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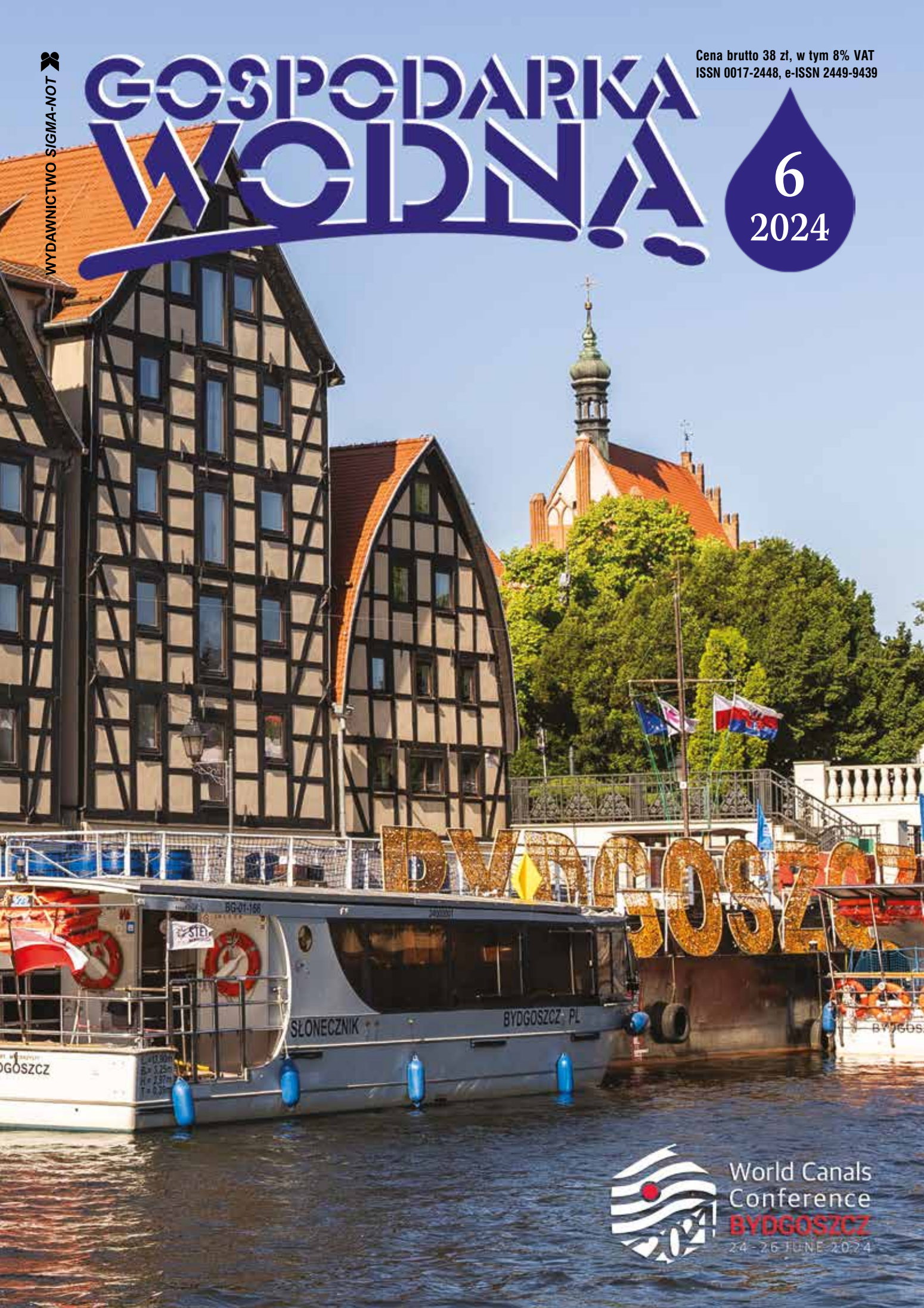

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World Canals Conference BYDGOSZCZ

Foreword by the Mayor of Bydgoszcz:

Distinguished guests, delegates and fellow waterways enthusiasts,

With great pride and pleasure, I welcome all those gathered in Bydgoszcz for the World Canals Conference 2024.

As we embark on this enlightening journey to explore the importance and potential of shipping canals around the world, I am honoured to highlight the key role of waterways in the economic development of our city and their contribution to the areas of tourism, recreation, sport and culture.

Our city of Bydgoszcz is unique in that it benefits from its location on two rivers – the Brda and the Vistula – and the Bydgoszcz Canal, which together form the Bydgoszcz Waterway Junction.

The Bydgoszcz Canal, an engineering marvel of the 18th and 19th centuries, has become a vital artery of trade, connecting Bydgoszcz with regional and international waterways. Its strategic importance in facilitating the movement of goods and fostering economic exchange cannot be overstated, as it has played a key role in shaping Bydgoszcz into the dynamic urban centre it is today.

As we participate in the World Canals Conference 2024, let us take the opportunity to showcase the transformative power of canals across the inland waterway network in driving sustainable development and supporting connection between communities. By sharing our experiences and best practices, we can set a course towards a future in which water transport and tourism thrive with maximum respect for nature, bringing benefits not only to Bydgoszcz, but also to cities and regions around the world.

I would like to thank the organisers, partners and participants for their commitment to deepening our understanding of the impact of canals and their importance in shaping the urban landscape. May our time together be fruitful, inspiring and memorable.

With sincere greetings,
Rafał Bruski, Mayor of Bydgoszcz

Bydgoszcz, June 24, 2024

Inland Waterways International

Who are we and what do we do?

On behalf of Inland Waterways International (IWI), please allow me to welcome you to the World Canals Conference (WCC) 2024 in Bydgoszcz and to this special edition of *Gospodarka Wodna*.

The significant role that waterways play in every aspect of life is undeniable. Connecting inland waterways, both old and new, can enhance regional connections, stimulate economic development, and provide numerous opportunities for healthy, sustainable communities.

At international events like WCC 2024 in Bydgoszcz, IWI serves as the platform that brings together experts from around the world to share experience, expertise, and new ideas for managing, preserving, and promoting canals and inland waterways. Instead of isolated, case by case solutions, IWI creates a collaborative environment where canal and inland waterway stakeholders can share strategies for educating the public and policymakers on the role of inland waterways in achieving development objectives at every level.

IWI Mission Statement: To be a key advocate for the conservation and promotion of inland waterways around the world, to support and strengthen the worldwide waterways community through public education, issue advocacy, and technical expertise, and to serve as an open platform for the exchange of relevant knowledge and information.

IWI Vision: The inland waterways of the world are recognized and appreciated for their heritage and environmental value, as well as for the role that they play in the economic, recreational, and cultural life of the countries or regions through which they pass.

IWI members hail from many countries and continents. They share a keen interest in the history and modern-day significance of inland waterways for both commercial and recreational use. Through its website, https://inlandwaterwaysinternational.org, and other media, IWI raises awareness of the benefits of inland waterways for a wide range of activities, spanning from commercial transport to water-based tourism and recreation. Member scholarship and expertise contribute to policy and practice through publications, webinars, panel discussions, and networking opportunities like the annual WCC.

We follow the restoration of disused and underused waterways and celebrate the landscape of globalinland waterways and their architectural heritage. IWI experts are examining the role that Inland Waterways can play in addressing the impacts of climate change. Innovative models for flood control, protection of landscape and infrastructure, and greener navigation practices are researched, shared, and tested through the IWI network.

For over 30 years, the World Canals Conference has brought together hundreds of experts, scientists, representatives from politics and administration, associations, companies and water sports enthusiasts from all around the world to a host city selected by IWI.

In Bydgoszcz 2024, we return to this premier annual event. You will be swept away by the flow of information on the latest trends in operation and management practices, creative non-traditional uses, and stunning stories of innovative transformation. Immerse yourself in the events, the people, and the Bydgoszcz WCC experience!

Sharon Leighton
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The Bydgoszcz Canal – 250 years of the history

Kanał Bydgoski – 250 lat historii

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The Bydgoszcz Canal, connecting the Oder and Vistula River tributaries, is a unique hydrotechnical monument. In 2024, the Bydgoszcz Canal celebrates its 250th anniversary. The goal of the article is to present the history of the Canal and changes in its role throughout the years. It points out not only to the main idea of its construction – to serve navigational purposes – but also to its recreation and leisure function that has accompanied the Canal's operation since mid-19th century until today.

Key words: Bydgoszcz, Bydgoszcz Canal, 250th anniversary of the Bydgoszcz Canal construction, Bydgoszcz Canal locks

Kanał Bydgoski, łączący dopływy Odry i Wisły, jest unikalnym zabytkiem hydrotechniki. W 2024 r. obchodzi 250-lecie budowy. Celem artykułu jest przedstawienie historii kanału i zmiany jego roli na przestrzeni lat. Ukazana została nie tylko nadrzędna, żeglugowa idea towarzysząca budowie, ale również funkcja rekreacyjno-wypoczynkowa, która towarzyszy kanałowi od połowy XIX w. do dnia dzisiejszego.

Słowa kluczowe: Bydgoszcz, Kanał Bydgoski, 250-lecie budowy Kanału Bydgoskiego, śluzy Kanału Bydgoskiego

INTRODUCTION

The Bydgoszcz Canal is a unique monument of hydraulic engineering. Launched in 1774, it was a highly anticipated project initiated by the Prussian king Frederick II, who ordered its construction in the spring of 1773. Over its 250-year existence, the canal has undergone numerous modernizations, and its role has evolved significantly. Its original purpose shifted over time, partly due to neglect of this waterway. Today, this once vital artery in water transport no longer plays any role in transportation. Its old section, in particular, is slowly becoming a tourist destination, a place for meetings, recreation, and leisure. This new purpose reflects the role the Bydgoszcz Canal served before World War II.

CONSTRUCTION PROJECTS

An 18th-century marvel of engineering, the Bydgoszcz Canal, became a topic of discussion thanks to a project by Franciszek Florian Czaki, a Hungarian-born cartographer in the service of Stanisław August Poniatowski. On July 9, 1766, during a session of the Crown Treasury Commission, he presented the concept of building a canal (Wilder, 1936). In his memorandum, the cartographer enumerated many advantages of the proposed waterway: "The greatest benefit would be the easy communication from the Vistula with many more significant rivers, which would undoubtedly bring considerable advantage in time to the nobility, merchants, and every citizen in particular. According to this plan, anyone engaged in trade could float from the Bug, Narew, and San to the Vistula, from the Vistula to the Noteć, from the Noteć to the Warta, from the Warta to the Oder, and from there easily reach Frankfurt, Wrocław, Szczecin, etc.; and half a mile above Frankfurt, one could float through the canal to the Spree River and to Berlin, and from there to Hamburg, where many goods could be easily obtained" (Wilder, 1936).

The construction of this new artery had to be postponed due to subsequent historical upheavals, and the project of building the canal connecting the Vistula and Oder River basins was ultimately realized by Frederick II Hohenzollern after the first partition of Poland.

"The authorship of the idea to build the Bydgoszcz Canal will thus be a dispute among seven Greek cities over Homer" (Winid, 1928). Apart from the King of Prussia, Frederick II, the advocates of the idea included the Prussian Minister of Foreign Affairs, Ewald Friedrich Hertzberg, as well as Hermann Jawein, and Franz Balthazar Schönberg von Brenckenhoff.

HISTORY OF CONSTRUCTION AND MODERNIZATIONS

In February 1772, Franz Balthasar Schönberg von Brenckenhoff arrived in the Bydgoszcz area with the task of preparing a report on the condition and potential of the lands to be incorporated into the Prussian state. On-site, he was most likely introduced to

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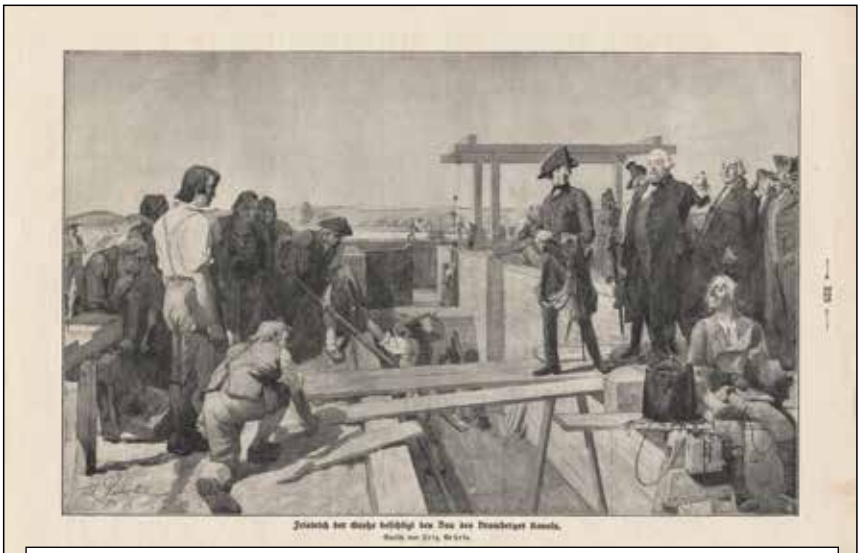

Fig. 1. Frederick the Great visiting the construction of the Bydgoszcz Canal (*source: private collection of Tomasz Izajasz*)

the idea of constructing the canal and ordered a more detailed study and measurements of the future waterway (Skrycki, 2013; Garbe, 2022). Hermann Jawein, along with Wilhelm Dornstein and Johann Philipp Peterson, were selected to develop a detailed plan and budget (von Schroetter, 1802-1812).

The construction of the canal began on March 1, 1773. To carry out the work, 8,000 to 10,000 settlers were brought in, recruited from Mecklenburg, Dessau, Thuringia, and Saxony. Despite efforts to provide the workers with the best possible accommodation, many lived in primitive huts and worked in harsh conditions. Consequently, every fourth settler did not return home, succumbing to malaria and dysentery (Winid, 1928).

The work was conducted in great haste, resulting in the construction of 10 wooden locks (9 on the canal and 1 so-called city lock on the Brda River), the original 26.077-kilometer-long cut, and a 16-kilometer-long feeder canal. The first attempt to open the canal was unsuccessful due to the raising of peat and soil from the bottom and damage to the lock at Prądy (Peterson, 1815). Repair work continued until September 14, 1774, when the successful floating of 13 barges took place. However, work on reinforcing the canal bed continued throughout the following year.

The first major modernization occurred in the late 18th c., marking the beginning of the construction of brick locks. During this period, the first brick locks in this part of Europe were built, made not only of sandstone. Work on these locks began in 1792. Additional workers and, more importantly, specialists, including the drainage works inspector Johann Philipp Peterson, were brought in for these projects (Klauschenz, 1995; Bartowski, 2006). The locks built at that time on today's old Bydgoszcz Canal had new, larger dimensions: 68.0 x 8.8 meters, with gate openings of 6.6 meters and a usable chamber length of 48.9 meters.

At the beginning of the 19th c., further works were carried out under the supervision of the inspector's half-brother Ernst Conrad Peterson, which included planting along the banks. It was partly thanks to him that the unique park known as the Planty was created, which is cherished by many Bydgoszcz residents today. The construction of the Bydgoszcz Canal contributed to the rapid development of Bydgoszcz. Its operation significantly boosted trade and crafts, and eventually the growing industry. It also impacted the demographic sphere through labor colonization (GStA PK, 1800-1806; Mincer, 1991).

Another major modernization took place between 1840 and 1852, which involved the replacement of more wooden locks, such as those at Prądy and Osowa Góra, with new, larger structures made of brick and granite (Winid, 1928). In the second half of the 19th c., with the increasing transit of timber, there was significant development in Bydgoszcz's timber industry. The canalization of the Brda River and the construction of the extensive Wood Port in Brdyujście between 1877 and 1879 led to the establishment of numerous sawmills and wood processing companies (Sławińska, 1969; Bromberek, Kosecki, 2015).

Between 1882 and 1884, a new innovative lock was built. The lock's unusual trapezoidal shape and its construction made it unique on a global scale (Izajasz, Grochowski, 2013). The Bydgoszcz Towage Joint Stock Company, established in 1891, played a significant role in the development of Bydgoszcz navigation, and after Bydgoszcz reintegration with Poland, it operated under the name Lloyd Bydgoski (Szczęchor, 2004).

An important success for the residents of Bydgoszcz, who advocated for further modernization of the canal, was the 1905 resolution by the German parliament regarding the reconstruction of the Oder-Vistula waterway. The improvement aimed to accommodate barges with a tonnage of 400-500 tons. A crucial

Fig. 2. Plan von der schiffbaren Verbindung der Netze mit der Brahe durch den Bromberger Canal (*source: GStA PK, I. HA Rep. 121, Nr. 9906, Peterson, Aufsatz über die Entstehung, den Bau und Retablissement des Bromberger Kanals (mit Skizzen), 1815*)

Fig. 3. Promenade along the old Bydgoszcz Canal (*source: private collection of Tomasz Izajasz*)

aspect of this modernization was the construction of a new section and the installation of more modern, large locks. The Bydgoszcz Canal was shortened to 24.7 km, which also reduced transit times for transports.

The construction of a new 1.7 km section and the building of two locks, Okole and Czyżkówko, each capable of lifting vessels 7.5 meters, allowed for bypassing five locks on the old section of the canal. Construction for this modernization took place from 1908 to 1915, and the entire waterway was put into use on April 1, 1915. A month later, in May, the canal reached its maximum planned depth of 1.4 meters. In the initial years of operation, there were issues with the functioning of the Okole Lock, which required repairs in 1917 and 1922 (GStA PK, 1899-1910, 1911-1919; Izajasz, 2014).

After Poland regained independence, inland navigation on the canal faced significant difficulties. This situation changed only after 1928, when waterway transport via the Bydgoszcz Canal, the lower Vistula, and the Warta was once again prioritized. During the September Campaign, Polish sappers partially destroyed facilities on the new section of the canal, which led to the resumption of traffic on the old section (Zyglewski, 2021).

Following World War II, the Bydgoszcz Canal's importance as a water artery increased, making it the second waterway after the Gliwice Canal capable of accommodating barges with a displacement of around 500 tons. However, over time, the canal's transport capabilities significantly diminished. Currently, due to its outdated infrastructure, the Bydgoszcz Canal is classified as a class II waterway.

RECREATION ROLE

Beyond its obvious role in transportation, the Bydgoszcz Canal, particularly its old section, was utilized as a place for recreation and leisure. In the mid-19th c., the canal locks (known as the park by the canal) became a showcase of the city and a public leisure, and entertainment area. During this time, the first restaurants and dance halls began to appear in the park; for instance, in 1838, the Kwiatowa Lock Restaurant was established. Various attractions were organized here, such as concerts, dances, outdoors painting, exhibitions, revue theaters, and winter ice rinks.

During the interwar period, the locks became one of the city's main attractions, drawing both locals and tourists who could enjoy peaceful relaxation along with the mentioned activities. Numerous restaurants and cafes extended practically from the second lock of the old canal section. The splendid Patzer Garden at the third lock offered a particularly rich array of activities for residents.

Apart from Patzer, popular establishments included restaurants located further west along the old Bydgoszcz Canal, near the fourth and fifth locks. Here, one could find Kleinert's Garden and Kruger's Restaurant, as well as Karl Rasmus's Restaurant and the aforementioned Kwiatowa Lock Restaurant near the fifth lock (Derkowska-Kostkowska, 2008; Rynka, 2021). The decline in the canal's economic significance after World War II was accompanied by the degradation of the old section, which by the late 1960s was in very poor condition. In the early 1970s, about a 600-meter beautiful section with two locks (II and III) of this historic hydraulic engineering monument was filled in.

Fig. 4. Patzer's Restaurant by the promenade on the old section of the Bydgoszcz Canal (*source: private collection of Tomasz Izajasz*)

Fortunately for today's residents of our city, the decision was made not to fill in the entire old canal. In the 1990s, the locks and bed of this historic monument were revitalized. At the turn of the 20th and 21st c., cultural life began to revive along the old canal. Increasing community efforts focused on the canal are turning the city's attention towards the water, exemplified by the growing number of outdoor events held here, such as "Ster na Bydgoszcz," concerts, shows, historical reenactments, and festivals, which increase every year. Regular sporting events

Fig. 5. The third lock on the old section of the Bydgoszcz Canal (*source: private collection of Tomasz Izajasz*)

are held on the old section of the canal, including double marathons, night marathons, and dragon boat races. Anglers and water tourists navigating the canal by kayak are also common sights.

PRESENT DAY

In 2005, the Bydgoszcz Canal was listed in the Register of Monuments of the Kuyavian-Pomeranian Voivodeship. The determination of canal enthusiasts led, through the initiative of Sebastian Malinowski, to the establishment of the Bydgoszcz Canal Museum in 2006. Many projects and investments have been realized in the old section of the Bydgoszcz Canal through the Bydgoszcz Civic Budget.

In 2021, with the support of EU funds, the Bydgoszcz Canal Museum, named after Sebastian Malinowski, was relocated from its original location at High School No. 3 to a larger, renovated building at 10 Staroszkolna Street. In 2023, the city of Bydgoszcz renovated the historic gates on three locks (IV, V, and VI) of the old canal section, strengthened the banks, and planted more shrubs and trees. A new concept for the revitalization and development of the Old Canal has also been prepared. Simultaneously, efforts are being made to officially recognize the Bydgoszcz Canal as a historical monument.

CONCLUSION

Over centuries, the Bydgoszcz Canal has played a significant role. However, its function has evolved over its 250 years of history. Initially conceived as a hydro technical monument for inland sailing purposes, it gradually transformed into a recreational waterway. The canal has not only contributed to the economy and industrial development of Bydgoszcz and its surroundings but also fostered cultural development and physical recreation by the water.

Now listed on the Kuyavian-Pomeranian Register of Monuments, the canal charms visitors with its rich history and natural beauty that surrounds it. It renaissance has elevated it to a more prominent symbol of Bydgoszcz, serving as a recognizable landmark for visitors.

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Bydgoszcz – the development of the city in harmony with the river. The city's riverine DNA

Bydgoszcz – rozwój miasta w harmonii z rzeką. Rzeczne DNA miasta

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The article addresses the issue of the relationship between the city and the river, using Bydgoszcz as an example. Currently, the main revitalization efforts in Bydgoszcz focus on the Brda River and the Bydgoszcz Canal, among other areas. For several years, the city has been consistently and systematically planning and implementing steps aimed at activating the rivers and revitalizing riverfront areas. The natural and socio-cultural potential of the riverside, as well as its development, have become increasingly desirable. The article presents the results of revitalization undertakings launched since the 1990s and highlights the main advantages and competitive strengths of the riverfront areas.

Key words: Bydgoszcz, a riverfront city, waterfront architecture, revitalization, riverfront areas, competitive advantages

Artykuł dotyka kwestii powiązań pomiędzy miastem i rzeką, za przykład biorąc Bydgoszcz. Główne działania rewitalizacyjne w Bydgoszczy skupiają się obecnie na rzece Brdzie i Kanale Bydgoskim. Od kilku lat miasto systematycznie i konsekwentnie planuje i wdraża przedsięwzięcia mające na celu aktywizację rzek i rewitalizację obszarów nadrzecznych. Przyrodniczy oraz społeczno-kulturowy potencjał nabrzeży oraz ich rozbudowa stają się coraz bardziej pożądane społecznie. Artykuł przedstawia rezultaty prac rewitalizacyjnych podejmowanych od lat 90. XX w. i podkreśla główne walory i przewagi konkurencyjne obszarów nadrzecznych.

Słowa kluczowe: Bydgoszcz, miasto nadrzeczne, architektura nadrzeczna, rewitalizacja, obszary nadrzeczne, przewaga konkurencyjna

INTRODUCTION – RIVERSIDE LOCATION AND THE POTENTIAL OF THE CITY

Bydgoszcz, with its 678-years long history, is uniquely characterised by its picturesque riverside location where the Brda River flows into the Vistula, and on the Bydgoszcz Canal. The city presents a dual perspective: one visible from its streets and another from the river. These two images meet and combine, integrating natural features with architectural and urban elements, and this synergy in turn creates the diverse and characteristic riverside landscape of areas along the entire length of the Bydgoszcz Canal, Brda, and Vistula. The interplay of water, embankments and boulevards, public spaces and surrounding buildings, operational river structures of unique technical and cultural value with lush greenery, contributes to the unique ambience of the city, with the riverside identity perceived as its main asset and distinguishing feature. This identity defines Bydgoszcz, shapes its riverside character, and determines its strengths and development opportunities (Muszyńska-Jeleszyńska et al., 2016).

Key environmental and cultural features shaping the riverside potential of Bydgoszcz include:

- Its location at the junction of valleys and rivers within the wide, latitudinally-oriented Toruń-Eberswalde ice-marginal valley, at the place where it merges with the Brda valley, extending eastward into the Vistula valley.
- Varied terrain relief – a system of vast flat terraces, high plateau areas, and particularly prominent features of the panorama, namely, edges of the ice-marginal valley and river valley.
- The Brda and Vistula Rivers and the Bydgoszcz Canal (which is the axis of the hydrotechnical system) and other surface water bodies, including relics of the old Vistula riverbed, reservoirs formed as a result of river engineering works that have cut off river distributary channels, artificial reservoirs, or pits filled with water, and weirs.
- A high proportion of parks and gardens, and diverse forest complexes within the city limits.

The several kilometres long riverside located within the municipality, particularly along the Brda River. Water and greenery form an integral part of both the urban development belts and zones and the natural areas making up the spatial and functional structure of the city. Complex functional interactions between the land and the river make the riverside a site of crucial cultural importance for Bydgoszcz.

The combination of these features, particularly the hydrographic attributes of the Brda, Vistula, the Bydgoszcz Canal and the Canal of the Upper Noteć River, along with hydrotechnical structures and riverside buildings, forms the Bydgoszcz

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Water Junction. This junction represents the city's riverine potential, promoting and identifying Bydgoszcz on the tourist map of Poland (Jankowski, 1975; Bydgoski Węzeł Wodny, 2004; Program rozwoju i rewitalizacji Bydgoskiego Węzła Wodnego, 2006). This network of interconnected, canalized, and navigable waterways spans approximately 100 km of embankments and is an important part of international waterways: E70 from Antwerp to Klaipeda and E40 connecting the Baltic Sea to the Black Sea. The Bydgoszcz Water Junction links the Vistula and Oder river basins, and through the Canal of the Upper Noteć, Lake Gopło, and the Warta-Gopło Canal, also connects to the Warta basin.

The unique system of rivers and canals within Bydgoszcz, shaped for centuries by natural forces and subsequently by intense economic activity, is rare on a European scale. Recognizing this riverside potential, Inland Waterways International (IWI) selected Bydgoszcz to host the World Canals Conference – WCC 2024: *Challenges between ecology and economic use – sustainable revitalization of canals focusing on nature*.

HISTORICAL AND CONTEMPORARY CITY-RIVER RELATIONS

Since the 12th c., the economic utilization of the Vistula and Brda rivers, and later the Bydgoszcz Canal from the 18th c., has been pivotal in Bydgoszcz's trade, industry, and navigation. Thanks to the economic boost provided by the construction of the Bydgoszcz Canal in 1772-1774, Bydgoszcz grew wealthy and could afford to develop the water transport infrastructure along with its surroundings. The Brda, Vistula, and Bydgoszcz Canal were not only factors of economic growth, but also the axis along which Bydgoszcz expanded, as numerous hydrotechnical investments and industrial and municipal developments were located along their banks (Zyglewski, 2017; Jeleniewski, 2014). Thus, the riverside areas have been a place of intensive development since the origins of the city, and many monuments and landmarks that are today symbols of Bydgoszcz were established by the river and in its immediate vicinity.

Today, it is enough to follow the river to reach historical structures such as the iconic Bydgoszcz granaries, the Polish Post Office building, the parish church, the post-industrial complex of Mill Island with Bydgoszcz Venice. Alongside these historical landmarks, modern developments like Opera Nova, BRE Bank, Bydgoszcz Marina, and Astoria Sports Club can be found. Recent years have also witnessed new residential and service developments emerging along the Brda and Bydgoszcz Canal.

A present, the river (Vistula, Brda, and Bydgoszcz Canal) plays a central role in the revitalization

Fig. 1. Bydgoszcz waterfront – BRE Bank, Bydgoszcz granaries, "Lemara" barge, Słonecznik (*Sunflower*) boats. *Photo: R. Sawicki*

Fig. 2. The Old Town and Mill Island (Rother's Mills). *Photo: R. Sawicki*

Fig. 3. Bydgoszcz Marina, Brda River in the city center. *Photo: R. Sawicki*

Fig. 4. Opera Nova, recreation and water sports on the Brda River. *Photo: R. Sawicki*

Fig. 5. Bydgoszcz Canal. *Photo: R. Sawicki*

efforts in Bydgoszcz. For several years, the city has systematically planned and implemented steps aimed at restoring the "riverside identity to the city" through the revitalization of the rivers and their surrounding areas, thus recognizing their natural, social, cultural, and recreational potential (Spadło, 2020; Wroński, 2010).

Numerous projects, co-financed by European Union funds, have emphasized the blue-green potential of the riverside zones, focusing on several key areas: revitalization, cultural heritage, greenery and recreation, water management, and inland waterway transport. Key projects include the redevelopment of Mill Island, Rother Mills, Brda and Vistula boulevards in Old Fordon, the industrial heritage trail Th_2O, and the Słonecznik and Słonecznik II (*Sunflower* and *Sunflower II*) boats.

The urban, development, and functional changes have been accompanied by other initiatives aimed at enhancing the attractiveness of the riverside area, namely:

- Improvement of water quality is a necessary condition for further investments in the immediate vicinity of the rivers and canals.
- Shaping the system of public-access riverfront green belts (the ecological river corridor) along with the infrastructure of walking paths, cycling lanes, and educational trails; protection of natural zones of river valleys, especially the banks, against uncontrolled and excessive development.

Introduction of various forms of riverside development requiring direct water access.

- Increased awareness of constraints on residential development in riverside areas; recognition of the importance of the view in investments complying with flood control safety measures.
- Availability of riverfront areas for business and services, resulting in their development as hubs of business activity in addition to their traditional sport and recreation functions (Spadło, 2020; Muszyńska-Jeleszyńska, Jadach-Sepioło, 2019).

The increasing popularity of cruises and active leisure, allowing for "riverfront city exploration" (Muszyńska-Jeleszyńska, Jadach-Sepioło, 2019), has made the development of water tourism a focus of local authorities' actions aimed at the development of waterways and riverfront areas. As Grzyb (2020) points out, the tourist offer of Bydgoszcz is underpinned by the extensive renewal of the riverfront.

COMPETITIVE ADVANTAGES OF RIVERSIDE AREAS

Given the unique riverside location of Bydgoszcz and the scope and diversity of its riverside, the area plays a significant role in the city's spatial and functional structure and can be approached as a development factor referred to as "milieu" (Parysek, 2005). Thus, all the positive characteristics of the riverside areas, including their natural and cultural environment, historical heritage,

unique location, diverse functions and land use, social and economic qualities, contribute to the competitive edge of the city. In the 21st c., successful urban development heavily relies on leveraging the existing advantages. Expert use of the natural and cultural environment of the city, preserved historical heritage, and emphasis on its uniqueness will be crucial in the process. Ensuring a friendly, healthy living and working environment for residents will make the city more attractive to investors (New Athens Charter, 2003). Therefore, the identification of urban areas that can act as growth centres seems to be crucial. Riverside areas, centrally located and attractive for location of various urban functions, abundant in architectural objects, and located within historical urban layouts, can be such a development factor or "milieu" (Parysek, 2005).

Basing on the concentration of specific qualities and the occurrence of selected features in the riverside areas, the following types of competitive advantages can be identified:

- **Riverside Identity**: Competitive advantages stem from the skilful utilization of the cultural and historical heritage of riverside areas and their undeniable value as sources of information, integration opportunities, and symbols. These areas are rich in objects, locations, and landscape complexes that provide evidence as to the history of hydrotechnical engineering, and consequently, to technical progress, highlighting the significance of the river in shaping the city's identity. Some of these objects have been part of the city's historical fabric for centuries, providing insight into both its past and present. Moreover, they reflect the history of local residents earning their livelihood on the river, such as bargemen, skippers, and raftsmen.
- **Attractiveness of Life and Leisure at the Riverside**: The undeniable opportunity for a healthy, safe, and appealing living and recreational environment for local communities along the riverside stems from the fact that numerous residential estates (comprising detached houses and blocks of flats) are traditionally situated by the river, surrounded by green spaces, yet with convenient transport links to the city centre.
- **Functional Diversity (Microdiversity)**: The array of functions and diverse developments in riverside areas can serve as a source of competitive advantages. This is especially true for riverbanks within city centres, which, in addition to serving as residential areas, also function as hubs for business activity, culture, science, education, and public administration.
- **Uniqueness of Location**: Another method by which a city can maintain a competitive edge over other municipalities is by emphasising the uniqueness of its location and space, showcasing the qualities of its natural environment (such as old river beds, gorges, waterfowl sanctuaries, or historical parks), preserved elements of cultural heritage like river engineering structures, or new structures of waterfront architecture, tourist attractions, sport facilities, and recreational amenities.

CONCLUSION

The experience of Bydgoszcz in leveraging the potential of its two rivers (the Brda and Vistula) and the Bydgoszcz Canal, primarily for development of tourism, recreation, and meeting the local social and economic needs, showcases a wide range of best practices. Initiatives launched since the 1990s concerning the Vistula and Brda rivers, the Bydgoszcz Canal, and the surrounding riverside areas have led to the creation of an attractive, central riverside space, with the Brda River serving as its main recreational axis. This area features boulevards with landscaped elements, continuously improved accessibility amenities, and attractive riverside developments.

There's an increasing availability of infrastructure for active leisure activities by and on water, as well as entertainment opportunities. The growing interest of residents in riverside areas is further fuelled by improved transport accessibility. Walking and cycling paths are being constructed along the banks of the Brda, Vistula, and Bydgoszcz Canal, while infrastructure like marinas and mooring places facilitate access from the river's side.

The vicinity of rivers and the canal is the focal point of the city's bustling everyday cultural, sports, and business life. Investments in water management, environmental protection, tourism and recreation, and culture have enabled the city to organize a variety of recurring events, such as the Bydgoszcz Water Festival "Ster na Bydgoszcz" (*Steer Towards Bydgoszcz*), the River of Music, the Boat Race for the Brda Cup, and Bydgoszcz Water, a river swimming competition in the city centre. It's worth noticing that riverside investments are developed in alignment with the municipal strategy and plans for the area.

Considering the blue and green potential of the city, "...we dream of Bydgoszcz immersed in greenery, with parks, green squares, and walkways, linked to the Brda and Bydgoszcz Canal into a vast green and blue network..." (Adamowski et al., 2017).

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TOMASZ KOCOŃ[a)]

Inland waterways development plans in Poland in the light of National Masterplan of Inland Navigation by 2030

Plany rozwoju śródlądowych dróg wodnych w Polsce w świetle Krajowego Programu Żeglugowego do roku 2030

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The article provides a description and a review of measures indicated in the National Masterplan for Inland Navigation by 2023 (KPŻ2030). The Masterplan is the first planning document for inland navigation to have taken into account the development of inland waterways, as well as strategic and regulatory measures. The Masterplan also includes a diagnosis of the use of inland waterways for transport and goals for the inland navigation sector to be achieved by 2030.

Key words: inland navigation, waterways, KPŻ2030

Artykuł stanowi opis i przegląd działań wskazanych w Krajowym Programie Żeglugowym do roku 2030 (KPŻ2030). KPŻ2030 jest pierwszym dokumentem planistycznym dla żeglugi śródlądowej, który uwzględnia rozwój śródlądowych dróg wodnych oraz działania o charakterze strategiczno-regulacyjnym. W KPŻ2030 zawarto również diagnozę transportowego wykorzystania dróg wodnych oraz cele dla sektora żeglugi śródlądowej, które mają zostać osiągnięte do 2030 r.

Słowa kluczowe: żegluga śródlądowa, drogi wodne, KPŻ2030

INTRODUCTION

On October 3rd, 2023, the Council of Ministers of Poland adopted a development program called the "National Masterplan of Inland Navigation by 2030" (NMIN2030). This is the first comprehensive masterplan for the inland navigation sector in Poland (Fig. 1). NMIN2030 includes activities aimed at supporting the development of enterprises and the shipping market, as well as maintaining and increasing the competitiveness of inland waterway transport.

NMIN2030 includes investment projects aimed at the revitalization of the existing hydrotechnical infrastructure and a number of sectoral tasks focused on the digitalization of the inland navigation sector, modernization of the fleet, and strengthening its resistance to climate change. Additionally, it aims to create conditions for the development of water terminals (ports and berths) and to enhance the attractiveness and skills of the inland navigation labour market.

KRAJOWY PROGRAM ŻEGLUGOWY do roku 2030

Fig. 1. National Masterplan of Inland Navigation by 2030 (*source: Uchwała nr 180/2023 Rady Ministrów z dnia 3 października 2023 r. w sprawie ustanowienia programu rozwoju pod nazwą „Krajowy Program Żeglugowy do roku 2030"*)

POLICY FRAMEWORK FOR THE DEVELOPMENT OF INLAND NAVIGATION SECTOR ON EU AND NATIONAL LEVEL

Sustainable and Smart Mobility Strategy is the official EU transport strategy, with the main goal of enhancing the digital and green transformation in the EU transport system. Regarding inland navigation, one of the targets for waterway transport is: "Transport using inland waterways and short sea shipping will increase by 25% by 2030 and by 50% by 2050".

NAIADES III – Boosting future-proof European inland waterway transport – in line with the *Sustainable and Smart Mobility Strategy,* the European Commission tabled a 35-point action plan in June 2021 to boost the role of inland waterway transport in our mobility and logistics systems. The core objectives are to shift more cargo over Europe's rivers and canals, and to facilitate the transition to zero-emission barges by 2050.

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Strategy for the sustainable development of transport until 2030 is a Polish transport sector strategy aimed at increasing the transport accessibility, improving users safety, and enhancing the efficiency of the transport sector by creating a coherent, sustainable, innovative, and user-friendly transport system at the national, European, and global levels. For inland navigation, the main goal is: "Comprehensive development of waterways of transport importance and strengthening the integration of sea ports of basic importance for the national economy with the hinterland."

DIAGNOSIS OF CURRENT STATE OF INLAND WATERWAY TRANSPORT IN POLAND

According to Main Statistics Office in Poland ("Statistics Poland"), the current inland waterway network has been shaped by the natural configuration of river and canal connections built mainly in the 18th and 19th c. In 2021, the national inland waterway network covers 3,768 km, of which actually 3,549 km of inland navigable waterways are being exploited (Fig. 2). In comparison with other EU countries, this length is significant. Only Germany, Finland, France, and the Netherlands have longer networks of waterways.

Based on research conducted by Statistics Poland in 2021, in Poland, 3,464.6 thousand tonnes of goods were transported via inland waterways, amounting to 493.0 million tonne-kilometres. This was a decrease compared to the previous year by 526 thousand tonnes (13.2%) and 23.3 million tonne-kilometres (4.5%). Polish inland waterway shipowners transported 1,747.9 thousand tonnes (50.5%) in international transport, while 1,716.7 thousand tonnes of freight (49,5%) were transported domestically. Year-on-year, there was a decline in shipments between ports abroad by 5.7%, however, its contribution to the total international transport of goods remained dominant, amounting to 79.5% in 2021 (a growth of 1.5 pp). The volume of exports decreased by 2.8% to 272.6 thousand tonnes, and imports decreased by 37.4% to 83.6 thousand tonnes. Exports accounted for 15.6% of total international freight, with Germany being the

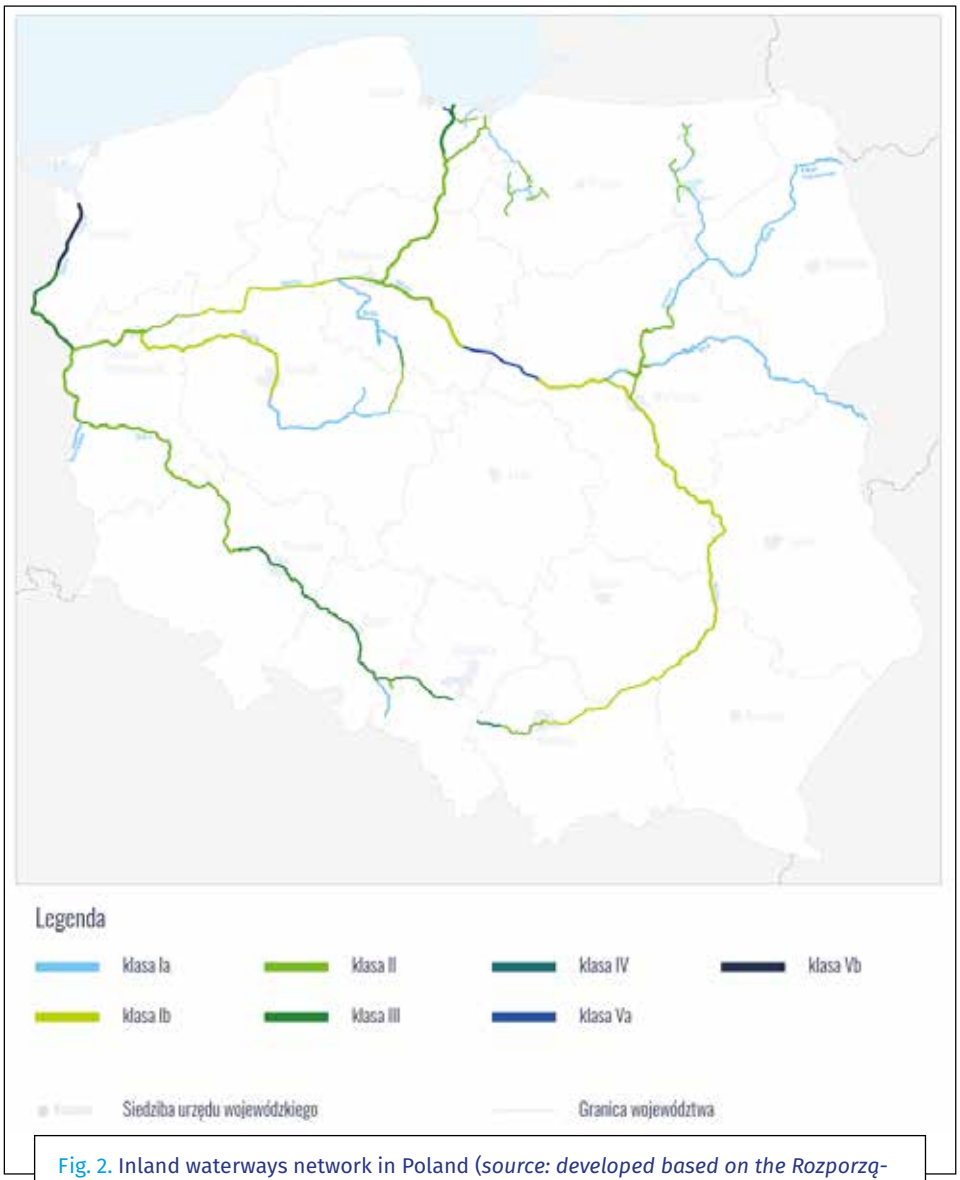

Fig. 2. Inland waterways network in Poland (*source: developed based on the Rozporządzenie Rady Ministrów z dnia 7 maja 2002 r. w sprawie klasyfikacji śródlądowych dróg wodnych*)

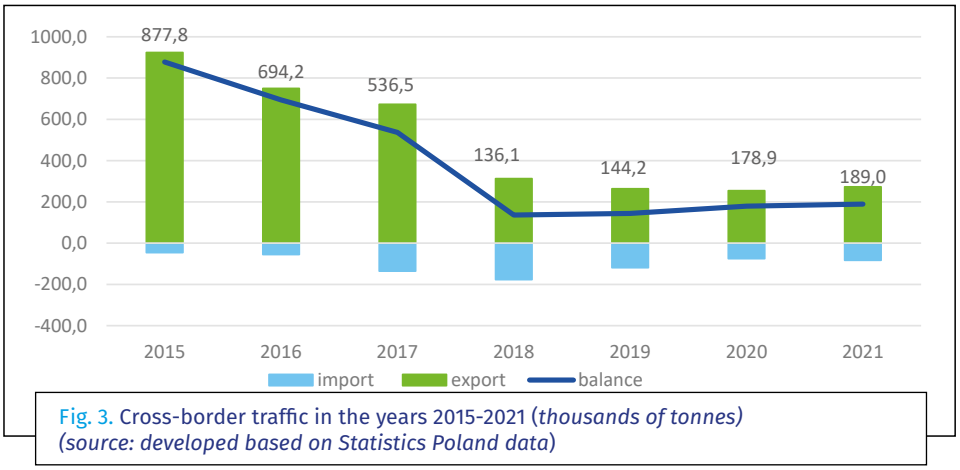

Fig. 3. Cross-border traffic in the years 2015-2021 (*thousands of tonnes*) (*source: developed based on Statistics Poland data*)

Table 1. Cargo transported in domestic inland waterway transport in Poland, 2015–2021 (*source: developed based on Statistics Poland data*)

Year/Cargo (milion tonnes)	2015	2016	2017	2018	2019	2020	2021
	3,83	2,97	2,54	2,43	2,35	2,10	1,72

main destination. The share of freight flowing through this route represented 81.4% of total exports of goods by inland waterways.

To summarize, data gathered by Statistics Poland indicated that between 2015 and 2021, there was a decrease in transported cargo via Polish waterways by approximately 55% (Tab. 1).

However, regions with the highest concentration of regular inland waterway transport, measured by transport performance, include:

- Oder Waterway: West Pomeranian and Lower Silesian Voivodeships.
- Lower Vistula region: Kuyavian-Pomeranian and Pomeranian Voivodeships.

In the context of cross-border traffic, the difference between exports and imports via waterways is constantly decreasing, from 0.88 million tonnes of cargo in 2015 to 0.19 million tonnes of cargo in 2021 (Fig. 3).

OUTCOME OF TRANSPORT DIAGNOSIS

ODER WATERWAY TRANSPORT CORRIDOR

The development of inland navigation in the Oder waterway transport corridor will increase territorial, social, and economic cohesion between:

- The highly industrialized Czech region of Ostrava (Silesian-Moravian Region).
- The Upper Silesian conurbation and Wrocław.
- The Szczecin-Świnoujście Seaports complex.
- As well as through the Oder-Spree and Oder-Havel canals, with the Federal Republic of Germany and other Western European countries.

The Oder waterway corridor is characterized by a high level of cargo supply, including general and container cargo, liquid cargo, and bulk cargo (Fig. 4). The Oder is also the only waterway used for regular cargo transport along its entire length, encompassing both domestic and cross-border waterway transport.

LOWER VISTULA WATERWAY TRANSPORT CORRIDOR

The lower Vistula waterway transport corridor (section: Gdańsk-Toruń) is characterized by a high level of urbanization. The transport network plays a crucial role in integrating the Port of Gdansk, Poland's largest seaport, with its hinterland, both along the north-south and east-west axes. Gdańsk, where the seaport is located, is a significant industrial and service centre classified among the cities with the greatest economic potential in the country. However, it also serves as a major cargo supplier, leading to congestion on the road and railway networks (Fig. 4).

MAIN GOAL AND SCOPE OF NMIN2030

The implementation of NMIN2030 will focus on regulatory activities and investment projects. Investments carried out under NMIN2030 will aim to enhance navigation conditions on sections of waterways used for regular transport, particularly to strengthen hinterland connections of seaports. Regulatory activities will focus on adapting all significant aspects of the inland navigation market to the challenges associated with sustainable development and climate change (Fig. 5).

The development of the inland navigation sector, coupled with the improvement of navigation conditions on Polish waterways, will also help overcome and prevent challenges such as food, energy, and flood security, as well as cybersecurity.

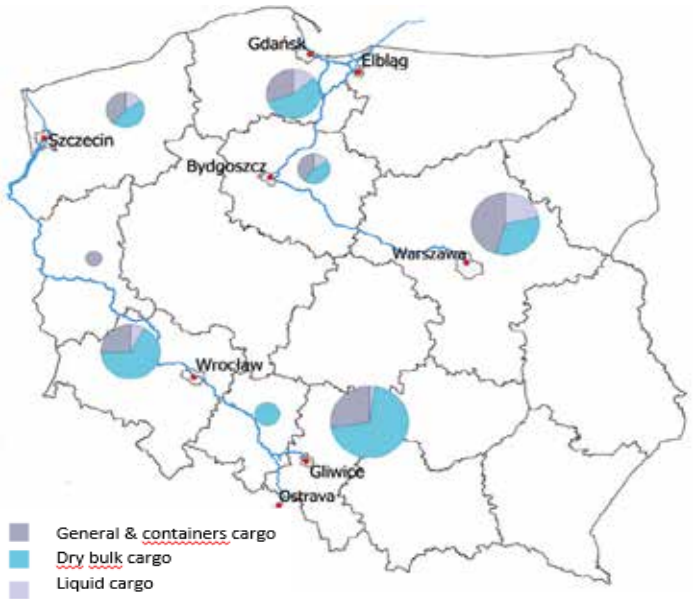

Fig. 4. Cargo supply on Polish waterways (*source: original work based on the results of the inland waterway traffic model*)

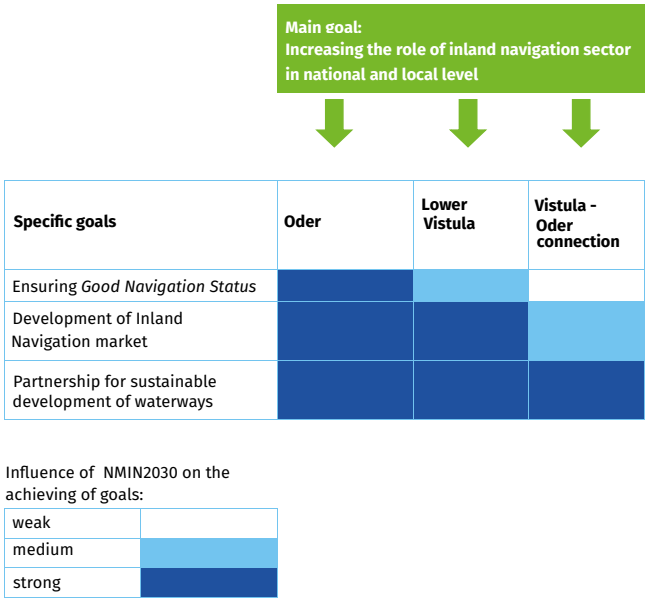

Fig. 5. Scope of intervention of NMIN2030 (*source: Uchwała nr 180/2023 Rady Ministrów z dnia 3 października 2023 r. w sprawie ustanowienia programu rozwoju pod nazwą „Krajowy Program Żeglugowy do roku 2030"*)

Fig. 6. Investment included in NMIN2030 (*source: Uchwała nr 180/2023 Rady Ministrów z dnia 3 października 2023 r. w sprawie ustanowienia programu rozwoju pod nazwą „Krajowy Program Żeglugowy do roku 2030”*)

Increasing the capacity of waterways and inland ports may be crucial for providing humanitarian aid or transporting cargo (including transit), such as grain and other agricultural products, or, in the event of immediate economic needs, fossil fuels (hard coal and lignite). Maintaining the availability of infrastructure and supply factors of water transport will enable a timely response and counteraction to crisis situations causing disruptions in supply chains in strategic areas of the country.

SPECIFIC GOAL NO. 1 – *ENSURING GOOD NAVIGATION STATUS*

Navigation Status according to NMIN2030 includes:

- Maintaining a channel depth of 1.8 m on the Oder (Gliwice-Ognica) and on the lower Vistula from Toruń to Martwa Wisła, enabling navigation on up to 80% of days per year.
- Maintaining a channel depth at 2.5 m on the Oder (Ognica-Szczecin) and on the Martwa Wisła.

● Ensuring bridge clearances at a level allowing the transport of at least two layers of containers through regulatory means.

● Maintenance of waterways in accordance with Article 43 of the Inland Navigation Act.

● Ensuring the availability of the River Information Services System (RIS) with future development.

Increasing the role of inland water transport requires ensuring *Good Navigation Status* on waterways, especially on connections between seaports and hinterlands. Specific Goal No. 1 consists of 11 investments based on the outcomes of the diagnosis of inland waterway transport (Fig. 6).

Beside investments, Specific Goal No. 1 also includes regulatory activities such as:

● Revision of the classification of waterways as an outcome of the implementation of investment projects.

● Adopting of regulations that will ensure and secure bridge clearance and operational parameters.

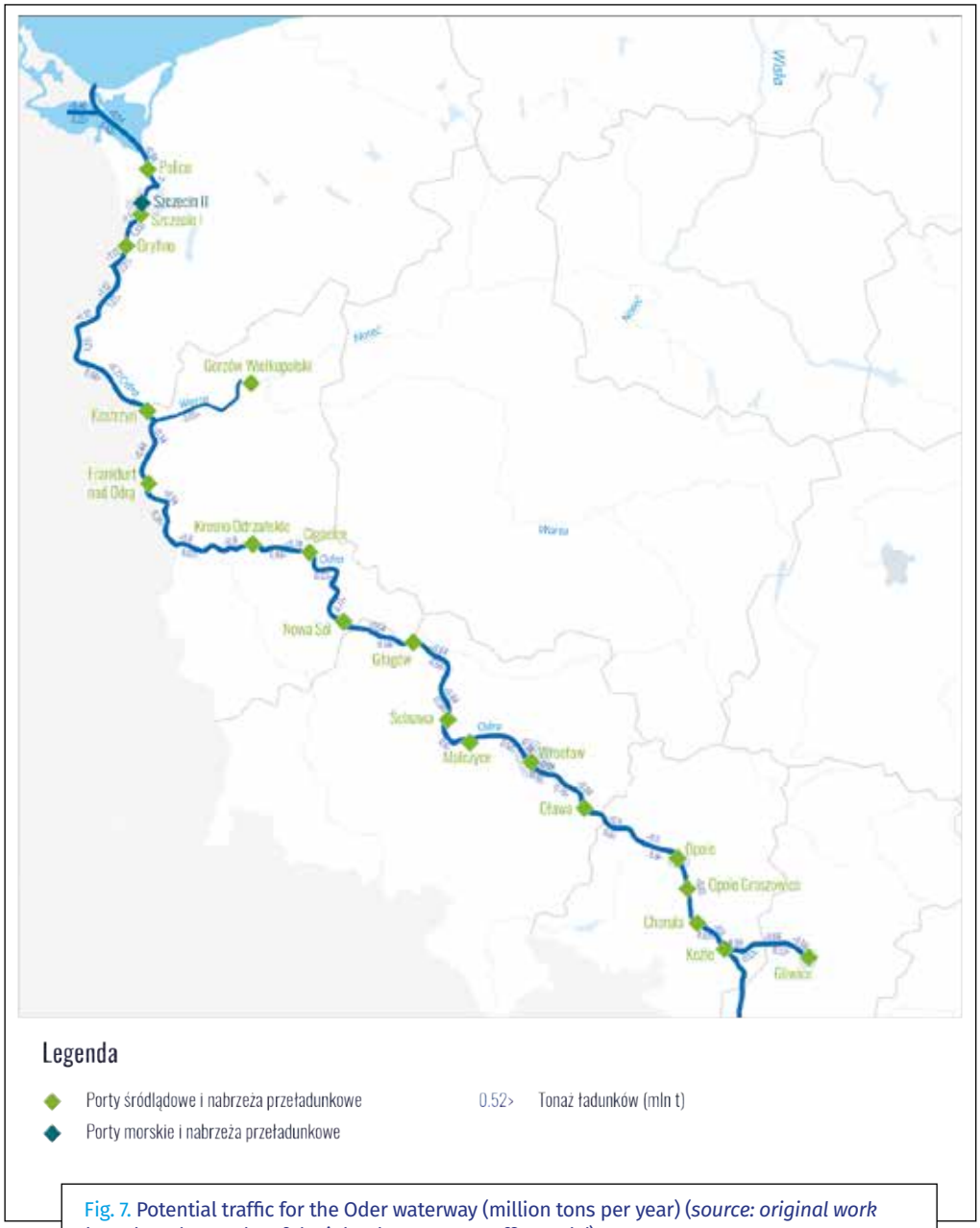

Fig. 7. Potential traffic for the Oder waterway (million tons per year) (*source: original work based on the results of the inland waterway traffic model*)

SPECIFIC GOAL NO. 2 – DEVELOPMENT OF INLAND NAVIGATION MARKET

An important factor in developing the competitiveness of inland water transport is its efficiency, understood as the ability to carry out transport operations utilizing the capacity of inland vessels and waterways. Furthermore, in establishing a competitive edge, it is crucial to adapt the sector to the challenges related to fleet transformation and digitalization of transport operations, supported by the digitalization of inland navigation public administration.

In Specific Goal No. 2, Development of Inland Navigation market, planned activities include several milestones to be achieved:

● Creating a strategy for development of inland ports and berths as a part of the intermodal strategy.

● Digitalization of fee collections for waterway and infrastructure (locks) usage.

● Digitalization of inland navigation public administration – an integrated hull and crew database will help provide safe and effective service for sector users.

● Increasing the availability of River Information Services (RIS),

● Enhancing fleet transformation – deploying greener and climate-resilient vessels operating in the shallow conditions of Polish waterways.

Increasing the effectiveness of the Inland Navigation Fund – dedicated to supporting shipowners regarding the modernization and transformation of the inland navigation fleet.

SPECIFIC GOAL NO. 3 – PARTNERSHIP FOR SUSTAINABLE DEVELOPMENT OF WATERWAYS

The sustainable development of the transport sector, as specified in the Polish transport strategy (*Strategy for the sustainable development of transport until 2030*), requires the creation of a policy framework and regulatory conditions for inland water transport as outlined by NMIN2030. Towards interventions for Specific Goal No. 3, sectoral activities have been defined, aimed

at shaping policies for the development of waterways and the inland navigation sector.

An element of such activities is to take into account all important components, factors, stakeholders, and users that shape the future of sustainable river management. In *Specific Goal No. 3, Partnership for sustainable development of waterways*, planned activities include several milestones to be achieved:

- Conducting environmental and economic analysis of strategies, plans, documents, and projects related to the inland navigation sector and waterways network.
- Creating and ensuring operational conditions for waterways included in Trans-European Transport Network (TEN-T).
- Creating an infrastructure plan for the Vistula-Oder connection (International Waterway E70) – based on regional and local partnerships to ensure navigation conditions allowing for regular recreational and tourist activities alongside irregular transport operations.
- Supporting the schooling system – promoting and enhancing the attractiveness of employment in the inland navigation sector.
- Establishing a new systemic approach for water-way management,
- Promoting the inland navigation sector and waterways.

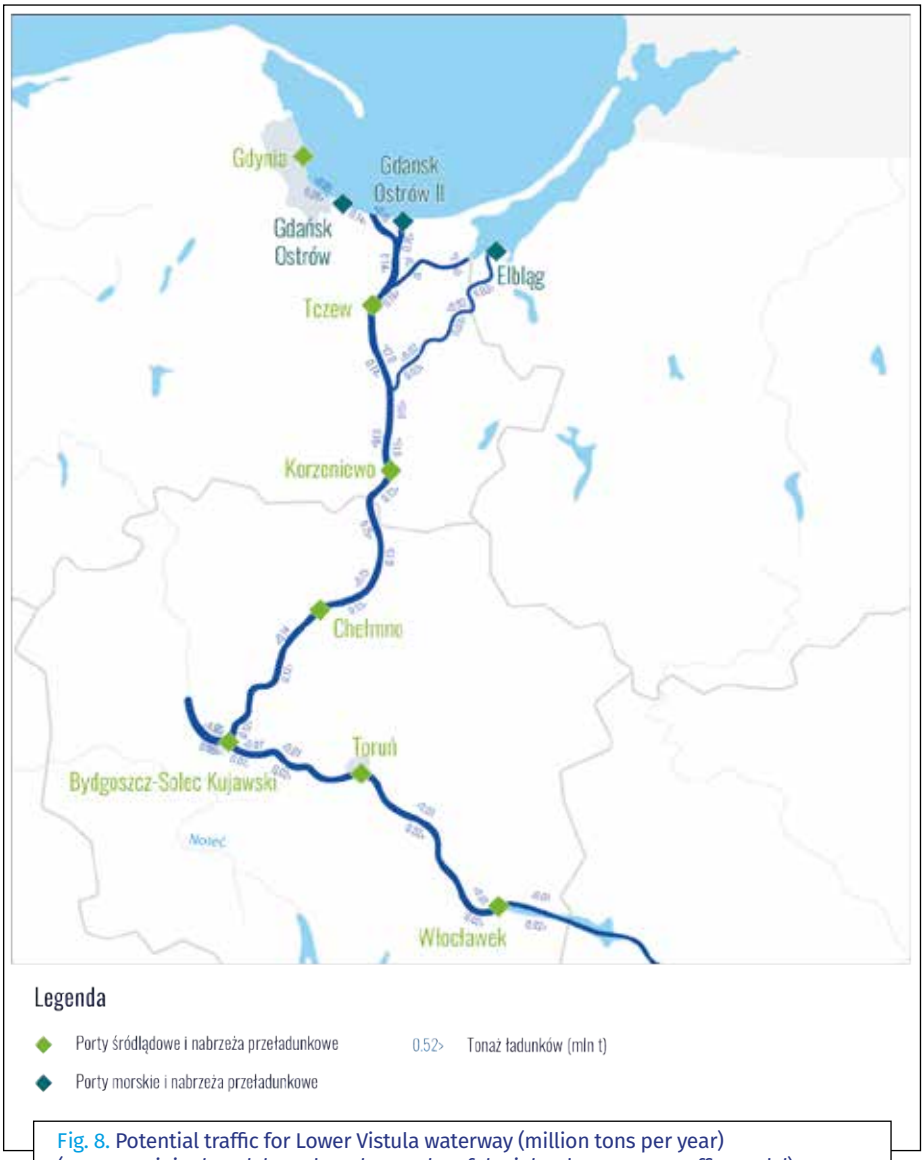

Fig. 8. Potential traffic for Lower Vistula waterway (million tons per year) (*source: original work based on the results of the inland waterway traffic model*)

IMPLEMENTATION OF NMIN2030 – OUTCOME

The implementation of NMIN2030 aims to increase the role of the inland navigation sector at the national and local levels. This can be achieved by realizing a line of actions, including:

- Elimination of bottlenecks in main waterway corridors.
- Improving waterway transport safety.
- Supporting the development of the inland navigation market, including fleet transformation.

Enhancing socio-economic activities related to the the economic use of waterways.

The potential transport effects will be evident in the growth of cargo transport on the main Polish waterways (Oder and lower Vistula). Based on results from waterway traffic prognosis, the estimated potential of Polish waterways is around 6.8 million tons of cargo transporter per year (Fig. 7 and Fig. 8) .

Expenditures for NMIN2030 (approximately 2 billion PLN) are expected to result in:

- Increased usage of waterway transport (potential growth by 38% compared to 2015) and halting to downward trend of waterway cargo transport.
- Strengthening hinterland connections of seaports, thus enhancing competitiveness among Polish seaports.
- Increasing revenues from waterways and infrastructure usage.
- Improved level of flood protection.
- Creation of new business opportunities and strengthening of the Polish labour market.

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Potential environmental possibilities of constructing a lateral navigation canal on the Czarnków – Krzyż Wielkopolski part of the Noteć River

Potencjalne możliwości środowiskowe budowy lateralnego kanału żeglugowego na odcinku Czarnków – Krzyż Wielkopolski na rzece Noteć

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Inland waterways in Poland possess significant potential; however, they are not extensively utilized due to their classification parameters. One avenue for enhancing their importance is through investments, which could include the construction of lateral navigation channels. This study aimed to assess the feasibility of such a project on a selected section of the Noteć River (part of International Waterway E70), considering environmental characteristics, nature protection forms, existing infrastructure, and monuments. Two variants were developed to assess potential collisions with existing infrastructure, quantify environmental damage, and identify navigational bottlenecks along the waterways.

Key words: lateral navigation channel, International Waterway E70, inland waterways, bottlenecks for navigation, the Noteć River

Śródlądowe drogi wodne w Polsce mają ogromny potencjał. Nie są jednak szeroko wykorzystywane ze względu na ich parametry klasyfikacyjne. Jednym ze sposobów na zwiększenie ich znaczenia są inwestycje, które mogą uwzględniać budowę lateralnych kanałów żeglugowych. Celem niniejszego artykułu jest ocena wykonalności takich projektów na wybranych odcinkach rzeki Noteć (stanowiącej część Międzynarodowej Drogi Wodnej E70), z uwzględnieniem charakterystyki środowiskowej, form ochrony natury, istniejącej infrastruktury i zabytków. Opracowano dwa warianty w celu oceny potencjalnej kolizji z istniejącą infrastrukturą, oceny ilościowej szkód dla środowiska i zidentyfikowania wąskich gardeł wzdłuż dróg wodnych.

Słowa kluczowe: lateralny kanał żeglugowy, Międzynarodowa Droga Wodna E70, śródlądowe drogi wodne, wąskie gardła w żegludze, rzeka Noteć

INTRODUCTION AND STUDY AREA

Poland has an extensive system of waterways with a total length of 3,768 km (Inland waterways transport in Poland, 2023). However, apart from the lower Oder River and the lower Vistula River, they do not have favorable classification parameters. Due to years of neglect in inland navigation (Skupień et al., 2016) and development plans (KPŻ, 2030), there has been a gradual marginalization of this crucial transport sector. Historically, thanks to the construction of the Bydgoszcz Canal in 1773-1774 (Winid, 1928), the Noteć River played an essential role in the waterway connecting Western Europe with the waterways of Eastern Europe. However, presently, the International Waterway E70 fails to meet AGN requirements (Maruszczak, 2019), and infrastructure neglect combined with ongoing climate change (Skupień et al., 2019) have led to its primarily local use, mainly by small tourist vessels. A renewed increase in the importance of the Noteć River in the European waterways network can only occur through infrastructure investments. However, these investments may conflict with the preservation of valuable natural habitats and the conservation of hydrotechnical facilities along the waterway.

The research area encompasses the section of the Noteć River between Czarnków and Krzyż Wielkopolski (Fig. 1). The Noteć River is located at the bottom of the Toruń-Eberswalde Ice Marginal Valley (Solon et al., 2018), a route that drained meltwater westward during the last Pleistocene glaciation. The valley area consists of peat, sandy, and silt deposits, and is bordered by plateau sections to the north and south, composed of post-glacial clays and sands. The detailed study area includes a section of (a) the lower Noteć River regulated from 128.3 km of the waterway (lock no. 15 – Lipica) to 176.2 km of the river, and (b) a short section of the lower Noteć River freely flowing from 176.2 km to 182.1 km near the town of Stare Bielice (Habel et al., 2017).

The Noteć River valley is characterized by high natural values. Several forms of nature protection have been established in the research area, including: (i) protected landscape areas "Dolina Noteci" and "Puszcza nad Drawą," (ii) Natura 2000 – SPA "Nadnoteckie Łęgi," (iii) Natura 2000 – SAC "Dolina Noteci," and several smaller nature reserves and ecological sites.

The research aimed to determine the potential for constructing a lateral navigation channel along the Noteć River between Czarnków – Krzyż Wielkopolski, considering morphometric features of the environment, the current inventory of infrastructure facilities, and

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Fig. 1. Study area of Noteć River on the background of satellite image (*source: Geoportal.gov.pl*)

environmentally and culturally valuable areas. Taking into account these variables and design guidelines from current shipping regulations (Journal of Law of 2022, item. 1170), an innovative aspect of the study was the indication of bottlenecks for navigation and conflicts for the proposed lateral waterway channel variants.

MATERIALS AND METHODS

The research was based on public spatial databases characterizing the features of the natural environment and infrastructure facilities in the study area. The data used included: the Geological Map of Poland (Polish Geological Institute – National Research Institute database), Nature Protection Forms (General Directorate for Environmental Protection database), Digital Topographic Object Database BDOT10K (Geoportal Inspire), Map of the Polish Hydrographic Division (Hyrdoportal ISOK) and the Register of Monuments (National Heritage Institute database).

Spatial analyses were performed using QuantumGIS (v.3.4.12) and the System for Automated Geoscientific Analyses (SAGA) (v.2.3.2) (Conrad et al., 2015) software, employing geoprocessing tools and terrain analysis. The foundation for determining the variants of the lateral navigation channel was the Digital Elevation Model (DTM) with a horizontal resolution of 1 m × 1 m and a vertical resolution of 0.15 m, provided as ASCII XYZ GRID files in the metric coordinate system 1992. This allowed for the calculation of various indicators, such as DTM, Valley Depth (VDEP), and Vertical Distance to Channel Network (VDCN). The analysis facilitated the determination of the most optimal course for the lateral navigation channel based on morphometric conditions. Subsequently, the navigational course was verified against infrastructure facilities, such as weirs and locks, road and railway networks, power lines, urbanized areas, monuments, and the spatial scope of nature protection forms.

The lateral navigation channel variants were planned in accordance with the guidelines contained in the Regulation of the Council of Ministers on the classification of inland waterways (Journal of Law of 2022, item. 1170). These guidelines specify parameters for ships with a maximum length of 185 m, a width of 11.4 m, and a draft of 3 m, which ar characteristic of navigability class Vb. The lateral navigation channel can be constructed using an earth structure with slope and bank reinforcements in a trapezoidal shape, with a slope inclination varying from 1:1.5 to 1:4 depending on the depth. In urbanized areas, vertically driven sheet pile walls will be used for construction, which will reduce the total width of the canal and enable the creation of marinas, tourist facilities, and transshipment wharves. The radius of the navigable channel arc should be at least 800 m along its axis. The width of the shipping channel is 45 m in a rectangular section and 73 m in a trapezoidal section, with a constant draft for the vessel of 3.5 m. According to the regulation, lock dimensions are 18 meters long and 18 meters wide.

RESULTS

The morphometric features of the river valley are a determining factor in the possibility of establishing a lateral navigation canal. The valley floor is relatively slightly varied, with the elevation differences for the proposed variants being 16.49 m for the first variant and 16.46 m for the second variant (Fig. 2A). The values of the VDEP index indicate the locations of terrain obstacles (Fig. 2B). Variant II, which locates the lateral navigation canal closer to the edge of the plateau, encounters more obstacles due to its location. The next indicator, VDCN, also highlighted areas of potential collision with infrastructure objects (Fig. 2C). Additionally, low VDCN values indicated the lowest areas of the river valley, including oxbow lakes, which were utilized in variant I.

The research identified two variants for establishing a lateral navigation canal on the northern side of the Noteć River. Variant I, stretching 41.37 km, utilizes oxbow lakes and small streams in the valley bottom, following a route characterized by the lowest ordinate in the study area. Variant II, covering 41.15 km, prioritizes long straight sections to facilitate navigation, resulting in more diverse morphometric conditions along its course. Both variants of the lateral navigation channel were found to have 7 collisions with infrastructure facilities, forms of nature protection, and 9 monuments. Additionally, Wieleń emerged as a bottleneck for navigation due to its strong development of buildings, monuments, and its location near the edge of the plateau, impacting navigation along the analyzed part of the waterway.

CONCLUSIONS

The research facilitated the identification of two potential variants for constructing a lateral navigation canal on the section of the Noteć River between Czarnków and Krzyż Wielkopolski. This assessment considered environmental features, the presence of protected areas, monuments, and infrastructure facilities.

Both variants of navigation routes correspond to navigability class Vb. They mainly traverse arable land and pastures, with sections adjacent to artificial surfaces (cities). The proposed variants differ in their course. Variant I primarily utilizes oxbow

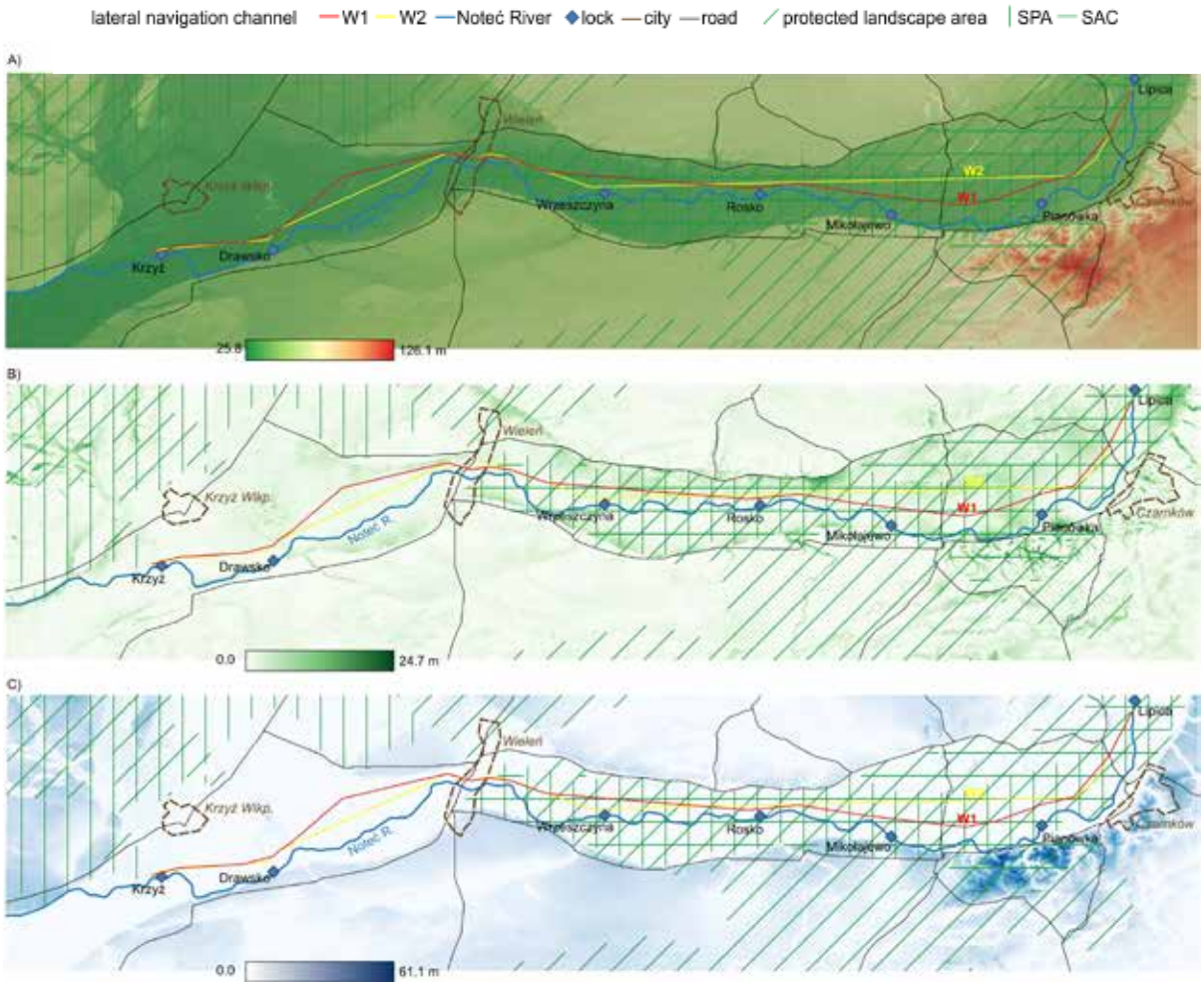

Fig. 2. Projected course of the lateral navigation channel overlaid on analyzed morphometric parameters A – DEM, B – VDEP, C – VDCN, and infrastructure facilities (*source: analysis based on DTM – Geoportal.gov.pl*)

lakes, existing small rivers, and artificial channels, while minimizing altitude fluctuations in the research area. On the other hand, variant II runs close to the northern border of the valley, maximizing the length of straight sections to reduce the curvature of the channel, thus offering a more navigation-friendly option.

When designing the route for the variants, challenges arose regarding the overlap with protected areas, rendering it infeasible to circumvent them. Considering the environmental restrictions stemming from EU directives, this serves as a key factor in determining the feasibility of establishing new lateral navigation channels. Additionally, the proposed routes intersects with existing communication infrastructure, such as roads and rails, necessitating reconstruction during detailed planning. A bottleneck for navigation was identified along the route, particularly in Wieleń, stemming from its significant urban development within the river valley bottom. Bottlenecks represents a constraint on the navigation conditions of inland waterways. Regarding the bottleneck in Wieleń, it is proposed to construct a channel using sheet piling for its cross-section, allowing for a reduced design width and facilitating the routing of the lateral navigation channel.

The research provides a new perspective on the feasibility of reinstating navigation on the International Inland Waterway E70 while meeting the minimum standards required for a waterway of international importance.

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Urbanization and flooding dynamics: A case study of the Seveso River in Northern Italy

Urbanizacja a dynamika powodzi: studium przypadku rzeki Seveso w północnych Włoszech

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This research focuses on the geomorphological assessment of the Seveso River, one of the principal watercourses inflowing the city of Milan, Lombardy region. The river has experienced substantial alterations due to human activities, leading to heightened flood occurrences. The study utilized GIS analysis, River Habitat Survey (RHS) methodology, land use change analysis, the Indicators of Hydrologic Alteration (IHA) method, and flood risk analysis to examine the Seveso River's evolution, its ecological status, and flood risk. Results indicated significant anthropogenic modification and high flood risk, with 11% of Milan's population residing in Seveso flood-prone areas. These findings underscore the need for effective mitigation strategies amid increasing urbanization and extreme rainfall events.

Key words: land use change, River Habitat Survey (RHS), flooding risk assessment, Seveso River

Badanie skupia się na geomorfologicznej ocenie rzeki Seveso w regionie Lombardii, jednego z głównych cieków przepływających przez Mediolan. Rzeka poddana została istotnym zmianom wynikającym z działalności człowieka, co doprowadziło do zwiększenia częstotliwości zjawisk powodziowych. W badaniu wykorzystano analizę GIS, metodę River Habitat Survey (RHS), analizę zmian użytkowania gruntów, metodę Indicators of Hydrologic Alteration (IHA) oraz analizę ryzyka powodziowego. Jego celem była ocena ewolucji rzeki Seveso, jej stanu ekologicznego oraz ryzyka powodzi. Wyniki wskazały na istotne zmiany antropogeniczne i wysokie ryzyko powodzi, obejmujące 11% populacji Mediolanu zamieszkujące obszary narażone na zalanie wodami rzeki Seveso. Ustalenia te podkreślają konieczność opracowania skutecznych strategii ograniczania ryzyka w sytuacji, w której procesy urbanizacyjne narastają, a ekstremalne zjawiska pogodowe stają się coraz częstsze.

Słowa kluczowe: zmiana użytkowania gruntów, metoda River Habitat Survey (RHS), ocena ryzyka powodziowego, rzeka Seveso

INTRODUCTION

The Seveso River is one of the three main rivers inflowing the city of Milan, Lombardy region, Northern Italy. The Seveso River's spring is located in the Southern Alps, west of the city of Como, and along its course, the waterway undergoes significant changes of its geomorphological characteristics, transitioning passing from natural conditions to a highly-channelized and buried settings. Its original watercourse has been deeply modified since Roman times, and the current torrential nature of the river necessitates serious solutions, such as permeable pavement and green roofs (Hamidova et al., 2024). However, it was only since the 1950s, due to intense urbanization, that flooding events became more frequent and dangerous. In particular, 104 flooding events were recorded from 1976 up to 2017, resulting in considerable damages and inconveniences for residents (Raimondi et al., 2020). The last flooding event was recorded on October 31, 2023 after 36 mm of rain fell in only one hour. Significant impact was observed in the northern part of the city, causing problems with urban roads and the metro line for six hours.

The aim of this study is to:

- Assess the geomorphological changes of the Seveso River watercourse through a dedicated multi-temporal historical and GIS analysis.
- Correlate flooding events with surface sealing and anthropization.
- Assess the river disturbance as well as hydrological alteration of one of the most human-influenced river systems.
- Evaluate the percentage of the population potentially subject to Seveso's flooding.

The study emphasizes how urbanization and canal construction shape the Seveso River's evolution, impacting its geomorphology, ecology, and flood risk dynamics.

METHODOLOGY

The methodology employed in this study encompasses several key approaches:

- GIS analysis of historical maps from the 6th-3rd c. BC to modern times.
- Land use analysis spanning from 1954 to 2021.
- River Habitat Survey (RHS) methodology.
- Flood risk and population vulnerability analysis.
- Indicators of Hydrologic Alteration (IHA) method.

Data from historical maps dating back to the 6th-3rd c. BC (Milan, 6th-3rd century BC), modern cartographic data from the Geoportal of Lombardy, field survey results using the RHS

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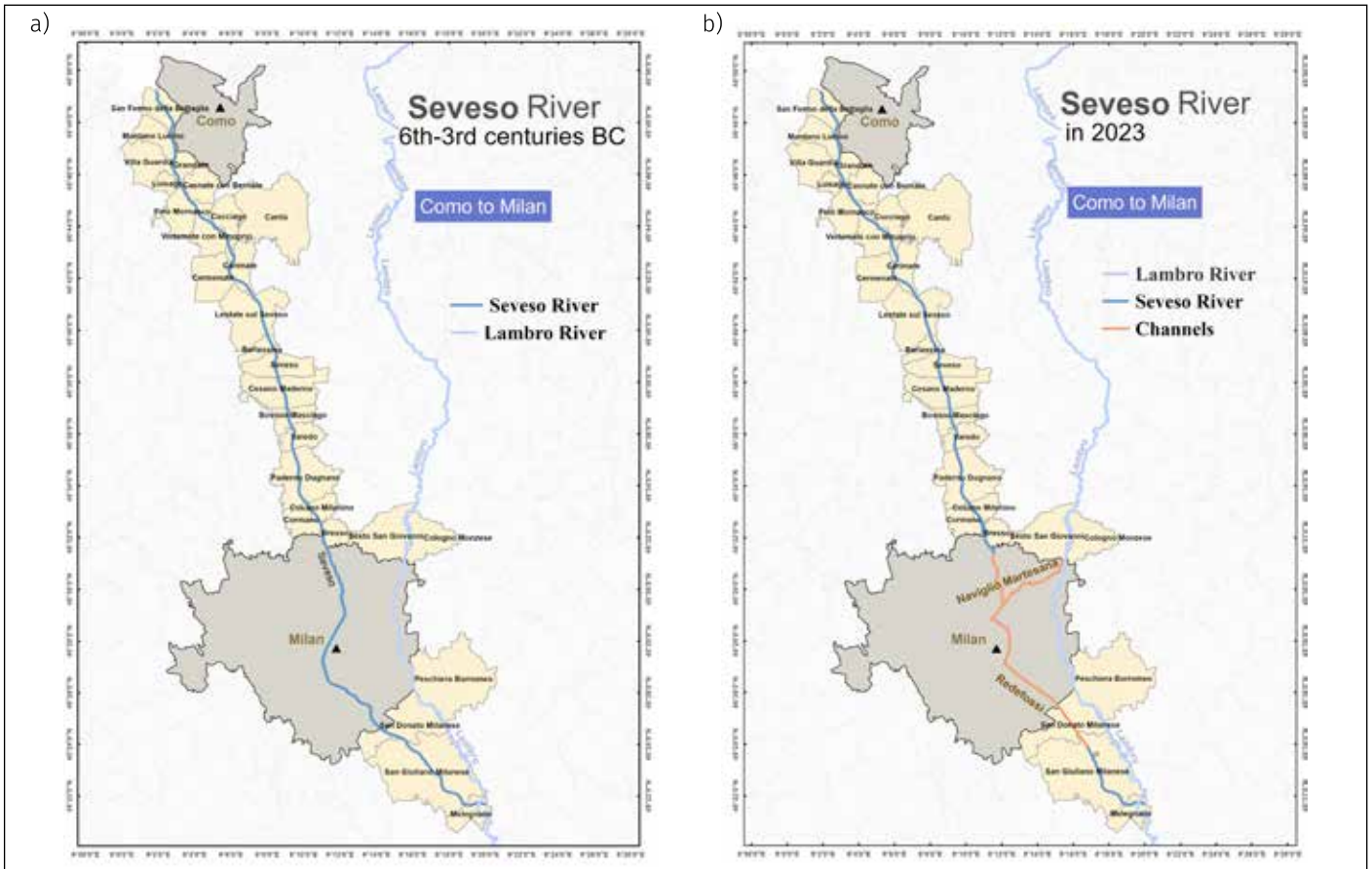


Fig. 1. a) Seveso River in 6th-3rd c. BC (Milan, 6th-3rd c. BC); b) Seveso River in 2023 (*source: Geoportal of Lombardy*). During the 19th c., the river was connected to the Naviglio Martesana and subsequently buried via the Redefossi channel (*source: Becciu et al., 2018*)

Toolbox 1.5 methodology (RHS Toolbox 1.5), hydrological regime assessments using the Indicators of Hydrologic Alteration (IHA) method, and population/risk data from sources including ISTAT (ISTAT, 2023), 'Piano Gestione Rischio Alluvioni', and the Municipality of Milan were utilized in the study. These methodologies collectively enabled a comprehensive analysis of the Seveso River's evolution, ecological status, anthropogenic modification, and flood risk, providing valuable insights into the complex interactions between human activities and hydrological processes in the Milan area.

RESULTS

The Seveso River's evolution was studied using GIS analysis, encompassing historical maps from the 6th-3rd c. BC (Milan, 6th-3rd c. BC) up to modern cartographic representation through data available from Geoportal of Lombardy and 'Istituto Nazionale di Statistica' (ISTAT, 2023). The results highlight differences in the riverbed's position and changes in the river's geomorphology (Fig. 1). The outcome obtained from the comparative analysis of maps highlights the impact of anthropogenic changes, notably exemplified by human interventions such as the establishment of buried canals along the city of Milan.

The historical development of the river reflects significant human intervention. In 1496, the Naviglio Martesana canal was redirected to Milan, contributing to an increase in the water volume of the Seveso River. However, as the city's population grew and wastewater from households was deposited into the river, its volume further increased, resulting in frequent floods. To manage these floods, the first underground channel, called Redefossi, was constructed and completed in 1786. Particularly noteworthy is the burial of the Seveso River in Milan, which was completed in the 19th c. (Becciu et al., 2018). The burial of the Seveso River exemplifies the intricate interplay between urban expansion and modifications to natural features during historical periods of urbanization. Particularly noteworthy is the burial of the Seveso River in Milan, which was completed in the 19th c. (Becciu et al., 2018). The burial of the Seveso River exemplifies the complex relationship between urban expansion and modifications to natural features during historical periods of urbanization.

The increase in floods along the Seveso River was particularly observed in the 1950s, attributed to factors such as economic development and the expansion of urban landscapes (Becciu et al., 2018). Considering this, a land use analysis around the river was conducted, spanning from 1954 (Fig. 2). GIS land-use analysis along the Seveso River were conducted for the years 1954, 1980, and 2021 (Geoportal of Lombardy), revealing significant changes in the areas within 500 meters of the riverbank. In 1954, the predominant land use was agricultural, but in the following years, a notable transition occurred with an increase in green vegetation. Simultaneously, urban areas expanded along the riverbanks. By 2021, urbanization intensified, resulting in a significant reduction in agricultural and vegetation areas.

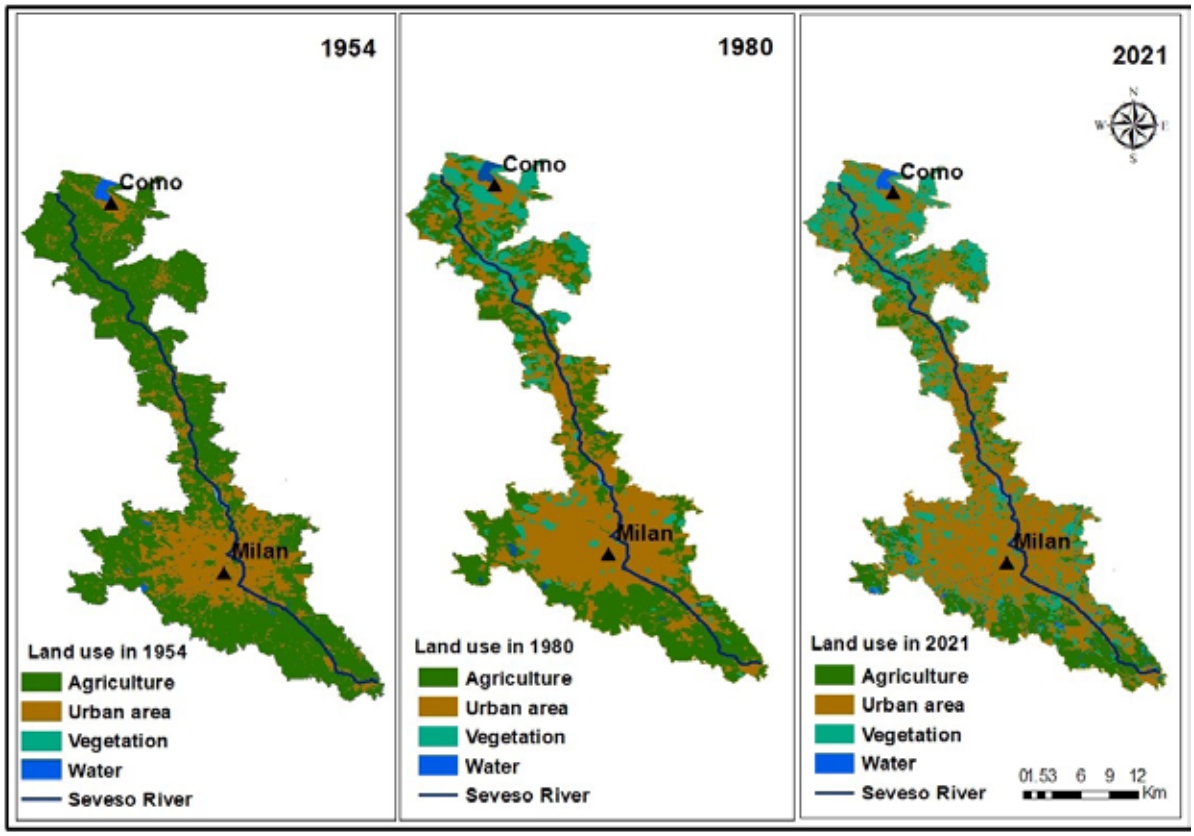


Fig. 2. The land use surrounding the Seveso River for the years 1954, 1980, and 2021 (*source: Geoportal of Lombardy*)

In addition to analyzing changes in land use, assessing the hydromorphology of the river was essential for understanding the broader ecosystem dynamics and how human activities impact the Seveso River's ecological health and overall functionality. By employing the RHS (River Habitat Survey) methodology (EA, 2003), a field survey covering a 500-meter stretch of the Seveso River was conducted near Milan city on December 15, 2023 (Fig. 3).

The area chosen for this study along the Seveso River is densely populated and closely surrounded by infrastructure. The methodology recommends conducting surveys over a 500-meter distance to gather sufficient data for analysis. Study parameters included vegetation, structural components, hydraulic properties, and channel morphology. In the RHS tool (RHS Toolbox 1.5), the Habitat Modification Score (HMS) and the River Habitat Assessment Technique (RHAT) were applied to analyze river changes and evaluate its ecological conditions (Fig. 4). The results indicate a poor ecological status (WFD score 3) and a high level of anthropogenic modification in the researched area (HMS class 5).

To assess the overall impact of the aforementioned factors (land use and hydromorphological changes) on the flooding hazards of the Seveso River, a flood risk analysis was conducted. This analysis, based on the data from the Geoportal of Lombardy, focuses on assessing flood risk along the Seveso River. The results show a significant flood risk in Milan, especially in the heavily built-up, channeled, and covered parts of the Seveso River within the city (Fig. 5). These results underscore the significance of considering river damming and urbanization as factors contributing to river flooding.

Fig. 3. Surveyed area: Seveso River entirely flowing within artificial banks, Milan (*source: original work*)

After conducting the flood risk analysis, it is important to assess changes in the hydrological regime of the Seveso River to understand variations in water stages, which contributes to a more comprehensive evaluation of flood risk dynamics in the area. To determine changes in the hydrological regime of the Seveso

River, the Indicators of Hydrologic Alteration (IHA) method was proposed by Richter et al. (1996). The result is a list of 33 hydrologic parameters with their characteristics, grouped into five statistics categories:

1) The magnitude of monthly water conditions.
2) The magnitude and duration of annual extreme water conditions.
3) The timing of annual extreme water conditions.
4) The frequency and duration of high and low pulses.
5) The rate and frequency of water condition changes, as described in detail by Richter et al. (1996).

Hydrological data was utilized, including daily water stages (in cm), obtained from APRA for the gauging stations: Asnago (1998-2022), Palazzolo (1999-2020), and Niguarda (2013-2020). The IHA results indicated the following observed changes in the longitudinal profile of the Seveso River: a shift of the date of maximum water stage (from October 6, 2023 – November 7, 2023; group 3), an increase in the count of high-water stage (from 14 to 32.5; group 4), and occurrences of water stage reversals (from 115 to 135.5; group 5) (Fig. 6).

Based on the aforementioned results, it is evident that the combination of human influence on the river and extreme meteorological events can expose the population to flooding risk.

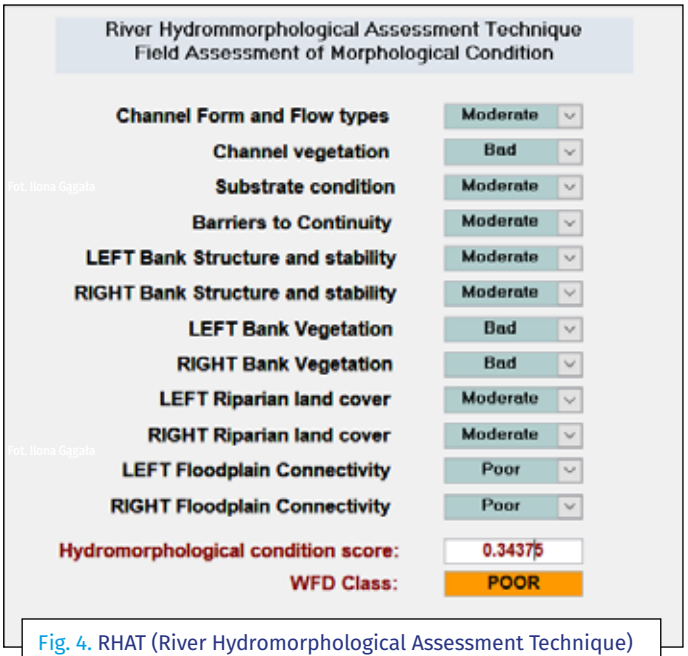


Fig. 4. RHAT (River Hydromorphological Assessment Technique) result (*source: RHS Toolbox 1.5*)

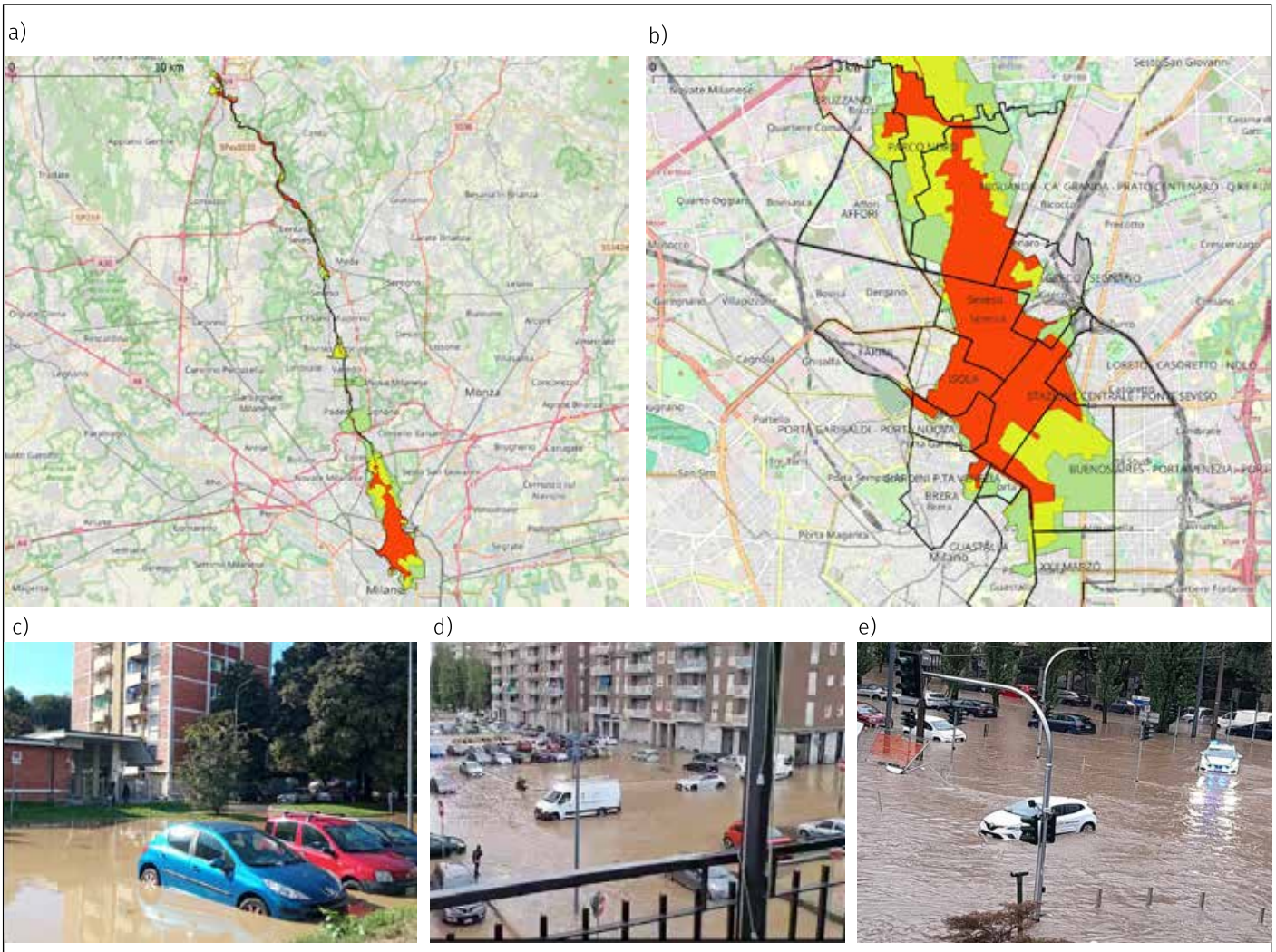


Fig. 5. a) Seveso River flood hazard map from Como to Milan; b) Milan's flood risk zones: red for high, green for medium, yellow for low risk. Flooded zone pictures (*source: Geoportal of Lombardy*); (c) Via Demonte; (d) Via Val Maira; (e) Viale Suzzani (*source: photos acquired by a resident citizen*)

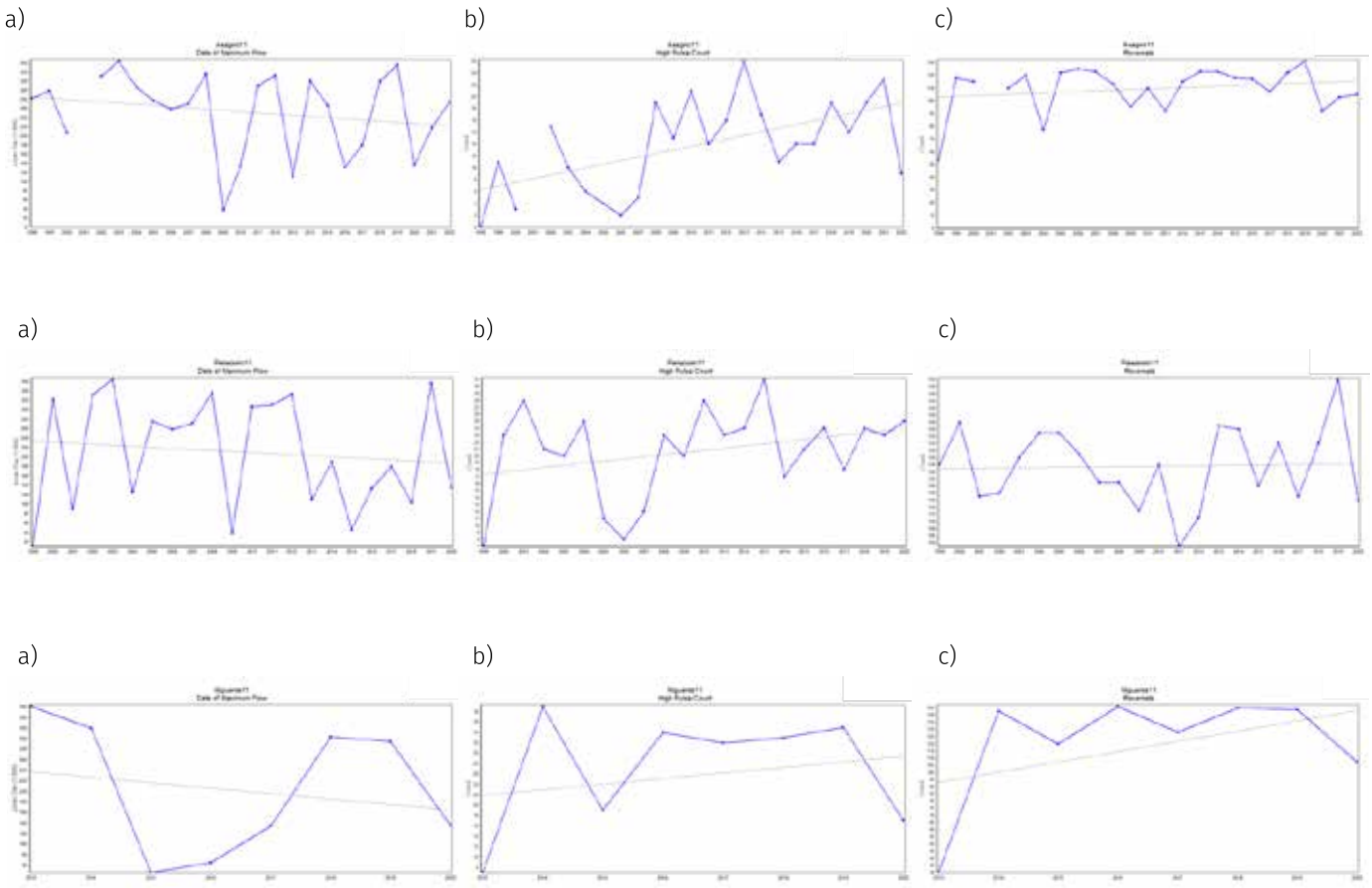
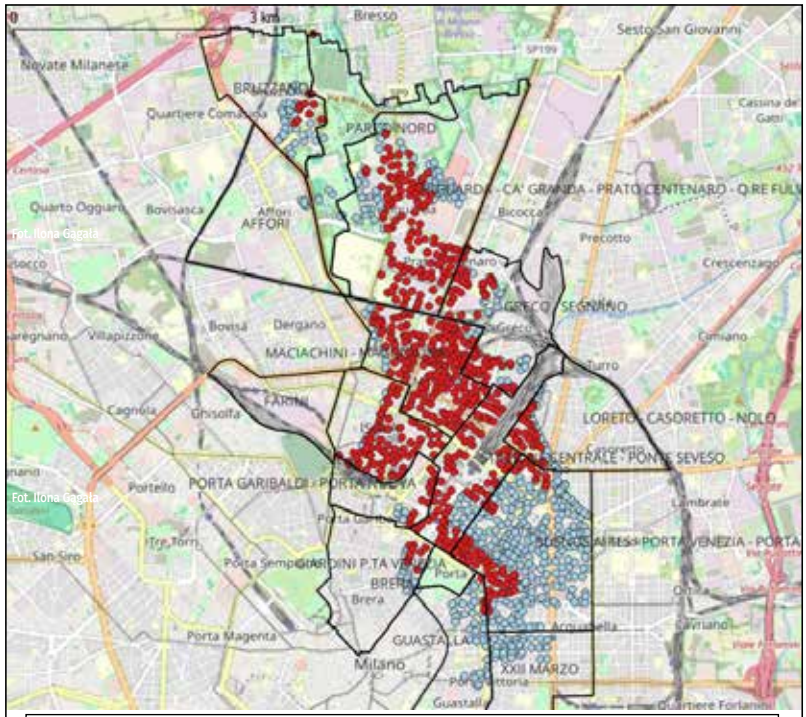


Fig. 6. Seveso River – Date of Maximum Water Stage: a) Maximum water stage shifted October 6, 2023 – November 7, 2023; b) Count of high-water stage from 14 to 32.5 cm; c) Occurrences of water stage reversals from 115 to 135.5 cm (*source: ARPA*)



Fot. Ilona Gagała

Fig. 7. In Milan city, 84,148 people lived in the maximum danger area (represented by red dots); 71,720 people lived in the medium-low danger area (represented by blue dots) (*source: PGRA, 2020; ISTAT, 2023*)

Utilizing freely available data from ISTAT, the 'Piano Gestione Rischio Alluvioni' (PGRA, 2020), as well as data from the Municipality of Milan, it was determined that 11% of Milan's population resides in an area classified as at hydrogeological risk from flooding of the Seveso River (Fig. 7).

In particular, the PGRA was utilized to assess the spatial distribution of areas vulnerable to hydrogeological risk, and consequently, determine the percentage of the population potentially affected in these areas. ISTAT and data from the Milan Municipality were employed to evaluate social vulnerability, specifically to calculate the population density and the proportion of foreigners in the study area. Indeed, both of these indices are considered to be positively correlated with increased social vulnerability (Cutter et al., 2003).

CONCLUSION

In conclusion, the comprehensive study of the Seveso River's evolution reveals a complex interplay between natural processes and human interventions, ultimately impacting the river's geomorphology, ecological health, and flood risk dynamics.

Through meticulous analysis spanning from historical maps to contemporary GIS data, it becomes evident that anthropogenic activities, such as urbanization and the construction of canal systems, have significantly altered the river's course and morphology over time. The increase in urbanization, coupled with more frequent extreme rainfall events, has deepened the alteration of the river's hydrological condition, leading to serious flooding problems for the city of Milan. Despite the implementation of various strategies aimed at mitigating flood risks along the Seveso River, the river continues to contend with recurring flooding issues. However, a system of large lamination tanks, dedicated to containing millions of cubic meters of floodwater to be released after the flood event has passed (CONAF, 2023), is being built as risk mitigation strategy to reduce hydrogeological risk. It is hoped that these measures will lead to fewer floods in the near future and provide greater resilience for the surrounding territory.

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Why is navigation difficult on the lower Vistula River?

Dlaczego żegluga wzdłuż dolnej Wisły jest trudna?

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The lower Vistula River natural conditions limit the possibilities of river regulation. River regulation works performed at the end of the 19th c. did not take into account the massive transport of bed load that, in a wet year, can reach $1.5x10^6$ tons of material. During low river stage periods, sandbars appear, forcing the river to strongly meander. The movement of sandbars was analysed based on the Sentinel-2 satellite images. The comparison of sandbars distribution on 04/09/2016 and 30/07/2017 indicated an average shift of 443 m. Sonar measurements performed in that period show that, during one year, the thalweg changes its position moving from one bank to another. In places where the thalweg alternates between the banks, the river depth over sandbars falls below 1 m.

Key words: lower Vistula River, river channel regulation, sediments, sandbars, navigation

Naturalne warunki dolnej Wisły stanowią ograniczenie dla regulacji rzeki. Wykonane w końcu XIX w. prace regulacyjne nie uwzględniały ogromnych mas rumowiska wleczonego, którego transport w warunkach roku mokrego może sięgać 1.5×10^6 t. Przy niskich stanach wody na powierzchni pojawiają się piaszczyste ławice, które wymuszają kręty układ nurtu. Do badania ruchu ławic wykorzystano analizę obrazów satelitarnych Sentinel-2. Porównanie położenia ławic na obrazach z 2016-09-04 i 2017-07-30 wykazało ich przesunięcie o średnio 433 m. Wykonane w tych latach pomiary echosondą pokazują, że w ciągu jednego roku nurt zmienia położenie, przemieszczając się spod jednego brzegu na przeciwległy brzeg. W miejscach, gdzie nurt przerzuca się między brzegami, głębokości nad ławicami spadają poniżej 1 m.

Słowa kluczowe: dolna Wisła, regulacja kanału rzecznego, osady, piaszczyste łachy, żegluga

INTRODUCTION

The Vistula River has a long history of being used for inland transport, dating back to the 10th c. However, it was only in the 14th and 15th c. that it became an important corridor for shipping, with intensive transport of grain and timber. In the 18th c., transport was reduced due to the partition of Poland by Prussia, Austria and Russia. The political boundaries between these countries made water transport more difficult, and taxes created unprofitable conditions for trade. Continuous system of the Vistula River was split into three domains. The boundaries between the occupying countries of Poland are still physically visible on the river, manifested by different river training methods.

The most intensive navigation occurred on the lower Vistula River in Prussia. This section was an important waterway for transport to Gdańsk and Królewiec, as well as to the Oder River, which was connected by the Bydgoszcz Canal. In Russia, the Vistula River was regulated only in certain places where there was a need to protect the banks from erosion or to stabilize channel in cities with bridges. This discontinuous system of river training works on the Vistula has not changed over time and is still visible today, making navigation on the entire river very problematic. The load of river barges used on the lower Vistula River was limited to 300 tons due to problems with transition depths.

The importance of inland shipping has always been marginal in the Polish transport system. The peak of inland shipping activity was in 1979, with a total of 23.2 million tons transported, representing a 0.8% share of total transport. In 2022, the mass of goods transported by inland shipping is 2.0 million tons, accounting for a 0,1% share of total transport. Proposed by European Agreement on Main Inland Waterways of International Importance (AGN) in 1996, the plan to increase inland shipping also includes new waterways in Poland. Two new waterways, E-40 and E-70, run along the lower Vistula River. The minimum standard of European waterways in the AGN plan is class IV. The new plan from the Prime Minister's Council in 2023, with a perspective extending to 2030, outlines the directions for the development of inland shipping. These include the intensification of inland shipping in connection with sea harbors. For the lower Vistula River, this plan requires the improvement of the waterway class between Toruń and Gdańsk. The specific conditions of the lower Vistula River, such as the intensive transport of suspended sediments and bedload along with the river channel pattern changed according to 19th c. design, make typical river training questionable. The difficulty in maintaining conditions for navigation on the lower Vistula River using standard river training structures was one of the arguments for plans dating back to the 1950s to build a cascade of reservoirs on the lower Vistula River as an option for improving waterway conditions. In the so-called Vistula Plan,

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it was proposed to build a cascade of 8 reservoirs. This plan is still seen as a way to improve navigation conditions and produce 455-780 MW of hydro-power (Szydłowski et al., 2014).

The aim of this paper is to show why navigation of the lower Vistula River is difficult in the context of channel processes and sediment transport.

GEOLOGICAL HISTORY AND SEDIMENT TRANSPORT ON THE LOWER VISTULA VALLEY

The macro-region of the Lower Vistula Valley was formed at the end of the Pleistocene and the beginning of Holocene. The Lower Vistula Valley separates the macro-regions of the East and South Pomeranian Lake Districts from the Iława and Chełmno-Dobrzyń Lake Districts. The topography of the Polish Lowlands reflects the geological history of deglaciation and climate change (Galon, 1972). The formation of river valleys in the Polish Lowlands was significantly influenced by the periodic release of large amounts of meltwater from the margin of ice sheets, accompanied by the inflow of river water from the southern part of the country, which was not glaciated. During subsequent stages of deglaciation, as the edge of the ice sheets moved north, river runoff took place through ice-marginal paleo valleys. The outflow of meltwater from the eastern part of Poland was along the Biebrza-Narew Ice-Marginal Valley, and later along the previously created eastern part of the Warsaw-Berlin Ice-Marginal Valley.

After the recession of the ice sheet (17.7 ka BP[1)]), the meltwater formed the Warta-Noteć Basin. This was an important stage in the formation of the Toruń-Eberswalde Ice-Marginal Valley. The river runoff was directed from the Płock Basin and Toruń Basin to the valley of the middle Noteć, Gorzów Basin, and Kostrzyń Basin, connecting with the Eberswalde gateway located north of Berlin. This paleo-marginal valley was additionally supplied by the waters of the Wilia, Niemen, Bug, Vistula, Warta, Odra and Elbe.

The ice-marginal valley had an average width of 10 km (maximum 20 km), and its base was approximately 30 m below the surface of the moraine plateaus (Kozarski, 1965). The mouth of the ice-marginal valley was in the North Sea. The length of the paleo Vistula was about 2000 km, making it the third largest river after the modern Volga and Danube rivers (Starkel, 2001).

An important stage in the development of the lower Vistula was during the Bølling period (13-12 ka BP) when near Bydgoszcz, the river runoff was shifted from the Toruń-Eberswalde Ice-Marginal Valley directly to the Bay of Gdańsk in the Baltic Sea (Drozdowski, 1974). The opening of the Vistula directly into the Baltic Sea (then the Baltic Ice Lake) caused rapid headward erosion, which led to the formation of higher river terraces (Starkel, 2001).

From a geological perspective, the Vistula River is very young. It has a rich source of sediments in the upper part of its catchment, which is built on mountains with easily erodible sedimentary rocks from the Tertiary period and loose sediments of Quaternary age. The suspended sediment transport of the Vistula River and other major rivers in Europe is shown in Table 1.

The sediment of the lower Vistula is composed of fine sand. The representative diameter (median value on the sieve curve) of bed load grain is d_{50} = 0.5 mm (Habel, 2013). In the suspended sediment, silt dominates, with the diameter of suspended sediments being d_{50} = 0.02 mm (Brański and Kondzielski, 1986).

Table 1. Comparison of the suspended sediment transport and denudation rate of major European rivers *(source: after Allen, 2000)*

River	Suspended sediment transport (10^6 t/year)	Denudation rate (t/km^2)
Rhine	0.72	3
Elbe	0.84	6
Oder	0.13	1
Vistula	2.5	13

The lower Vistula River has a very low longitudinal slope. Field measurements performed by Habel (2013) on the Silno and Toruń river section (721-735 km) show that the longitudinal slope does not vary significantly and is in the range of I = 0.000165-0.000176. However, due to regulation works, the channel of the lower Vistula River has high velocities in the cross-sections and a large excess of energy for sediment transport. According to Babiński and Habel (2016), the average annual mass of bedload transported on the lower Vistula River in the regulated reach around the city of Toruń (732 km) in the period 1971-1995 did not exceed 1.0 × 10^6 tons. However, the intensity of transport during the wet year of 1975 was higher and reached 1.5 × 10^6 tons.

HYDROLOGY OF THE LOWER VISTULA RIVER

The catchment area of the Vistula River is 194 × 10^3 km^2, and the total length is 1047 km. At the beginning of the 19th c., for navigation purposes, the beginning of the Vistula chainage (length measurement) was set on the upper Vistula River at the confluence of the Przemsza River (0 km), continuing to the Bay of Gdańsk (939 km). In hydrographic division, the lower Vistula stretch is defined below the confluence with the Narew River. However, the water administration has another division where the section of the lower Vistula starts below the dam of the Włocławek Reservoir (km 679).

Hydrological measurements of the rivers in Poland are performed by the Institute of Meteorology and Water Management (IMGW – Instytut Meteorologii i Gospodarki Wodnej). Long-term hydrological data on the lower Vistula are available from Tczew (909 km) and are shown in Table 2. According to run-off magnitude, the Vistula is the second largest river in the Baltic Sea basin after the Neva River in Russia.

The total length of waterways in Poland is 3768 km. However, during the 1980s, a period of the most intensive development of inland shipping, commercial navigation was limited to only 1829 km of the waterways.

Table 2. Characteristic discharges of lower Vistula River at Tczew gauge (*source: Atlas..., 1996*)

Lower Vistula River characteristic discharges	Discharge at Tczew gauge Q (m^3 × s^{-1})
Average low flow (MLQ)	419
Average mean flow (M)	1080
Average high flow (MHQ)	3840

[1)] ka BP – thousand years before present

An important parameter is the waterway class, which in Poland has been defined in 2002 by the Prime Minister act – Dz. U. Nr 77, Poz. 695. This classification is a result of unification with European Union law. Waterways classes Ia, Ib, II and III have local importance, while waterways classes IV, Va and Vb have international value. In Poland, only 201 km of waterways have classes IV and V.

The lower Vistula waterway below the dam in Włocławek to the Tążyna River confluence (43 km) has class Ib, the reach below the Tążyna River to city of Tczew (190.5 km) has class II, and below Tczew to the mouth in the Bay of Gdańsk (32.7 km) has class III.

Habel (2018) calculated the duration of low-flow conditions at the Fordon gauge (located at 774.9 km) and states that in average and wet years, water levels drop below mean low water stages for 90 days a year, while in dry years, this occurs for 200 days. The confluence with the Tążyna River is very characteristic because it marks the boundary between Russia and Prussia, which existed during the partitioning of Poland from 1815-1918.

Prussia and Russia had different priorities in water management and river training for navigation. Below km 718 on the territory of Prussia, the lower Vistula River was protected from flooding by a system of dikes. To protect the dikes from destruction during winter ice jams, a plan for river channel regulation was designed. Works on channel regulation were performed from 1856 to 1878 according to the design of the Prussian engineer Sewerin, who had previously worked on the regulation of the Rhine River. The scale of river training works was impressive, with 599 groins, 91 side arm closings, and 2173 km of longitudinal dams being built. The river channel was straighten, narrowed, and side arms were closed. Before the regulation, the average width of the lower Vistula channel in the reach of 719-814 km was 785 m (Babiński, 1992). In the river training plan, the width of the regulated channel between km 735-886 was set to 375 m for mean discharge (Monografia..., 1985). Unfortunately, it became clear at the beginning of the 20th c. that the regulation did not improve the navigation conditions (Ingarden, 1921). The boundary between the Russia and Prussia occupation zones is still visible today on the lower Vistula River. On satellite images, we can easily notice the difference between the natural and regulated reaches of the lower Vistula River (Fig. 1).

Another important change in the hydrology of the lower Vistula River occurred in 1895 with the opening of a new artificial cut-off near the village of Świbno, creating a new mouth for the river directly into the Gulf of Gdańsk. This shortening of the river course created conditions for strong erosion of the main channel. In 1917, to protect the side arms of the Vistula River in the Martwa Wisła, Szkarpawa, and Nogat delta, they were separated from the main channel by sluices.

CHANNEL PROCESSES ON THE LOWER VISTULA RIVER

The alternate sandbars are river bedload accumulation forms having a size similar to the river channel cross-sections dimensions (depth and width). They are often called meso-forms. The term “alternate” means that they are located in a regular pattern close to the left and right banks of the river channel, creating a sinuous pattern of the thalweg. The alternate sandbars are a characteristic feature of the morphology of the lower Vistula River channel, but they are also common in other regulated rivers with a large bedload transport.

Bedload transport is a complex process in which individual sand grains roll on the surface of ripple marks, ripple marks move over the surface of larger forms – dunes, and the movement of dunes advances the whole alternate bar. An example of these different scale forms can be seen in the picture (Fig. 2).

Fig. 1. Reach of the lower Vistula River 710-722 km with the visible border between the natural and regulated channels (Sentinel-2 image, 2016-09-04) (*source: A. Magnuszewski*)

Fig. 2. Sandbar with dune and ripple marks on the lower Vistula River at 767 km (2017-07-08) (*source: A. Magnuszewski*)

To study the movement of sandbars on the lower Vistula, we can use multi-spectral satellite images. The spatial resolution of Sentinel-2 images is 10 meters, so the sandbars are well visible during low flow conditions. Comparison of the images from consecutive years shows the movement of sandbars. The boundaries of the sandbars visible on the Sentinel-2 images create polygons with centroids. The distance between the centroids of sandbars in consecutive years provides information on the length of shift in the river channel. Examples of such visualization are shown in Fig. 3a-b.

In the study by Kryniecka and Magnuszewski (2021), the length of the sandbars shift on the lower Vistula was calculated for the channel reaches 852-866 km, 870-874 km, and 879-885 km. In the period from September 4, 2016 to July 30, 2017, the average length of the sandbars shift was 433 meters. The hydrological conditions during that period were close to the long-term average mean discharge. An important factor for the length of the shift is the maximum discharge during a flood. Another analyzed period, from July 30, 2017 to September 20, 2018, with a flood discharge of 2280 m^3/s, caused the shift of the sandbars to a distance of 548 meters. The consequence of sandbars movement on the lower Vistula River is permanent changes in the thalweg pattern and remodeling of river channel morphology. Examples of thalweg changes between September 6, 2016, and July 14, 2017, are shown in Fig. 4a-b. The thalweg location was measured by sonar with GPS receiver (Lowrance hds-5).

A characteristic feature of the thalweg on the lower Vistula is its twisting pattern. The large transport of bedload in the form of sandbars forces changes in the thalweg. Over the course of one year, the thalweg shifts from one bank to the other. The continuous movement of the sandbanks is accelerated by floods. The length of the sandbar shift depends on hydrological conditions. This process creates difficult navigation conditions, as the thalweg changes its location and, additionally, at the passages between the banks, the water depth drops below 1 meter. In low flow conditions, as shown in Fig. 5, the transition depth of the waterway, even of the lowest class Ia, is not met.

Changing depths at the lower Vistula River waterway force the water authority to perform frequent soundings to find the passage of the thalweg between the sandbars. Characteristic for this part of the river are shore navigation signs which indicate the line of waterway transit between the sandbars (Fig. 6).

Fig. 3a. The shift of the sandbars on the lower Vistula channel between 854-857 km in the period from September 4, 2016 to July 30, 2017, measured on satellite Sentinel-2 images (*source: A. Magnuszewski*)

Fig. 3b. The shift of the sandbars on the lower Vistula channel between 860-864 km in the period from September 4, 2016 to July 30, 2017, measured on satellite Sentinel-2 images (*source: A. Magnuszewski*)

Fig. 4a. Lines of thalweg on the lower Vistula River between 854-857 km (red line 6 September 2016 and green line 14 July 2017) (*source: A. Magnuszewski*)

Fig. 4b. Lines of thalweg on the lower Vistula River between 860-864 km (red line 6 September 2016 and green line 14 July 2017) (*source: A. Magnuszewski*)

Fig. 5. Depths on the thalweg of the lower Vistula River between 817-818 km, measured on July 14, 2017 (*source: A. Magnuszewski*)

CONCLUSIONS

Regulation works performed at the end of 19th c. by Prussia did not take into account the massive bedload transport on the lower Vistula River. The channel was regulated by narrowing and straightening with the use of short groins. A straight channel with high velocities of water creates conditions for intensive bedload transport, typical of alternate sandbars. The movement of sandbars forces the thalweg to change its position by shifting between the channel banks. The lower Vistula River has constantly changing bed morphology, which makes it difficult to delineate waterway route. The water authority is constantly conducting sounding of the river channel and correcting the position of navigation marks located on the banks. The transition depths during low flow are not big enough to sail even by small vessels with a draft of 0.5-0.7 m. Navigation conditions are very difficult for large vessels due to shallow passages between the sandbars and the small radius of thalweg turns.

Fig. 6. Shore navigation signs on the right bank marking the orientation of waterway transit to the opposite bank (*source: A. Magnuszewski*)

Fig. 7. Anchorage on a sandbar on the lower Vistula River during low flow (*source: A. Magnuszewski*)

Sandbars during low flow form a regular pattern of small islands. This pattern of small sandy islands on a major lowland river has unique environmental value. To protect it, the area of the Nature 2000 – Valley of the Lower Vistula River (*Dolina Dolnej Wisły*) has been declared to protect the whole reach of the river below Włocławek dam on the lower Vistula River.

Sailing on the lower Vistula River is difficult for large commercial vessels but very attractive for small tourist boats with shallow drafts. Staying for a night on a small sandy desert island is a unique occasion to enjoy the wild nature and observe wildlife (Fig. 7). It is even more exciting when we realize that after a few months, the sandbar will disappear. This potential for the tourist trips on the lower Vistula is still not fully discovered. Sailing on the lower Vistula River during low flow still requires some knowledge not only of navigation marks but also of river hydraulics and fluvial forms.

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Gather with Global Innovators at the 2025 World Canals Conference

September 21-25, 2025, Buffalo, New York, USA

Two hundred years after the grand opening of the Erie Canal, in September 2025, Buffalo invites the world's canal community back to New York State's 'Queen City' for the World Canals Conference. The conference is the marquee event for inland waterways experts and enthusiasts from all over the world to gather and learn from one another, delving into how canals everywhere are addressing challenges and thriving.

The conference will honor the canal's 200-year legacy while highlighting the innovative transformation driving its next century of service. Study tours will take conference attendees to both historic canal sites and major economic revitalization projects centered on the Erie Canal. Attendees will also hear from waterway experts from around the world about new technologies in canal operations, sustainability, tourism, and heritage development on the world's inland waterways.

BUFFALO: AN IDEAL CONFERENCE LOCATION

The Erie Canal connected the port city of Buffalo with other cities along the Great Lakes and to the Atlantic Ocean in New York City. This historic connection is central to Buffalo's history and is the major reason the city became a commercial and industrial powerhouse in the 19th century. After the canal opened, Buffalo became the largest inland port in the fledgling nation and the 'grain capital' of North America. In the mid-20th century, following a steep decline in commercial traffic on the canal triggered by competition from the railroad and opening of the St. Lawrence Seaway, Buffalo's once thriving Inner Harbor became desolate and underutilized.

Beginning in 2005, the Erie Canal Harbor Development Corporation successfully spearheaded an incredible era of waterfront transformation, reclaiming the historic junction of its canal and lakefront as one of America's brightest treasures. Today, the revitalized Canalside area in downtown Buffalo is part of a reinvigorated city bustling with new energy, business, and tourism. The city's famous grain elevators, historically used to store canal cargo, have been repurposed to host live performances, events, and historical tours. Buffalo is receiving recognition for its vibrant art scene, diverse dining, outstanding outdoor recreation, treasured architecture, and dramatically transformed Canalside waterfront.

WITNESS HISTORY REPEATING ITSELF

Conference attendees will attend the sendoff ceremony of the replica 1825 canal boat Seneca Chief, a signature event commemorating the Erie Canal's bicentennial. This vessel was the first to traverse the Erie Canal in 1825 with a grand procession led by then-Governor of New York, DeWitt Clinton. The boat has been reconstructed using traditional methods and will recreate Governor Clinton's journey from Buffalo to New York City.

CONFERENCE HOSTS

The Erie Canal's historic role in shaping settlement, growth, and national identity was recognized by the Congress of the United States with the formal establishment of Erie Canalway National Heritage Corridor in 2000. The Erie Canal as a system is still fully navigable and is proudly operated by the New York State Canal Corporation, an agency of state government. These two organizations, in partnership with Erie Canal Harbor Development Corporation and Visit Buffalo Niagara, are serving as conference hosts.

Stay tuned for updates. New York State and Erie Canal communities are thrilled to welcome the world to Buffalo in 2025. Sign up for updates and registration at www.wcc2025buffalo.com (*Website will be live at the end of June 2024.*).

World Canals Conference BYDGOSZCZ

24 - 26 JUNE 2024

Organiser

BYDGOSZCZ

Under the auspices of

Inland Waterways International

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