

DEVELOPMENT OF AREAS BY THE VISTULA RIVER IN WARSAW IN THE CONTEXT OF FLOOD ISSUES AS AN EXAMPLE OF ADAPTATION TO CLIMATE CHANGE

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ABSTRACT

In Warsaw, measures are taken to safeguard the city against dangerous, extreme natural phenomena. These measures include mitigating the urban heat island phenomenon, protecting against storms, floods, and preventing the low water level in the Vistula river (the ADAPTCITY project). The following article concerns the development of the Vistula areas in Warsaw in relation to the risk of flooding. The article discusses the first comprehensive concepts for the development of areas on the Vistula in Warsaw, which have been in progress since the second half of the 19th century. The article presents flood prevention measures in the area of Warsaw. An example Warsaw district located on the banks of the Vistula, namely Białołęka, was characterized, as the area is at risk of flooding. The case study covered new housing estates being developed in the flood plain area of Białołęka.

Key words: flood plains, Vistula, Warsaw housing estates, flood control

INTRODUCTION

Rivers had always exerted a significant influence on the formation of cities. The proximity to water offered a number of utilitarian benefits, thanks to which the development and prosperity of the area were possible. From the point of view of an architect or an urban planner, a river provides a strong bond that crystallizes city space. It shapes the surroundings in the closest proximity of its impact, and in its own way, it imposes a specific structure on city parts (Pancewicz, 2004). Nowadays, it is a challenge for developing cities to face climate change, together with violent natural phenomena, e.g. floods that accompany it, as can be observed in recent decades. Actions are taken to adapt the functioning of the municipal structure and buildings to new water

conditions (ADAPTCITY project). Currently, the process of developing flood plains is progressing on an increasing scale. This phenomenon is intensifying and leads to the creation of numerous housing estates in flood-prone areas.

The article is aimed at presenting the development of the Vistula river, as well as examples of residential building investments within flood plains. The discussed issue is set in the context of the capital's flood control, which provides one of the priorities in the light of adaptation to climate change. This subject is rarely addressed in the source literature, as flood-related problems are a relatively new issue in the field of research on architecture. Studies on the methods to design architecture and landscape in flood risk areas are scarce, despite the issue being of topical, important and complex nature. Research results obtained

from case studies conducted in city district Białołeka are presented in this article, in order to fill the existing cognitive gap.

THE VISTULA AND FLOODING

The Vistula valley acts as a wildlife corridor that enables biodiversity to occur at the scale of Europe. The valley connects the north with the south and the east with the west in terms of migration of fauna and flora. The central section of the Vistula consists of a wide, freely meandering river, the characteristic features of which include: high banks, sandy beaches, oxbows, islands (Duda-Gromada, 2007 quoted after: Andruszkiewicz, 2007; Angiel, 2011). The Vistula flows through Warsaw along a distance of 28 km. The river is characterized by significant differences in the levels of the water surface, namely of up to 7 m. Since the beginning of the 20th century, the river bed has lowered by about 220 cm and it continues to lower in the aftermath of each flood wave. Nowadays, the Vistula waters flow at an altitude lower than they used to. This poses infrastructural and urban-planning problems, as well as prevents tourist shipping (Maciejewska, 2018). Varsavianists Lech Królikowski and Marek Ostrowski believe that the instability of the river bed and the destruction caused owing to floods provided an important factor that shaped the spatial development of the city, both on the escarpment and in the Vistula valley – in area of Powiśle (Królikowski and Ostrowski, 2009). The beginnings of settlement in the area of today's Warsaw date back to 14–8 millennium BC (Królikowski and Ostrowski, 2009). The first settlements were densely established on the right bank of the Vistula, on the highest dune landform in town Otwock. According to prof. Andrzej Zahorski, in the 10th and 11th centuries in the north of Warsaw, today's Bródno Stare, by the Brodnica stream, a gord was established that can be considered the first trace of administrative organization in these areas. The original traces of settlement also include Jazdowski Gord) and the gord in Służew. Neither the aforementioned gords, nor the later medieval ones that served as watchtowers on the right bank of the Brodnica river, influenced the foundation of the city. Warsaw was established as a result of a decision-making act.

According to current forecasts, the water level in the Vistula is defined as a 20-year flood (Trzaska, 2010). This term stands for the probability of a flood to occur in a given area every 20 years. Over the last several decades, flood stages have occurred in the upper Vistula region almost every year. The highest water stages took place in 1970, 1997, 2001 and 2010. The problem of flooding, although most significant in the southern part of the river basin district, also affects other parts of the Vistula. High water stages resulting from precipitation and snowmelt on the upper Vistula cause a flood wave along the entire river course. Rybczyńska-Szewczyk (2014) states that it should constitute a priority of local and regional authorities responsible for Poland's water management to strive at increasing flood control in the Vistula basin area while maintaining the principle of respecting ecosystems.

DEVELOPMENT OF THE VISTULA AREAS IN WARSAW

The natural values of the Vistula valley are considered unique in Europe. Within Warsaw, the valley is asymmetrical – its right bank is flat, while the left bank is high. This layout largely determines the way the banks of the Vistula are developed (Duda-Gromada, 2018). Until the second half of the 19th century, when the first comprehensive concepts for the development of the Vistula areas began to emerge, the course of the river was not yet straightened. The initial Vistula development plans shared the common feature of combining the necessary flood protection measures with making the Powiśle area available for the planned development. The industrial, poor area of Powiśle, given its difficult access to the city center, remained underdeveloped due to the Vistula waters flooding that occurred on a nearly annual basis and to the financial loss it generated. A schematic outline of the Vistula area development and implementations is shown in Table 1.

In the aftermath of the flood that hit Warsaw in 1819, the Government Commission resolved to create fortifications on the west bank of the Vistula. The construction of the boulevard in Tamka Street was interrupted by the November Uprising, thus the land was

Table 1. The Vistula area development (own elaboration based on Duda-Gromada, 2007; Stefanowska, 2012)

Period	The Vistula area development projects
1819–1841	Fortifications to the west shore, construction of a boulevard in Tamka Street, a stone boulevard to Solec.
1904	Construction of Czerniakowski Port, the first river port in Warsaw.
1916	<p>River course straightening plan – under the direction of Tadeusz Tolwiński</p> <ul style="list-style-type: none"> – General regulation of the Vistula within Warsaw and outside the city. – Linking inland navigation and rail transport. – Creation of the main reloading port on the right bank near Golędzinów and two smaller ports: near the Citadel and Żerań.
1925–1928	Construction of flood embankments: Siekierkowski, Potocki, Golędzinów–Pelcowizna–Żerań embankments and the embankment between Kierbedzia Bridge and the railway bridge on the Praga side of the Vistula.
1936	“Warszawa frontem do Wisły” (“Warsaw facing the Vistula [own trans.]”) – an initiative of Stefan Starzyński, the President of Warsaw.
1945	<p>Sketch of the plan for central districts by the municipal assembly Warszawski Zespół Miejski</p> <p>The Vistula valley from the Vistula escarpment to the flood plain on the right bank of the river was to remain recreational green areas.</p>
1955–1965	<p>General plan for 1955–1965 – under the direction of Józef Sigalin and Stanisław Dziewulski</p> <p>Development concepts in Powiśle together with the culture park Centralny Park Kultury i Wypoczynku in Powiśle Południowe and green areas near the 10th-Anniversary Stadium.</p>
1963–1975	<p>The Vistula program</p> <p>Regulation and cleaning of the water cycle in connection with the overall water management of the country.</p>
1982	<p>Perspective spatial development plan for the capital city of Warsaw – 1982</p> <ul style="list-style-type: none"> – In the area of Śródmieście – from Czerniakowski Cape to the Citadel, the Vistula shoreline was to be shaped in the form of concrete steps 40 × 100 cm to a low boulevard 30 m wide and 5.4 km long. – On the right bank, a similar lay of the land was to be introduced in Praga (2.5 km long). – Hydrotechnical works and inland navigation – 1982.
1992	<p>Plan of 1992</p> <p>The arrangements for the river were intended to protect the natural character of the Vistula valley. Apart from Śródmieście, the Vistula was included in the ecological zone, which was to be prohibited from implementing residential and industrial buildings.</p>
2009	Development project for the left-bank Vistula boulevard.

eventually strengthened in 1841. It was then that the stone boulevard was opened from Solec to the point at which the Kierbedzia Bridge was later built. In 1915, a year after the outbreak of the World War I, Warsaw, previously occupied by the Russians, went under German occupation. In 1916, the Germans restored self-government to the city and enlarged the city area by more than threefold.

Along with the increase of the capital city area, architectural association Koło Architektów, under the

direction of Tadeusz Tolwiński, drew up a river regulation plan. In addition to the proposed innovative concept of green wedges in the city, the following postulates were mentioned in the chapter entitled *Vistula*: general regulation of the Vistula within Warsaw and outside the city, the connection of inland navigation and rail transport, the creation of the main transloading port near Golędzinów on the right bank of the Vistula, and the creation of two smaller ports: one near the Citadel and the other in the vicinity of Żerań. In 1925, the

construction of flood embankments was commenced. In 1928, the embankments of Siekierkowski, Potocki, Golędzinów–Pelcowizna–Żerań, and the embankment between the Kierbedzia Bridge and the railway bridge on the Praga side of the Vistula, were built (Duda-Gromada, 2007).

In 1930, the Warsaw City Council adopted the general plan for the development of the city, which contained: “dolina Wisły jako wielki miejski wentylator” (“the Vistula Valley as a city fan of greenery [own trans.]”). Air masses from the Vistula were to reach residential quarters through green wedges. New roads and water facilities were planned, such as the port in Żerań and the Wisła–Bug Canal stretching from Żerań to Małkinia, as well as the port in Saska Kępa. Between 1934 and 1939, during the presidency of Stefan Starzyński, the idea of restoring the Vistula to the inhabitants of Warsaw first emerged. “Warszawa frontem do Wisły” (“Warsaw facing the Vistula [own trans.]”), the program announced by the president of Warsaw, was aimed at making the riverbanks and the Vistula itself a resting and recreation area for the inhabitants of Warsaw. These plans, only partially implemented, were thwarted by the outbreak of the World War II. Once the war was over, the river was teeming with life mainly due to passenger and cargo shipping. However, since the 1970s, it lost its connection with the city and its inhabitants. Warsaw “turned its back” on the Vistula (Karczewski, 2017).

By the end of the war, in March 1945, shortly before the liberation, a plan for the central districts by municipal assembly Warszawski Zespół Miejski was drawn up, March 1945, under the supervision of Zygmunt Skibniewski, an architect. The entire Vistula valley from Vistula escarpment to the fluvial terrace on the right bank was to be retained as areas of greenery. Development concepts regarding the Powiśle area, together with the creation of the culture park Centralny Park Kultury i Wypoczynku in Powiśle Południowe, and with areas of greenery near the 10th-Anniversary Stadium, were introduced 10 years later under the provisions of the general plan for 1955–1965 – under the direction of Józef Sigalin and Stanisław Dziewulski.

The Vistula program, developed in 1963–1975, was aimed at regulating and cleaning the water cycle

in connection with the overall water management of the country. The main assumption was based on the concept of cascading the river along its entire length. A total of three cascades and eight dams on the Vistula were to be built. The Vistula waterway obtained due to cascading was to be about 900 km long. The main purpose of damming was to obtain parameters proper for a navigable route. The project implementation was commenced from 1963 to 1970 with the construction of a complex in Włocławek. The subsequent assumptions, however, were not implemented. Economic problems that hit Poland in the 1970s forced the authorities to abandon the planned project.

According to prof. Aleksander Tuszko, the cascaded Vistula in the capital was to contribute to the creation of lake district called Pojezierze Warszawskie, an extremely attractive area for the city and its inhabitants, based on the buffer zone of the Kampinos National Park, Zegrzyński Reservoir, including Żerański Canal (Tuszko, 1979). Water reservoirs were to be created next to the river steps, and new spatial and landscape solutions would be implemented together with them. It was back then that critical opinions on the project began to appear. Professor Andrzej Kostrowski claimed that small retention and a well-planned network of canals would bring greater benefits than massive hydrotechnical undertakings (Kostrowski, 1979). This opinion refers to the current directions of water management that consist in restoring the natural character of the river and adjacent areas, creating retention, which in turn reduces the risk of flooding.

Perspective spatial development plan for the capital city of Warsaw of 1982. It included three main issues concerning the Vistula valley: hydrotechnical works, general development program and navigation. Recreation was to be the main strategic function of the river. Until 1990, the plan provided for full regulation of the river with the help of spurs and navigable dams, so that the navigable waterbed would amount to 225 m. The plan included the formation of a shoreline, 400 m in width. In the area of Śródmieście (from Czerniakowski Cape to the Citadel), the Vistula shoreline was to be shaped in the form of steps made of concrete, 40 × 100 cm, to a low boulevard, 30 m in width and 5.4 km in length. On the right bank of the

Vistula, a similar structure was to be built in the Praga (2.5 km long). The width of the embankment area in Śródmieście was supposed to equal 450–500 m and 600–900 m in the northern and southern parts of the city.

The Plan of 1992. The arrangements related to the river were made in order to protect the natural character of the Vistula valley. Apart from the Śródmieście area, the Vistula was included in the ecological zone, which was to be banned from having residential and industrial building development implemented.

Development project for the left-bank Vistula boulevard. Works on the development of the boulevard began in 2009. The contest for the project was won by the concept developed by the RS Architektura group. The project concept assumed that the composition of the left-bank boulevard would consist in a system of squares and linear connectors, along with a promenade intended for pedestrian traffic, bicycle paths, park greenery and fountains. The design tasks also included the modernization and reconstruction of the Vistula waterfront along a section of almost 2 km, together with its adaptation for the needs of ship mooring. The concept also included the introduction of a marina and water bus stops, as well as an artificial beach for recreational purposes. At the promenade, service pavilions, cafes and galleries, as well as an observation deck, were to be constructed. In the summer of 2015, the first stretch was opened. In September 2017, an architectural and urban competition for the third stage of the Warsaw boulevards from Świętokrzyski Bridge to the Czerniakowski Cape was held. The project was won by the WXCA Architectural Studio. According to the design by the WXCA Studio, a vision of a beautiful river bank is to be implemented, with lots of greenery, though also marked with some rather futuristic development. Moreover, an apartment-hotel complex, cultural and sports facilities, and a conference space on the Vistula, are to be created. Construction works on this stage have been commenced in 2019. The boulevards are supposed to be put into use in 2020.

Over the past, at least 100 years, various development plans for the Vistula in Warsaw have emerged. The motto “Warszawa frontem do Wisły” (“Warsaw facing the Vistula [own trans.]”) is being implemented

slowly and fragmentarily, despite the fact that the vision of beautiful parks, new recreation areas and housing estates by the water is attractive. Additionally, flood control is an important issue that must be implemented simultaneously.

FLOOD PROTECTION ACTION IN THE AREA OF WARSAW

A total of 1,790,658 inhabitants inhabit Warsaw (Główny Urząd Statystyczny [GUS], 2020), and the population density equals 3,461.9 people per 1 km², (GUS, 2020). These data translate into a dynamically developing housing market. In order to meet the needs expressed by clients, developers are looking for new, attractive investment areas in parts of Warsaw that have not been developed so far. The development of flood plains in the proximity of the Vistula has proven to be a response to the growing demand for apartments in a good location close to the infrastructure center and at a good price. New housing estates are being introduced in flood risk areas, the fact of which is far from new in Warsaw, since most of the city (Wilanów, Sadyba, Powiśle, Praga, Saska Kępa) was built on flood plains (Maciejewska, 2020). The flood embankments provide the main stronghold of security measures, as according to experts, in case of emergency, they can be blown up in the outskirts of the city. The problem arises when high water levels persist for several days. In such a situation, water seeps through the embankment or under it, which results in flooding – the presence of water in underground garages and basements. In 2010, the water level in the Vistula exceeded the emergency level (that is 650 cm) by 129 cm (Bezpieczna Warszawa, 2010). Under such pressure of the water, the embankments began to seep through. The embankments are not the only flood protection measure, though. In the public consciousness, however, they seem the most synonymous with protection against great flood. The Vistula embankments are approx. 5 m high, whereas in Warsaw, they are higher – approx. 6 m. For the water from the Vistula to overcome the embankments in Warsaw, the flood wave would have to reach 8.5–9.0 m in height. Old embankments are at the greatest risk of breaking. Bushes, trees and various obstacles are also

regularly removed from the Warsaw embankments. In 2010–2017, the expenditure on flood control in the capital was to amount to PLN 40 million. According to Dr Piotr Kuźniar, a hydrologist from the Warsaw University of Technology, the most sensitive points in Warsaw include the zoo area, where the embankment is very low, and the flood gate at Praski Port.

In Warsaw, activities that consist in adaptation to climate change are conducted under the LIFE+ program. The most urgent task is to adapt Warsaw to the challenges resulting from excess rainwater. In addition to large projects, such as introducing water reserves along the Wiślostrada, the main emphasis is placed on small retention, increasing the permeability of surfaces, as well as supplying urban greenery with water from retention or green roofs, such as the ones implemented in the Copernicus Center. The abovementioned activities are very important, as the sewage system in Warsaw, built in the 19th century, faces problems with draining rainwater. William Lindley, the creator of this system, designed it in a combined sewer system model, i.e. sewage and rainwater are transferred through one outflow. It is unrealizable to separate these two systems today. The siphon under the bottom of the Vistula that transfers water to the "Czajka" sewage treatment plant has a limited capacity and is not capable of handling a large amount of rainwater that is channeled into the sewage system (Żakowska, 2016). Infrastructure is also being designed to solve the problem of flooding in the southern part of the city, namely in Wilanów. Flooding in this part is related to the Służewiecki Stream, which is responsible for draining 10.5% of the city's area (water from Mokotów, Ursynów, Włochy and Ochota). Further, under Przyczółkowska Street, there is a culvert, which periodically receives four times more water than it should. As a result of this bottleneck, damming of water occurs, which leads to flooding in the area.

The activities that influence flood control in the capital city include the project for the restitution of meadows on the Vistula, conducted in 2014–2016 by city property board Zarząd Mienia m.st. Warszawy in cooperation with the Faculty of Biology, the University of Warsaw. Thanks to this program, a total area of 67 ha of the Vistula section in the following districts: Białołęka, Praga Północ, Praga Południe,

Śródmieście, Mokotów and Wilanów, had the proper, diverse species composition of flood plain meadows restored. Activities undertaken under this project are intended to increase the retention of flood plain meadows by the Vistula and contribute to the increase in the attractiveness of recreational areas by the Vistula. Concerns have been made regarding the lack of legal rules that the city should adhere to when establishing building development conditions in flood-prone areas. Regulations in this regard have been provided by the 2017 Water Law, according to which the prohibition of building development is in force in areas with a high risk of flooding (Ustawa z 2017 r. – Prawo wodne). These provisions can be verified on maps in the IT system for protecting the country against emergencies (Polish acronym ISOK).

BIAŁOŁĘKA DISTRICT – CASE STUDY

The case study covered new housing estates in flood plains in Warsaw in the Białołęka area (Table 2). The examined housing estates are fenced, in a nest-like layout or in the form of a building development quarter. The specific climate of the estate is influenced by spatial solutions, the body of buildings, their dimensions and distances between them, the choice of materials and the solution related to greenery and elements of urban architecture within internal courtyards. In the comparative table below, categories, e.g. regarding the development of the building in the context of flood risk, the pros and cons of the investment, have been listed. Here, we should describe the analyzed material and the methods applied.

Białołęka is the northern right-bank district of Warsaw. Like other Warsaw districts on the right bank of the Vistula, Białołęka is located just above the Vistula higher water levels, in areas with high groundwater levels. In the past, these areas were swampy or consisted of the remains of a postglacial ice-marginal valley, down which glacier waters used to run. Right-bank Warsaw is drained by a few rivers. Their catchment area has been developed in the process of urbanization. Thus, it releases water at a gradually more rapid pace (Kucińska, 2015). Białołęka is fortified with flood control. Between the Żerański Port in the south of the district and the Vistula,

a double-sided floodgate has been built in order to stabilize the water surface. The floodgate's chamber measures 85×12 m, with a length of 104 m and, until recently, it was the second-largest facility in the world in terms of its size and type. The construction of Żerański Canal that connects the Vistula with the Zegrzyński Reservoir was started in 1919 and stopped in 1920. It was continued after the war was over. In 1963, the canal was put into use and is still used today. The bottom of the floodgate and of the canal to the Vistula is at the ordinate level of 74.5 m, which is about 2.5 m lower than the lowest water level in the Vistula (Szymańska, 2014).

The channel is of great local importance. It serves as a valued recreational area, both in terms of water sports and hiking-cycling tourism. One of the most popular cycling routes in the capital city runs along the canal, connecting Warsaw with Zegrze and Nieporęt. Moreover, the second-largest combined heat and power plant (CHP) in Warsaw is located in Żerań. Due to the discharge of technological water from the CHP plant to the port, the water in the canal is warmer than the one in the Vistula, which affects the population of fish. Żerański Canal is, thus, appreciated by anglers. Plans have been made to build a high-pressure gas pipeline along Żerański Canal, which involves the felling of several thousand trees. Despite the residents' opposition, the construction is to take place, and the compensation measures will include new plantings and revitalization of the area.

Białołęka is a very dynamically developing district. Many housing estates are being built here. However, the urban infrastructure has not kept pace with the newly emerging development investments. Investments under study (Table 2): Nadwiślańskie Housing Estate (Osiedle Nadwiślańskie), and Atal Marina I in Białołęka are located at Żerański Canal. These are fenced estates, which, however, can be circumvented from the canal side and a closer look at urban interiors and the ongoing life may be taken.

Both housing estates are medium-high rise building developments (4–5 storeys). They are fitted with underground storeys. Nadwiślańskie Housing Estate is a quiet, classic residential architecture, with an interestingly rimmed triangular corner right at the entrance to the estate. The buildings are painted white,

with wooden windows and doors. From the side of the Żerański Canal, the inhabitants are provided with small terraces at the ground level, which rises here in the form of an escarpment.

On the other hand, Atal Marina I stands in opposition to the aforementioned housing estate. This residential complex cannot be passed by indifferently. The complex of five Atal Marina I buildings has irregular balconies supported by diagonal poles. The design relates to the dynamics of water, waves, and also to ship masts and rigging. In the part facing the road and facing Żerański Canal, the balconies are supported with poles. The complex also includes terraces at the ground level. Wood, darker plaster and glass balustrades were used to complete the facade. A risk of groundwater approaching the area exists. During excavation works for other investments, dampness was observed in the garages of Atal Marina I. Both housing estates are located on escarpments. To get to the water surface, one needs to cover a difference ranging from one meter to several meters. The partially elevated ground floors in both housing estates can be considered a protection against high water. Embankments have been designed in Nadwiślańskie Housing Estate. Atal Marina I is also slightly backfilled, whereas the cascading lay of the land descends towards the canal. Owing to the floodgate at the inlet to the canal, a stable water surface level is maintained.

The area of new multi-family investments at the Żerański Canal is exposed to a 100-year flood, namely the probability of high water occurrence is 1%. The bottom of the floodgate and of the canal leading to the Vistula is at the level of 74.5 m, which is about 2.5 m lower than the lowest water level in the Vistula. Therefore, the area of the studied housing estates in Białołęka in the area of Żerański Canal can be considered relatively safe in terms of flooding. The inhabitants of this area complain more about the poor road infrastructure, the planned high-pressure gas pipeline to run in the vicinity of their estates, and the progressive felling of trees, which drastically changes the natural character of the area. Despite the quiet, tree-covered surroundings and relatively distant main roads, traffic noise that reaches the estate from the waterway side is louder than that from Krzyżówka Street.

Table 2. Designing architecture and flood protection measures of Warsaw housing estates in flood plains (own study and elaboration)



Fig. 1. Nadwiślańskie Housing Estate – escarpment overlooking Żerański Canal (photo by E. Maciejewska)



Fig. 2. Nadwiślańskie Housing Estate – terraces on the embankment (photo by E. Maciejewska)

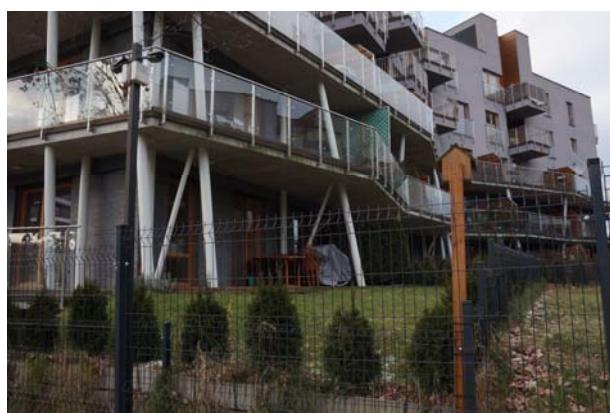


Fig. 3. Atal Marina I – balconies and terraces (photo by E. Maciejewska)

Nadwiślańskie Housing Estate (Figs. 1–2)	
location: Białołeka, Krzyżówka Street	
implementation: 2013–2016	
structure type:	complex of 5 buildings
overground/underground storeys:	4/1
residential premises:	163
area of premises:	from 30 to 137 m ²
flood risk:	100-year flood, 50 m from Żerański Canal
Advantages (+)	Disadvantages (-)
– ground floors elevated above ground level	– proximity to the cement production plant, power plant and Polfa Warszawa plant
– gardens, partial embankments	– view of the Stołeczne Przedsiębiorstwo Energetyki Cieplnej (currently Veolia Energy Plant)
– building setting above the groundwater level, standard foundation	– no ground parking spaces
– floodgate to stabilize the water surface	
Atal Marina I (Fig. 3)	
location: Białołeka, Krzyżówka Street	
implementation: 2012–2014	
structure type:	
overground/underground storeys: 4–5/1	
residential premises: 178	
area of premises: from 31 to 89 m ²	
flood risk: 100-year flood, 50 m from Żerański Canal	
Advantages (+)	Disadvantages (-)
– low embankments	– problems with water in garages occurred as excavation works for another investment started
– the building setting above the groundwater level, standard foundation	– planned construction of a high-pressure gas pipeline in the vicinity
– floodgate to stabilize the water surface	– dampness in garages
– the estate has a terraced lay of the ground, which is favorable for surface runoff	
– unusual architecture referring to nautical style	
– irregular terraces mounted on steel poles imitating tree trunks/yacht masts	

CONCLUSIONS

Having analyzed the data on newly built housing estates in Białołęka, Warsaw, it may be concluded that the buildings are shaped in a manner that is typical of this type of facilities in other parts of the city. However, local conditions and limitations were taken into account, such as elevated ground floors, partial embankments, and the cascading lay of the ground in the interiors of the housing estates that allow water runoff. Nevertheless, groundwater still seeps into cellars, while the resulting moisture leads to the formation of mold. The problem of new Warsaw estates, which also applies to complexes located in flood plains, is related to the insufficient quality of the road infrastructure. A shortage of exit roads and surface parking spaces may be noticed. With increasing vehicle traffic, unmodernized roads in flood plains burst, and damage occurs. In the long run, the increasing intensity of housing development in flood plains will also exert a significant impact on the reduction of biologically active areas. Without reservoirs of areas that can absorb excess water, such as green roofs, ponds, permeable sidewalks, runnels and absorbent basins, undesirable flooding will occur.

The situation in riverside areas is changing dynamically with the current climate changes in various contexts, such as spatial and functional, aesthetic and cultural. The development of riverside areas and flood risk areas is becoming an important planning challenge. All over the world, the process of cities “turning towards” the river is gaining more and more importance and many investments are undertaken, often of a very wide range and diversification (Duda-Gromada, 2018). Areas once treated marginally have been gaining in value for several decades (redevelopment of city waterfronts (e.g. London’s Docklands or HafenCity in Hamburg). An analysis of the water issues, including risk and possible scenario assessment, should always precede further design decisions. In Great Britain, one in six new homes is located in a flood-prone area, which provides an enormous challenge for architects, urban planners, engineers and authorities in the face of the current challenges posed by climate change.

Warsaw is yet another city where measures are taken to adapt the city to dangerous natural phenomena such as floods, flooding or counteracting low

water level in the Vistula. Detailed strategies are included in the ADAPTCITY project, in force in the capital city since 2019. Concerns have been raised of no legal rules that the city should follow when establishing development conditions in areas at risk of flooding. Regulations in this regard were provided by the 2017 Water Law, according to which the prohibition of building development is in force in areas with high flood risk, to be verified by checking ISOK maps. In Warsaw, where inhabitants have experienced the effects of floods more than once, a need arises for further research in the area of adaptation to extreme weather phenomena. The issue poses an important and current problem.

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ZAGOSPODAROWANIE TERENÓW NAD WISŁĄ W WARSZAWIE W KONTEKŚCIE ZAGADNIEŃ POWODZIOWYCH JAKO PRZYKŁAD ADAPTACJI DO ZMIAN KLIMATU

STRESZCZENIE

W Warszawie podejmowane są działania mające „uodpornić” miasto na niebezpieczne, ekstremalne zjawiska przyrodnicze, do których można zaliczyć ograniczenie miejskiej wyspy ciepła, zabezpieczenie przed nawałnicami, powodziami, a także przeciwdziałanie niskiemu stanowi wody w Wiśle (projekt ADAPTCITY). Tematyka artykułu dotyczy zagospodarowania obszarów nadwiślańskich w Warszawie w kontekście problemu zagrożenia powodziowego. Przedstawiono pierwsze kompleksowe koncepcje zagospodarowania terenów nad Wisłą w Warszawie, które powstawały od drugiej połowy XIX wieku. W artykule przedstawiono działania przeciwpowodziowe na obszarze Warszawy. Scharakteryzowana została przykładowa dzielnica nadwiślańska – Białoleka, gdzie występuje ryzyko powodziowe. Studium przypadków objęte zostały nowe osiedla powstające na obszarze zalewowym na Białolece.

Słowa kluczowe: tereny zalewowe, Wisła, warszawskie osiedla, ochrona przeciwpowodziowa