Water and Survival in War: Upholding IHL's Protective Purpose and Documenting the Hidden Toll", International Review of the Red Cross,107(930), 2025, 1141-1168; and Michael Talhami and Mark Zeitoun, "The Impact of Attacks on Urban Services II: Reverberating Effects of Damage to Water and Wastewater Systems on Infectious Disease", *International Review of the Red Cross, 102* (915), 2021, 1293–1325.

challenges for armed forces who must comply with IHL, particularly in situations of asymmetric warfare. These challenges may be further exacerbated when a State perceives an existential threat to its security, heightening the risk that military considerations will outweigh legal obligations relating to the protection of civilians and civilian objects.

At the same time, the misuse of water systems by one party does not diminish the legal obligations of parties to the conflict. IHL applies equally to all parties and in all circumstances, and its application cannot be conditioned on reciprocity. The obligation to respect the principles of distinction, proportionality, and precautions remains fully applicable, even where an adversary fails to comply with the law.

Violations by adversaries, whether committed by non-state actors or by States, must nevertheless be factored into military planning processes. This includes anticipating the risk of collateral damage resulting not only from one's own operations, but also from the adversary's potentially unlawful attacks on critical infrastructure. In contexts where water systems are integrated into densely populated areas, where reverberating effects are foreseeable, planners must account for cascading impacts on essential civilian services. The persistence of non-compliance in certain contemporary conflicts underscores the need to integrate such risks into damage assessments while maintaining strict adherence to IHL obligations.

ACCOUNTABILITY AND INSTITUTIONAL SAFEGUARDS

Effective protection of water infrastructure requires robust accountability mechanisms. Systems for evidence collection, documentation, and prosecution strengthen deterrence and reinforce compliance. [12] Coordination among military institutions, prosecutors, and judicial bodies is essential to ensure reliable documentation of incidents and compliance with domestic and international obligations. Accountability mechanisms, including evidence collection in conflict zones, must remain impartial and free from politicization; where national processes are inadequate, international scrutiny mechanisms, such as fact-finding missions or Commissions of Inquiry by the UN should be encouraged to uphold IHL standards

At the individual level, awareness of legal consequences contributes to discipline and morale. Compliance with IHL not only protects civilians but also reinforces institutional legitimacy and cohesion within armed forces. Clear communication of legal obligations, to both military personnel and external audiences, supports transparency and strategic credibility.

Moreover, the United Nations Security Council Resolution 2573 (2021), [13] which calls for the protection of civilian infrastructure in armed conflict, including water systems, reinforces existing legal obligations and underscores the political importance of safeguarding essential services.

ENVIRONMENTAL PROTECTION AND EVOLVING NORMS

Environmental considerations are increasingly integrated into operational planning processes. Measures aimed at avoiding widespread, long-term, and severe damage to the natural environment may influence the choice of means and methods of warfare. Operational decisions, including the selection of munitions, the intensity of operations, and the targeting of facilities presenting contamination risks such as chemical plants or oil installations, require careful assessment of potential impacts on groundwater, water bodies, and surrounding ecosystems. In certain contexts, this may result in limiting the use of heavy munitions or adjusting operational approaches, including greater reliance on ground deployments, where this is assessed to reduce the risk of large-scale environmental harm.

Environmental analysis is not confined to pre-strike assessments. Post-strike evaluations are conducted to determine whether and to what extent water bodies or ecosystems have been affected. The findings of such assessments should be used to refine future collateral damage estimates and improve precautionary planning

[12] See Kaelin, Pellaton and Kebebew, "Water and Survival in War", ibid.

[13] UNSC, Resolution 2573 (2021).

methodologies.

At the same time, questions arise in operational contexts regarding the scope and prioritisation of environmental protection. It may be argued that conducting hostilities in sparsely populated natural areas reduces risks to civilians when compared to urban warfare. Military planners also face practical constraints, including the need for freedom of manoeuvre and the fact that natural terrain outside urban centres may be considered more suitable for operations. Debate persists as to the extent to which environmental protection obligations extend beyond considerations directly linked to human survivability.

Nevertheless, under customary IHL, the natural environment is protected as a civilian object and may benefit from additional safeguards independent of immediate human harm[14]. Legal interpretation has progressively moved beyond a purely anthropocentric approach, recognising that ecosystems warrant protection in their own right. Significant efforts have been undertaken to clarify these obligations and translate them into operational practice. Practical implementation tools, including doctrinal guidance, environmental checklists, and targeting support materials, are being developed to assist armed forces in systematically integrating environmental considerations into military planning. This evolution reflects a broader shift toward more holistic protection of civilian infrastructure and freshwater ecosystems in contemporary conflict settings.

Black smoke from industrial oil depot fire. Photo by tannujannu on Adobe Stock.

[14] See AP I, Art. 55; ICRC Customary Law Study, Rule 43-45: https://ihl-databases.icrc.org/en/customary-ihl/v1/rule43. See also Principle 12 of the GWH, Geneva List.

3

DIRECT AND REVERBERATING EFFECTS ON ESSENTIAL SERVICES

Armed conflict generates direct, reverberating and cumulative impacts on essential services, civilian populations, and the environment that vary in form, scale, and foreseeability. A fundamental distinction exists between direct and reverberating effects.[15] Direct effects, such as the destruction of physical water infrastructure through explosive force, are typically immediate and more readily identifiable, documented, and assessed. Reverberating effects, by contrast, are systemic, delayed, and cascading in nature. Anticipating them requires a broader understanding of infrastructure interdependencies, ecosystem resilience, and the cascading consequences that may arise from damage to critical components (see box on next page).

Reverberating effects are frequently less visible than immediate physical destruction and unfold progressively over time, sometimes becoming apparent only months or years after the initial incident.[19] In the context of water systems, such effects stem from disruption of complex and interdependent infrastructure networks. Armed conflict may lead not only to displacement of qualified personnel, the so-called "brain drain", but also to direct threats, intimidation, or insecurity affecting engineers, technicians, and utility staff. When skilled operators are unable or unwilling to access facilities due to safety concerns, water treatment plants, pumping stations, and wastewater systems may cease to function safely even in the absence of extensive physical damage. The loss or withdrawal of technical expertise can thus transform limited structural damage into prolonged or systemic service collapse.

Reverberating effects also manifest through cascading technical failures.[20] Damage to pumping stations or electricity supply may reduce water pressure, increasing the risk of contaminated groundwater or sewage infiltrating drinking water networks, particularly where pipes are already degraded. Over time, shortages of treatment chemicals, impaired wastewater management, and environmental contamination further degrade freshwater ecosystems, contributing to outbreaks of waterborne diseases.[21] These outcomes are rarely attributable to

[15] See Mark Zeitoun and Michael Talhami, "The Impact of explosive weapons on urban services: Direct and reverberating effects across space and time", *International Review of the Red Cross, 98* (1), 2016, 53-70; and Kaelin, Pellaton and Kebebew, "Water and Survival in War", above note 9.

[16] UN Ukraine, "Kakhovka Dam Destruction: One Year On", 6 June 2024.

[17] See International Centre for Ukrainian Victory, "Impact of the War on the Global Food Security", 2024.

[18] See Joshua Joseph Niyo, "Systemic Impacts of War in Protracted Conflicts", Articles of War (Lieber Institute, West Point, 22 October 2024.

[19] Kaelin, Pellaton and Kebebew, "Water and survival in war", above note 9.

[20] See Zeitoun and Talhami, "The Impact of explosive weapons", above note 13.

[21] See Talhami and Zeitoun, "The Impact of Attacks on Urban Services II", above note 9.

The destruction of the **Kakhovka Dam** in Ukraine in June 2023 provides a stark illustration of this distinction. The immediate direct effect consisted of the catastrophic release of water, flooding downstream settlements and causing loss of life and large-scale displacement. However, the reverberating effects extended far beyond the initial flooding. The sudden drainage of the Kakhovka reservoir disrupted drinking water supplies for over 700,000 people,[15] impaired irrigation systems supporting extensive agricultural areas,[16] affected cooling water supplies to industrial facilities, and generated severe ecological consequences across the Dnipro River basin. Soil salinization, habitat destruction, contamination from flooded industrial sites, and long-term impacts on groundwater and fisheries demonstrated how the loss of a single upstream installation can produce cascading and transboundary consequences. These impacts were not limited to the immediate blast radius but unfolded over time, illustrating the systemic[17] and cumulative nature of reverberating effects.

a single strike; rather, they result from the cumulative weakening of system resilience, infrastructure interdependencies, diminished technical capacity, and reduced community coping mechanisms.

The functional interdependence between water and electricity systems illustrates this dynamic. Attacks on electrical infrastructure, even where water facilities are not directly targeted, can severely disrupt water supply services when treatment plants, pumping stations, and distribution networks depend on continuous power. Such cross-sector consequences are structurally embedded in modern infrastructure systems and can, in many cases, be anticipated and assessed in advance.

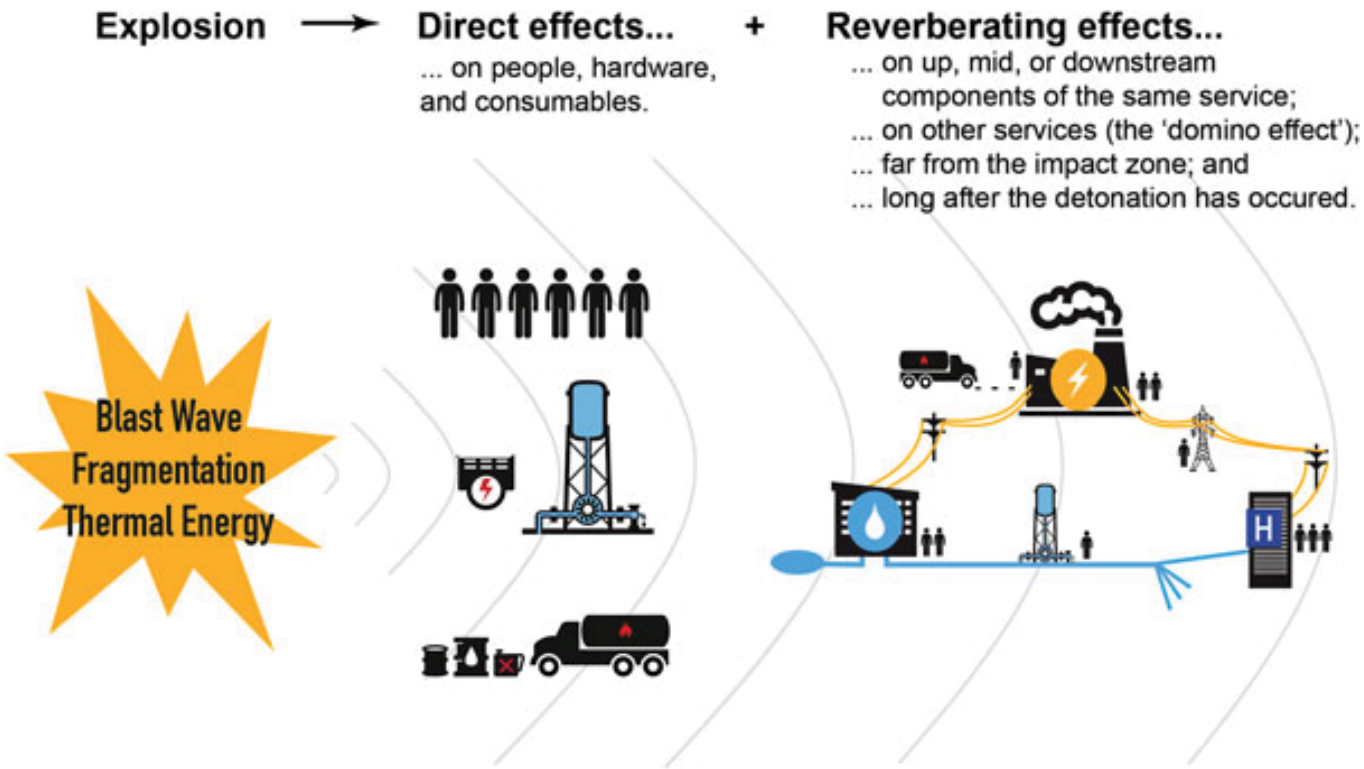

Figure 1 - Depiction of the impact (direct and indirect) of kinetic explosion on the components of urban services (Zeitoun & Talhami, 2016)

Iraq provides a well-documented example of the progressive degradation of water system resilience in protracted conflict settings. Prior to the 1990s, much of the country's urban water infrastructure operated at relatively high technical standards and remained largely intact during the Iran–Iraq War. However, cumulative damage resulting from the 1991 Gulf War, prolonged sanctions restricting access to maintenance materials and spare parts, environmental contamination linked to military operations and damaged industrial facilities, and further degradation following the 2003 invasion significantly weakened system resilience.[22] Repeated conflict-related pollution, including oil spills, damaged wastewater treatment plants, industrial discharge, and unmanaged waste, contributed to declining water quality in major river systems, compounding infrastructure deterioration.

By 2018, this long-term erosion of infrastructure capacity and environmental quality contributed to major water crises and cholera outbreaks. These events were not attributable to a single strike, but to gradual deterioration of baseline system functionality,[23] including reduced water pressure and insufficient treatment capacity. Low-pressure conditions led many households to rely on suction pumps and informal extraction methods, increasing the risk of bacterial intrusion and contamination. This systemic causal chain, linking infrastructure degradation, pollution, pressure loss, coping mechanisms, and disease transmission, is well established in engineering and public health practice and therefore reasonably foreseeable in operational planning contexts.

[22] See Center for Economic and Social Rights, "*Water* Under Siege in Iraq: US/UK Military Forces Risk Committing War Crimes by Depriving Civilians of Safe Water", April 2003.

[23] Baseline resilience refers to the inherent capacity of a water system, prior to or in the absence of conflict, to absorb shocks, adapt to disruptions, and maintain or rapidly restore acceptable levels of service delivery. It encompasses the physical robustness of infrastructure, the redundancy built into system design, the institutional and financial health of service providers, the technical capacity of operational staff, and the governance arrangements that enable coordinated response. The stronger the baseline resilience of a water system before conflict begins, the more it can withstand direct, reverberating and cumulative impacts without collapsing into total service failure. (Geneva Water Hub definition).

The scale and reach of reverberating effects depend significantly on which component of the system is affected. Damage to upstream elements, such as major pumping stations, treatment plants, or primary transmission lines, typically affects far larger populations than disruption at localized downstream points. Understanding system architecture is therefore essential for evaluating proportionality and applying precautionary measures.

As conflicts persist and infrastructure resilience progressively deteriorates, indirect and cumulative impacts become increasingly foreseeable. Patterns of system degradation, service disruption, and public health consequences become clearer over time, reducing uncertainty regarding downstream effects. As foreseeability increases, the corresponding requirements under IHL rises, particularly with respect to proportionality assessments and precautionary obligations.

The capacity to anticipate such impacts is significantly enhanced by access to specialized engineering expertise and robust civil–military coordination mechanisms, including dedicated civil–military cooperation (CIMIC) planning cells within headquarters staff structures (e.g. J9, G9, A9) responsible for integrating civilian considerations into operational planning.[24] Civil–military planning cells (often referred to as CIMIC Cells) are specialized joint staff elements responsible for coordinating, planning, and executing CIMIC activities between military forces and civilian actors. They function as a bridge between the military operation and the local civil environment, ensuring that actions are aligned with the mission's objectives. Strengthening these analytical and coordination capacities improves understanding of infrastructure vulnerabilities and cascading risks, making precautionary decision-making more informed and systematic. Investing in

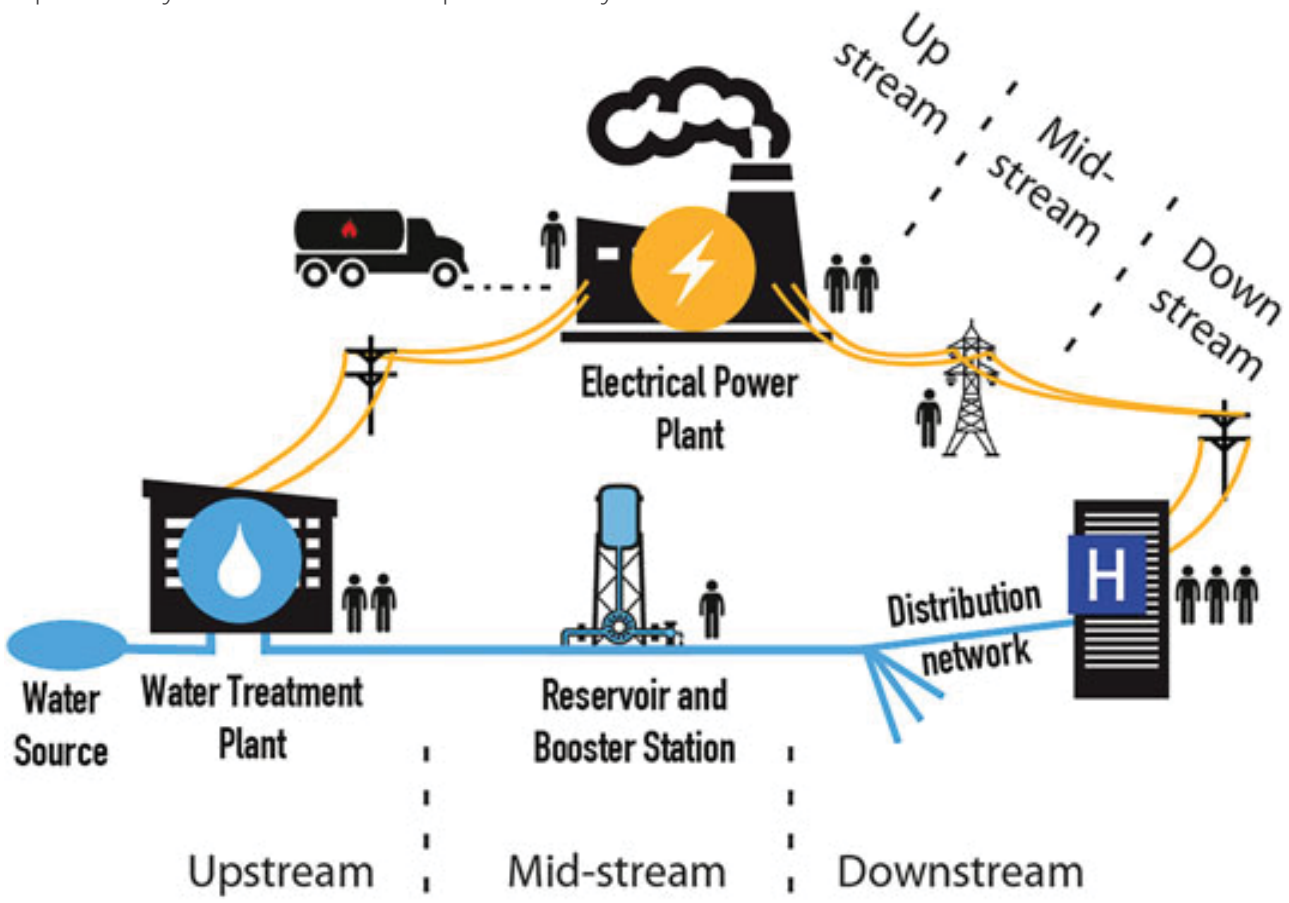

Figure 2 - Schematic representation illustrating the hierarchical structure and interdependencies of components within water and electricity service systems (Zeitoun & Talhami,2016).

[24] See NATO Civil-Military Cooperation Centre of Excellence, "CIMIC Handbook (2025)".

analytical and coordination mechanisms is therefore both operationally prudent and legally significant as it can prevent possible violations of IHL.

Beyond technical and humanitarian consequences, damage to water systems can generate broader reverberating effects, including social unrest, public demonstrations, loss of institutional trust, and destabilization of local governance. In protracted conflicts, large-scale service disruption may contribute to displacement and cross-border refugee flows, placing additional pressure on water resources, sanitation systems, and public services in neighbouring countries. Such spillover effects can strain already fragile water systems baselines in host communities, exacerbate competition over scarce resources, and introduce new regional stability challenges. The consequences of infrastructure damage may

The case of Aleppo illustrates how prolonged disruption of water services in urban warfare can generate devastating yet reasonably foreseeable consequences. Prior to the conflict, the city's water supply relied largely on centralized infrastructure drawing from the Euphrates River basin, including major pumping stations, transmission lines, a principal wastewater treatment plant, and chlorine supply facilities required for water purification. Much of this infrastructure was above ground, geographically fixed, and well known. The system was highly interdependent, relying on continuous electricity supply and transmission corridors crossing multiple areas of control.

Beginning in 2012, key installations sustained severe damage or became inoperable due to hostilities and loss of power supply. Transmission lines and pumping stations crossed shifting front lines, at times up to eight, making maintenance and repair extremely difficult and exposing technical personnel to significant security risks. The chlorine production facility serving the area was rendered inoperable, constraining treatment capacity even where pumping resumed. Damage to irrigation pumping stations further affected approximately 80,000 hectares of agricultural land, reducing food production and exacerbating economic vulnerability. Over time, cumulative degradation of water, wastewater, agricultural irrigation, and electricity systems led to declining water quality, unsafe coping mechanisms, and increased environmental contamination, contributing to the re-emergence of cholera by 2021.

therefore transcend national boundaries, affecting transboundary water and reshaping regional security dynamics.

Even where individual incidents appeared limited in isolation, sustained disruption of interdependent infrastructure networks predictably resulted in large-scale public health crises and socio-economic destabilization. Given the visibility and known function of the affected installations, these consequences were structurally foreseeable in the context of protracted urban conflict.

Preventing such outcomes requires systematic integration of critical civilian infrastructure mapping into intelligence preparation of the battlefield. Identifying water facilities, wastewater systems, pumping stations, treatment plants, and their interdependencies with electricity and other essential services is essential for informed operational planning. Specialized expertise, including engineers, hydrologists, and urban planners, enhances understanding of system architecture and vulnerabilities. Where direct access to such expertise is limited, planning can draw on geospatial tools, satellite imagery, systems mapping, and open-source intelligence. These requirements apply equally to deliberate targeting processes and dynamic operations conducted under time constraints. Institutionalized learning mechanisms, including structured pre-operational preparation and systematic post-operation assessments, are essential to strengthen future decision-making.

Targeting critical infrastructure may in some conflicts be deliberate rather than incidental. Claims that disabling such infrastructure can accelerate conflict termination must be weighed against the severe and often long-term humanitarian consequences that raise serious proportionality concerns and the likelihood of strategic blowback, including loss of civilian support and prolonged stabilization requirements. From a strategic perspective, such targeting may also prove counterproductive. As territorial control shifts, advancing forces may depend on the same water, electricity, and sanitation systems for sustainment and stabilization. Anticipating future operational phases, including stabilization and governance, is therefore integral to informed targeting decisions.

When water systems serve military purposes, they may qualify as military objectives, but this determination requires careful assessment of the two-pronged test, i.e., whether, by their nature, location, purpose or use, they make an effective contribution to military action, and whether their total or partial destruction, capture, or neutralization, in the circumstances ruling at the time, offers a definite military advantage.[25] Where armed forces protect or operate civilian services, insufficient distinction between civilian and military functions risks blurring legal protections. Passive precaution requires maintaining clear separation wherever feasible. Responsibility for protecting and operating critical infrastructure should, where possible, remain with civilian authorities. Where military involvement is unavoidable, careful communication and operational restraint are necessary to avoid actual or perceived militarization that could render infrastructure a lawful target. Critical infrastructure should not be transformed into a military objective through its use for troop accommodation or other military functions.

[25] See AP I, Art. 52 (2); ICRC Customary Law Study, Rule 8. See also Principles 6 & 8 of the GWH, Geneva List.

4 DIRECT, REVERBERATING AND CUMULATIVE EFFECTS IN MILITARY DOCTRINES AND PRACTICES

Legal advisers play a central role in operational planning. The systematic integration of reverberating effects into military decision-making requires not only legal oversight, but strengthened civil–military cooperation, structured scenario-based training, and sustained engagement with technical expertise. Embedding legal advisers throughout the chain of command and investing in peacetime preparedness are essential to ensuring that indirect and cumulative impacts are incorporated into operational processes in a consistent and informed manner.

Legal considerations should be integrated into mission briefings, targeting procedures, and operational planning cycles. Legal advisers are responsible not only for identifying constraints under IHL, but also for developing legally sound courses of action that mitigate risk while preserving operational effectiveness. Their role extends beyond compliance review to proactive guidance that supports precautionary and proportional decision-making.

Effective legal integration requires that legal assessments be operationalized at all command levels, not only at senior headquarters, but also among brigades and subordinate units. Clear communication of how legal considerations shape operational choices enhances both compliance and operational clarity. Familiarity with applicable legal frameworks enables commanders to exercise freedom of action within lawful boundaries, particularly in time-sensitive or dynamic operations where escalation to higher command may not be feasible and legal judgment must be applied at lower tactical levels.

Legal advising must also be aligned with operational realities. Legal officers require a thorough understanding of command structures, planning cycles, staff procedures, and practical constraints faced by commanders. Institutional integration, often through embedding legal advisers at battalion level or below, ensures that legal advice remains timely, context-sensitive, and actionable.

Despite doctrinal guidance and the presence of legal advisers, armed forces do not always possess sufficient practical capacity to identify and assess reverberating effects systematically. Strengthening this capacity requires sustained investment in peacetime preparation, including targeted training, simulations, and war-gaming exercises designed to integrate indirect and cumulative impacts into operational planning. Developing such expertise before conflict reduces cognitive burden during operations and ensures that analytical tools and relevant data are available when crises arise.

Preparedness must also include structured engagement with civilian expertise, particularly civil engineers, hydrologists, and infrastructure specialists, who can inform assessments of complex, interdependent systems. Consulting design-level experts responsible for major installations, such as dams or treatment plants, enhances understanding of structural vulnerabilities and cascading damage scenarios. While military engineers fulfil essential operational functions, their focus often centers on mobility and counter-mobility tasks; integrating civilian technical knowledge therefore strengthens the ability to anticipate and mitigate reverberating effects on essential services.

An all-of-society approach further reinforces preparedness by aligning civil and military capacities prior to crises. Military joint functions, such as NATO J9 civil–military planning cells, [26] provide an institutional foundation for integrating civilian considerations into operational planning. Deployed at tactical levels, these structures can facilitate engagement with civilian populations and support the protection of critical infrastructure, including water systems. Strengthening their engineering, analytical, and coordination capacities would enhance systematic assessment of vulnerabilities and cascading risks.

Broader societal resilience in the water sector must likewise be reinforced in peacetime. This refers to the capacity of institutions, service providers, communities, and interconnected systems to anticipate, absorb, and recover from disruptions to water supply and sanitation services. Identifying single points of failure in water infrastructure, such as pipelines without redundancy, and recognizing critical interdependencies, including electricity supply, digital control systems, and fuel logistics, are essential steps in reducing systemic vulnerability. Sustained political commitment and long-term investment are necessary to strengthen these capacities before conflict arises.

Within broader preparedness frameworks, structured methodologies have been developed to assess indirect and cumulative impacts arising from military operations. One such approach is reflected in NATO's "seven baseline resilience requirements", which provide a tool for evaluating potential reverberating effects across interconnected civilian systems.

These "seven baseline requirements" are grounded in three core civil preparedness functions that must be maintained even under the most demanding conditions: continuity of government, essential services to the population, and civil support to the military, as defined in Figure 3. The framework recognises the interdependence of these functions and the fact that disruption in one domain may cascade into others. Risk assessments based on graduated indicators, often expressed through tiered systems such as green, amber, or red, allow planners to evaluate how different operational choices may generate direct, reverberating and cumulative consequences beyond the immediate target.

Water is explicitly reflected under Baseline Requirement 4 (resilient food and water resources), acknowledging its central role in sustaining civilian life and broader societal resilience. More systematic integration of water-related reverberating effects into such assessments, particularly the cascading impacts of damage to water systems on health services, food production, energy supply, and population displacement, would further strengthen precautionary planning and operational decision-making.

The continued refinement of these NATO assessment tools illustrates a growing recognition within military planning processes that resilience considerations and reverberating effects must be incorporated into targeting and risk analysis, particularly where essential civilian infrastructure is concerned.

More systematic integration of water-related reverberating effects into such assessments would strengthen precautionary planning.

[26] See e.g., European External Action Service, "J9 Branch: The Human Dimension of EUMAM MOZ", 3 January 2026.

1. Assured continuity of government and critical government services, for instance, the ability to make decisions and communicate with citizens in a crisis.
2. Resilient energy supplies, ensuring a continued supply of energy and having back-up plans to manage disruptions
3. Ability to deal with uncontrolled movement of people and to de-conflict these movements with NATO's military deployments
4. Resilient food and water resources ensuring resilient supplies that are safe from disruption or sabotage
5. Ability to deal with mass casualties; ensuring that civilian health systems can cope and that sufficient medical supplies are stocked and secure
6. Resilient civil communications systems; ensuring that telecommunications and cyber networks can function even under crisis conditions, with sufficient back-up capacity. This also includes the need for reliable communications systems including 5G, robust options to restore these systems, priority access to national authorities in times of crisis, and thorough assessments of risks to communications systems
7. Resilient civil transportation systems; ensuring that NATO forces can move across Alliance rapidly and that civilian services can rely on transportation networks, even in a crisis

Figure 3 - NATO's Seven Baseline Requirements (2016) in NATO Chief Scientist Research Report on Resilience

Emerging technologies, including predictive Artificial Intelligence (AI) models, may enhance the analysis of indirect, cumulative and reverberating impacts. However, responsible integration of AI requires significant investment in reliable, high-quality data, as well as robust governance frameworks ensuring transparency, military accountability, and human oversight. The incorporation of complex predictive models, such as simulations of dam failure, into operational platforms remains technically challenging. In addition, predictive models face limitations in data-scarce or rapidly changing environments and risk automation bias. AI tools should therefore complement, not replace, human judgment, and safeguards must be implemented to mitigate automation bias and cognitive overload.

Burnt transformers after Russian shelling of Ukrainian energy infrastructure. Photo by abramovphoto on Adobe Stock.

5

TACTICAL FORESEEABILITY AND THE TARGETING CYCLE

Highly sophisticated computerized systems for conducting collateral damage estimates (CDEs) are employed within several military institutions. These systems are capable of integrating both direct and indirect weapon effects and can serve as important instruments for implementing proportionality and precautions obligations. Their effectiveness, however, depends on the availability of accurate, detailed, and context-specific input data.

CDE tools are particularly suited to operations that allow for extended planning cycles. Their applicability is more constrained in dynamic or time-sensitive contexts where information is incomplete, and decisions must be taken rapidly. Existing methodologies therefore face practical limitations and require adaptability to different mission types, operational environments, and levels of available intelligence. Continuous refinement of institutional CDE processes remains necessary to ensure alignment with operational realities.

Evaluating the effectiveness of CDE presents inherent challenges. While damage caused can often be documented, harm avoided is more difficult to quantify. Demonstrating the preventive value of precautionary decisions requires systematic documentation of targeting choices, rejected alternatives, and the civilian objects preserved as a result. Institutional learning depends on rigorous record-keeping and post-operation review mechanisms.

Data constraints significantly affect tactical foreseeability. Where direct access to urban environments is not feasible, alternative information sources, including satellite imagery, remote-sensing technologies, geospatial analysis, and open-source infrastructure databases, can support assessments. At the same time, national security considerations may limit information sharing, and internal need-to-know principles may restrict data flows across command levels. Disparities in analytical capacity between higher and lower tactical levels further complicate implementation. Ensuring that targeting decisions are taken at an appropriate level, where sufficient expertise and information are available, is therefore essential to maintaining the integrity of proportionality assessments.

Reducing civilian harm serves not only legal compliance but also operational objectives. Preserving essential services may strengthen civilian trust, reduce hostility, and facilitate stabilization. Water systems, in particular, may become a logistical asset in subsequent phases of operations, as advancing forces may depend on functioning systems for sustainment and governance. Secondary and tertiary effects, including the resource burden associated with repairing damaged systems or importing alternative supplies, should therefore be incorporated into tactical decision-making. In some circumstances, adopting protective measures that exceed minimum legal requirements may support long-term military effectiveness.

Environmental considerations must also form part of tactical planning. Freshwater ecosystems and environmentally significant areas may benefit from additional safeguards under international frameworks, including the Ramsar Convention and UNESCO natural heritage designations. Degradation of such areas may produce long-term ecological, reputational, and stability consequences that extend beyond immediate operational objectives.

Strengthening water protection at the tactical level may warrant dedicated institutional capacity. Establishing specialized units responsible for safeguarding water-related infrastructure and ecosystems could enhance expertise, resource allocation, and analytical focus within the targeting cycle. Such units could develop tailored methodologies for assessing water-specific reverberating effects and support commanders in implementing informed decision-making.

6

SCENARIO-BASED PLANNING

Scenario-based planning provides a structured methodology for testing how legal, operational, humanitarian, and environmental considerations interact under conditions of uncertainty. By simulating conflict environments involving infrastructure of both military and civilian significance, such exercises enable planners to explore strategic intent, operational alternatives, and the foreseeable consequences of different courses of action before decisions are taken in real time.

These exercises highlight the complexity of balancing military objectives with the protection of civilians and civilian infrastructure. They demonstrate the necessity of assessing not only immediate direct effects, but also reverberating consequences, including cumulative impacts on essential services, public health, and environmental systems. Scenario-based planning strengthens understanding of how proportionality and precaution must be applied in practice, particularly in relation to the choice of means, timing, and sequencing of operations.

Scenario simulations also expose the operational constraints that shape real-world decision-making. Limited information, uncertainty regarding dual-use status, dynamic control of territory, and difficulty anticipating long-term consequences all complicate legal and operational assessments. By confronting these challenges in advance, military institutions can reduce cognitive burden during actual operations and improve the practical foreseeability of cascading effects.

Importantly, scenario-based planning encourages broader analytical perspectives. Exercises frequently reveal that environmental considerations, such as impacts on river systems, groundwater, or ecosystems, may receive insufficient attention when planning is narrowly focused on immediate humanitarian or military outcomes. Incorporating environmental protection explicitly into scenario analysis supports a more holistic application of IHL and reinforces emerging recognition of ecosystems as civilian objects warranting protection.

More broadly, scenario-based approaches serve as institutional learning mechanisms. They allow armed forces to test assumptions, refine collateral damage estimation methodologies, integrate interdisciplinary expertise, and evaluate communication strategies regarding compliance with legal obligations. When institutionalized, such exercises contribute to stronger preparedness, improved coordination across civil–military structures, and more systematic integration of reverberating effects into operational doctrine.

In this sense, scenario-based planning is not merely a training tool, but a preventive instrument that enhances both operational effectiveness and civilian protection by strengthening anticipatory decision-making before crises unfold.

Urban building reflecting in a water puddle on pavement, showing worn metal storm drain next to infrastructure element. Photo by Bonsales on Adobe Stock.

RECOMMENDATIONS

STATES, MINISTRIES OF DEFENCE AND ARMED FORCES

1. Integrate reverberating effects into operational planning

Ensure that military planning and targeting processes systematically assess foreseeable indirect and cumulative effects of damage to water infrastructure and freshwater ecosystems and integrate the assessments into CDEs and operational risk analysis. Planning needs to anticipate cascading impacts on public health, food production, energy supply, environmental stability, displacement patterns, and operational sustainability. Reverberating effects must be incorporated into collateral damage estimation methodologies and operational risk matrices, (e.g., 'red' to avoid attacks that would predictably deprive a segment of the civilian population of access to water services for a contextually significant period).

2. Embed legal oversight throughout planning and execution

Legal advisers should be integrated at all relevant stages of operational decision-making to ensure consistent application of IHL, including distinction, proportionality, and precautions. Foreseeable reverberating effects on objects indispensable to civilian survival, including water systems, must be explicitly reflected in the assessments of proportionality and precautions.

3. Incorporate technical expertise into targeting processes

Planning cells should draw on interdisciplinary expertise, including engineers, hydrologists, environmental specialists, and public health experts, to assess infrastructure interdependencies and cascading risks. Formalised mechanisms for accessing civilian technical knowledge can improve anticipatory decision-making and reduce unintended harm.

4. Institutionalise learning and post-strike assessment

Operational simulations, scenario-based exercises, and structured post-operation reviews should explicitly evaluate indirect and environmental impacts. Findings should be systematically integrated into doctrine, training, and targeting procedures to progressively refine foreseeability assessments.

5. Integrate environmental protection into operational design

Environmental considerations, including risks to watercourses, groundwater reserves, and ecosystems, should inform the choice of means and methods of warfare. Operational design should account not only for immediate civilian harm but also for long-term ecological and socio-economic consequences.

6. Use technological tools responsibly

Predictive modelling, geospatial mapping, and AI-supported analysis should be employed to enhance infrastructure mapping and risk forecasting. Such tools must complement human judgment and legal review. Decision-makers should account for uncertainty, incomplete data, and potential bias in technological systems.

POLICY-MAKERS AND LEGISLATORS

7. Strengthen doctrine and regulatory frameworks

National defence policies, military manuals, rules of engagement (RoE), and targeting doctrines should explicitly address reverberating effects, protection of water infrastructure, and environmental considerations. Armed groups should integrate the protection of water resources and infrastructure and essential services into their rules, operational guidance and training. Relevant actors could also consider supporting the development of a Deed of Commitment in this area. Clear doctrinal guidance strengthens operational consistency and legal compliance.

8. Preserve civilian character of water systems

Where feasible, responsibility for managing and safeguarding water infrastructure should remain with civilian authorities. Where military protection is required, this alone does not deprive such objects of the protection given to them under IHL. However, such measures should be implemented in a manner that minimizes exposure to attack.

9. Invest in peacetime resilience and preparedness

States should strengthen baseline resilience of water systems before conflict arises, looking at it from a holistic perspective, including the interconnectedness of systems. This includes investing in infrastructure robustness, redundancy, emergency repair capacity, institutional coordination, and civil–military preparedness mechanisms.

WATER AUTHORITIES, INFRASTRUCTURE OPERATORS, AND BASIN INSTITUTIONS

10. Enhance infrastructure mapping and risk awareness

Water authorities should maintain updated mapping of critical infrastructure, interdependencies, and system vulnerabilities. Sharing appropriate technical information through structured coordination mechanisms can support precautionary planning.

11. Develop contingency and continuity plans

Preparedness plans should account for conflict-related risks, including power outages, contamination events, supply chain disruptions, and physical damage. Contingency planning strengthens system survivability under stress.

12. Strengthen civil–military coordination channels

Formal coordination mechanisms between water authorities and defence institutions should be established in peacetime to facilitate rapid communication, deconfliction, and protection measures during crises.

INTERNATIONAL ORGANISATIONS AND DONORS

13. Support capacity-building and technical guidance

International actors should support the development of operational guidance, environmental checklists, and training materials that translate legal obligations into practical planning tools. Capacity-building efforts should prioritise interdisciplinary integration of legal, military, and technical expertise.

14. Promote evidence-based policy development

Further research and data collection on direct, reverberating and cumulative impacts of damage to water systems can strengthen risk modelling and inform policy reform. Evidence-based approaches enhance both operational effectiveness and civilian protection.

Rusty turbine generator. Abandoned destroyed by war and overgrown by plants and moss machinery of Tkvarcheli Tquarchal power plant, Abkhazia, Georgia. Photo by Mulderphoto on Adobe Stock.

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