KAPITEL 8 / *CHAPTER 8* [8]
FLOOD CONTROL CHALLENGES: UNDERSTANDING CAUSES AND EFFECTIVE SOLUTIONS

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Introduction

The ongoing global shift towards urbanization remains a defining trend of our times. From the twentieth century to the present, urban populations have surged tenfold, contrasting with a doubling of rural inhabitants. Today, half of the world's population resides in urban centres, a stark contrast to the less than 15% recorded in 1900, with urbanized areas covering approximately 3% of the planet's total landmass [1]. This urbanization wave significantly influences both the quantity and quality of water resources.

The expansion of urban areas is often synonymous with a proliferation of impervious surfaces, disrupting the natural hydrological equilibrium of these regions. This disruption manifests in a sharp rise in rainwater runoff volumes entering natural water bodies, carrying with it a heightened level of pollutants, thus posing a substantial environmental challenge. Consequently, the regulation of rainwater runoff has emerged as a critical governmental priority in nations such as Australia, Canada, Germany, Japan, the United Kingdom, the United States, and others. The term "stormwater management" has firmly entrenched itself in international scientific and technical discourse [2].

It's crucial to note that stormwater management solutions must be tailored to the unique circumstances of each city, even within the same country or region, as emphasized by analysts. Effective regulation of rainwater runoff not only enhances the reliability and efficiency of drainage systems in urban and industrial settings but also fosters favourable conditions for rainwater utilization while mitigating anthropogenic impacts on the environment. Implementing science-based rainwater management practices not only reduces potential damages but also safeguards drinking water sources from contamination and promotes the judicious use of water resources.

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8.1. Flooding - the state of the problem

Flooding during heavy rainfall isn't limited to specific regions like Europe, Asia, America, or Australia; it's a global issue affecting both developed and developing nations alike. It stands out as one of the most prevalent exogenous geological processes due to its dynamic development and widespread impact. This complex phenomenon primarily affects economically advanced areas, arising from disruptions in water regimes and territorial balances.

The consequences of flooding are multifaceted, leading to adverse changes in geological environments and the intensification of hazardous geological processes. It results in soil erosion, waterlogged territories, and pollution of surface and groundwater sources. Two distinct types of flooding are recognized: anthropogenic and natural.

Anthropogenic flooding stems from disruptions in groundwater balances and moisture transfers within the aeration zone. This disruption is often caused by increased water input, alterations in water exchange within geosystems, or the deterioration of groundwater discharge conditions due to human activities. On the other hand, natural flooding occurs during periods of intense precipitation, elevated water tables in areas with shallow groundwater, and heightened moisture levels in the aeration zone. However, the boundaries between anthropogenic and natural causes are often blurred.

Many local flooding factors have a human-made origin, as highlighted by sources [3, 4]. These factors include:

- Inadequate functioning or absence of stormwater networks and other drainage systems in urban areas.
- Alterations in soil cover conditions.
- Suboptimal operation of protective drainage systems.

Ukraine has a comprehensive legislative framework aimed at preventing flooding. However, the development of regional land flooding in the country is primarily attributed to the imperfect implementation of the basin principle in water resources management. This includes issues such as departmental fragmentation, spatial and temporal inconsistencies in flood protection measures within river basins, and more. Table illustrates the evolving dynamics of flooded areas in cities and towns across Ukraine [4].

Table - Dynamics changes in flooded areas of cities and towns in Ukraine

Administrative unit of Ukraine. Region	The territory was flooded in 1982			The territory was flooded in 1999-2004			Ratio of indicators 1999-2004 to 1982	
	City and town	Village	Total flooding area, 10^3 ha	City and town	Village	Total flooding area, 10^3 ha	City and town	Area of the regional delineation of land flooding
Vinnytsia	4	175	30,2	10	122	89,5	2,5	2,96
Volynska	1	HB*	0,02	11	36	12910,0	11,0	**
Dnipropetrovska	30	124	104,3	43	226	728,5	1,43	7,00
Donetska	10	95	35	42	41	303,5	4,20	8,67
Zhytomyrska	1	HB	0,2	55	HB	1975,9**	55,00	**
Zakarpatska	HB	HB	HB	27	32	302,4	HB	HB
Zaporizka	13	196	72,9	24	32	319,3	1,84	4,37
Ivano-Frankivska	HB	HB	HB	HB	HB	HB	HB	HB
Kyivska	5	18	21,1	23	5	810,7**	4,60	**
Kirovohradska	5	8	1,0	11	HB	14,2	2,20	14,2
Luhanska	38	113	48,1	34	60	16,4	0,89	0,34***
Lvivska	1	8	15,2	17	119	21,7	17,00	1,43
Mykolaivska	8	126	73,5	10	80	1282,0	1,25	17,5
Odeska	35	127	136,9	40	374	1352,0	1,14	9,90
Poltavska	13	292	81,4	22	HB	851,3	1,69	10,45
Rivnenska	HB	HB	0,3	19	17	1279,2**	HB	HB
Sumska	9	13	39,7	20	HB	42,3	2,22	1,06***
Ternopilska	HB	HB	HB	10	80	HB	HB	HB
Kharkivska	17	213	77	32	158	301,9	1,88	3,92
Khersonska	15	111	62,2	19	85	1045,4	1,26	16,85
Khmelnytska	12	HB	1,7	19	1	HB	1,58	HB
Cherkaska	4	47	35,4	8	10	8,0	2,00	0,22**
Chernivetska	14	24	2,6	18	HB	41,6	1,28	16,0
Chernihivska	8	HB	43,2	11	HB	442,6**	1,37	**
Republic of Crimea	11	151	110,8	12	153	442,5	1,09	4,0
Total	**254**	**1841**	**992,7**	**537**	**1631**		**2,11**	

8.2. Causes and factors contributing to urban flooding

Causes and factors contributing to urban flooding can be categorized into two groups: natural and man-made.

Natural factors of flooding include:

Climatic conditions: Precipitation in the form of storms and melting snow plays a significant role. Climate cycles, such as 11-year cycles, influence groundwater regimes, which are interconnected with the atmosphere through the aeration zone. However, the impact of regional climate on urban flooding is not always straightforward, and flooding processes often exhibit azonal characteristics [5].

Relief characteristics: The topography determines the runoff conditions for stormwater and meltwater and influences their infiltration into the soil. Areas with steep slopes and no local depressions facilitate surface runoff. In contrast, low slopes, depressions, and lowlands retain water, promoting infiltration into the soil [5].

Hydrographic network: The density and structure of rivers, streams, and drainage systems significantly impact natural groundwater drainage and subsequent flooding. A sparse, underdeveloped hydrographic network hinders drainage, leading to shallow groundwater accumulation. Conversely, deep depressions and river valleys aid in efficient groundwater drainage [6].

The lowering of the surface in coastal cities due to tectonic movements and earthquakes: This phenomenon can occur gradually over time or suddenly during seismic events. *Tectonic movements:* Slow sinking of the surface can result from ongoing tectonic shifts and movements of the earth's crust. For instance, Venice in Italy is slowly subsiding into the sea due to geological processes. Similarly, in the Netherlands, about 40% of the land lies below sea level due to gradual sinking. *Earthquakes:* Rapid subsidence can occur during earthquakes, causing sudden changes in the surface elevation. Daily seismic activity around Lake Baikal, for example, leads to the sinking of coastal areas and subsequent flooding. In Odesa, Ukraine, the coastal territory is moving towards the sea at a rate of 5-6 mm/year due to various geological factors, including tectonic activity.

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Additionally, earthquakes can trigger an increase in the Groundwater level, raising it by approximately 1-2 meters, exacerbating flood risks in coastal cities. Understanding these geological processes is crucial for developing resilient urban infrastructure and flood management strategies in vulnerable areas.

Man-made factors significantly contribute to urban flooding by disrupting the natural groundwater regime and balance:

Excessive regulation of river flow: Many regions experience a rise in groundwater levels due to excessive control of river flows and inadequate drainage systems. The construction of numerous reservoirs and ponds, especially prevalent in Ukraine with over 1,000 reservoirs and 28,000 ponds built in the latter half of the 20th century, has led to waterlogging and saturation of soils. This has resulted in widespread flooding in large areas.

Siltation of riverbeds: Human activities such as ploughing coastal strips and steep slopes contribute to the siltation of riverbeds. The absence of a well-designed spillway network in urban areas further exacerbates the problem. Inadequate vertical planning of built-up areas can also impede the efficient drainage of stormwater and meltwater, increasing the risk of flooding.

Technical condition of water supply and sewerage facilities: A considerable portion of water supply and sewerage networks have exceeded their standard depreciation period, with over 34,370 kilometers (30%) in an emergency state [7]. This compromised infrastructure poses environmental safety threats to urban areas. High losses of drinking water (30-35%) and wastewater (10-50%) due to network leaks exacerbate water management challenges. Ukraine experiences significant technogenic water losses of 3.6 billion m3/year, whereas the annual domestic water consumption stands at 4.5 billion m3 [8, 9]. Wastewater leakage not only leads to land flooding but also contributes to deteriorating sanitary conditions in urban areas.

Discrepancy between storm sewerage and water supply systems: The lack of synchronization between storm sewerage systems and water supply networks often results in the failure to discharge wastewater effectively during heavy rainfall events, leading to inundation issues.

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Damage and clogging of drainage systems: The malfunction, clogging, and damage to drainage systems designed to prevent flooding in settlements and agricultural areas exacerbate flood risks. Additionally, unauthorized obstructions such as bridges blocking drainage collectors further impede drainage efficiency, as do damages to power lines connected to these systems.

Impeding natural surface and groundwater flow with various engineering communications (railways, roads, gas and oil pipelines, building foundations, etc.) without adequate water-permeable structures, as well as the siltation and pollution of existing ones;

Unauthorized construction in zones influenced by water bodies (rivers, reservoirs, canals) etc. [7, 10];

Presence of extensive areas with hard surfaces that reduce transpiration and evaporation;

Technogenic subsidence of land surfaces;

Flooding of mines, etc.

The wide-ranging and intensive anthropogenic impacts result in significant transformations of the geological environment. Particularly notable is the reconstruction of the underground hydrosphere, as human development of any territory inevitably disrupts the natural conditions of water supply, circulation, and discharge of groundwater, thus disrupting natural water exchange conditions. In urbanized areas, the extent of anthropogenic influence on water exchange is so substantial that practically no territories remain unaffected by disruptions in the natural groundwater regime. The degree of such disruption depends on various factors, primarily the structure of the geofiltration environment, the type of water exchange basin, the depth of underground development, the nature of the construction, and the magnitude of anthropogenic loads [11]. Urban territories are characterized primarily by heterogeneous development, diverse land use conditions, the presence of multifunctional zones such as residential, industrial, green, storage areas, etc., as well as numerous transportation arteries, engineering communications, and agro-industrial complexes. Within each functional zone, there may be specific variations associated with building types (high-rise, low-rise, old, new), engineering network schemes, relief organization, landscaping, and building density. Considering the diversity of the geofiltration structure in urban agglomerations, significant variability in water exchange can be expected. The main anthropogenic factors affecting the state of the underground hydrosphere within urban territories include infiltration losses of water from domestic and industrial sources, increased underground drainage due to artificial dewatering and water intake for domestic and industrial purposes, and the engineering development of territories and underground spaces. The underground space within developed areas is part of a natural-technical system.

8.3. Enhancing Resilience: Engineering Solutions for Urban Flood Management

Flood control strategies can be broadly categorized into two key approaches: preventive measures and remedial actions to address existing flooding. The pivotal challenge in flood control lies in selecting the most effective measures tailored to specific circumstances.

Preventive measures aim to avert the onset of flooding in developed areas by addressing potential factors that may contribute to flooding during construction and subsequent operations. Anthropogenic conditions often serve as the primary sources of groundwater influx, contributing significantly to the flood process. Research has indicated that flooding can begin as early as the initial construction stages [5, 12-15], such as during land preparation (vertical planning, road construction altering natural runoff patterns, excavation works like pits and trenches, temporary water supply installations, etc.).

As construction progresses, including the installation of permanent underground utilities and stormwater drainage systems, and during ongoing facility operations, disruptions to the hydrogeological conditions intensify, exacerbating flood risks.

Optimizing Groundwater Levels in Urbanized Regions through Engineering Techniques:

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– Diversion of Surface Runoff: Implementing strategies to redirect a portion of surface runoff into stormwater drainage systems, preventing excessive groundwater accumulation.

– Utilizing Municipal Water Intakes: Operating municipal water intakes to utilize pumped water for technical purposes, thereby reducing groundwater levels.

– Employing Water-Reduction Devices: Utilizing specialized devices designed to reduce water levels effectively, contributing to groundwater management.

– Regulating Rainwater Runoff: Employing advanced practices such as rainwater storage and regulation tanks, filtration systems, green roof installations, permeable coatings, bio-ponds, and artificial wetlands to manage rainwater runoff. These techniques help in temporarily retaining rainwater, filtering it into the ground, or utilizing it for non-potable purposes.

– Mitigating Infiltration: Addressing infiltration issues by minimizing impermeable surfaces like buildings and asphalt. Urban areas often have high development density, with up to 90% coverage by pavements in certain zones, contributing to rapid runoff and groundwater recharge.

– Special Measures for Flood Prevention: Based on predictive assessments, appropriate measures should be implemented in both developing and developed urban areas to proactively mitigate potential or ongoing flooding risks.

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Conclusion

The issue of flooding has long been a concern, but its severity is amplified in the current era of ongoing climate change. This work delves into the complexities of flooding, highlighting the cause-and-effect dynamics and shedding light on the growing flood-prone areas in Ukraine. A comprehensive analysis has been conducted, examining both natural factors like climatic conditions, terrain features, and hydrographic networks, as well as human-induced factors such as riverbed silting and the subpar technical condition of water supply and drainage systems.

One of the most promising strategies to combat flooding is the regulation of rainwater runoff across entire basins, adopting the concept of a "sponge city" where rainwater is effectively managed where it falls. While this approach is highly effective, its widespread implementation is hindered by cost constraints, presenting a challenge for our country at present.

The article thoroughly explores various methods of rainwater regulation, emphasizing techniques such as accumulation, temporary retention, and soil filtration. The array of available methods aims to maximize rainwater infiltration into the soil, promote on-site storage, or facilitate collection in engineered structures. These approaches represent crucial steps towards mitigating the impact of flooding and fostering sustainable water management practices.

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