



Living in the flood plains in Warsaw

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ABSTRACT: Formation of cities was always dependent on water. Location over the water areas gave the opportunity for development and increase of prosperity. And although water was also a threat and cause of damage, the benefits of its neighborhood prevailed. Today, the challenge for developing cities is a climate change observed in recent decades, which results in violent natural phenomena, e.g. floods and hurricanes. One of the main problems faced by residents of housing estates located on the water is the increasing risk of flooding. Actions are taken to adapt the functioning of the urban structure and buildings to new water conditions. Currently, the process of floodplain development is progressing on a larger scale. This phenomenon is intensifying and as a result many housing estates are created in areas exposed to flooding. The approach to flood issues in the context of architecture and spatial planning has evolved in recent decades. The new water paradigm is expressed in striving to keep it in place.

How did the settlement in the floodplains look once and today in Warsaw? The research study was preceded by a historical feature and then the article drew attention to the ways of shaping new housing estates in flood areas in Warsaw. Using the case study method, new housing estates developed in the flood plains have been analyzed, with a listing of their strengths and weaknesses and the assessment of solutions. Issues were discussed on how to protect the buildings from the harmful effects of water. On the basis of the conclusions from the Warsaw case study, project guidelines for floodplains in Warsaw were developed, the aim of which was to identify the most important priorities in the development of floodplains and increase the security of investment arising in these areas.

Key words: flood plains, flood defense, Warsaw housing estates, waterproof architecture

1 DEVELOPMENT OF FLOOD PLAINS IN WARSAW AS A RESEARCH PROBLEM

The article is an attempt to present the specificity of flood plains in Warsaw and new housing estates built in these areas. The research study was preceded by a historical feature and then the article drew attention to the ways of shaping new housing estates in flood areas in Warsaw. New housing estates emerging in the floodplain areas (Mokotów, Wilanów) in Warsaw were analyzed using the case study method, listing their strengths and weaknesses and assessing solutions. Aim of this study was this study was demonstration that erecting buildings in floodplains is possible using appropriate solutions protecting the building against harmful effects of water as well as proof that flood plain development is closely related to urbanization and this process is ongoing. Based on the conclusions, design guidelines for new estates in flood plains were drawn up.

2 INTRODUCTION

Built environment globally is vulnerable to natural disasters, which are increasing due to the impact of socio-economic development, land use development and changes in climate condition [Ezeokoli et al. 2019]. Since the 1960s, the footprint of the world has increased 2.5 times and it is expected that this indicator will continue to grow due to population growth and consumption [Feyen et al. 2019]. Although architectural and water connections have existed practically always, these dependencies are now intensifying on an incredible scale. Professor Lucyna Nyka writes: "This is the first attempt carried out to such an extent to cross natural-built borders, architecture - water and to highlight the many benefits resulting from such mutual opening." [Nyka 2012]

Nowadays, the occupation of available flat land within flood plains remains an enticing option for a growing population [Garcia & Loáiciga 2014]. Over half of the world's wetlands were intentionally drained for agriculture by the 1990s [Watson & Adams 2011] and since 2014 more than half of the human population lives in urbanised areas [United Nations, 2015]. The growth of urban areas imposes great pressure on the environment; therefore, proper management of the city and its ecosystem needs to be a part of modern city planning [Markiewicz 2015]. Although the 21st century is heralded as the age of water scarcity, flood losses continue to grow [Kundzewicz & Kaczmarek 2000]. By experts [Majewski 2007, Kowalczak 2011] disasters related to extreme hydrological and meteorological phenomena taking into account the upward trend. The current scale of anthropopressure, i.e. the total human impact on the natural environment, raises many new problems and dilemmas. Expanding cities, where the share of impervious surfaces is increasing, are exposed to local flooding and floods. The preferred approach since the introduction of the Floods Directive (2007) - integrated flood risk management, includes activities focused on coherence with water [Januchta-Szostak 2012].

2.1 *Warsaw – old ways of dealing with flooding*

Varsawianists Lech Królikowski and Marek Ostrowski believe that instability of the riverbed and damage caused by floods were an important factor shaping the Warsaw spatial development both on the embankment and in the Vistula valley - in Powiśle. The first habitats were created in large numbers on the right bank of the Vistula and date back to the 14-8 millennium BC [Królikowski & Ostrowski, 2019].

Speaking of floods and floodplains in Warsaw, it is impossible not to mention about *Urzecze*. It is an ethnographic microregion located in the northern part of the Middle Vistula Valley with a length of about 40-45 km. Warsaw districts of Mokotów, Wilanów, Praga-Południe and Wawer were part of *Urzecze*. A specific cultural landscape related to the proximity of the river and floodplains developed in here. The most important features of this region included dykes, polders, willow and bindugi (river harbors), tritiums (elevated roads in wetlands), terpy (hills under houses), numerous windmills and extensive use of wicker. Olęders – Dutch and German settlers living mainly in the floodplains settled here. Although their settlements were exposed to periodic flooding, they did not want to build flood embankments, explaining that the Vistula floods not only do not harm them, but are even necessary to maintain the fertility of fields and meadows. Government recommendations, not the will of the inhabitants of these areas, led to the construction of levees. The catastrophic flood of July 1884 and the construction of a water uptake for the city water supply were impulses to regulation of the Vistula in Warsaw [Gutry-Korycka et al. 2006].

The specific location of the Olęder settlements in the floodplains affected the way architecture and urban planning were shaped. The buildings were directed parallel to the watercourse, on hills and embankments. An artificial platform called tritus in Mazovia or terpa in other parts of the country was made. Single-roof buildings were erected on the embankment, in which the residential part was connected with the barn and shed. It was possible to take care of the farm without leaving the house. Houses often had arcades. The residential part was oriented upstream, thanks to which the flood water flooded the apartment first, and then washed the manure from the farm part to the fields. The houses were equipped with a wide staircase to the attic, followed by residents with their animals and property in the event of flooding the ground floor. The buildings were surrounded by fascines, thanks to which larger fragments of trees, shrubs

and other objects carried with the current were kept, which could damage buildings. In addition, the mule carried by the flooding river was stopped in the fields. Planting poplars and willows was an additional treatment aimed at retaining water and ice. Residents built drainage and irrigation canals around their homes, set up fish breeding ponds, storage reservoirs, laid dykes and levees.

2.2 *New housing estates in the floodplain on the Vistula in Warsaw*

Warsaw in 2018 had almost 1,778,000 inhabitants which gives mean density of 3338 inh./km² [Central Statistical Office (GUS), 2018]. That translates into dynamically developing housing market in recent years. Occupying floodplains near the Vistula has become a response to the growing demand for flats in a good location in relation to the center and infrastructure as well as at a good price. New settlements are entering areas at risk of flooding, which is nothing new in Warsaw because most of the city (Wilanów, Sadyba, Powiśle, Praga, Saska Kępa) was built in the floodplains. Flood embankments constitute the main bastion of protection, which, according to experts, can be blown up on the outskirts of the city. The problem occurs when high water levels persist for several days. Then the water seeps through the shaft or under it, which results in flooding - the appearance of water in underground garages and basements.

Flood protection actions in the capital area include, above all, construction and modernization of flood embankments and ensuring good technical condition of hydrotechnical facilities. The Vistula embankments are about 5 m high, in Warsaw they are higher - about 6 m. In order for water from the Vistula to overflow through Warsaw embankments, the flood wave would have to be about 8.5-9 meters high. Old shafts are most at risk of breaking. Shrubs, trees and various obstacles are regularly removed from the Warsaw ramparts. In 2010-2017, expenses for the capital's flood protection in Poland were to amount to PLN 40 million. The most sensitive points in Warsaw are the zoo area, where the embankment is very low, and the flood gate in the Prague Port. Climate change has increased the risk of sudden, intense rainfall resulting in urban floods. Rainwater drainage has problems with the Warsaw sewage system created in the nineteenth century. The creator of this system - William Lindley, designed it in a combined model, that is, sewage and rainwater are transported in one outlet.

In 2010, the water level in the Vistula exceeded the alarm level and embankments began to soak. The embankments are not the only flood protection. In society's consciousness, however, it is most synonymous with protection against great water. There are voices that there are no legal principles that the city should adhere to when determining the development conditions in flooded areas. Regulations in this respect are introduced by the Water Law, according to which the building ban applies in areas of particular flood risk, which can be checked on ISOK maps.

2.3 *Case study – new warsaw estates on the flood plains*

New housing estates built in the floodplains in Warsaw in the Vistula districts: Wilanów and Mokotów have been analyzed. All of the examined estates are fenced, usually in a nesting arrangement or in the form of a quarter. The specific climate of a given housing estate is influenced by spatial solutions, shaping the body of objects, their dimensions and distances between them, the choice of materials as well as the solution of greenery and small architecture in internal courtyards. The comparative table lists categories, among others regarding the shaping of the building in the context of flood risk, pros and cons of the investment.

2.4 *Mokotów*

Mokotów is a left-bank district of Warsaw. It is inhabited by the largest number of Varsovians (almost 220,000). A potential flood threat occurs in Dolny Mokotów (Stegny, Sadyba, and Czerniaków). Along with the construction of flood embankments during the war, the development of flood plains in Dolny Mokotów is gradually progressing. In addition to the former single-family and service and commercial buildings, many new multi-family housing estates are being built.

Many multi-family investments are being built in Dolny Mokotów, near Bartycka and Bluszczańska streets. The undoubted advantage of housing estates in this part of Warsaw is their

good location. It is close to the center, and the outlet to Czerniakowska Street gives you the opportunity to conveniently get to other parts of the city. Despite the objectively good location on a city scale, it turns out that in practice public transport stops are quite distant (about 15 minutes walk) and many residents do not use collective transport when choosing their own car. The estates are located near the old urban fabric and existing infrastructure: schools, kindergartens, clinics or hospital. Residents can take advantage of many surrounding green areas, including walking routes along the Vistula River. The area of the examined settlements is covered by the local land development plan.

Both in this part of Warsaw and in many others, where new housing estates are being built, the problem is insufficient road infrastructure and the lack of ground parking spaces. The plans envisage the construction of Czerniakowska Bis and Nowoprojektowana Streets departing from Czerniakowska Bis. The area of Bartycka Street is called the "Bartyckie Sea" due to the high levels of groundwater. At the high level of the Vistula, water floods the basements. This happened in Dorózkarnia located at the corner of Bartycka and Siekierkowska, as well as in the underground garages of new buildings in the Bluszczańska area. The area is protected by flood embankments and no river flood has occurred in this area since its construction. A characteristic feature of the architecture shaping in this area are raised half-storey ground floors, under which underground garages are partly elevated above ground level. At some buildings, gardens adjacent to ground floor apartments are shaped on embankments. The ground floor level of buildings can be reached by stairs and by elevator or stairs lead directly to the cage. The buildings are set on stilts, they also have garages made in the technology of a "white bath" - designed for floodplains, wetlands. There were situations when water leaked into the garage of buildings causing flooding and needed the intervention of professionals, uncovering foundations and improving insulation. On a daily basis, you can also see water flowing through a thin trickle in the expansion grooves in the garage floor, which may indicate water seepage at the joint of foundation slabs.

Multi-family housing estates in this area are low-rise buildings up to 4 floors or medium-high floors of 5-6 floors. The studied housing estate Wiślany Mokotów at Bluszczańska St. are classic modernist blocks forming quarter buildings with courtyards. They have balconies or loggias, they are brightly plastered, they have stone imitation cladding. The Mokotów Park Apartments buildings on Bernardyńska Street have a different character. These are massive blocks in a dark tone, covered with graphite cladding made of boards and wood. The estate was built off the beaten track, next to a canal. There are adequate distances between the buildings. Thanks to this, one can feel the space in it, despite the considerable height of the buildings. The Apartamenty Mokotów Park complex has a self-cleaning lake, which is a great decoration of the complex, but is also important for water protection. Many specialists claim that developers in the area of Bernardyńska Street were illegally draining wet meadows and draining excess water to the Czerniakowskie Canal, which affected this reservoir. Research of scientists from SGGW confirms this situation. According to some specialists, to protect the Czerniakowskie Lake against progressive disappearance, single-family housing without a basement would be preferable.

Architecture shaping and flood protection of Warsaw settlements in floodplains

Wiślany Mokotów II



il. 1: Garden on the embankment

Location: Mokotów, street: Bluszczańska
 Architect: Europrojekt Architects
 Implementation: 2013-2016
 Structure type: Complex of 3 buildings (1st stage, ultimately three stages)
 Function: Residential, service
 Above-ground / underground floors: 4/1
 Residential premises: 396
 Premises area: 31 to 93 m²
 Flood risk: 20-year water and high groundwater level

Pros [+]	Cons [-]
<ul style="list-style-type: none"> - Buildings built on stilts - High ground floors, raised 1.2-1.5 m. - Waterproof brick cladding in the basement - Entrance to the staircases by stairs or using a lift from ground level - Parter buildings are occupied by commercial and service premises. - Gardens on embankments - Large internal courtyard with playground and gym 	<ul style="list-style-type: none"> - Wetlands - high groundwater levels - Flooded streets after storms - Mosquito nuisance in summer - Water flows in garages in expansion joints - Floods in underground garages have occurred (Wiślany Mokotów II)

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Apartamenty Mokotów Park



il. 2: Massive graphite blocks just above the canal



il. 3: Estate just above the canal

Location: Mokotów, street: Bernardyńska
 Architect: Britt Plan
 Investor: Marvipol
 Implementation: 2012-2014
 Structure type: Complex of 3 buildings (2 stages)
 Function: Residential, service
 Above-ground / underground floors: 4-6 / 1
 Residential premises: 416
 Premises area: 36.9 to 156.2m²
 Flood risk: Buildings exposed to 20-year water

Pros [+]

- Park inside the estate with a self-cleaning lake fed with rainwater and water from the Czerniakowski Canal
- Sophisticated greenery design inside the estate
- Finish the facade with durable materials: sandstone, wood and titanium-zinc facing.
- Temporary water reservoirs were created for the construction of the foundations, to which water from the excavation was transferred to underground garages, then the water goes back to the underground water.
- Application of a series of filters (separators) separating petroleum pollution from parking lots
- Closed water management, intended to ultimately raise the level of groundwater (through the infiltration system of the estate lake, from which excess water is to flow into groundwater).
- According to the design assumptions, the rainwater from the "clean roofs" of the estate will also be directed to the Czerniakowski Canal.
- In the basement – 60cm concrete walls with a bottom plate do not let water in.

Cons [-]

- High groundwater level
- Wetlands
- A mushroom appeared in the basement
- Multi-family housing in this area involves more hardened surfaces may cause problems with water retention
- According to experts, multi-family investments in this region have a negative impact on the Czerniakowski Lake, which can be completely drained. There is indication of the desirability of single-family housing in this area.

2.5 Wilanów

Virtually the entire Wilanów district is located in a flood hazard zone, exposed to 20-year, 100-year and 1000-year water. Historically, this area was part of Urzecze - an ethnographic microregion near Warsaw, on which a specific cultural landscape related to the proximity of the river and floodplains developed. Wilanów is protected by levees built in the 19th century. The construction of the embankments in Zawady is solid. The base is strengthened by a wide embankment of Wał Zawadowski street, from Siekierki to the edge of Warsaw to Góra Parkowa. It can be considered that they are like three shafts side by side. Wał Zawadowski underwent a thor-



ough modernization after 2010. At high water levels in the Vistula River or after heavy rainfall, water appears in the depressions of the embankment. The problem is groundwater, which always appears when the water is high on the Vistula (this is typical for areas close to the river).

Many residents consider the area to be safe, despite the floodplain. According to many, the guarantor of safety is the embankments and the proximity of several strategic objects: sewage treatment plant, municipal heating plant and ash dump. It is believed that if there is a risk of flood embankment breaking, decisions will be made to blow up embankments in suburban areas to protect strategic facilities. Thus, new housing investments nearby would not be destroyed.

Wilanów is currently intensively built-up. New multi-family and single-family buildings are emerging. Areas marked on the maps as exposed to flood waters are gaining new inhabitants every year. In Zawady, where single-family housing dominated, multi-family buildings are being built. This part of the city is intensively concentrated. Houses are built on small plots, at the expense of green areas and new access roads. In Zawady, the small-town atmosphere of the Warsaw suburb, which functions in conjunction with the center, persists. The area of Wilanów and Zawady does not have the best public transport, so most people move by car, then wandering in traffic jams. Streets are often blocked and highlight deficiencies in road infrastructure.

A common feature of multi-family buildings in the Wilanów-Zawady area is the low building height. The newly built buildings are 3-storey with one underground floor. Building designers ensure that adequate moisture protection for foundation slabs has been made. The ground floor storeys are raised above the area of 0.5 m to 1.5 m. Differences in the area level ramps or embankments. The buildings have spacious terraces, large glazing, and the flats located on the ground floor have gardens on the embankment, or raised terraces. The buildings are set up densely on plots of land, tightly filling the space, contrary to the expectations of investments located further from the city center, which should better serve recreation.

There is a real threat that the increase in the density of the built-up area and the hardening of Zawady communication routes will reduce biologically active surfaces that absorb excess groundwater, which are a natural phenomenon in such close proximity to the river. Therefore, there is an indication for the construction of buildings without a basement in this area. Another important issue is the inclusion of small retention in landscape architecture projects, thanks to which surface runoff is slowed down. Some new residents are complaining about bad air, mold and mosquito infestation during the summer season [Maciejewska 2018]. Ogrody Wilanowa estate is a representative of the newly built buildings in Zawady. This housing estate has been further analyzed taking into account strengths and weaknesses.

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Ogrody Wilanowa		
 <p>il. 4: Strewn area behind the fence</p>	<p>Location: Wilanów, Bruzdowa Architect: Jasiński Kruszewski Architects Investor: Pro-Urba Polska Implementation: 2006-2008 Structure type: Complex of 7 buildings Function: Residential Above-ground / underground floors: 3/1 Residential premises: 94 Premises area: 62 to 144 m² Flood risk: Buildings exposed to 20-year water and high groundwater levels</p>	
	 <p>il. 5: Development of a housing estate in a dumped area</p>	<p>Pros [+]</p> <ul style="list-style-type: none"> - Raised ground floor - Reinforced concrete underground garage in the white bathtub technology, entry to the garage from ground level - Modernized levees

2.6 Project guidelines for new development of floodplains in Warsaw

On the basis of the conclusions from the Warsaw case study, project guidelines for floodplains in Warsaw were developed, the aim of which was to identify the most important priorities in the development of floodplains and increase the security of investment arising in these areas. On a city and residential scale:

- Proper preparation of the land for investments without accelerating construction procedures at the expense of quality, so that the building does not get improperly and subsequent water problems in the basement.
- Improvement of rainwater retention and downturn of surface runoff, more biologically active surfaces should be designed. Thus, the risk of flooding (river, city or groundwater floods) would be minimized.
- The road system solutions should include: modernization and construction of new roads to housing estates and designing ground parking spaces.

On a residential scale:

- Selection of the highest location on the plot subject to flood risk.
- Stabilization of the ground (retaining wall, reinforcing geotextiles, piles).
- Foundations: of non-absorbent materials, eg concrete blocks, "white bathtub", band drainage. The thermal insulation of foundations must protrude significantly above ground level and contain extruded polystyrene.
- Architecture taking into account local conditions and restrictions: like waterproof or amphibious buildings, flood protection: walls, embankments, door and window flood covers, flood gates, flow grates, non-return valves, band drainage, no basement or carefully waterproofed concrete technology and selection of water resistant finishing materials.

3 SUMMARY

"Floods cannot be avoided, but the effects can be minimized" - such a slogan becomes the leitmotif of many flood strategies and programs in the UK, Germany or Austria and in the Netherlands, where 55% of the country is at risk of flooding, and 26% of the land is below sea level [Kundzewicz 2013]. After analyzing data on newly emerging Warsaw settlements in the floodplains, it can be concluded that shaping of architecture in floodplains basically does not go beyond the frames of a classic building. Architecture takes into account local conditions and restrictions: elevated ground floors, embankments, cascade shape of the interiors of the housing estates enabling the outflow of water, lakes storing rainwater. Despite these treatments, it happens that groundwater soaks into basements, and moisture causes mold. In floodplains, moisture-filled air can affect health. Some residents of the new housing estates complain of considerable moisture, appearing molds and mosquitoes in the summer. The problem of new Warsaw settlements, which also concerns complexes in floodplains, is associated with the insufficient quality of road infrastructure. There are no exit roads or above-ground parking spaces. The streets are getting jammed. In addition, non-modernized roads in floodplains do not withstand more and more traffic, they break, they have puddles and damage. The increasing intensity of residential buildings in flood plains already has and will have an increasing impact on the reduction of biologically active surfaces that can absorb excess water. The new housing estates and their surroundings lack a pattern of numerous foreign settlements (in Germany, the Netherlands, Great Britain) of well-designed landscape architecture that would limit surface runoff and increase rainwater retention. Without taking into account low retention, there may be problems with flooding and with poor water drainage.

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