Politecnico di Torino

Master's degree in Urban and Territory planning
A.Y. 2023/2025
Graduation session of December 2025

Integrating Flood Risk Reduction Strategies into Municipal Land-Use Planning:

A Comparative Study of Turin (Italy) and Astana (Kazakhstan)

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Abstract

The topic of this thesis is to describe a comparison analysis of the geological and hydrological features of two different cities that have almost identical structural planning, however, still differ in climate conditions and geographical locations. The main attention is focused on the comprehensive examination of flood characteristics, seasonal river level rises, and possible scenarios of overflowing the main rivers of Turin and Astana, which divide them in half. The rivers Po in Italy and Ishim in Kazakhstan play a significant role in shaping the city environment, as their banks are lined with a dense concentration of residential and industrial developments. The study utilized several methodologies to make a detailed study that can not skip any important aspect. First, the official geological and hydrological data is collected, including flood maps, land-use plans, and policies from local authorities and geoportals, which allows for visualization and analysis of spatial features of the catchment and surrounding areas. While policy research lets us understand exactly how the local government laws can regulate the issues of flood risk and the exposed areas. Second, using software based on geographic information systems (QGIS) to analyze flood-prone and vulnerable urban zones. And finally, after comparing and putting the findings together, we can suggest ways to improve flood risk integration and urban resilience. The suggested methodology is directed to increase the resilience of the urban environment, decreasing the vulnerability of the residential areas, and minimizing possible economic and ecological loss during emergencies connected to flooding and overflowing.

Keywords: Flood, River, Policy, Urbanization, Territories, Hazard, Sustainability, Mitigation

Table of Contents

Introduction

Nowadays, almost every city is facing serious challenges in the field of natural hazard management due to the rapid growth of urbanization, climate change, and the increase in frequency of extreme natural phenomena. Floods are known as one of the most destructive natural disasters that affect urban territories that are located along rivers and other water bodies. They lead to severe economic, social, and ecological damage. Disrupt the functioning of the city's infrastructure, affecting residential, industrial, and commercial areas, as well as leading to degradation of the quality of citizens' lives. In conditions of global warming and the changing of the rainfall regime, it is important to work and develop integrative natural and anthropogenic strategies that could help minimize the flood risk to a minimum.

The relevance of the topic is caused by the importance of urban planning's ability to adapt to continuously changing climate and hydrological conditions. Additionally, the actuality of the topic is also confirmed by my personal experience, since I face the consequences of these natural disasters, seeing how they complicate the lives of people almost every year. My unfortunate experience pushed me to understand the depth of the problem and the importance of finding a solution. The integration of the flood risk reduction strategy into municipal land use planning allows us to increase the sustainability of urban territories, minimize potential damage, and enhance the safety of the residents. Despite the usage of different approaches to manage flood risks in separate countries, there is a need for a comparative analysis of these practices in order to find the most effective methods of planning and adaptation.

The last decades have already shown that urbanization and integration of the natural risks have become the key factors in urban planning and sustainable development topics. Modern research is accepting that big cities with high building density are more often exposed to floods, since their urban territories are mostly located around the river floodplains or low-lying areas. While infrastructure and population become more vulnerable to extreme hydrological events. *(Vandecasteele & Lavalle, 2015) (Rentschler, 2022)*

Meanwhile the climate change and the increasing weather and hydrological anomalies lead to an increase in the flood mitigation strategy's meaning in municipal politics and land use. Recent research made by the ecopolitics of the EU is pointing out that the significant increase in sustainability of the cities to the flood needs not only rearranging the technical ways of protection but also social vulnerability, effective monitoring, and spatial planning. *(Directorate-General for Environment, 2025)*

In actual research, there are two cities to compare: Turin (Italy) and Astana (Kazakhstan). They were chosen based on their structural similarities; both of them are built along the river that splits the city into two parts, connected by several bridge systems. However, the difference in the local climate and topological and geographical features makes the analysis more interesting in terms of flood behavior. These differences create unique conditions for city vulnerability research and the effectiveness of existing strategies. Special attention is given to the river overflow study, and the density of residential and industrial areas on the sides of the rivers, including relevant policies.

The scientific innovation of this research lies in the comparative approach to the analysis of the cities with an analogous structure, but different climate conditions. The thesis structure is built in a way to achieve the best logical presentation of the material and a consistent opening of the research aim. The next part represents the methodology of the study, the source of the data, GIS instruments, and their analysis criteria. Then, leads us to detailed results of the spatial analysis and a comparative study of the city's vulnerability. Finally, the last part describes the revealed patterns and practices of risk management. That brings us to the main goal of the work, formulating a conclusion and recommendation for the problem resolution.

Finally, one of the key results of the project is creating a robust international cooperation between Italy and Kazakhstan in terms of flood hazard management. The analysis can determine both the strong and weak sides of the existing strategies of the two cities, which opens possibilities for mutual experience exchange. The final results can contribute to the development of joint initiatives aimed at reducing damage to the places located along the rivers, etc. In particular, based on data analysis and modeling, adaptive measures applicable to both contexts can be proposed, including the improvement of early warning systems, enhancement of urban planning, and integration of natural risk considerations into spatial development policies. Moreover, similar studies can help to form professional and scientific connections between universities and research centers of both countries, which later can lead to collaborative projects, professional exchange, and the creation of common educational programs. This approach not only boosts the effectiveness of the fight against flood consequences but also strengthens scientific cooperation on an international level. In the long-term perspective, the systematic exchange of knowledge and practical solutions between Turin and Astana can allow for the production of a more sustainable approach and enlighten the situation.

This research paper is also directly connected to several Sustainable Development goals (SDGs), as stated by the United Nations organisation. First of all, the work is contributing to Goal 11 - Sustainable cities and communities, since it is focusing on identifying and integrating the strategies that are developing the resilience of the urbanized territories to floods and other natural risks. The investigation promotes the realization of the target 11.5, which aims the reduce the number of people who suffer from the environmental and economic problems, connected with water, in our specific case is the river.

Except that, the project is also connected to Goal 13, which is climate action. This is explained easily because we are analysing the effect of the climate factors on the frequency and intensity of the flood waters. Also, it is developing recommendations for adaptation of the city environment to the changing conditions. In the broader sense, the work is also slightly interconnected with Goal number 6 - Clean water and Sanitation, because it considers the questions of rational water resources management and protection of the river system.

This is how the research project not only solves the local tasks of vulnerability rating of the separate cities, but also contributes to achieving the global goals aimed at the formation of sustainable, safe, and adaptive to climate change urban systems. It demonstrates how the scientific approach based on spatial analysis and interdisciplinary methods can serve as an instrument of the practical realization of the principles of sustainable development, connecting ecological, social, and management parts into one united strategy of territorial sustainability.

Thus, the research paper guarantees both theoretical and practical contributions. Theoretical significance lies in the systematization and comparative analysis of flood risk factors. The practical part is represented through the development of solutions or recommendations of strategies that decrease the risks in urban planning and help to maintain a resilient and strong infrastructure that protects its citizens and holds the economy stable.

Methodology

"Methodology is the study of the organization of activity." (Novikov) Methodology of this exact research is based on a mix of the comparative, spatial, and analytical approaches, aimed at identifying the specific features of integration of the flood mitigation strategies into the system of municipal land use planning. The main purpose is to understand how geographical, climate, and administrative differences between two cities as Turin and Astana, can affect the productivity of the water risks management policies and adaptation to climate change.

In order to justify our research paper and make it more organised, a 5-step methodology system was developed. All 5 steps are aimed at achieving the best possible result of the research. The chosen methods are suitable for finding a successful solution to the given challenge. The ready structure is simplifying the work process, thanks to the clear systemization. An authentic research paper is usually based on a complex approach that includes spatial analysis; in our case, it's the analysis of Turin and Astana. The study of urban planning documents and comparing the policies of hazard mitigation. The aim of the research is to find similarities and differences in approaches to flood risk management in Turin and Astana, and propose unique ideas depending on the context. To achieve my goal, I utilize official geoportals with municipal information, such as Geoportale Piemonte, and software that utilizes geographic information systems (QGIS) to create a clear representation of the situation.

The 5-step methodology includes:

1. Part 1: Historical and Geographical Background of the Study Areas

To provide a trustworthy foundation for the flood risk analysis in Turin and Astana, it is important to research each city and its main river system. This kind of analysis leads to a better understanding of the reason why some of the territories are more flood vulnerable, how previous water rises affected the city's construction planning, and also how the same geographical features increase or decrease the danger. The historical and geographical data were collected from different sources for the provision of authentication and completeness. For Turin academic publications, historical maps, the history of urbanization, and historical flood municipal documents were used. For Astana, it was the national hydrological research, the governmental Ishim river connected document, historical data, and scientific research about city development and the evolution of the river flow. The study of historical river evolution and the nearest urban territories helped us to understand the specifics of settlement, river regulation, and riverbank construction.

Geospatial data was used for the description of the natural features of each city. Including climate, topology, hydrology, and land-use. For Turin, the analysis was centered around the River Po, its tributaries, and morphology. For Astana, however, it was more focused on the seasonal changes, the water level differences of the Ishim River, and the level of urbanization in both cases.

Geographic information systems (GIS) were used for the integration of the historical cards and the modern municipality data about urbanization and hydrology, which helped us to get a visual and analytical picture of the changes over time. The combination of historical and geographical analysis allows us to identify the key factors affecting the vulnerability of cities in terms of floods. An understanding of the River system evolution, urbanization, and previous floodings creates the foundation for the future spatial, political, and risk analysis. This step provides the next comparison of municipal strategies to rely on the real physical and historical conditions of each research city.

2. Collecting flood maps, land-use plans, and policies from local authorities

For preliminary research, it is important to collect all necessary systematic data, including primary as well as secondary knowledge from official sources, such as municipality or city authorities. For both of the cities, it is needed to collect official river flood maps and hydrological data provided by national authorities that are responsible for such monitoring of urban development and sustainability. These maps are a key element for identifying the territories that are the most vulnerable and also understanding the frequency and scale of flooding.

In addition to cartography data, statistical data about the density of the population, infrastructural features, and land use dynamics are considered. It is important due to the influence of these factors on the flood hazard intensity and the amount of harm that can be done. It is also taken into account the data about previous floodings, which took place in the same area in a certain time period. This could significantly help to see the trajectory and evolution of the danger.

Special attention is paid to the urban planning documents that regulate and manage building construction in the risk zones. Research work also includes general plans of the cities, detailed plans of territories, rules of land use, and construction standards. Additionally, the collection of strategy documents, adaptation, and mitigation of climate change consequences, plans for protection, and national regulations defining the procedures for emergency management. All data is being systematized and processed for the opportunity of future comparative analysis. This approach makes it possible to compare the data from the two cities, identifying similarities and differences in their approaches to planning and risk management.

All data is carefully verified for authenticity and trustworthiness. This guarantees the reliability of the research and can minimize fake results that could lead to the wrong conclusion. Also, more than one resource is used to make the data more diverse, increasing the accuracy of the information.

3. Comparing policies and governance around flood risk planning

The third part of the methodology is dedicated to the high-quality analysis of governmental policies and strategies for the management of flood risks. By analysing the content it is defined the main urbanistics regulations, protection plans, and national and local climate change adaptation programs are defined. Inside the analysis, there are different aspects, such as the degree of integration of flood risk consideration in the urbanistic regulations and land use rules. Secondly, the presence of restrictions for building in the flood potential zones. Also, existing mechanisms of citizens and interested parties in decision-making are connected to the problem. And finally, the consistency of municipal plans with national adaptation strategies.

The comparison is made in the common criteria, which helps to determine the weak and strong sides of both cities' solutions, to find the weak points of the regulation systems, and see the best practice examples.

4. Using GIS to analyze flood-prone and vulnerable urban zones

I chose to work with QGIS software for a simple reason of its reliability, supported by previous experience. Since the university program included an intensive practice of this specific software, it can be trusted due to its high quality, functionality, and convenience. QGIS offers a wide choice of possibilities for visualization, analysis, and geospatial information processing. It is all highly important for the investigation of hazard zones and population, and building numbers. The program allows us to collect different types of data. For example: maps, hydrological and geological data, land use data, and population data. All of that can be collected into one system to build the spatial analysis and create a visual map, which can simplify the interpretation of results to the maximum.

Based on the maps collected in the first step, we can locate the territories with the highest possibility of flood risk, which can be layered with the density of buildings maps, which include the commercial, residential, and industrial areas. Paying attention to transportation infrastructure, which is also a significant part of urban planning. The next step is summarizing the total amount of urbanized areas in the hazard zones, and the analysis of vulnerability of the public infrastructure, like schools, hospitals, and common spaces. It is necessary to always consider the density of population, because these areas are at the highest risk in terms of social and economic aspects.

Thanks to the program, it is not only easy to follow the research process, but also the conclusion can become way more accurate and flexible. That all makes it a perfect instrument to compare two separate territories differing in climate and geographical conditions. The final results of spatial analysis are later visualized by maps, diagrams, and tables that provide a clear representation of flood risk exposure. All this material is used later in the next step.

5. Putting the findings together to suggest ways to improve flood risk integration and urban resilience

The final step is to synthesize the results of the spatial analysis and political study, concluding the entire research work. The primary objective is to formulate practical recommendations for enhancing the integration of flood risk-reducing strategies. Recommendations include not only improvement of the regulatory framework but also developing interagency cooperation, enhancing the early prediction and warning systems, as well as involving new adaptation approaches to urban planning, considering climate change.

Part I: Historical and Geographical Background of the Study Areas

1. Torino data

To understand the full effect of floods and urban planning aspects in Torino and Astana, it is extremely valuable to consider their historical-geographical context of development, as well as the roles of the rivers that are located in these cities' structures. Without considering the context of climate conditions, historical facts, and the spatial organisation of the territories, it is impossible to objectively assess the existing risks and develop effective strategies for addressing them. Historical-geographical analysis lets us observe why and how the fragile zones were formed, which natural and anthropological factors affected the modern configuration of the city structure, as well as understanding how previous floods and natural disasters led the direction of the urban planning policies. In cities similar to Torino *(Figure 1)* and Astana, the rivers were playing a significant role in the building of the city's identity, industrial development, and infrastructure, but immediately became a potential danger.

Torino

Figure 1. Torino.

I chose Torino *(Figure 1)* as an object of my studies not only for its unique natural, geographical, and urban characteristics, but also because it is the place I have lived and studied for years. This allows me to observe the special features of the city not only from the academic point of view but also through my own experience. Torino, city, capital of Torino provincia and of Piemonte region, northwestern Italy. It is located on the Po River near its junction with the Sangone, Dora Riparia, and Stura di Lanzo rivers.

(Metych). Moreover, Torino is an industrial and cultural center of Northern Italy, and it is actively involved in initiatives about sustainable development, ecological management, and adaptation to climate change. Torino aims to become: a city at the forefront of sustainability, thanks to a broad and consolidated alliance that will continue to work with and for the community. *(Luca Coppolella)*. All these are making it a perfect study area for analyzing modern approaches to integrating flood risk reduction strategies into municipal land-use policy and for comparing them with the experiences of other cities, such as Astana. Turin has a long history dating back to Roman times, but much of its modern growth and importance dates from the 19th and 20th centuries. It became a major industrial center (especially for automobile manufacturing), largely associated with companies such as Fiat, which played a large role in urbanization, population growth, and the development of infrastructure. *(Metych)*

Climate of Torino

In Torino, the capital of Piedmont, the climate is moderately continental, with cold, damp winters and hot, muggy summers. The city is located at 250 meters (800 feet) above sea level, at the foot of the Alps, and along the Po River. *(Figure 2.)* Because of its position, in summer, it is not as hot as the rest of the Po valley, while in winter, it is a little less foggy. *(Climatestotravel.com.)* Because of its location, Torino is quite vulnerable and exposed to seasonal floods. Precipitation is fairly well distributed through the year, with late spring and autumn being wetter. Annual rainfall is around 950 mm. *(Climatestotravel.com.)* During my life in Turin, I personally viewed the consequences of the heavy rains and the increased water level, which showed me how crucial it is to consider the hydrological risks during the city planning process.

River Po

Figure 2. Po River map location.

The Po River *(Figure 2)*, the longest river in Italy, rises in the Monte Viso group of the Cottian Alps on Italy's western frontier and empties into the Adriatic Sea in the east after a course of 405 miles (652 km). Its drainage basin covers 27,062 square miles (70,091 square km), forming Italy's widest and most fertile plain. *("Po River | Italy, Map, Facts, & History")*. In Turin, the river Po is one of the biggest and valuable water arteries of Northern Italy. Throughout centuries, it has been

Defining the characteristics of the population distribution and industrial growth. Its floodplains historically were used for agriculture, transport connections, and city manufacturing development, which led to significant urban pressure on the riverbanks. Over the years, the urban fabric has become densely built in the plains near the Po River, while hillier zones tend to have more dispersed and less dense construction. *(Climatestotravel.com.)* Many floods, recorded in different time periods, pressured the government to include strategies of river regulation, building dams, and reconsidering the city construction principles. Torino is located mostly on the right side of the Po, and the river historically served as a huge transport and commercial route. Main agriculture and industry works were developed along its riverbanks. With the city's development in XIX–XX centuries, the riverside zones became the urban centers, which led to building density and flood vulnerability.

River formation

Studies showed that during the Late Holocene, the Po River flowed south from its current course, forming wide meanders and islands. But later, mostly due to the uplift of the Po Plain, the river shifted its flow northward, toward the base of the Turin hill. *(M. and Gianotti)* Lately, we can observe a tendency to restore the natural characteristics of the river. In some of the areas, it is decided to also reinstate meanders and improve the ecosystem, which helps to increase biodiversity and decrease the flood risk. *(Figure 3.)*

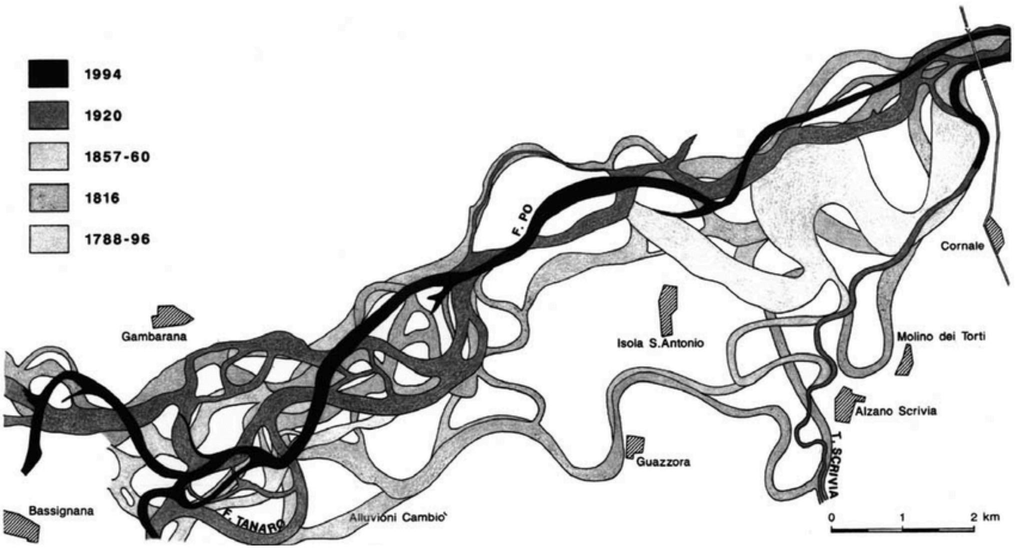


Figure 3: Channel changes of the Po River between the inflows of the rivers Tanaro and Scrivia, drawn by historical maps until 1920, then by aerial

Flood history

Unfortunately River Po is famous for its flooding history. One of the most destructive disasters was the flood in October 2000. When the heavy rains led to the water level rising and flooded part of Turin, resulting in the death of 29 people and severe damage. *("River floods") (Figure 4)* "By the time the rain stopped, the situation was devastating; 10 municipalities and 100 districts were isolated, 15,000 residents were affected, and the cost of the damage was estimated as some billions of euros." *(bushp)*

"Heavy and prolonged rainfalls have involved the entire Po River basin. The upper Po River basin in the Piedmont Region is a catchment basin of approximately 37,000 km², which includes the entire Piedmont Region, the Aosta Valley Region, and parts of Switzerland. The majority of the basins of the area suffered strong flood episodes; the strong rainfalls seriously damaged most of the mountainous portions of the basins and also part of the city of Turin. The areas, which were affected by the strongest precipitation, have been especially the Northern and Western sectors of the Piedmont region: that's where the majority of the rivers tributary to the Po River come. The Po River flood lasted long, staying at the very top value even for 8-10 hours continuously, despite all the overflowing points, because at each point it got a new influx from different tributaries. The maximum rate of the Po River's flow in Turin has been 2350 m% and has exceeded the historical maximum of 2230 m% in the year 1949." *(Cassardo et al., 2001)*

Figure 4: Screenshots from the recordings during the October 2000 flooding. The footage is taken from the DVD "Eventi alluvionali in Piemonte 2000-2002" by Arpa Piemonte (Regional Agency for Environmental Protection), produced by Fabula, from the "Video Archive" section, which includes recordings from November 2–6, 1994; October 13–16, 2000; and June 4–6, 2002. Courtesy of the ARPA Piemonte. Licensed under the Creative Commons Attribution license. A portion of the footage is also available on the YouTube page of the Consiglio Regionale del Piemonte (Piedmont Regional Council). (bushp)

2. Astana data

Astana

Figure 5: Astana location

Kazakhstan, a landlocked country of Central Asia. It is bounded on the northwest and north by Russia, on the east by China, and on the south by Kyrgyzstan, Uzbekistan, the Aral Sea, and Turkmenistan; the Caspian Sea bounds Kazakhstan to the southwest. Astana *(Figure 5.)*, a city, capital of Kazakhstan, located along the Ishim (Esıl) River. It lies in the sparsely populated north-central part of Kazakhstan is located at the geographic center of the country's habitable area. *(Denis Sinor, Distinguished Professor Emeritus of Uralic and Altaic Studies and of History, et al.)*

I chose Astana as a comparison analysis for Turin, because compared to Italy in total, it is considered a modern capital with rapidly developing city infrastructure and unique climate characteristics, which are opposite to Turin's climate. Astana is relatively younger than Turin, and the city structure keeps building and modifying each day since its foundation in 1991. My choice is also determined by the fact that the Ishim River, which flows through the city, forms specific zones of flood risk, and urbanization of the riverbanks is actively developing. This case allows us to study how exactly many modern cities integrate the strategies of flood risk avoidance in land use, and also compare them with historical Italian strategies.

Climate of Astana

Since I was born and spent most of my life in this city, I can justify that Astana is a modern, dynamically developing city that manages administrative, living, industrial, and recreational functions. Many constructions are happening around the river, parks, and common spaces, along the river, where citizens and tourists can spend their free time, or do sports activities. Industrial zones are mostly located far from the center to get rid of unnecessary attention to the center. This kind of structure makes Astana interesting for research from the perspective of the integration of flood risk ideas. The city mixes intensive urbanisation, developed infrastructure, etc., which is directly connected to the natural risks. Astana is located in the zone of the harsh continental steppe climate. Winter periods are relatively cold, with an average temperature of -20°-30°C, and summer is around +25-30 °C. This kind of weather diversity is making the city especially vulnerable to extreme natural events, including show storms, freezes, and floods. (*Yearly & Monthly Weather - Astana, Kazakhstan*)

Ishim River

Ishim River, a river in northern Kazakhstan and the Tyumen and Omsk *Oblasti* (provinces) of south-central Russia. A left-bank tributary of the Irtysh (Ertis) River, it rises in the Niyaz Hills in the north of the Kazakh Uplands (Saryarqa), flows west through Astana, and then flows north through Petropavl (Petropavlovsk) and the flat Ishim Steppe before entering the Irtysh at Ust-Ishim. Its total length is 1,522 miles (2,450 km), and it drains an area of 55,600 square miles (144,000 square km). (*Encyclopaedia Britannica*) It is common to meet an overflow or floods during the snow melting process and spring rains, while in the summer, the river becomes low-lying. The river provides the water management of the city and is being used for recreation; moreover is playing an important role in the city ecosystem.

River formation

The river has changed throughout history. It is caused by anthropological and climate effects. The river erodes its banks in specific places and deposits sediments in others, which is slowly changing the river flow, the length, and the depth of it. In its natural phase, the river builds meanders that are relocating with time, enlarging the floodplain. The dam, channel construction, and regulation of the river flows for flood protection or hydroelectric purposes can decrease the meander amount and change the natural hydrological regime.

Flood History

Historically Ishim River was not as dangerous as European rivers, but there were definitely a few cases of spring floods fixed, especially during extreme snow melting periods. In recent years, the government has built several dams, water collection structures, and regulating channels that could control the water level and protect the residential and administrative zones. One of the latest floods occurred in April 2024. The municipality described the flood as insignificant or minor. An average water level that was measured at the hydrostations outside of the city was 615 cm. *(Informburo.kz)* *(Figure 6.)* The city connects the water level growth with global warming, which caused the ice to melt in the riverbed. However, the water of the melted ice is decreasing, so hydrologists are predicting a low water level in the near future. *(Informburo.kz)*

Figure 6: Esil River in Astana on 16 April 2024.

Figure 7: Tengri news on 25 May 2024

3. The comparison of the cities

Similarities

The reason why it was mentioned that Astana and Torino are similar in some way was their city morphology. Both cities are based on the riverbanks of the massive rivers, which play a significant role in forming the city planning and spatial structure. In Turin, the city has developed along the Po River, which begins in the Alps and runs through the city, dividing the city into east and west parts. *(Figure 8,9) (Britannica Editors, n.d.)*

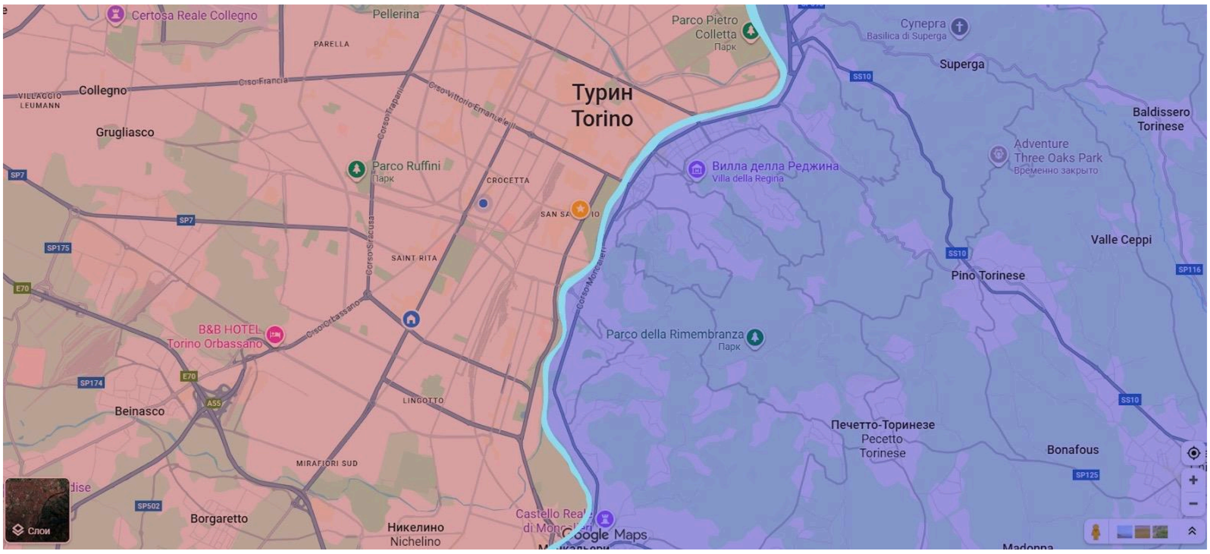


Figure 8: Torino

In Astana, however, the city is located along the Ishim River, which divides it into left and right-bank areas, where the old and new city structures are developing gradually. This kind of structure, with the presence of the river and division of the city into 2 parts, creates the common form of urban division and transport axes. Both of the cities are using the water element network as an element of the planning, recreation, and zoning. For example, planning of the riverbanks, walking routes, and transport corridors along the water structure in Torino and the Ishim River in Astana. *(Great Runs, n.d.), (Explore Kazakhstan, n.d.)* It helps to consider them as comparable examples relating to the risk zone policy analysis, land-use, and city development in the context of the river.

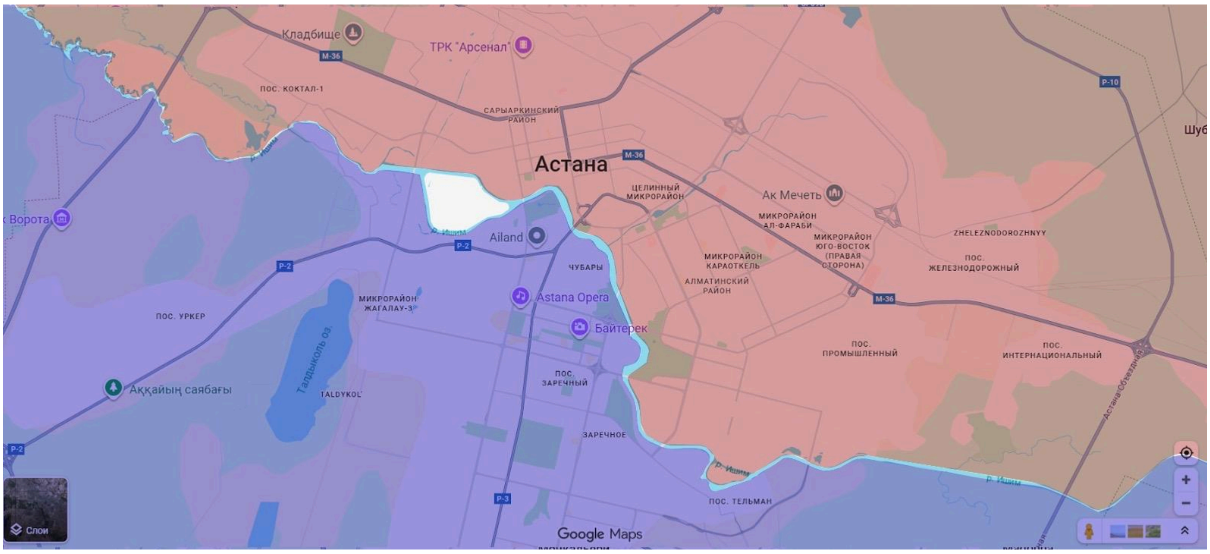


Figure 9: Torino

Differences

However, even though the cities have some common points regarding the structure, their geographical conditions, and urban planning are significantly different. Torino is located in the pre-Alpine valley and is built next to the Alps mountains and hills, which creates a complex terrain with elevation changes and slopes. *(Forno & Gianotti, 2021)* These kinds of geographical features are leading to rapid water runoff, but at the same time, they increase the risk of local floods and problems connected to the rainwater and snow melting.

On the other side, Astana is located in the flat steppe area on the territory of central Kazakhstan, with minimal elevation changes and a wide open view. *(FIDE, n.d.)* The flat terrain means that the floodwater will not run off the slopes, and it will run mainly to the low-lying territories. That is creating the long-term flood risk. Moreover, the climate conditions are also different, as Turin includes an Alpine and pre-Alpine context, while Astana has a harsh continental steppe climate. These differences mean that the methods and politics of flood risk management, the approach for land-use and protection of the territories, have to be adapted to both climate and geographical conditions.

For the clear and structural visual representation of the comparison of both cities' characteristics, it is possible to see the table below. That table reflects the main geographical, climate, and other parameters of Torino and Astana. This kind of shape of visualization can allow us to see clearly not only the similarities, but also key differences between two cities, starting from the climate features, finishing with the flood causes. The table only concludes the written analysis and serves as a base for future comparative analysis.

Category	Torino	Astana
The Geographical location	The north of Italy, in the pre-Alpine valley.	The central-north Kazakhstan, on the flat steppe.
The River	The largest river of Italy, the Po, which divides the city of west and eastern parts.	The Ishim River divides the city into its left and right parts.
Terrain type	Hilly, with elevation changes and slopes. It is surrounded by mountains and hills.	The flat steppe area on the territory of central Kazakhstan has minimal elevation changes.
Climate type	Moderately continental, with heavy precipitation, connected to Alpine climate.	Sharply continental climate with cold winters and hot summers.
Flood cause	Risks are connected to the Alpine snow melting and heavy rainwater.	Risks due to the snow melting and the slow water runoff. The water stays in the low-lying areas.
Main similarities	The city is divided into two parts, separated by a river. The presence of the historical center and urban planning around the riverbanks. Green, industrial, public, and residential places around the riverbanks.	
Main differences	Hilly terrain, compact historical structure, and an old industrial center.	Flat terrain, modern layout, rapid urbanization of industrial and residential areas.

Table 1

Part II: Data collection

1. Turin data

GeoPortal Piemonte

In the research framework for Torino territory analysis, the official regional resource Geoportale Piemonte was used as the primary source. The portal allows free open access to the spatial data of Piemonte and its administrative areas. This portal is basically a modern geoinformational platform, where many different thematic layers are collected, from topographical maps and orthophotos to data about hydrological objects, soil, land use, and urban planning. Which is very useful and easy to use in comparison to the geo portal that Astana is ready to suggest. One of the most valuable instruments that resources can propose is the interactive map, which allows for visualizing the potential flood risk areas, the dynamics of the river water level of the river Po, and the effect of these factors on the built territories that surround the area of the river, and more.

In comparison to Kazakh portals, where similar data is shown fragmentarily and mostly in the form of static maps, Geoportale Piemonte guarantees full interaction with spatial information for the users; they can turn on or turn off layers, overlay them, regulate the transparency of the data, and compare historical and modern maps. These possibilities allow us to work on the deeper analysis of the hydrological processes and their connection to urbanization, rate the changes of the river body, and identify the weakest territories.

Exploitation of the Geoportale Piemonte data is specifically important for the research, since they provide the accurate and relevant geospatial information that is necessary for the risk modelling in the QGIS environment. Using the portal information, it is planned to build spatial layers, reflecting the boundaries of the flood zones, the density of urban development, and the pattern of land use along the river Po. This is going to allow us to match actual physical and geographical parameters with regulatory documents and strategies, creating a scientifically grounded foundation for comparative analysis with Astana. Moreover, the integration of these data with a unified GIS model will provide the opportunity for a visual representation of the results of the research. As well as the development of recommendations for the solution of the flood risk issue.

The map that is taken from the Geoportale Piemonte presents the territory of Torino and its surroundings, including the river Po, and adjacent drainage basins. The map belongs to the category of “Difesa Suolo” (The protection of soils and territories) and reflects the data from the part PGRA - Piano di Gestione del Rischio Alluvioni (The management of the flood risks plan)

Visually, on the map, you can find a few key elements. *(Figures 10, 11, 12)* Blue and dark blue colors represent the zones of increased hydrological danger, the zones where the risk of the river overloading is higher than usual. Darker zones indicate areas with more frequent and intense floods, while lighter zones represent potential flood extents under extreme scenarios.

The map provides information about the general and secondary water bodies (Reticolo principale and Reticolo secondario) and lakes (Lago ACL), which play a significant role in the regulation of the water runoff. Along the river, we can observe the wide blue lines, which are floodplain areas that are subject to periodic floods. They are located in most areas of Turin, including both industrial and residential zones, which makes the risk management issue more relevant. This map contains the layering of the transport and city infrastructure (yellow and gray zones), which helps us to understand and analyze which urban development areas are located at potential risk.

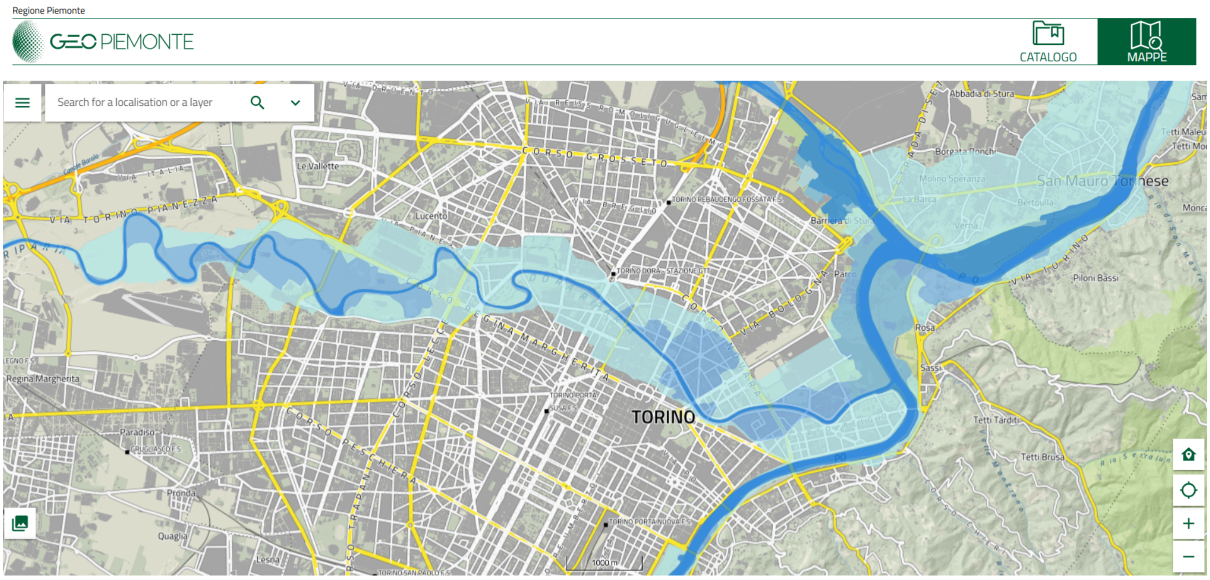


Figure 10: GeoPiemonte A view

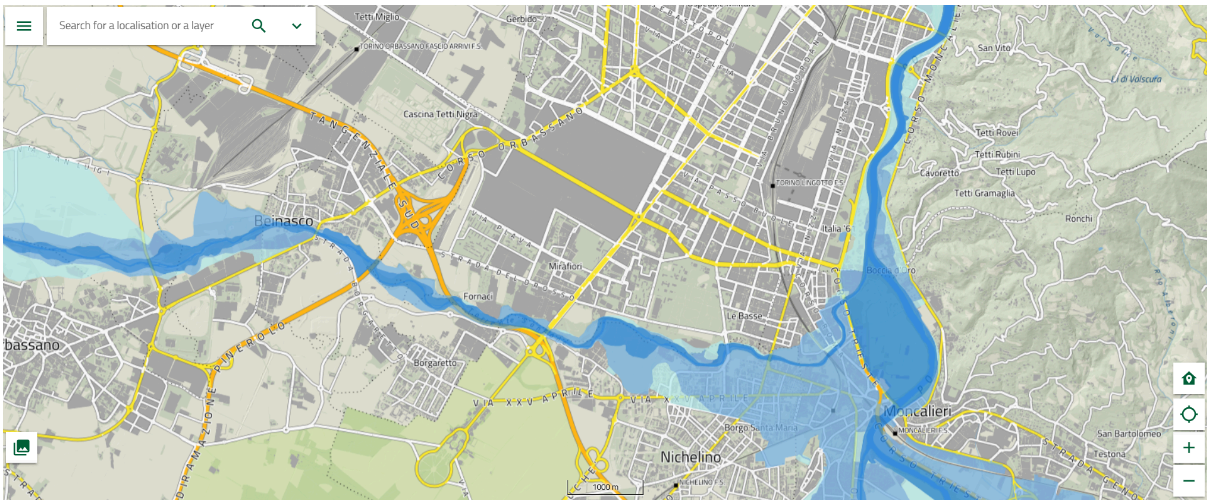


Figure 11: GeoPiemonte B view

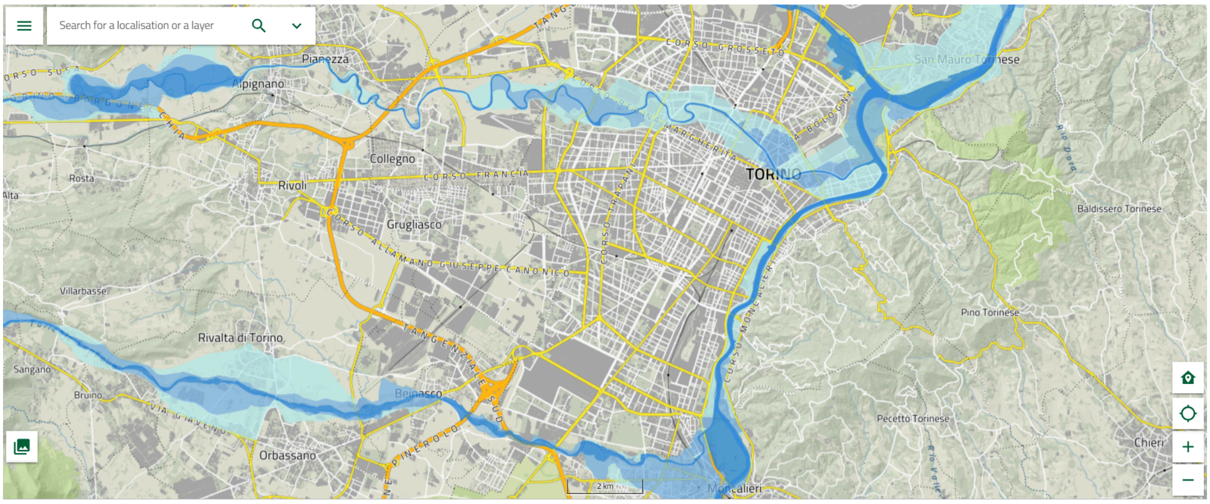


Figure 12: GeoPiemonte C view

For investigation, this map is taking a significant role as an analytical instrument. It allows us to identify the weakest points, to work on the comparative analysis of risk management, and use the ready data while modelling in QGIS. Thanks to the layering system of the Geoportale Piemonte, we can change the level of detailing, open additional parameters, for example, the level of danger (Pericolosita) or risk (Rischio) in different years, which can let us understand the dynamics of the hydrological situation in the different time periods.

Thus, the map is serving not only as a visualization, but a fully functional source of the spatial analysis, based on which we can build a deep geographical analysis of the flood effect on the city environment of Turin, and also compare the similar results of Astana, which is especially valuable for strategy research.

ADBPo

The next map, which was taken from the official resource Autorità di Bacino Distrettuale del Fiume Po (ADBPo), it is possible to find the areas with possible flood danger around the river Po in Turin's territory and its neighboring areas. The portal ADBPo is considered one of the most important governmental instruments for flood risk and hydrological processes management of the river Po. This map *(Figure 13)* reflects the results of the different flood scenarios modelling, from moderate to extreme, and demonstrates which territories can be affected during a sudden water rise. Different shades of blue mean the zones with the diverse percentages of the flood possibility, including not only the main water body, but also adjacent low-lying areas, water collecting pools, and urbanized zones.

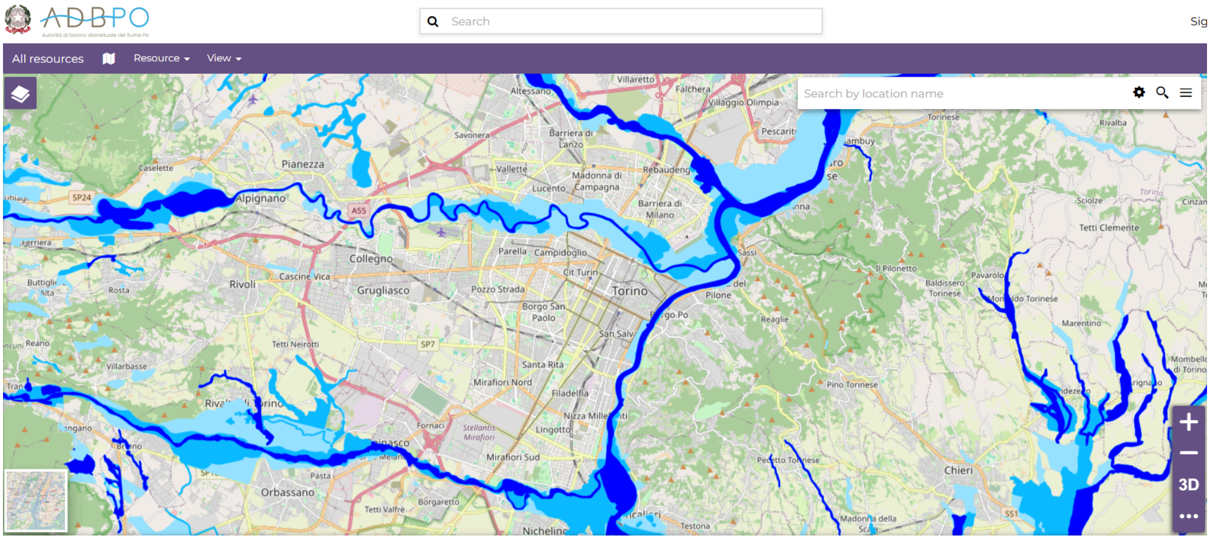


Figure 13: ADBPo

This website is specifically important for our investigation because it allows us to get the most relevant and trustworthy spatial data, which was accepted and confirmed by the national ecological services of Italy. The information from the ADBPo portal is being integrated into the GIS system and is being used to support the previous maps in the spatial plan construction.

Citta Metropolitana di Torino

Another official portal, Città Metropolitana di Torino considered a mostly complex and informative resource for natural risks and territorial planning data in the Piemonte region. In the part "Cartografie del Piano Provinciale di Protezione Civile" there are collected several interactive and statistical maps are collected that were designed within the citizen protection program for rating of the vulnerability and mitigation of the danger or emergency situation. These are mostly connected to the natural processes, including floods, landslides, and riverbank erosion. The special value for the research paper is bringing the part connected to the maps "Aree inondabili – Progetto di Piano stralcio di integrazione al Piano per l'Assetto Idrogeologico (PAI)", where you can find the official boundaries of the risk zones along the river Po and etc.. The zones of potential risk. These maps were based on the hydrological scenario models with different intensities and demonstrate which territories are at risk of repeating the historical floods or extreme meteorological patterns.

However, the portal allows access to the historical materials, which fix the real-life flood events in Torino and its surroundings. For example, for events of 1994 and 2000, you can observe the spreading of the flood waters around the city territory and compare it with the modern boundaries of the urbanized zones. Separate maps show not only the areas of the flood, but also the calculation of the number of people who live in the endangered zones, which makes it possible to calculate the demographic risk. This kind of data is important for complex analysis because it can help us connect the spatial parameters of the flood with the socio-economic characteristics of the flood.

An interest can also be brought by thematic maps of the hydrological net, water collecting pools, and existing water collectors. Thanks to them, it is possible to rate the interconnection between the natural specialties of the relief and engineering objects that affect the flood regimes. The data about the density of the population and the distribution of the infrastructure can complete the picture and let us understand how human actions increase or decrease the effect on the natural factors.

All of that makes the website Città Metropolitana di Torino not only the source of reference data but a full working instrument for analysis. Integration of the presented data into the QGIS system can allow us not only to visualize and compare the risk zones with spatial parameters like land use, density of the buildings, transport nets, but also to manage the retrospective analysis of vulnerability dynamics of the territory. Thus, the current resource has the key meaning for forming the justified base of the comparative research between Torino and Astana, since it provides authentic and systematic data about relationships between the natural processes and the city environment, confirmed by Italian citizen protection structures.

2. Astana data

During the data collection about the second city, I decided to consult the professional urbanists who work in city construction planning in Astana and nearby cities. Their professional help allowed me to understand the structure of the available data sources and find the most accurate and relevant platforms for getting the data, connected with risk management and land use. As a result, I was suggested to use the 3 main sources and a couple of additional sources which have information about hydrological aspects of the Ishim River, flood risk zones, and safety measures.

Astana GeoPortal

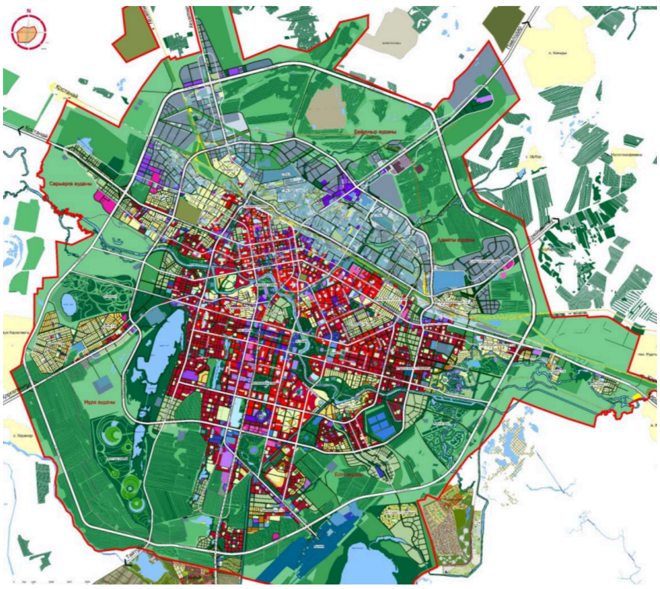


Figure 14: GeoPortal map

Astana has its own geo-informational center in Nur-Sultan city. Nur-Sultan is the previous name of the city. The website includes an interactive map with detailed information about the city's territory, its limits, and its functional systems. The map *(Figure 14)* provides the river location, agricultural and reen zones, transportation, and residential infrastructure. But the most important is the potential flood vulnerable zone and territories. The map has the data about the hydrological objects and

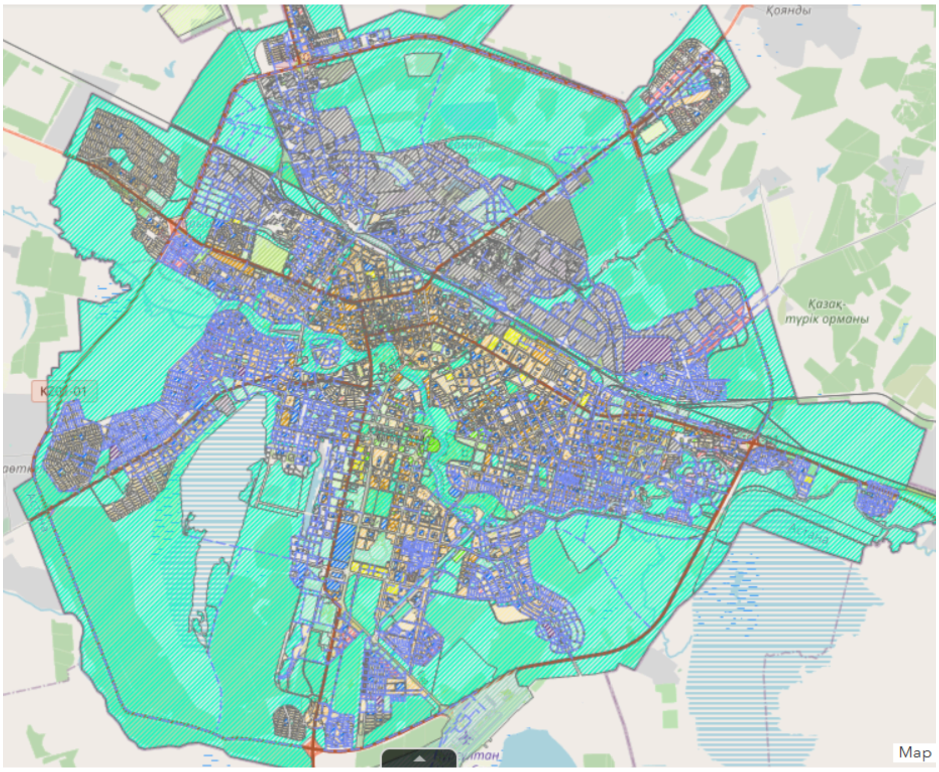


Figure 14: GeoPortal map

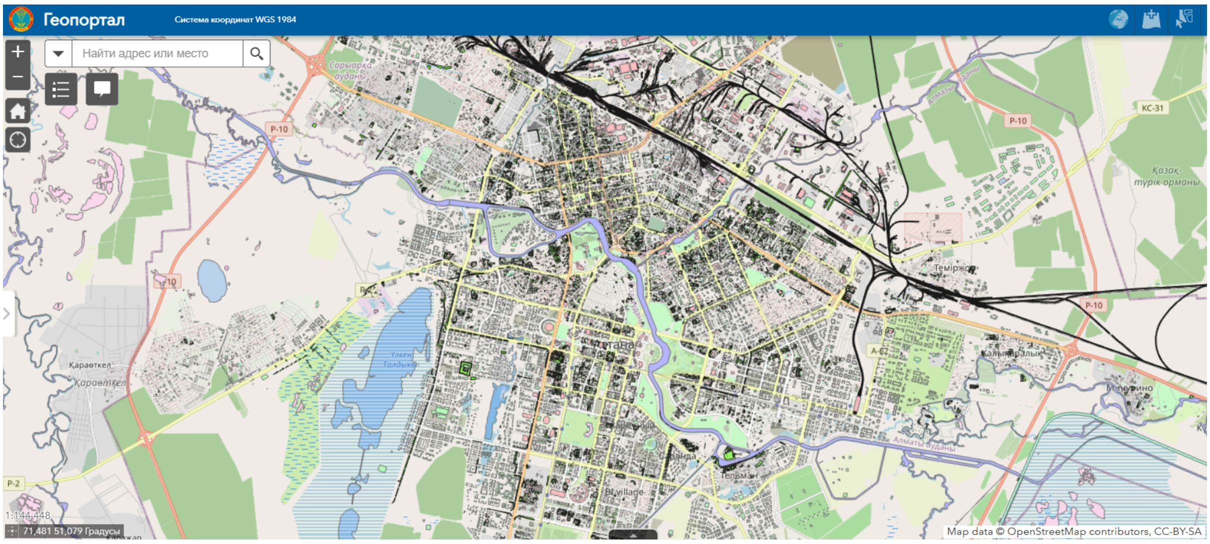


Figure 14: GeoPortal map

Floodplains, which let us describe the dynamics of the water bodies and find the most endangered zones. Moreover, the resource includes data about control and protection construction, as dams, contra-regulators, water collecting systems, etc., which can help us collect more ideas for risk minimizing and regulations. With the help of this map, it is also possible to visualize the connection between the natural characteristics of the territory and urban infrastructure. As well as analyzing the effect of the anthropological factors on flood risks. This kind of instrument is useful for land use planning, monitoring of the city environment, and building the risk strategy, helping municipalities, researchers, and citizens to get fresh and safe information about potential risks and safety measures.

Legend

The website's first important part is the interactive map itself, which helps to study the details of the city territory from the perspective of every possible urbanistic issue. However, the map would be almost useless without the legend, which contains every possible component of the presented data, as boundaries, buildings, public and agricultural spaces, transport, etc. Following the website, we can find a few different sources of land-use information, except that we can also see the river dynamics, points of possible flood risk, residential and industrial territories, and finally, every possible construction to mitigate the flood risk.

The legend assists the user in quickly navigating the different data types that are shown in the map, and also understand the functions of each object.

The table below provides the description of every legend component, which can allow us to get the structured and detailed information about each category. This table presents the translated category name from the original language (Russian) to English for better understanding between international communities. Here, it is possible to find the category, the group it is related to, and the original name with the color mark. The utilization of the map and legend together provides us with a complex understanding of the spatial analysis, and allows us to use it in future flood risk research. (*Table 1*)

Group	Original name	Category
Boundaries	граница города	The city boundaries
	границы административных районов	The administrative boundaries
Residential buildings	малоэтажная (1 - 3 этажа)	1-2 floors
	средней этажности (3 - 4 этажа)	3-4 floors
	многоэтажная (5 - 9 этажей)	5-9 floors

	повышенной этажности (10-17 этажей)	10-17 floors
	высотная (18 и более этажей)	18+ floors
Public spaces	объекты государственного и административного значения	Municipality and administrative buildings
	объекты государственного и специализированного значения	Municipality and special buildings
	детские дошкольные и школьные учреждения	Schools
	высшие и средние учебные заведения	Universities
	объекты здравоохранения	Heathcare
	объекты социального обслуживания	Social centers
	учреждения спорта, культуры и искусства	Sport, culture, and art centers
	объекты религиозно-культового значения	Religious centers
	объекты общественного и коммунального обслуживания	Commercial centers
	насаждения общегородского пользования (парки,скверы)	Parks

Recreational spaces	природно-ландшафтные территории	Green spaces
	реки и водоемы	Water bodies
Special zones	кладбище	Cemetery
	полигоны ТБО	Polygons
	золоотвал	Ash dump
Transport infrastructure	объекты внешнего транспорта	Intercity transport
	объекты внешнего транспорта	Objects of transportation
	объекты транспортной инфраструктуры	Roads
	магистральные улицы и дороги	Train Roads
Engineering infrastructure	объекты инженерно-коммунальной инфра-ры	Objects of engineering/communicational infrastructure
	Контррегулятор паводковых вод реки Есиль	Floodwater control on the Ishim River

Table 2

Emergency department official website

Another website (чс-ник.kz) observes information about more possible flood risk zones of Astana, developed by the Emergency Situation Department of Aqmola region. These maps describe the potential flood zones in the different districts of the city, including Almaty, Saryarca, and Esil. The information presented in the maps, which highlights flood risk zones, allows citizens and researchers to identify the weaknesses of the territories and find solutions to protect themselves and the city. The website concludes the importance of people's awareness about possible natural risks, such as floods. And, asks for active usage of the given materials for citizens' safety. This is especially relevant in the context of climate change. Being able to use these maps promotes a better understanding of the risks and helps in city and infrastructure danger protection actions.

The next three maps *(Figures 15, 16, 17)* that were borrowed from the website present the potential zones of possible flood risks in the different parts of Astana: Saryarca, Almaty, and Esil. Each map contains two different colors that signify the different levels of danger. Yellow color indicates the moderate level of the risk, while red is the sign of the high possibility of danger, the zones with the biggest vulnerability. The maps also include the legend and information about different territories, their features, and land details. The utilization of these cards significantly assists in the research work because they give a visual representation of the location of the flood risk zones around the city, showing how residential, industrial, and infrastructural zones can be affected by this specific natural disaster.

Figure 15: Flood risk zones of Esil district.

Figure 16: Flood risk zones of the Almaty district.

Figure 17: Flood risk zones of the Saryarka district.

In the frame of future work, this data is going to be integrated into GIS GIS-based program as QGIS, for the capital analysis. Based on that, it is possible to create a digital model of vulnerable zones, layer it with information from previous land use maps, infrastructure, and calculate the potential effect of the water level rising on the city environment. This kind of work structure is going to help visualize endangered zones and build a comparative analysis with Torino, which can become a foundation for the next steps.

CyberLeninka

The last website is CyberLeninka. It contains the article “Recognizing the flood-prone zones for residential areas in the upper part of the River Ishim during the rise of water level.” An article deeply describes the complex methodology of forming maps of flood areas, which also includes the calculation of dangerous levels of water in the upper part of the river. *(Figure 18)* This data makes it possible to justify the spatial distribution of the risk zones and identify the boundaries of the potentially flooded territories.

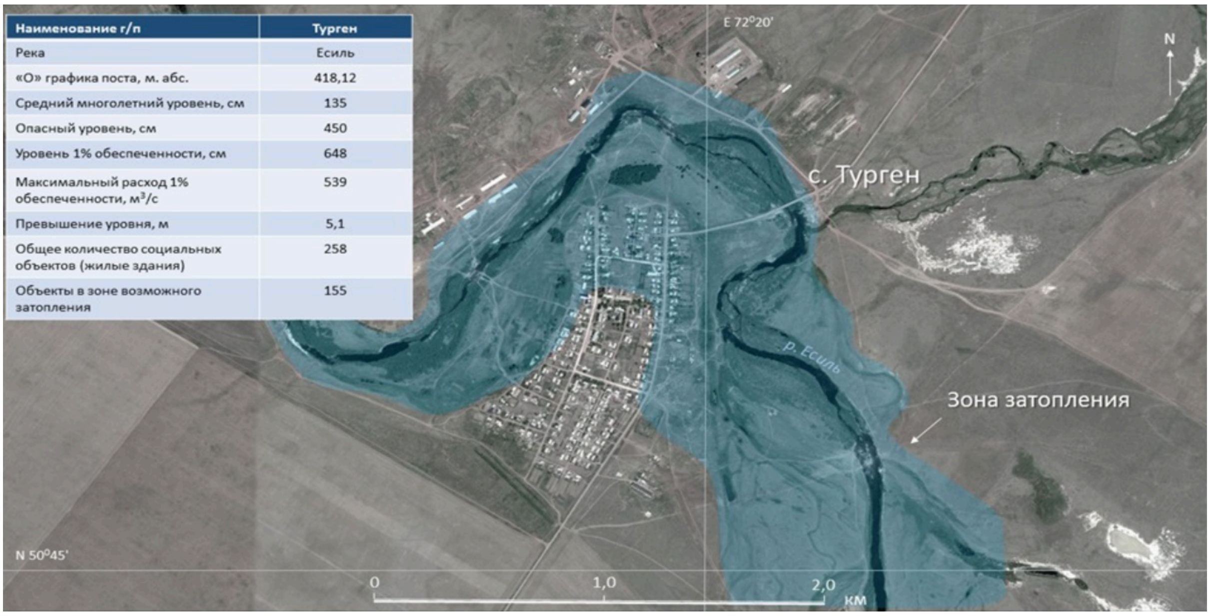


Figure 18: Flood risk zones from CyberLeninka

For my research, this source is valuable because it holds a justified methodology, supported by scientific calculations, connected to a specific river system of Ishim, the key object for the comparative analysis with Turin. The publication is allowing us to use the access to the data about the formation of the flood zones in this region, which natural, geographical, and hydrological factors can affect their duration and intensity. The exploitation of this source allows us to connect the layers we got from the GIS analysis with the scientific research, increasing the authenticity of our future risk zone mapping.

In total, the article can be extremely useful as a source; it is a significant step toward ensuring the authentication of scientific evidence in the historical-geographical context and the methodology phases related to mapping flood-affected areas. And in the end, integration of this data into the next steps of the research, as analysis, policy comparison, and recommendation suggestions.

Part III: GIS analysis

This part includes the spatial analysis aimed at fulfilling the visualization and assessing the flood risk distribution in the Torino and Astana territories. The application of the GIS system allows us not only to reflect the potential flood-prone zones, but also to compare them with the city infrastructure characteristics, density of the population, and location of the objects of the critical infrastructure. The building of the thematic maps in QGIS gives us the opportunity for a visual assessment of the vulnerability of specific city areas. And also helps to identify spatial characteristics that can not be found with text or statistical data. Thus, this part serves as a connection bridge between collected theoretical materials, policies, and real physical-geographical features of the research cities, which is considered a base for the future comparative analysis and work on solutions and recommendations for damage mitigation.

1. Torino analysis

a) Basic cartography of territories.

Before the primary spatial analysis, it is necessary to form a base cartographic image of the research cities and their main water bodies. At this step, we work on the creation of the base maps, which show the geographical location of Torino and Astana, the channel location of the rivers Po and Ishim, and the features of the land-use and basic infrastructure. This type of cartographic base is serving as a starting point for the next parts of the analysis, which can help to understand the spatial context, highlight the key natural and urban elements, and ensure the accuracy of the next operations about layering the thematic layers and risk areas. The base cartography also facilitates visual comparison of the territory and serves as the foundation for interpreting differences in vulnerability to flood events. *(Figure 19)*

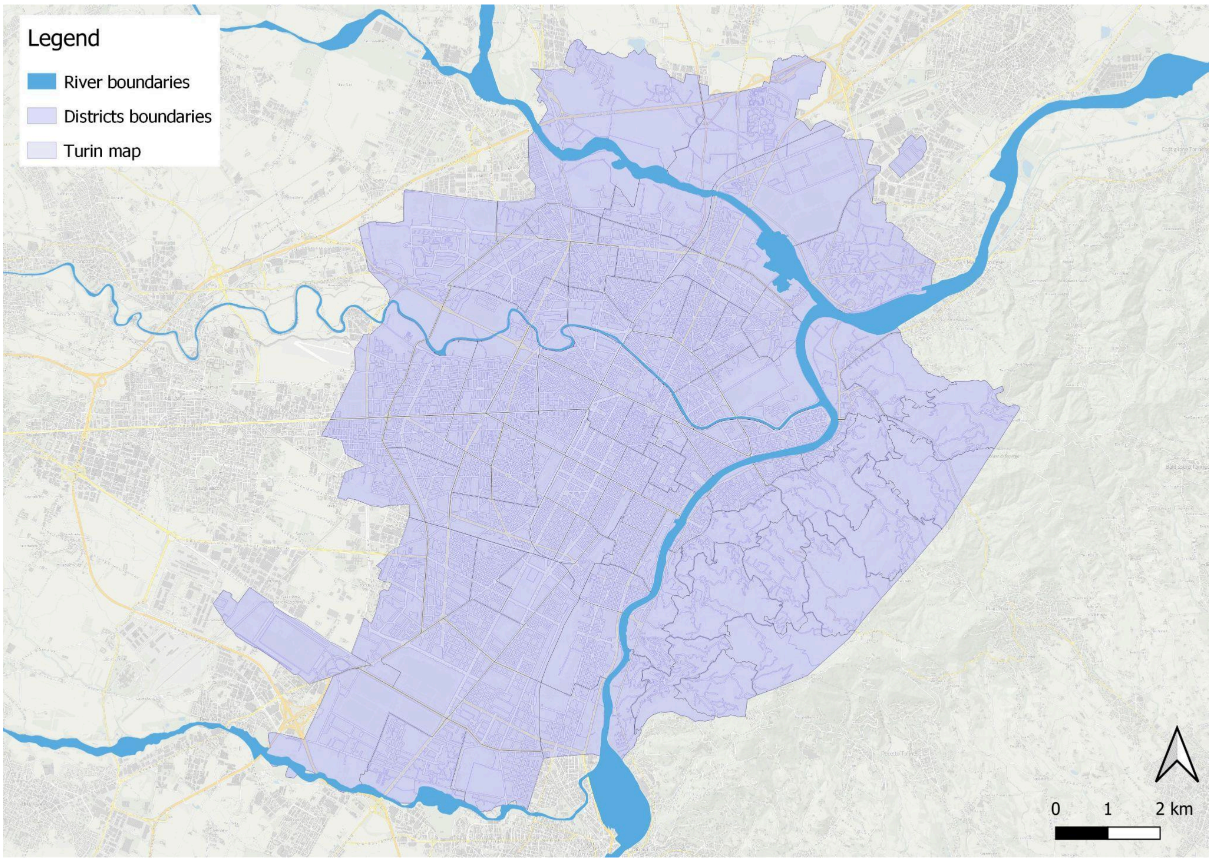


Figure 19: Basic map

b) The city building density, land use map

The construction of the building density map and land-use classification enables us to identify the functional structure of the city territory and determine the characteristics of residential, industrial, recreational, and vacant zones. This type of analysis is necessary to determine which parts of the territory are more vulnerable to flooding, based on their current use and the level of object concentration. Comparing building density with maps of potential flood risk areas allows us to assess the potential impact of flooding on the population and infrastructure and to highlight the critical districts that need special attention during planning, adaptation, and protection systems. So, the map of the land use is serving as a key instrument for the understanding of the spatial vulnerability of the city systems.

The next map *(Figure 20)* reflects the basic classification of the land-use, including the categories like: agricultural territories, green spaces, and forest areas. These layers allow to understand the common spatial structure of the city landscape, and define the relation between natural and urban territories. Similar visualization is especially important for the next analysis of flood vulnerability, that is, how we can understand what areas stayed in their natural form and which were used for the active city construction. All the shapefile layers were extracted from the Geoportale Piemonte, which guarantees a high level of accuracy and official origin of the cartographic data.

Moreover, the base maps were adjusted to the unified style by using the same coordinate reference system for both cities. This allows us to complete the next analysis, like layering the land-use classification, building typology, or flood-prone zones with the exact geographical position. Creation of the united cartographic base for Turin and Astana makes it easy to compare the visual materials. When both of the maps use the same logic of symbols, colors, and the way of visualizing hydrological elements, it simplifies the interpretation of the differences in the river morphology, the risk area, and the vulnerable zones.

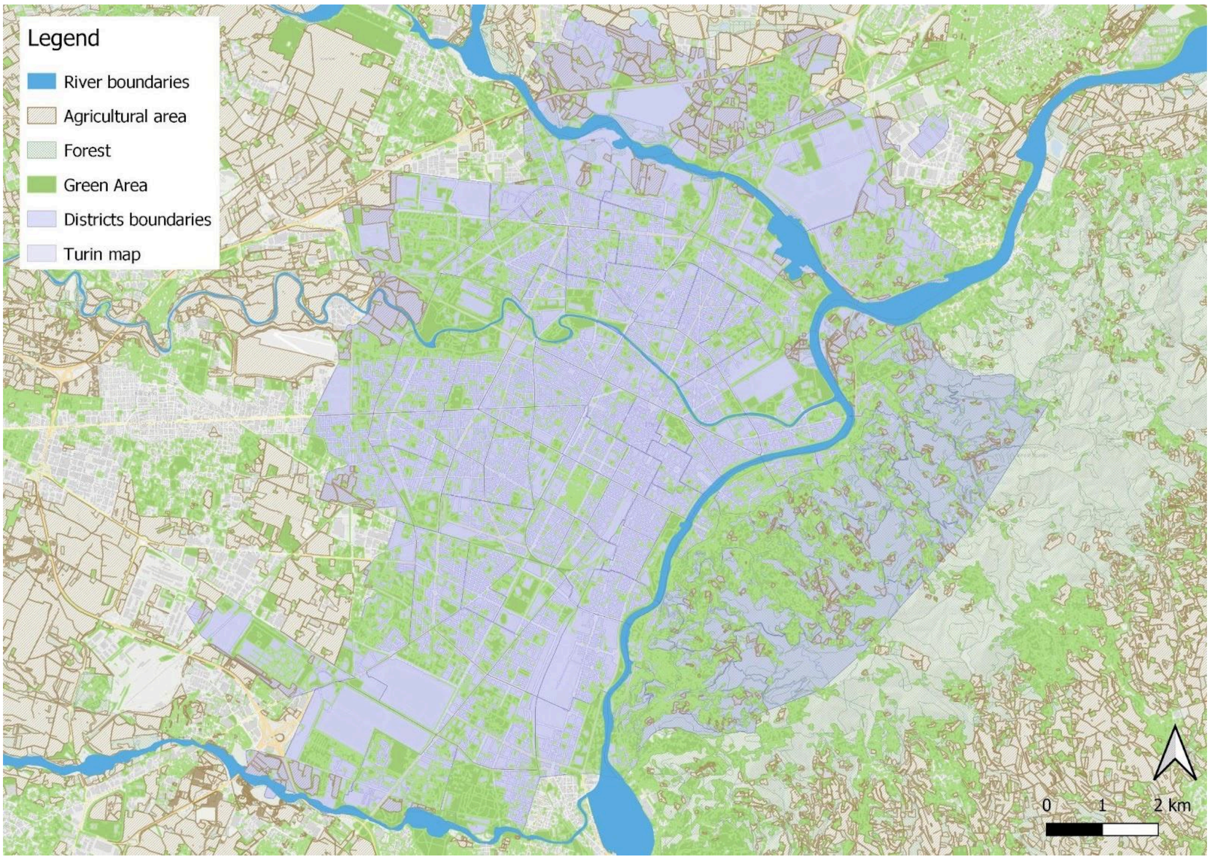


Figure 20: Land-use map

The next map *(Figure 21)* introduces the detailed visualization of the key urban infrastructure objects, which were downloaded from the same portal's official WMS shapefiles. Different categories of buildings and constructions, which include also the educational places, hospitals, and emergency rooms, industrial buildings, etc., were included in the separate building typology map. The schools, private educational structures, were reflected as separate symbols, which allows us to grade their geographical relation to the risk zones, and find the districts with the highest social value. Hospitals and emergency rooms are highlighted with special symbols to be more recognizable, which gives us an effortless analysis of their spatial location. And last, industrial constructions are included in the new layer, because I believe that they are bringing a new side of the danger during the flood events. In total, this map is serving as an important analytical instrument, demonstrating which elements of the city infrastructure potentially can be influenced by flood processes, and seeing how the policy of Turin is dealing with this kind of scenario.

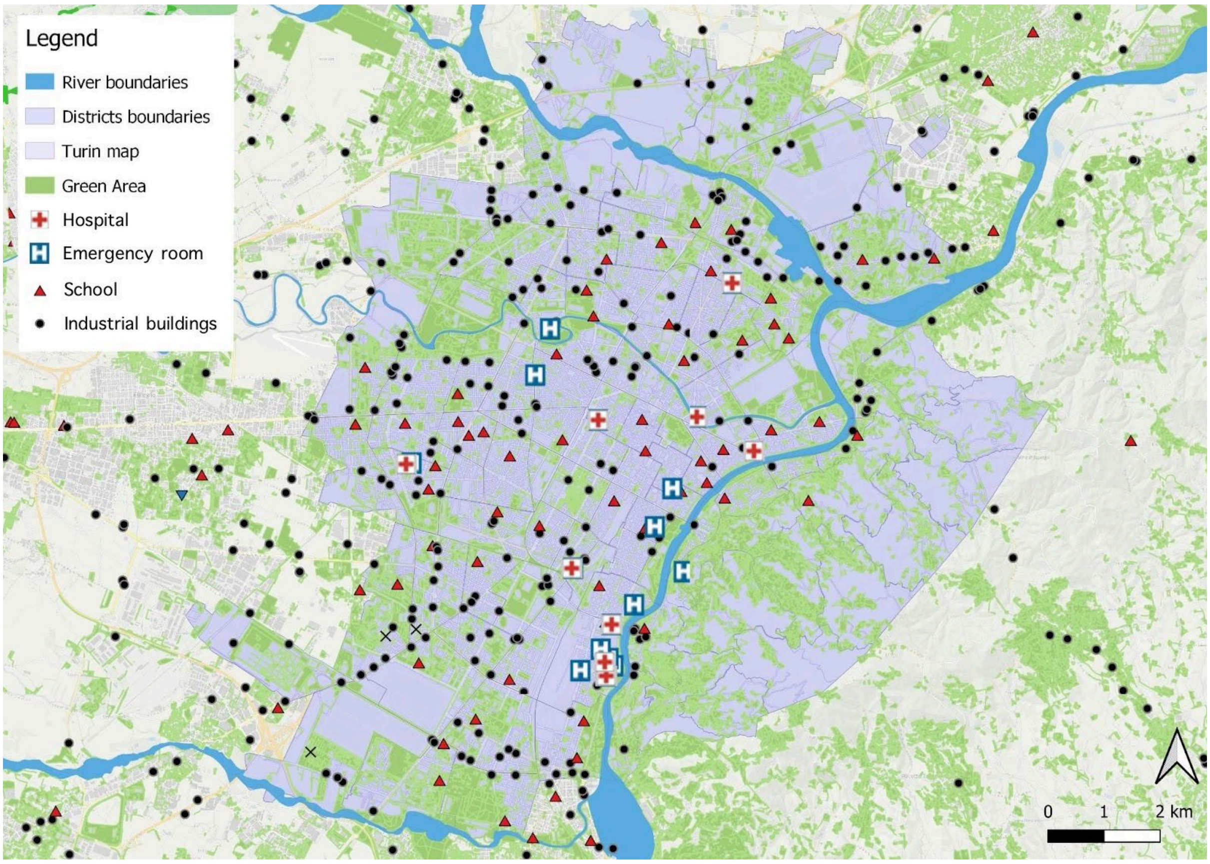


Figure 21: Building typology map

c) Visualization of the potential flood-prone zones in Torino.

This step is made for the visualization of the potential flood risk along the riverbank of the Po River, and within the Torino city territory. *(Figure 22)* Since Torino has bigger data about the flood risk zones, it is possible to use many different sources to find the perfect location of the vulnerable zones. For that, we are going to use the official data from PGRA (Piano di Gestione del Rischio Alluvioni) and PAI (Piano di Assetto Idrogeologico) published at the ADBPo and Geoportale Piemonte. These maps have the gradation of the danger levels, reflecting the possibility and the scale of the catastrophe. From the areas with a low level of danger to the districts that are in extreme risk. The transfer of the data into QGIS allows for reflecting these territories as the thematic layer and visually defining the areas that are located within the riverplains. The ready map can give us the opportunity to grade the geographical extent of the flood risks and identify which parts of the city are potentially at risk from the floodwater. The next comparison of this map with other maps of the buildings and infrastructure lets us find the vulnerable zones and grade the consequences.

The last section presents the complex visualization of the zones with potential flood risk in Torino. All the maps were created based on the data from several official sources from the online cartographic services, including Geoportale Piemonte, ADBpo, and AIPo (Agenzia Interregionale per il fiume Po). The map connects the hydrological net, city boundaries, the districts map, and the key objects of city building infrastructure, including residential, industrial, or public places.

The main focus is attached to the reflection of the 3 levels of flood risk, which are traditionally used in flood risk management policies in EU countries.

They are:

- Flood-prone zones with a once-in-50-year event;
- Flood-prone zones with a once-in-200-year event;
- Flood-prone zones with a once-in-500-year event;

These categories help us understand which zones are rarely affected by the risk and which are constantly in danger. From the map, it is clearly visible that the most vulnerable places are the territories along the riverbanks of the river Po, especially in the south and the east-south parts of the city area. The width of the river body is significantly larger than in the other parts, which is why the volume of the flood waters is higher. This is making these territories more sensitive to the risk, even during the medium-danger events. The north and north-eastern parts are also in the high-risk level, but the floodwaters, even in the high-risk level, concentrate in the localized area without spreading into the urban territories.

For the policy strategy study, it was decided to use only the zone with the medium risk intensity for 200 years. This level is the most balanced for the rating of the real danger. On one side, it reflects serious but still possible scenarios; on the other side, it counts the extreme consequences that have to be considered in future strategy planning. Thus, this map is serving as a base instrument for identifying the most sensible zones and for future analysis of policy management.

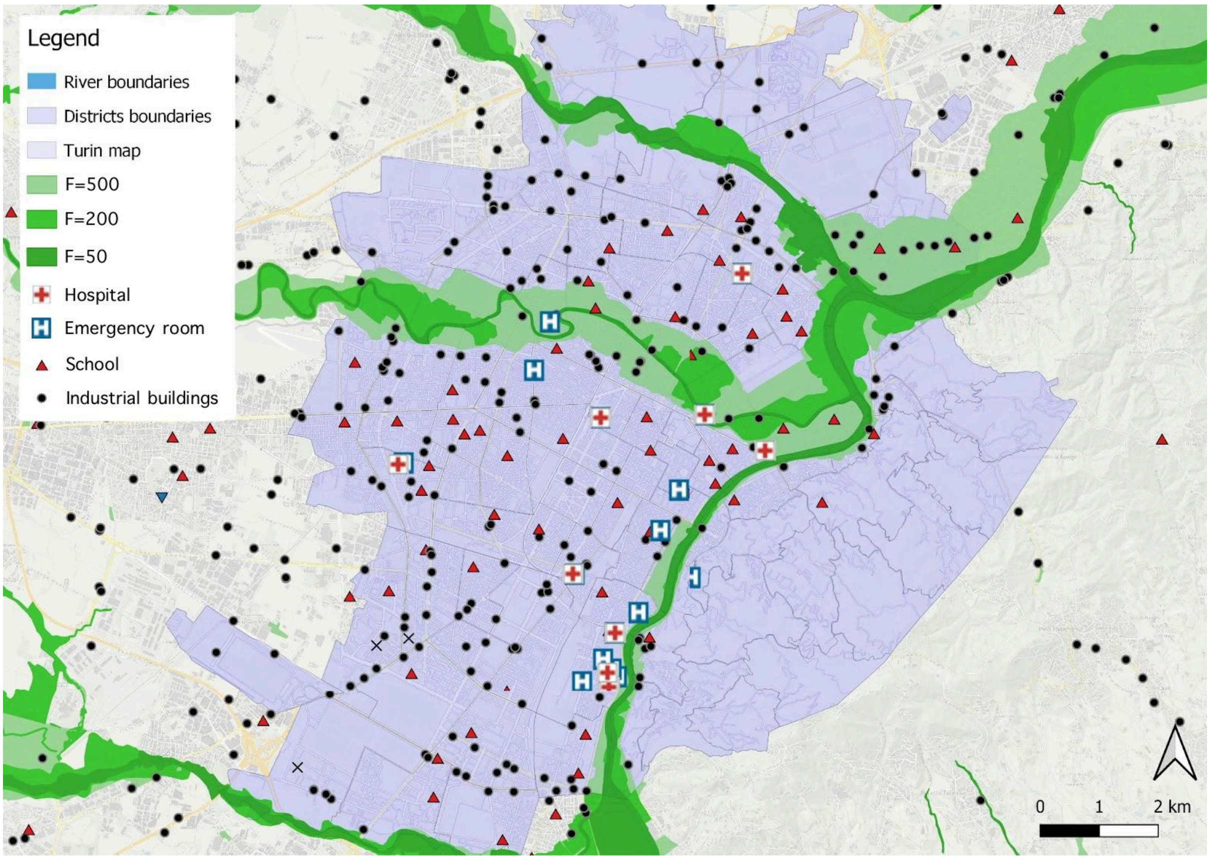


Figure 22: Flood-prone zones map (A)

The next map *(Figure 23)* represents a more detailed and close look at one of the more sensitive zones of Truin, which are included in the "floor-prone areas" category. That is stated according to data from flood risk management of regional planning (PGRA - Piano di gestione Del rischio Alluvioni) and policies that were established by Piano Assetto Idrologico-Geologico (PAI). The areas shaded with the red lines identify the territory where the flood risk is significantly larger; the risk belongs to the same category that is shown in the previous map (Frequency=200). Even if the density of the urban territory is pretty high in these areas, with a lot of residential buildings, social places, and a few industrial constructions, from the local analysis, it is visible that the risk is only affecting one problematic place.

According to the policy documents of Torino, any construction and reconstruction works in these areas have to be regulated with strict limitations. New buildings can be built only on the condition that there are hydrological calculations, water protection events, and with proven evidence that the flood situation will not be worsened. The map perfectly illustrates how these rules are being used in practice. The biggest part of the urban construction is already following all the policy rules, and the development of the territories inside the risk zone is limited or needs special engineering decisions. So, this part of the territory helps to visually connect the spatial data with the risk management policy and demonstrates that even with the high building density, the critical danger is localized. The city is following the policies to mitigate the risk increase in this part of the city.

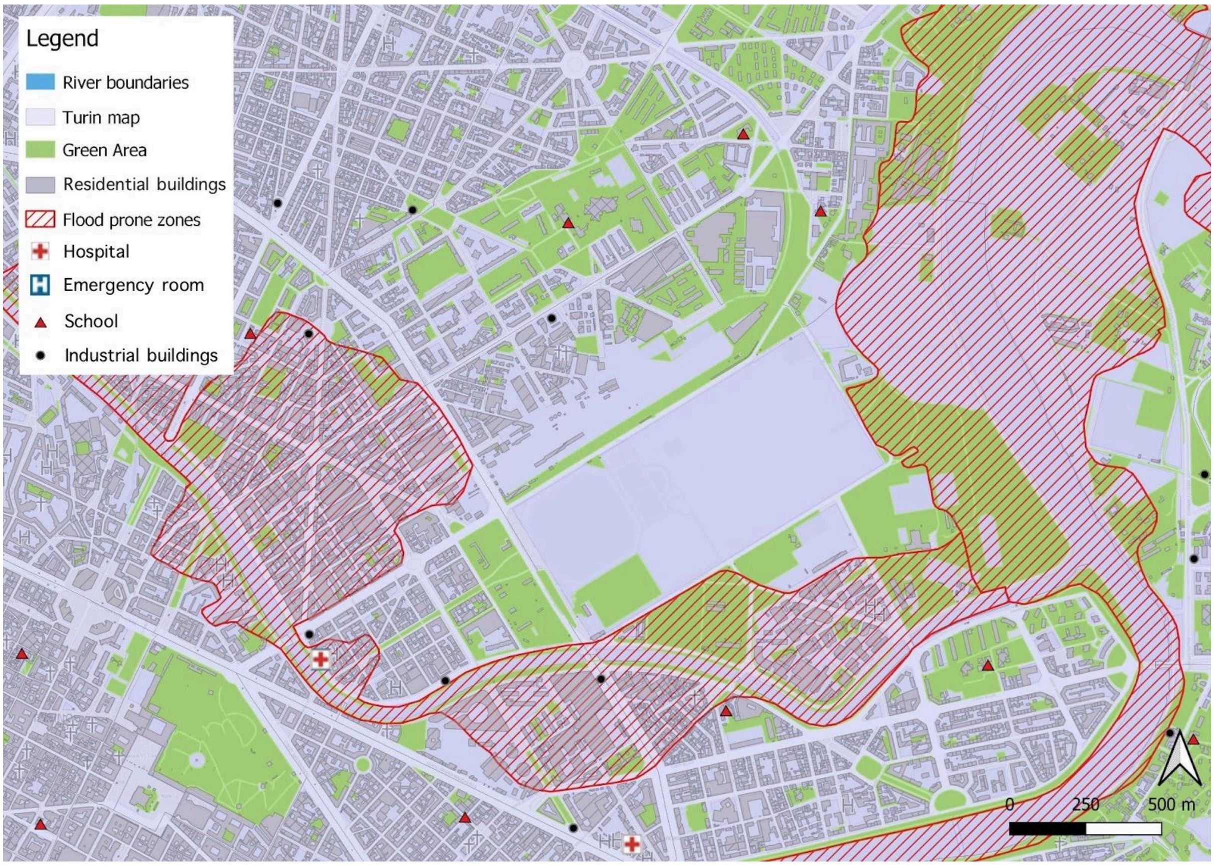


Figure 23: Flood-prone zones map (B)

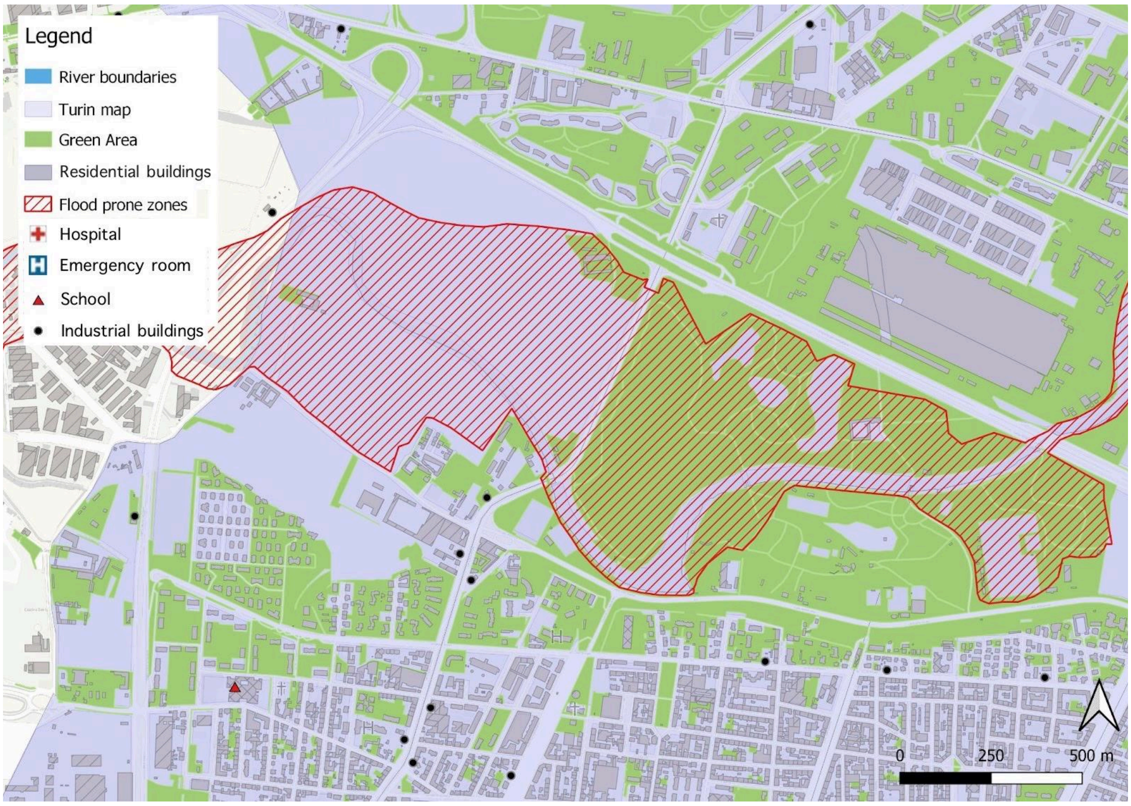


Figure 24: Flood-prone zones map (C)

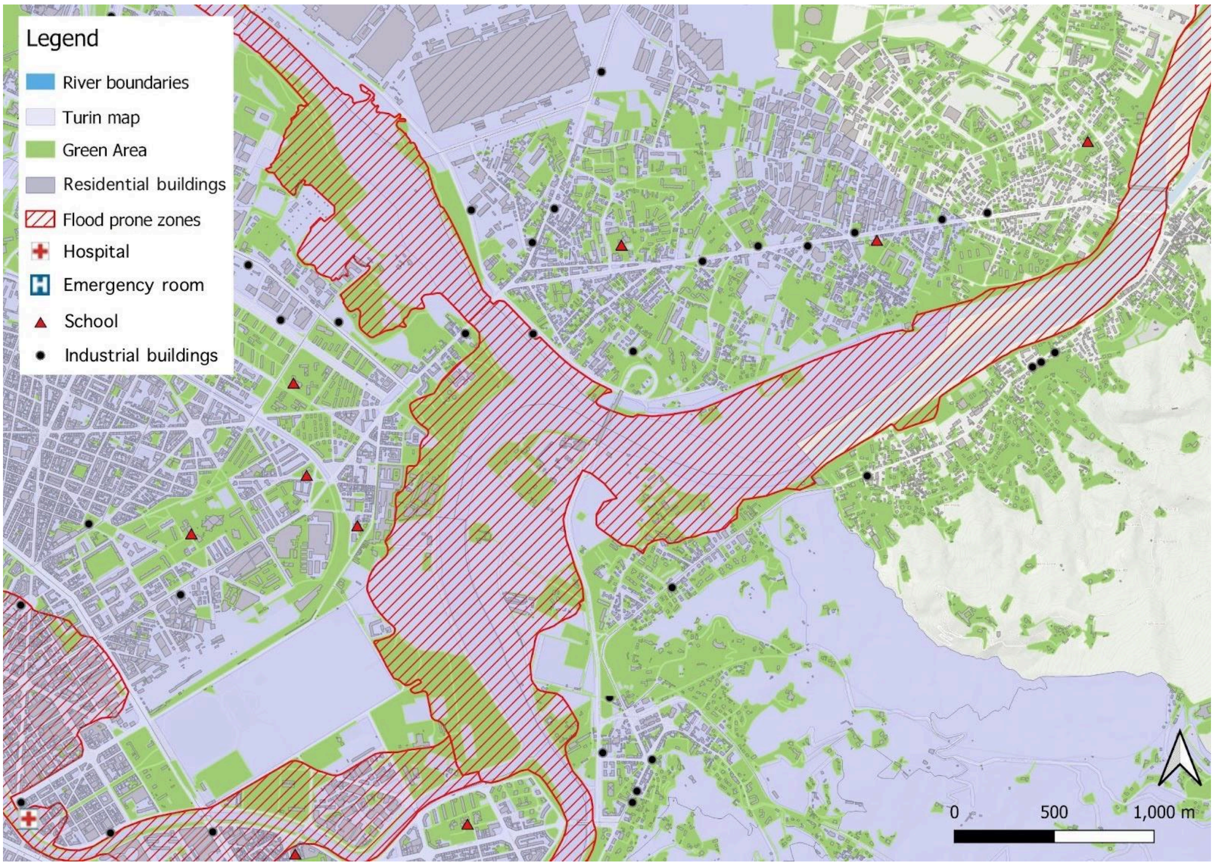


Figure 25: Flood-prone zones map (D)

From the technical point of view, the study area is under several key regulatory provisions governing construction and land use in areas with hydraulic risk. Particularly, according to the PAI - Piano di Assetto Idrologeologico, the areas that are included in the "Falce fluviali di pericolosita media o elevata" (Medium to High danger) are considered as zones where it is prohibited to build new large constructions, or it is allowed but only after assessing the impact on the hydrological balance of the territory (valutazione di compatibilità idraulica). In addition, the rules of the PGRA, which were designed with the impact of the European Directive 2007/60/CE, require the municipalities to include these zones in danger and risk maps, also, provide the regular monitoring of the water levels and integrate the data about flood scenarios into municipal plans of land use (*Piano Regolatore Generale Comunale, PRGC*).

In practice, it means that in the area shown on the map, any of the future urban planning decisions have to comply with the R3-R4 risk categories, which allows only limited use of the territory, the public spaces with low intensity, natural protecting zones, recreational territories, or engineering constructions that can't increase the flood risk. The construction of residential houses, hospitals, or critically important infrastructure in the red zones is strictly prohibited.

The comparison of all three maps demonstrates well the heterogeneity of the urban fabric within the boundaries of the potential flood risk in Turin. In some of the places, for example, in the south or the south-east, it is visible that there are absolutely no buildings inside the red risk zone, which is directly connected to the strict following of the rules of PAI policies and municipal rules of planning, which prohibit construction works in areas of high flood risk. These territories are mostly busy by green zones, parks, agricultural areas, and recreational spaces that fully obey the politics of “non aggravio idraulico”, directed to the mitigation of the increased hydraulic load and saving the natural power of the territory to absorb the flood water.

However, in the other places, especially closer to the historical center, we can see the areas where construction objects are available even in the risk zones. I can explain it only through the historical features. Since Torino was developing even before the modern policy of hydrological protection, these buildings come from the previous stages of the city's urbanization, when the understanding of the risks and their management approach was significantly different from what we have now. According to PGRA and local PRGC, similar areas are going under the strict limitation of the reconstruction, modernization, or changing of the functional purpose regime. Also, any of the constructional changes need a complex hydrological justification.

Moreover, the differences in the maps also reflect the topographical features of the shoreline. In the areas where the river is wider, the water has a larger area of potential water spread, which is why the building in this place was historically avoided; these zones remain as green areas/parks to this day. Oppositely, where the Po valley forms the natural hills, the possibility of the city infrastructure being closer to the river is significantly higher.

That is how the given comparison visually represents the relationships between 3 factors: historical development of the city, modern policy limitations, and geomorphological features of the river valley. This exact collaboration explains why some of the parts stay empty, and others include the objects that today can be classified as a risk zone.

2. Astana analysis

a) Basic cartography of territories.

For Astana, the plan is very similar; however, there is a description of each step anyway. As a first step, we form the base cartography foundation, which shows the geographical location of the city, the channel of the River Ishim, and the connected water-collecting territories with the basic element of the city’s planning structure. At this step of the research paper, we create the basic maps in QGIS that include the layer with the relevant satellite images, the boundaries of the city structure, transport infrastructure, and the boundaries of the administrative areas. This kind of cartography allows for getting the spatial context of analysis and understanding the specialities of the city location against the river, and highlighting the areas where the relation between natural and urban components is more visible. This map serves as a base for connecting the layers and receiving the correct interpretation of the next analytical steps.

On the base map of Astana *(Figure 26),* it is possible to find the administrative borders of the city and the central part of the Ishim River, which is considered a key natural element of the city's structure. In comparison with Turin, which has an existing, developed, and high-accuracy regional geoportal system known as Geoportale Piemonte, where you can find the full collection of the official shapefile layers for the different types of data, from hydrological to infrastructure, the possibilities of open data in Astana are visibly limited. The available governmental resources represent the information more fragmented, mostly in the form of static PDF maps, reports, or separate interactive layers that can't be downloaded into the QGIS program. That is why, during the creation of the cartographic base and other maps, I had to work differently. All the map elements were redrawn by hand via GQIS, according to the interactive layers, and visual data of the official Kazakh geoportals, including the public maps of the emergency department, and materials of the regional under-departments.

Structurally, Astana is significantly different from Torino. First, the city has only 3 large districts, while Turin is imagined as a more complicated administrative separation. Secondly, the terrain of Astana is way simpler. The city is located on flat territory, without noticeable natural barriers, in comparison to Torino, which is surrounded by hills. This is making the process of generating the base map easier, but at the same time, it makes flood risk more uniform. There are no hills or mountains in Astana, which could serve as a protection zone or direct the flow of water. Except that the flow of the Ishim is less curved and mostly straighter than that of the Po. *(AstanaGenPlan)*

Thus, the base map of Astana was created not with the help of the direct installation of the shapefile data, like in the situation with Turin analysis, but by hand-drawn contours, boundaries, and hydrological objects, based on the visual sources. This shows the differences in accessibility of the spatial data between two cities.

Figure 26: Base map

b) The city building density, land use map

The construction of a density map and analysis of the land-use structure in Astana allows us to define the distribution of the residential, industrial, and recreational buildings in the districts. The usage of the data from the municipality's geoportal and also layers of OpenStreetMap with satellite pictures gives an opportunity to classify the territory for its functional purpose.

The represented land-use map *(Figure 27)* demonstrates the spatial organization of the natural and functional zones of Astana. It allows us to understand the organization between natural, agricultural, and urban planning. The way of representation is repeating the pattern that was made for the Torino maps for easier understanding. Same as for Torino, the green color shows the large natural areas like city parks, forests, recreational zones, etc. Besides ecological functions, these areas are playing a key role in the formation of the city's sustainability. They serve as the natural water absorbents and help to reduce the amount of flood waters.

The yellow areas on the map mean agricultural zones. Due to the fast and aggressive expansion of the city structure, there are still some places that keep functioning as agricultural areas. However, most of the agricultural territories are located outside of our study area, outside of the city boundaries. Even if the amount of these territories is small, their presence is proving the ability of the urban territories to cooperate with natural structures. This feature is considered a specialty of Central Asia. That means that even if the city is focused more on urban development, it still can provide the needed food supply and economic functions.

In total, this map can conclude the contrast between highly dense urban territories and more open natural-oriented peripheries. Besides, the spatial organization of the green and agricultural territories can help to assess the potential of the city for the implementation of nature-based decisions, which could help to increase flood resilience.

Figure 27: Land-use map

The building typology map *(Figure 28)* reflects the organization of the key elements of the social infrastructure, as for Torino, I included mostly schools (red triangles), hospitals, and industrial buildings (red crosses). These objects play a significant role in the city's life-supporting system, and their spatial attachment can help assess the level of social protection and access.

In the urban structure of Astana, the residential zones are represented as the main functional category, forming the frame for everyday life. These territories are meant for the long-term residency of the population, and include the multi-apartment residential complexes as well as individual constructions for peripheral microdistricts. Following the urban planning policies, it is allowed to add social and domestic services as educational centers, small stores, small offices, parking areas, storage rooms and etc, into the residential complexes if they do not need sanitary protection. The residential structure of Astana has a difficult, multilayered character. The central areas with high density can cooperate with the new small districts, where the social infrastructure is still developing. Moreover, the residential area can be well cooperated with the green areas, engineering nets, and transport corridors. All that shows the complexity of the city environment, and the importance of integrating the planning in terms of flood risk. *(AstanaGenPlan)*

The public spaces of Astana connect the social, cultural, educational, and administrative objects. These territories include the health-related buildings, cultural centers, schools, universities, shopping centers, offices, public zones, administrative buildings, and scientific research organizations. Here you can find the different levels of the educational centers, huge multifunctional complexes, and services. The public zones are playing a key role in the spatial structure of the city, providing accessibility to the critically important infrastructures. Their distribution is demonstrating the centralization tendency of Astana. The majority of the key objects focus on the central and nearby districts. This raises the imbalance between the new and old parts of the city and shows the need for future planning, especially in terms of the flood risk. The majority of the schools and hospital centers are concentrated in the central part of Astana in places with a high density of residential buildings. The reason for that is the historical construction of the city's structure. It is also noticeable that a significant part of these objects is located near the Ishim riverbank. This can create conditions where the potential risks that are connected to the floods can directly affect the availability of the critical infrastructure, especially considering the seasonal water level rise. In the peripheral areas, the density of the social objects is way less. This reflects the planning strategy of the city, where the development of the new residential construction is often in front of the social infrastructure. *(AstanaGenPlan)*

The industrial territories of the city have a clear function and include the large production units, public utilities, and engineering infrastructure. This category includes the active heat and electricity generation enterprises, water supply stations, gas distribution networks, railway repair bases, heat and electrical equipment service workshops, as well as factories producing building materials and food industry facilities. An important element of the industrial landscape is wastewater treatment plants and settling ponds, which form a separate utility cluster. The spatial distribution of the industrial zone in Astana is traditionally located outside of the residential area. However, due to the fast spread of industrialization, it is possible to see the interaction between these two. It creates additional challenges for sustainable development, it is important to balance between the economic and ecological safety. Also, important to count the possible risks connected to the flood, especially in the districts near the river. In comparison with Turin, where historically industrial zones are actively reorganizing into the new functions, the industrial section of Astana stays stable and a dominating element of the city. *(AstanaGenPlan)*

Including the building typology map in the GIS analysis can let us see the infrastructure location, and also connect it with the potential risks. In the future, this map can be used for the assessment of the conflicts between the developing zones and the zones of potential risk. And the most important thing to see is how successful the local policy is against the flood risks in the most vulnerable places. We can see how strong the results are, and suggest the measures for the risk reduction.

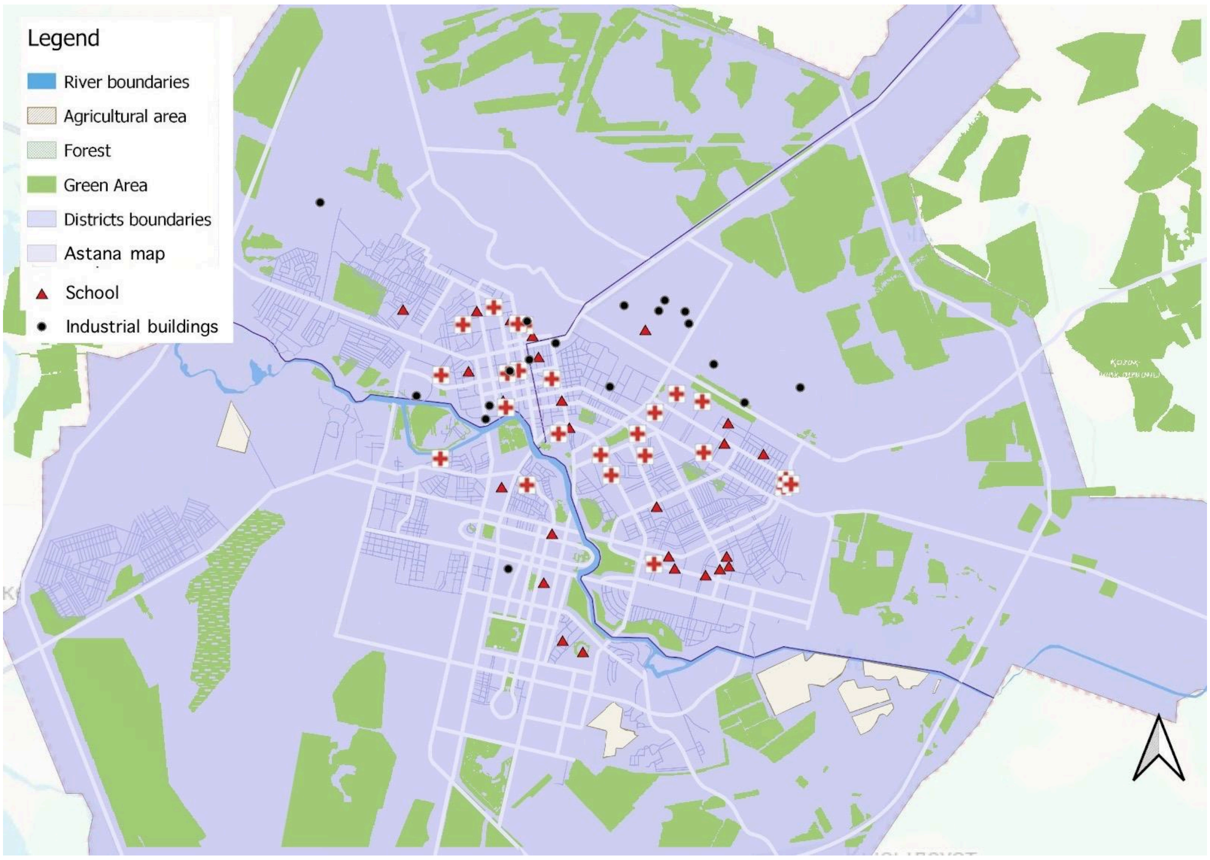


Figure 28: Building typology map

c) Visualization of the potential flood-prone zones in Turin.

The visualization of the flood-prone areas in Astana is completed with the data extracted from the department of emergency situations and the city's monitoring services. In QGIS, it is possible to import the maps of the flood risk zones, which reflect the scenarios of river water spreading along the river Ishim. However, since the absence of the shapefiles with information, all the maps are drawn by me with the help of the QGIS program. The special interest is provided by areas that are located within the river channel and low-lying fragments of the territory, where the spring snow melting and uneven precipitation distribution can lead to the collection of the flood waters. Creating the different topic layers in QGIS allows for visually highlighting the boundaries of the risk and finding the most vulnerable areas, which is considered a key step for the next comparison with the map construction and infrastructure.

The next map *(Figure 29)* shows the trial reconstruction of the spatial distribution of the high- and medium-risk flood zones in Astana. The map was created based on data collected from the official maps of the emergency department in the Akmola region. Since, in comparison to Turin, Astana does not suggest any standardized risk scenario maps, like 50, 200, and 500-year scenarios, as well as shapefiles or WMS/WFS data that could be downloaded and used, all the risk zones were applied and layered by hand, with the help of different software and visual maps. This highlights the key difference between the cities. Torino uses the cartographic system PGRA, which allows to use of accurate hydromodes and the status of risk, while Astana has only fragments of the information scattered along the internet. What caused the scientific research to be more complicated.

Dark green points on the map indicate the areas with a high risk of flooding, while lighter green areas are the zones with medium vulnerability. Most of the points are mainly grouped along the river Ishim, which is connected to the hydrological data, like low-lying terrain, weak drainage, and seasonal water level rise. All these reasons create a high possibility of the flood risk according to the data that was mentioned before. However, it is obvious that there is a row of dots located inside the city structure far away from the main river and its canals. This can be explained by the problem of the high level of the groundwater, which can reach less than 2 meters from the surface in 75% of the city's territory, and by the presence of the artificial water objects, canals and etc. All these factors can lead to local flooding even at a distance from the river source.

The map shows different social objects that might be more vulnerable than an ordinary building, as hospitals, schools and etc. We can notice that the flood areas and these social objects are quite close and interacting with each other. This highlights the lack of a system of strict restrictions on construction and planning in vulnerable areas, which is also confirmed by an analysis of Astana's urban planning documents. Unlike Torino, the city does not use strict restrictions on construction in floodplains and prioritizes engineering protection measures rather than risk prevention through land use regulation.

Comparison of the spatial data on the map with the existing risk management system demonstrates that the current policies of Astana work only partially. On the one hand, the engineering constructions significantly reduced the effects of the spring floods and protected the central areas. On the other hand, an absence of the relevant, regularly updated maps of danger can not allow us to forecast the vulnerability of some of the objects. Moreover, accepting constructions in potentially dangerous places can increase the long-term risk. construction of the hospitals and schools inside the high and medium risk areas indicates that the existing planning system does not integrate the risk assessment into the city planning decisions, as well as in European countries.

In total, the analysis of the map shows that the flood risk management policy of Astana needs to be improved in terms of preventive and planning regulations. Not only in terms of the engineering interventions. Everything has to be well monitored, people need an open access to the GIS risk maps and limitations to the constructions on the potential risk zones.

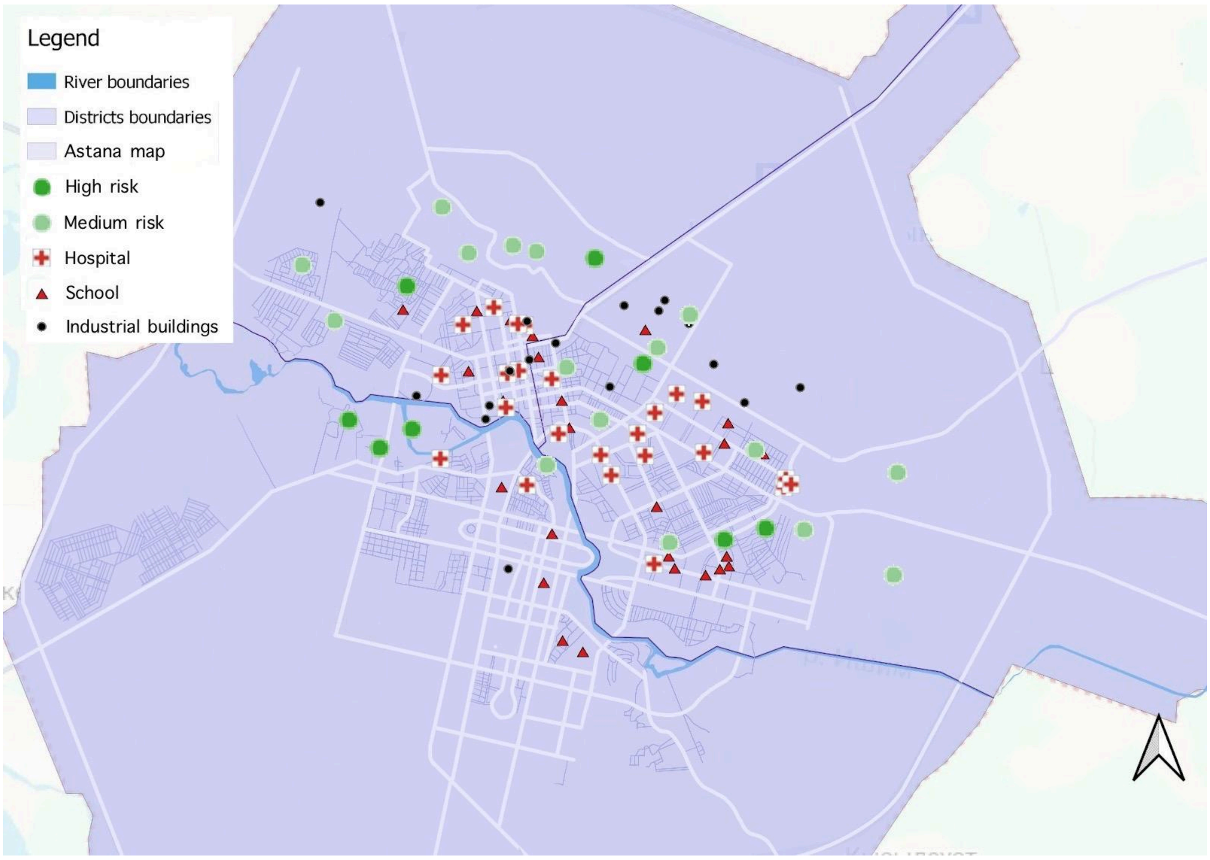


Figure 29: Flood-prone zones map

To see a more detailed situation, I used the Geoportal maps layered with the building typology and risk maps. *(Figure 30, 31)* These maps only prove the previous point. The closer view of the risk lets us see how close the residential and social buildings are to the risk areas. On the different fragments of the map, it is visible that a significant number of socially important objects are located in proximity to the bed of the Ishim River or its small tributaries. This is especially visible in the areas of the central part of the city, where the hospitals are literally located within a few meters from the river, and a few schools are inside the high and medium-risk zones. This kind of building morphology can be explained by the historical development of the city. Most of the places were built before the risk maps, or at a time when the engineering methods were considered to completely mitigate danger.

Except for socially important objects, the map shows the industrial buildings and separate production sites near riverbeds and small watercourses. This can be dangerous, since some of the industrial constructions can lead to ecological danger if it will be affected by the flood risk. Accidental emissions, leaks, or destruction during flood periods may lead to pollution of water bodies. Some of the territories have industrial buildings around the risk zones, marked as the black dots. As in Torino's policy, Astana also mentions that similar constructions must be strictly limited in the danger zones, must be monitored, and protected. In Astana, this policy exists in the law documents as the Civil Protection Law and Water Code. However, they are implemented by fragments, because each territory is being regulated by the local plans, not by the complex risk analysis.

Another interesting element is the green area distribution, as parks and natural areas. In most cases, the green areas are the ones that is located next to the high-risk zones. From the point of risk policy, it can be judged as a positive thing. The natural buffers can reduce the scale of the flood effect and decrease the load on the street infrastructure and residential areas. However, the same map shows the opposite tendency; some of the green zones are very near the residential buildings without transition buffers, which breaks the modern concept of floodplain zoning and increases the risk to nearby neighborhoods.

The presence of separate high-risk areas within the urban development, quite distant from the main channel of the Esil River, is also important. This is due to the hydrogeological characteristics of the territory. The groundwater level in Astana stays actively by 3–3.5 meters during the year, reaching its maximum in spring, which leads to flooding of areas not located near the river. Secondly, the city has poor natural drainage, as confirmed by studies conducted by the Committee of Geology and Mineral Resources of the Republic of Kazakhstan. Flat terrain, widespread clay deposits, and man-made leaks from utilities lead to the formation of local “pockets” of risk. On the maps below, these areas are marked with green dots, and they coincide with areas of dense mid-rise residential development.

In terms of the effectiveness of current risk management policies, it is visible that Astana mainly implies engineering measures like counter-regulators, channel straightening, dams, and bank reinforcement. Although these measures do protect the city from large-scale flooding, they do not allow for full consideration of local hydrological features or for the early identification of vulnerable points in the urban structure. The map shows that even with the engineering infrastructure, a significant part of socially important facilities are located in potentially dangerous areas. This shows that land use and urban planning policies do not make sufficient use of risk maps in decision-making, and that data on flooding remains fragmentary.

Overall, analysis of these maps shows that in Astana, there is significant overlap between areas of potential flood risk and socially important facilities and elements of urban infrastructure. This situation explains the limitations of current policy, like engineering protection measures are implemented, but without stable, regularly updated hazard maps and strict flood zoning, certain hazardous areas continue to develop without consideration of the risks. To improve the situation in Astana, as this analysis shows, it is necessary to integrate more detailed spatial information into urban planning decisions and to introduce strict rules for the location of new facilities within the coastal zone, as implemented in Turin under the PGRA and the European Floods Directive.

Figure 30: Flood-prone zones map A

Figure 31: Flood-prone zones map A

Part IV: Policy comparison

The management of flood risks can be impossible to be considered only as a technical or engineering task. It is closely connected to the politics of the territorial planning, regulatory, and legal frameworks and mechanisms of interagency coordination, which can form the foundation for decision-making in the field of sustainable development of the cities. This part of the research paper is concentrated on the analysis of the policy instruments used in Torino (Italy) and Astana (Kazakhstan), with the purpose of identifying the differences and similarities of the institutional approaches, rights regulations, and strategies of integration of the flood risk decreasing into the municipal land use.

This kind of comparative analysis can allow us to understand how exactly two different administrative and climate contexts can affect the structure of the risk management systems. Torino is represented as a city with deeply rooted European traditions of spatial planning, integrated into common European directives and regional plans for the management of risk and dangers. Astana is opposite, developing its own system on the remains of the post soviet heritage and modern climate challenges, adapting the international principles into national conditions and steppe continental climate.

The aim of the analysis is not only the description of the legal frameworks, but also to identify the effectiveness of the existing integration mechanisms of the flood risk management into the policy of land use, as well as to understand the potential of the experience exchange and adaptation of the successful practices between the two countries.

The next parts are dedicated to the key documents that regulate urban planning and ecological politics, the structure of the institutes, which are responsible for the warning and liquidation of the flood consequences, but also instruments of the monitoring, social participation, and long-term planning. This point serves as a bridge between scientific and practical analysis, connecting spatial data such as maps, models, and statistics with a political foundation that explains how this data is being transformed into solutions, promoting the sustainability and safety of the urban environment.

1. Torino policy

a) DIRETTIVA 2007/60/CE and Piano di Gestione Rischio Alluvioni

The flood risk management system of Torino is integrated into the United European and Italian regulatory framework. The base document in this system that I found is considered (Art. 6 della Direttiva 2007/60). "Article 6 of the Floods Directive 2007/60/CE requires Member States to prepare flood hazard and risk maps at the level of river basin districts or management units, at the most appropriate scale for the areas at significant potential flood risk (APSFR) identified pursuant to Article 5, paragraph 1, following a preliminary risk assessment." *(Autorità di Bacino Distrettuale dell'Appennino Settentrionale, n.d.)* The directive requires preparation of the preliminary rate of the risk, a map of the danger or hazard, and plans of management of the flood risk (PGRA) on the river basin level. For the basin of the river Po, this plan was made by Autorità di Bacino Distrettuale del Fiume Po (ADBPo) as “Mappe della pericolosità e del rischio di alluvione”, which was changed and modified in 2022 and 2023, with the publication of maps “aree allagabili” zones of potential flood danger for the whole district, including Turin.

The Directive 2007/60/CE considers the flood as a natural phenomenon that can not be fully prevented. It is also mentioned that human activities have only increased the scale and frequency of the negative effects. High building density, shrinking of the natural river floodplains, and climate change can lower the terrain's ability to safely process a large volume of water. Since many of the large European rivers cross national borders, it is also mentioned that it is important to coordinate every planned activity with other countries that share the river with Italy. For this purpose, uniform flood risk management rules have been introduced at the EU level.

According to the Directive, each country must complete three sequential stages. The first stage consists of a preliminary risk assessment, during which the country analyzes its territory, identifies historical flood sites, assesses the extent of damage, and identifies areas where flooding may occur in the future. Particular attention is paid to areas located along rivers and coastal zones, since this is where the danger is most significant. Based on this assessment, areas are identified as having a “significant risk,” that is, areas where possible flooding could lead to the most serious consequences for the population, the economy, or the environment.

The next step is the risk and danger maps. Danger maps are showing how the water can escape the banks during different flood scenarios, including the river depths, the area of the flooding, and flow characteristics. Risk maps can conclude or add something to this data. Like showing how many people, objects, infrastructures, or natural territories can be in danger. Finally, to show which industrial places can cause ecological danger in the case of a flood event.

On the third step, the EU countries are obligated to prepare the official flood risk management plan. This document must include the aims of the risk reduction, measures that are necessary for achieving them, and methods of population protection. During the development of the plan, it is important to include different aspects. As lives and health are preserved, natural territories protection, economic stability, and climate change influence are considered. Management measures can be engineering, like constructing dams, bank improvement, etc., or natural, like working on the river floodplains. Also, organizational, working with the public announcements, evacuation plans, and lastly, limitations, which can prohibit dangerous constructions.

The Directive requires the regular monitoring of each step. Starting from the preliminary assessment to the risk maps and management plan. They keep updating them every 6 years. This is connected to the constant changing of conditions, as climate change, new resource opportunities, new data, and new engineering ideas.

The flood risk management plan has to contain the results of the preliminary assessment, the danger maps, and the goals of risk reduction. Also, the list of measures, expected results, the list of responsible people, etc. The plan has to include the full cycle of risk management, from preventing new risks, to protecting territories, and reacting to the next situations to be able to repair all the consequences.

The document's main idea is not to completely eliminate floods, which is impossible, but to create a systemic approach to flood risk management and significantly reduce their negative impact on people, nature, the economy, and cultural heritage across Europe by ensuring sustainable development.

Basically, PGRA describes the flood events in Torino, their reasons, and ways of mitigation and protection. “District-level APSFRs correspond to critical nodes of strategic importance where high or very high risk conditions involve major residential and production facilities, numerous service infrastructures, and major communication routes.” *(PGRA)* The APSFR zone includes the territory of Turin and neighboring communes as Moncalieri, Nichelino, La Loggia, Vinovo, Beinasco, Collegno, Venaria Reale, Borgaro Torinese, Settimo Torinese, San Mauro Torinese, Castiglione Torinese and etc. The reason for the flood is described as the rivers used to be wide, but over time they were narrowed, straightened, and enclosed in concrete channels. This caused a rise in the water, and since there is no more space to flow freely, it goes to the urban territories.

According to the document, there is a developed protection system along the river Po, located in Moncalieri, Torino, and San Mauro areas. There are dams, retaining walls, and engineering fortifications. In the southern part of the APSFR, the left dam is calculated for Tempo di Ritorno 200, basically for the flood that returns every 200 years. While the right part leans on the city's road infrastructure, which needs modernization to mitigate the spread of the flood waters.

Also, the document describes several flood events throughout the years.

The flood of 2000 is considered one of the most memorable episodes. The key numbers were:

- 2350 м^3/s from the river Po in Torino;
- 700 м^3/s from Dora Riparia in Torino;
- 2000 м^3/s from Stura di Lanzo;

The flood brought huge damage to the residential, industrial, and transport objects along all of the main riverbanks.

The flood of 2016 affected mostly Chisola and Sangone. The document describes the record level of the La Loggia - 7,41 m. And significant water levels in the Po in Moncalieri and Torino. However, there were dam failures and flooding of key urban areas mentioned as well.

The document provides the calculations of the water discharge for the flood risk over a period of 200 years, which statistically happens once every 200 years. These values are being used to assess the maximum capacity of the riverbeds and to project flood protection structures. According to the calculations, the discharge during these types of extreme events can get around 2900 м^3/s in Moncalieri, and up to 4360 м^3/s down to the San Mauro area. Values of discharge figures are lower, but still significant: on the Dora Riparia, the estimated discharge is between 530 and 630 m^3/s, on the Stura di Lanzo, up to 2,080 m^3/s, on the Sangone, around 820 m^3/s, and on the Chisola, approximately 400 m^3/s. This data can allow us to assess the potential magnitude of the floodwater and to find the scale of the necessary engineering and ecological events.

There are some key strategy aims that are directed at the long-term flood risk reduction and increasing the sustainability of the Torino agglomeration territory. One of the priorities is to reduce peak water flows before they enter the urban area. For that, it was decided to create the regulation constructions primarily for Dora Riparia in Alpignano, also to repair the natural morphology of Stura di Lanzo, which will allow for partial redirection and absorption of flood runoff.

Another important direction is completing all the protection measures that were designed by the PAI plan. These measures are connected to the key parts along the Po inside the Moncalieri, Torino, and San Mauro areas. As well as other zones that can be endangered by floods. The realisation of these projects has to guarantee the policy protection of the urban territories during extreme floods.

Moreover, PGRA emphasizes the need to improve the overall resilience of the territory through a combination of engineering solutions, nature-oriented approaches, and organizational measures. Such a complex approach includes the improvement of the riverbed condition, repair of the natural flow, and perfection of the municipal flood risk management.

The document includes a wide range of events that are designed to decrease the flood risk in the APSFR zone. It unifies the engineering decisions, as well as natural and administrative approaches. The engineering part includes the modernization of existing constructions along the main rivers, Po, Dora Riparia and etc., including the development of the dams to the best standards, which corresponds to the hazard. The separate attention is getting the creation and modernization of the structures, which could temporarily hold the flood waters behind the city boundaries. Also, it is planned to repair and maintain natural floodplains, improving riverbed conditions and managing sediment, which helps increase river capacity and improves their ecological condition.

The organizational part of the measures includes the development of the monitoring system and easy notification, the updating of the hydrological data, improving the public informational system, and working on educational campaigns. The significant place is taken by measurements that improve the preparedness of municipal services to emergency situations, the development of the response plans, and the repair mechanisms for the damaged territory.

At the national-regional level, the requirements of the directive are implemented by Piano di Gestione del Rischio Alluvioni (PGRA) and connected with Piano di Assetto Idrogeologico (PAI) (Hydrogeological Management Plan), the plan of hydrological management that defines the zoning in the danger or risk areas and regulates the exploitation of the territory in the vulnerable zones. The Piemonte region is supporting the current publication of PGRA at the Geoportale della Regione Piemonte; however, since January 2024, the visualization methods have been updated, which makes access to the layers easier for municipalities and researchers. *(Regione Piemonte Difesa del suolo, 2024)*

At the same time, there is a working national system of operating preparedness through the Dipartimento della Protezione Civile, known as civil protection, and its regional branches. For the Piemonte region, there is a 3 coloured system of the hazard scale: green, orange, yellow, and red. Also, the separation of the territory into 11 meteo-hydrological homogeneity zones. *(Regione Piemonte – Protezione Civile, n.d.) (Figure 18)*

Finally, ISPRA (the Italian National Institute for Environmental Protection and Research) is operating on the methodological and statistical framework for assessing hydro-geological hazards, including the public platform IdroGEO and regular updates of the synthetic monitoring of the cities and regions. For the Piemonte region, this data is used as background information for aligning priorities and monitoring. *(IdroGEO)*

b) The data and mapping

For the planning, Torino is using several levels of map support. First, as it was mentioned before, the maps ADBPo are maps of the danger or risk of the floods. They are managed by Aree a pericolosità and Aree a rischio with the directive standards, including the levels of the frequency, often, rare, or extreme. Including also the depth and possible scenarios. *(Autorità di bacino distrettuale del fiume Po)*

Next is the regional web-maps and warning services. Regione Piemonte publishes alerts or zones of the warning and meteo-hydrological scenarios, which are important for the feedback connection in the urban planning acts. ARPA Piemonte supports reliable maps of the current danger with a high frequency of updates, integrating into local protocols. *(Regione Piemonte)*

And the last one is the provincial metropolitan maps of the civil protection. On the portal Citta Metropolitana di Torino, it is possible to find the thematic maps of Aree inondabili (PAI), Inquadramento idrogeologico, and also materials for assessing the population that lives in the risk areas. *(Regione Piemonte)*

As a result municipality is forming the levels of the spatial regulations. From the united European maps PGRA to the regional levels of the warning and after to the local zoning with the strict urban planning restrictions. Constructing rules and bans on the new buildings.

c) Managing procedures, monitoring, and public participation

PGRA of the basin Po is saying that prioritizing the action must be oriented on APSFR (known as Areas of Potential Significant Flood risk), and working on the solutions is agreed by the administration that regulates the infrastructure and society. This fixes the multi-level model of risk management, where the municipality's solutions are built into the river's safety aims and investments. "Flood risk management is, therefore, a complex and critical component that interferes with public safety and quality of life. Communication and public participation in the construction of flood risk management plans play a strategic role in sharing and legitimizing the plan itself" *(cit., Po River Basin Authority, 2011, p.4). (Participedia)*

The practical operating cycle includes several steps. First is the early diagnosis of the ARPA data. Second, are emergency measures Protezione Civile, depending on the scenarios of the emergency. Then, post-event analysis, damage assessment, lessons learned, with feedback into cartography and urban planning documents. And finally, the periodical update PGRA/PAI, including the new data of the observations and climate trends. This is a critical condition for the municipality regulations not to be old and outdated, and it remains a real danger level. *(Dipartimento della Protezione Civile)*

Such a comparison will create a valid base foundation for the discussion, like which elements of Italian models from PGRA maps to the municipal restrictions are possible to adapt to the harsh climate conditions of Astana, and where we should modify them.

2. Astana policy

While Astana is a modern capital of Kazakhstan and one of the fastest developing cities of Central Asia, it presents a special interest in the context of the flood risk decreasing strategies studies in the system of municipal and national planning. Despite the fact that the city is located in the steppe zone, the harsh continental climate, flood events that are connected to the seasonal spring snow melting, and irregular rainfall patterns often threaten the environmental infrastructure, residential districts, and social objects. These conditions require a systematic approach to the management of the water resources, engineering protection, and spatial development.

The regulatory and legal framework of Kazakhstan in the field of emergency and liquidation of emergency situations, as well as urban planning regulation, has undergone a lot of significant changes in the last few years. The changes were mostly aimed at getting closer to the international standards of sustainable development. The most important instruments are still the Water Code of the Kazakh Republic, the governmental program about emergency risk management, and the standards of building protection. They are regulating the building construction in potentially dangerous areas. On the regional level, the development and realization of the flood protection measures is managed by the Minister of Emergencies of the Kazakh Republic together with the municipality of Astana and specialized units of monitoring and response.

The specialty of the Kazakh approach is a gradual shift from reactive management (focused on solutions for consequences) to preventive and adaptive planning, where the key role is played by the utilization of geoinformational technologies and hydromonitoring data. The development of the interactive flood maps and creation of the counter-regulators for the Ishim river are reflecting the desire for a long-term sustainability system formation.

At this point, there is a basic strategy document and an institution's analysis. They are defining the flood risk management in Astana. Also, the analysis of their relation with the urban planning development politics and ecological safety, and finally, the practical measures that are being realized for minimizing the flood consequences. Special attention is paid to the interrelation between the governmental structures, municipal organs, and scientific communities.

Thus, the policy and regulation base of Astana review allows not only to identify the current state of integration of the flood-risk management into city planning, but also, understand the directions, where the Turin’s experience can be adapted to the central Asia conditions. Contributing to the creation of a safer and sustainable city environment.

a) Institutional and regulatory-legal framework

Hydrological characteristics of the Astana that are described in the Astana General Plan 2023 allow us to deeply understand the vulnerability of the city territory to the flood processes and explain why engineering measures remain a key element of the local policy. “The city's hydrographic network consists of the Ishim River and two small tributaries, the Sary-Bulak and Ak-Bulak. The river is 2,450 km long (170 km from its source to Astana). A 562-km stretch of the river lies within the Akmola region, with a drainage area of 177,000 km^2. Within the region, the river covers 48,000 km^2” *(AstanaGenPlan).* These parameters show that the flood situation is forming far away from the city's territory. This means that the local measures inside Astana can not fully compensate for the risks that are forming away from the borders. The authors' proposals for correcting the riverbed, strengthening the banks, and installing additional hydrometric posts and monitoring systems indicate the need to move to integrated riverbed management, which combines engineering protection with continuous monitoring of water level, ice, flow velocity, and water quality. It is also mentioned that Astana’s counter regulator function very well, regulates even large-scaled flood waters, but it is still necessary to modernize.

In Kazakhstan and particularly in the capital, the flood risk is connected mostly with the spring overflowing of the Ishim River, which goes through the city. Also, with the features of the flow regulation of Astana’s reservoir. The risk management is based on the combination of the water management planning and the civil protection system. Hydrological calculations and modelling of the flood were made with a scientific and project approach. By creating maps of the flood potential zones, which are used within the general plan and the complex water master plan of Astana. These maps serve as a base for identifying the limitations for construction inside the floodplain areas. And for projecting engineering events, as building dams, bank protection, and the regulation of the river flow. The organizational structure of the system is defined by the Civil Protection Law of the Kazakh Republic. This law takes responsibility for notifying and predicting the flood risks, monitoring, evacuation, and recovery of the city. Thus, the flood risk management system of Astana city follows the common logic of the European approach, including risk assessment, cartography, land-use planning, engineering protection, and response readiness. *(JICA) (Nurlan Ongdas*; *Farida Akiyanova*; *Yergali Karakulov; Nurlybek Zinabdin, 2020)*

The flood risk management system in Kazakhstan is based on the combination of the national legal act, governmental programs, and regional strategies that aim to decrease the vulnerability of the population and infrastructure. The central document is the Water Code of the Republic of Kazakhstan (2003), which defines the legal bases of the rational use of the water resources, regulates the river basins, and warns about negative water effects. Especially, parts 119-122 of the code include the rules about developing complex schemes with protection of the residential areas from flood risks, and also, for the installation of water protection zones. These standards are serving as the base for the integration of the risk management principles into urban planning and territorial planning *(The Water Code of the Republic of Kazakhstan, 2003)*

A significant component of the governmental politics is the Governmental program for the emergency situation risk management for 2020-2025, which was accepted by the government of the Republic of Kazakhstan, № 1029 from 30th of December 2019. The program defines the priority directions, including the development and integration of the flood forecasting and early warning systems. Also, the modernization of the infrastructure of the water management objects and the improvement of interagency coordination mechanisms *(Kazakhstan Government, 2019)*

Realization of the policy is coordinated by the Minister of Emergency of the Kazakh Republic, who is responsible for the development of the response actions, the implementation of the engineering protection measures, and the organization of the civil defense. The department is controlling the territorial units, including the emergency department of Astana, which is monitoring the potentially dangerous areas, forming the flood-prone zones, and organizing the preventive works in the spring snow melting periods. *(МЧС РК, 2023)*

b) Regional and municipal mechanisms of planning

Figure 32: Flood in Astana

At the capital city level, the significant role is played by the municipality of Astana city, inside the structure, there an emergency management, architectural offices, urban planners, and ecology. One of the most significant directions is the integration of flood risk management into the general city plan. As the active general plan of Astana 2030 year development (2019) says, special attention is paid to the water-collecting questions, the flood water management, and the safety of constructions along the riverbanks of the Ishim. The document highlights the zones of limited construction within the floodplain. Also, it defines the areas that need engineering protection and urban improvements. (Figure 31) *(General plan of Astana, 2019)*

An additional role is played by the system of building design standards, especially the part about the engineering protection of the territories, buildings, and construction from flood risks. (СНиП РК 2.06.15-85). These regulations define the minimum levels of the foundation depths, allowed dam height, and the distances to the water bodies. Their practical implementation reduces the possibility of the direct effect of the flood waters on the residential and industrial areas.

Main attention is also paid to the development of flood protection infrastructure. The most significant object in this context is the counter-regulator of the flood waters of the Ishim River, which was implemented in 2009. Its purpose is to regulate the water flow during the spring period and to prevent floods in the central districts of the city. Together with the dams, systems, water collectors, and channels, this object is building the base for Astana's flood protection system. *(Kazhydromet, 2020; Akimat of Astana, 2023).*

c) Utilization of geoinformational systems and open data

For the last few years, it has been possible to see an active integration of Geoinformational systems (GIS) into emergency risk management. Particularly, the National center of space science and technologies. (НЦКИТ) Together with the emergency services of the Kazakhstan Republic and "Kazhydromet" are developing the platform of monitoring of the flood water risks, where satellite pictures are integrated into hydrological models.

Moreover, the cooperation of the UNDP program and the World Bank in 2021-2023 resulted realized the pilot projects for integrating the digital models of the landscape and vulnerability maps for the cities, including Astana. These data are used for planning the engineering construction and authentication of the possible flood-prone maps. *(World Bank, 2023)*

On the local level, one of the key sources of information is considered the interactive website komissiya.kz, which was created by the emergencies department in the Akmola region. At the portal, it is possible to find the maps of the possible floods of Astana's districts. Also, the information about risk zones, infrastructure, and agricultural/industrial areas. The users can view the map legend, including the residential zones, water bodies, roads, engineering communications, and protection constructions. These data allow quick identification of the potentially vulnerable areas, which makes the source very valuable and important for the research work. *(komissiya.kz, 2024).*

d) The relation and participation of the citizens

One of the directions of the national strategy development is increasing the level of transparency and participation of citizens in of decision-making process. In order to realize the concept of transferring Kazakhstan into a "green economy" (2013), it was decided to integrate the mechanisms of social control, to have open access to the ecological data, and to develop the participation of the population in ecological monitoring. In Astana, similar functions are realised through the center of urbanistics, which coordinated the relations between research institutions, architecture offices, and municipal structures while working on the ecological and infrastructural decisions. *(Astana Urban Center, 2023)*

Slowly integrating the elements of the inclusive risk management, including the education of people on the behavioral rules during the floods. Even though the level of citizen participation is staying limited, the trend towards risk communication and community-based planning is demonstrating positive dynamics.

e) Comparative analysis and the value of the research

The political analysis of the risk management in Astana shows that lately the government is taking steps towards the side of integration of approaches into sustainable development, digitalization of the data, and adaptation to the changing climate. However, there are still problems, firstly, the fragmentation of data, poor integration of the GIS instruments with urban planning plans, and limited participation of citizens in the decision-making.

In the context of this particular research, these features are especially important for comparing with Torino experience, where flood risk management is considered as a part of the long-term spatial planning and fixed in the policy at each level, from the European to the municipality. The comparison is helping to identify the possibilities of transferring European policies of adaptive management into the context of Central Asia. Including the climate and institutional differences.

3. Policy comparison

The flood risk management policies in Torino and Astana demonstrate the significant differences, as well as some of the important similarities, connected to the geography, the scale of the urbanization, and the political base. Turin is working within the strict European directives, firstly Directive 2007/60/CE, which requires the detailed maps of danger and risks, regular updates every 6 years, international agreement, and strict integration with the water resources management plans WFD 2000/60/CE. Astana, on the contrary, relies on a more limited set of spatial data compared to European standards, using national regulatory legal acts on water supply and emergency protection, sectoral state programs, as well as local decisions of the akimat and the Ministry of Emergency Situations.

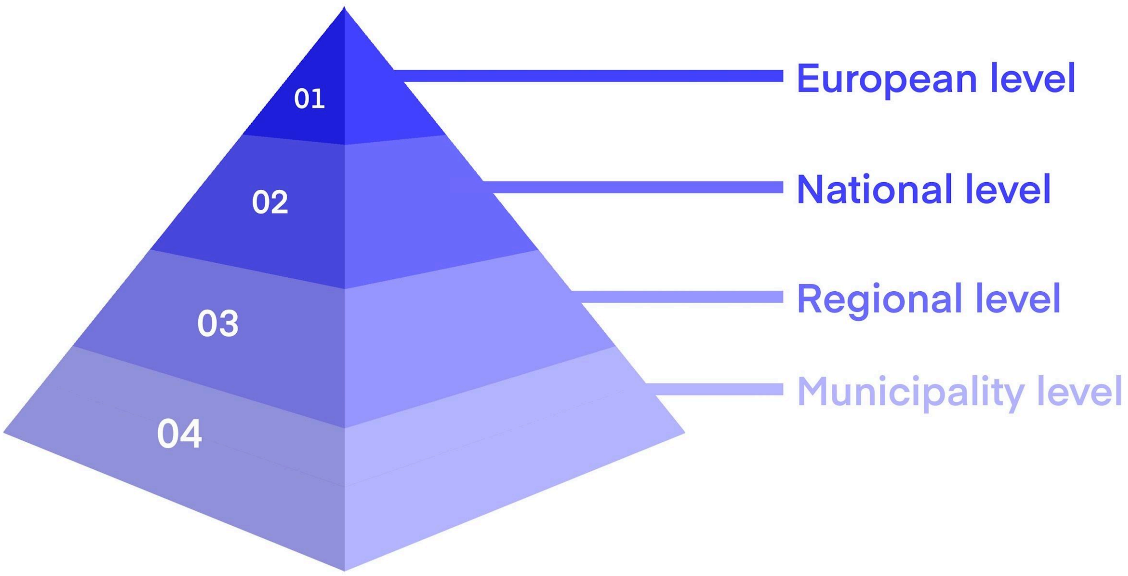
The main difference between them is in the scaling and the types of hydro systems. Torino is located around the interconnection of several large water sources, which are the Po, Dora Riparia, Stura di Lanzo, Sangone, and Chisola. These water river channels form wide flood zones and increase the difficulty of management. This is why the city has formed a system of APSFR, which means the areas with a potentially significant flood risk. This includes a few municipalities and developed protection infrastructure like dams, canals, regulating constructions and etc. Astana, however, is located along one river, with a more united system, which is making the flood dynamics more linear and manageable. The main danger is the spring snow melting and the water level.

The politics of Torino focuses not only on the structural but also on the non-structural measures. Building the dams at Dora Riparis, modernizing them, and systematic control of the river, bridges and etc. In Astana, the main attention is getting the engineering decisions that help to support the riverbanks, building the protective dams, and enlarging the river basin. Also, building the water reservoirs like the Vyacheslav and Sergeev reservoirs and the Kenesary canal. And lastly, annual preparations for the floods as snow cleaning, etc.

However, it is visible that systematic strategic integration between territorial planning, ecological goals, and risk management is weaker than in Europe.

From the side of cartography and risk assessment, Torino is using 3 obligatory scenarios: 500, 200, and 50 years. This helps to model the depth, speed, and direction of the water flow, and also to see how it affects on population, and what consequences it can bring to economics, infrastructure, and cultural heritage. Astana has the flood maps, downloaded to the national geoportal, but they are less detailed and do not correspond with the European classification. That is why the maps were drawn mostly by hand in the QGIS program.

From the point of view of the institutional logistics, Torino is operating within the multilevel system:



Where each of the 6-year cycles brings the obligatory updating of the maps and actions. In Astana, the system is more centralised, and the key decisions are taking place at the level of the emergency department and municipality. Also, the standards are updated very rarely; it is more of a reaction to the flood risk that has already happened.

Even with many differences in policy, it is impossible to ignore the similarities between these two cities. Both cities are working on the development of the monitoring and early notification systems, and both are trying to expand the capacity of the river. Both cities are facing the problem of the high density of the urban structures inside of the risk zones and need to synchronize the urban planning policies with the hydrological reality.

In total, Torino represents an example of integrated, policy-based, and multiscenarious risk management. While Astana is an infrastructure-oriented model that is slowly developing into a more complex approach, it still has limited access to data and lacks a unified strategy. The table below *(Table 3)* represents an easier visualization of the differences based on the text analysis.

Category	Torino	Astana
Risk management model	Multilevel system: European Union → National level → Piemonte region → Municipality	Centralized system: state → Ministry of Emergency Situations → Akimat. Fewer levels and weaker horizontal coordination
Key policy document	EU Floods Directive 2007/60/EC; PGRA; PAI. Everything has to obey the rules	Water code; Civil Protection law; Construction norms. Not obligatory
Risk map type	Official scenarios: (F=50 years), (F=200 years), (F=500 years) Hight quality APSFR maps	Flood zone maps are fragmented; interactive diagrams and reports are used; there is no standardized national system.
Geodata accessibility	High level: Geoportale Piemonte, ADBPo, ARPA, AIPo. Open access, shapefile access.	Limited, open access, but a lack of information. PDF or interactive portals; shapefile not available
Engineering protection	A combination of engineering, ecosystem decisions	Mostly engineering decisions; dams, canals, counter-regulations,
Monitoring and forecast systems	Strong ARPA, with often updates and notifications	Kazhydromet is making forecasts, but the net is less dense and detailed
Strong side of the system	Transparency, standardized clean data, strict rules, and integration into urban construction	Strong engineering protection, fast reaction of the emergency department, and fast development of digital instruments
Weak sides of the system	Bureaucracy, dependence on EU structures	Data fragmentation, insufficient detail, and sometimes development outpace risk analysis.

Table 3

Part V: Mutual Learning

1. What Torino could learn from Astana

Without considering highly developed and standardized European systems, Torino can learn a couple of practical and operational approaches. First of all, Astana demonstrates a high speed of decision-making thanks to the centralized flood management structure. For example, the notification measures, floodstream cleaning, pumping out floodwater, and dam development are happening significantly faster than in the multilevel EU system, where any type of measures has to be agreed between public utilities, the region, and national structures. For Torino, where the response process is sometimes longer due to a complex administrative system, adopting similar operational formats could significantly improve the effectiveness of responses in the event of a sudden hydrological event.

Moreover, Astana has significant experience in the creation of large engineering infrastructure, including the counter-regulator of Ishim with the system of protective dams that control flood waters. Even if Torino prioritizes ecological and natural solutions, Kazakhstan's experience shows that strong engineering measures can effectively complement existing strategies, especially during extreme scenarios. Another important point to pay attention to is the seasonal mitigation measures of Astana. For example, cleaning of sewers and drains, monitoring of snow levels, and preparedness of the short-term water reservoirs.

Another important component is the seasonal system of preventive measures, which works in Astana as a mandatory annual cycle. Regular cleaning of drains, monitoring of snow reserves, creation of temporary reservoirs for extra water, and control of groundwater levels all reduce the load on the Ishim riverbed and prevent flooding during the spring flood period. For Turin, where flooding is often connected with intense short-term rainfall, the implementation of these measures could be an effective addition to existing PGRA strategies.

The new detailed risk maps of Astana also highlight the importance of another aspect that Turin could learn from: continuous monitoring of urban development and linking socially significant facilities to risk maps. Previous GIS maps show that hospitals, schools, and industrial buildings in Astana are often located within potential flood zones, primarily along the Ishim River and in areas where groundwater is close to the surface. The Ministry of Emergency Situations of Kazakhstan classifies these areas as high and medium risk, which allows for annual adjustments to protective measures and evacuation plans. This approach could be useful for Torino , even with a PGRA, the municipality should compare new infrastructure projects with current risk maps more frequently to prevent construction errors and minimize the vulnerability of critical buildings.

Overall, Astana's experience demonstrates the value of responsiveness, engineering reliability, and seasonal preventive management. Combined with a more structured and environmentally focused European model, elements of the Kazakh system could strengthen Turin's resilience and improve its effectiveness in adapting to future floods.

2. What Astana could learn from Torino

The comparative analysis shows that Torino has way more developed and systematic flood risk management model, whose key approaches could bring a significant positive effect to the Kazakh system. The most important support element of Torino system is the Directive 2007/60/CE. It identifies strict standards of cartography and risk management. In cooperation with this document, the city is obligated to develop the danger risk maps for scenarios of 50, 200, and 500 years, and update them every 6 years, as PGRA (Piano di Gestione del Rischio) Alluvioni says. These data are directly used by Turin in terms of urban planning and construction, which is reflected in PAI and municipal PRG. This close integration makes it possible to avoid construction in the most vulnerable areas and to adjust the development of districts based on hydrological risk assessment.

Inside the work process, this system was visualized on the maps made by myself, on the map of the land-use of Turin, created with the help of the Geoportale Piemonte layers, it is clearly visible that inside of the danger zones most of the territories are the green corridors along the river, agricultural areas serving as the natural protectors, and compact urban structures.

This framework provides an example of how PGRA and PAI data inform development minimization policy in high-risk areas. The second map is the map of the building density, which illustrates that in most of the scenarios, socially important objects as schools, hospitals, etc., are located outside of the area of the possible flood risk. That is the result of the long-term politics about the limitation of industrialization inside the danger zones, and strict rules about the localization of the critically important objects. And the key map is the flood zone visualization map.

The layers built on the base of the PGRA data clearly show the different classes of the city territory vulnerability. In the zone of the 50-year risk, there are almost no large-scale urban constructions, which shows the strictness of the municipality's limitations in the high danger-level areas. The zone of the 200-year risk considers only small territories in two parts of the city, however, they do not include dense urban structures, only secondary use objects. Obviously, the 500-year zone has a bigger space of the flood spread, but it includes mostly parks, green corridors, and natural buffers that used to be a part of the historical landscape.

The consideration of Torino policy choices, which restricted the development of the most vulnerable floodplain areas early in the urban development process, is evident in this layout. As a result, there is far less chance of catastrophic floods having a negative impact on population growth and urban development. For Astana, this experience is especially relevant. In comparison to Turin, the city faces a row of institutional and technological limitations that harden the management of the flood risk. There is no unified standardized cartography system on the national level that can compare to the European models. Geodata is often represented in separate pieces or available only in the form of interactive maps, which can not be downloaded into GIS programs.

Implementing regular risk map updates in Astana, spatial data quality improvement, and strict limitation of the constructions in the danger zones of Ishim could significantly decrease the vulnerability of the fast-growing districts, especially on the left riverbank and in the new areas. This kind of approach could bring the city closer to the integrated European risk management model and improve sustainable development in the long-term perspective. The significant meaning is also brought by the Torino experience in the use of nature-based solutions. Restoring the natural flows and widening the green corridors along the river. The maps that were built in QGIS visually prove that these natural areas are quite important for the formation of the natural protection. For Astana, implementing these green buffers could serve as an additional help to the engineering protection, and at the same time improve the ecological state of the city.

Finally, Torino possesses a highly developed system of public access to the data. As Geoportale Piemonte, AIPo, ADBPo, flood maps, and others. There, it is possible to find the detailed maps, that is possible to be downloaded in an open format. In Astana, the data is available only in the interactive geoportal, but can not be used for systematic GIS analysis. The increase in data availability could improve the quality of the risk modelling and allow the city planners to make better, justified decisions.

That is how we understand that the advantages of the Turin model are concluded in the strategic integration of risk into the urban land-use planning, standardized cartography, ecologically oriented measures, and high accessibility of the spatial data. Astana could improve the complex approach to flood risk reduction, with the help of adaptation to these elements, together with its strong engineering base.

Conclusion:

This study compared flood risk reduction strategies in two cities, Torino (Italy) and Astana (Kazakhstan), and assessed how these measures are integrated into municipal spatial planning policies. These cities were selected because of their geographical similarity, as both are located on the banks of large rivers that divide their urban areas, and differ significantly in terms of their natural conditions, climate, urbanization intensity, and institutional approaches. Despite their shared vulnerability to flooding, Turin and Astana have developed their risk management systems in different historical, political, and regulatory contexts. The aim of the study was to identify which elements of these systems are most effective and what lessons the cities can learn from each other.

The study contributes to several United Nations Sustainable Development Goals that are directly related to natural risk management and sustainable urban development. First and foremost, the work is consistent with SDG 11, "Sustainable cities and communities," as its analysis of the integration of flood risk reduction strategies into spatial planning in Turin and Astana aims to improve the safety of the urban environment, protect people and infrastructure, and promote more sustainable spatial solutions. The study also touches on SDG 13, Climate Action, as it examines adaptation measures, monitoring systems, hazard mapping, and warning strategies that reduce the vulnerability of cities to extreme weather events. Finally, the study also aligns with SDG 6, Clean Water and Sanitation, as it analyzes the state of water bodies, water resource management, the impact of development on the hydrological regime, and the need for sustainable technical solutions, including counter-regulators, dams, and drainage systems. Thus, the study not only compares the two cities in their local context but also shows their place in the global sustainable development agenda and demonstrates how municipal policies and GIS tools can contribute to the achievement of international environmental and climate goals.

The analysis showed that natural conditions play an important role in risk management policies. Turin is located in the Alps Valley and is surrounded by a system of rivers and tributaries, which makes flooding more frequent and potentially more dangerous. This terrain contributes to complex hydrological processes and requires comprehensive solutions that include both technical and natural measures. Meanwhile, Astana is located in an area with a continental climate, where the main cause of flooding is seasonal snowmelt and the redistribution of water resources in the Ishim River basin. These differences have led to different priorities in urban management. Turin focuses on long-term prevention, while Astana focuses on technical protection measures and rapid response.

Significant differences in policies were also identified. Turin acts in accordance with the strict European Directive 2007/60/EC, which requires regular mapping, assessment of risk scenarios, and integration of the results into urban planning. Documents such as PGRA and PAI establish a detailed administrative structure, including zoning, building restrictions, and procedures for updating data every six years. In Kazakhstan, there is no single equivalent to the European directive. The risk management is distributed across the Water Code, the Civil

Protection Code, building regulations (SNiP), state emergency programs, and local municipal documents. These instruments are less systematic but allow for rapid decision-making.

This study makes an important contribution to our understanding of how a combination of political, geographical, and socioeconomic factors influences different approaches to flood risk management in cities. The study goes beyond conventional technical and engineering comparisons and offers a comprehensive interdisciplinary approach combining GIS analysis, land use policy research, and a comparison of international strategies and local experiences. The research is innovative in several aspects.

First, it offers a unique comparison of two cities with very different climatic, geographical, and political systems. Turin has a hilly topography, has experienced centuries of flooding, and is subject to complex European legal regulations. Astana, on the other hand, is a city on flat terrain, a new capital that is still developing and is prone to seasonal flooding. Comparing such different cities provides a deeper understanding of which elements of policy and planning are universal and which are strictly context-dependent.

Another important feature of the study is that the GIS data for Astana was created manually, as open spatial data, similar to Italy's Geoportale Piemonte, is rare in Kazakhstan. This makes the study significantly valuable, as the resulting maps fill a gap in the available information. Everything was independently collected, digitized, and structured data based on interactive maps, official emergency portals, and city web resources. This approach not only improves the quality of the comparative analysis but also creates a basis for further research based on the layers created.

Thirdly, the study broadens our understanding of the role of land use policy and spatial planning regulations in shaping urban sustainability. Unlike many studies that focus only on hydraulic structures, this study shows that the integration of technical measures into planning decisions, like restricting development, prohibiting development in risk areas, preserving green buffer zones, and adjusting spatial plans, can play a huge role. An analysis of the PGRA in Turin and Kazakhstan's national strategies shows that the effectiveness of risk reduction is directly connected to the degree of its integration into spatial development policy.

The innovation of this study is in its interdisciplinary nature, original data, comparative approach, and inclusion in the international context of risk management. This study serves as a basis for practical recommendations and helps to better understand how different types of cities can adapt to growing natural risks and climate change.

The study is limited by data availability, especially in the case of Astana, where scenario maps and an official geodata set are lacking. Differences in mapping standards make direct comparisons difficult. In the future, it will be important to develop hydrological modeling and climate scenarios, as well as to expand research to other cities in Kazakhstan and Europe.

The study shows that developing the flood resilience of cities needs a comprehensive approach that combines policy instruments, cartographic data, urban planning decisions, and modern analytical methods. Despite their differences, Turin and Astana can positively affect each other with their practices. Torino European model shows how strategic planning and consistent regulation reduce risks, while Astana's experience highlights the importance of operational efficiency, technical protection, and interagency cooperation. The comparison confirms a key conclusion: effective flood risk management is only possible through a synthesis of scientific data, sound land use policies, and constant adaptation to changing environmental conditions.

Bibliography

1. Aggiornamento e revisione del Piano di Gestione del Rischio di Alluvione redatto ai sensi dell'art. 7 del D.Lgs. 49/2010 attuativo della Dir. 2007/60/CE – II ciclo di gestione
2. Akimat of Astana. (2023). *General Plan of Astana until 2030*. Astana City Administration.
3. Astana Urban Center. (2023). *Projects and research on urban resilience*. https://astanaurban.kz
4. Autorità di Bacino del Fiume Po. (n.d.). *Mappe della pericolosità e del rischio di alluvione*. https://pianoalluvioni.adbpo.it/mappe-della-pericolosita-e-del-rischio-di-alluvione/
5. Autorità di Bacino Distrettuale dell'Appennino Settentrionale. (n.d.). *Aggiornamento delle mappe di pericolosità e rischio di alluvioni*. Retrieved 10.23.2025, from https://www.appenninosettentrionale.it/itc/?page_id=6103
6. Autorità di Bacino Distrettuale del Fiume Po. (n.d.). *Mappe della pericolosità e del rischio di alluvione*. Retrieved 10.23.2025, from https://pianoalluvioni.adbpo.it/mappe-della-pericolosita-e-del-rischio-di-alluvione/
7. Autorità di bacino distrettuale del fiume Po. (n.d.). *Home Page – Piano Alluvioni del Bacino del Po*. Retrieved 10.27.2025, from https://pianoalluvioni.adbpo.it/
8. Britannica, E. (n.d.). *Ishim River*. Encyclopaedia Britannica. https://www.britannica.com/place/Ishim-River
9. Britannica Editors. (n.d.). *Po River*. Encyclopaedia Britannica. https://www.britannica.com/place/Po-River
10. bushp. "Blog post – Moncalieri through time: water, landscape, heritage, and resilience." *AGREE*, (9 January 2025) https://agreeproject.org/blog-post-moncalieri-through-time-water-landscape-heritage-and-resilience/. Accessed 10 October 2025.
11. Cassardo, C., Cremonini, R., Gandini, D., Paesano, G., Pelosini, R., & Qian, M. W. (2001). *Analysis of the severe flood of 13–16th October 2000 in Piedmont (Italy). Cuadernos de Investigación Geográfica, 27,* 147–162. Universidad de La Rioja. https://dialnet.unirioja.es/servlet/articulo?codigo=258493
12. Città Metropolitana di Torino. (n.d.). *Cartografie del Piano Provinciale di Protezione Civile – Prevenzione e Pianificazione cartografie* [Web page]. http://www.cittametropolitana.torino.it/cms/protezione-civile/prevenzione-pianificazione/cartografie-pppp
13. Climatestotravel.com. "Turin climate: weather by month, temperature, rain." *Climates to Travel*, Climatestotravel.com., https://www.climatestotravel.com/climate/italy/turin. Accessed 10 October 2025.
14. Comune di Torino. (n.d.). *Sito istituzionale*. Retrieved 10.27.2025, from https://www.comune.torino.it/
15. Denis Sinor | Distinguished Professor Emeritus of Uralic and Altaic Studies and of History, I. U., Gavin R.G. Hambly | Professor of History, U. of T. at Dallas, & All.

(2025, October 11). *Kazakhstan*. Encyclopædia Britannica. https://www.britannica.com/place/Kazakhstan

16. Dipartimento della Protezione Civile. (n.d.). *Rischi | Dipartimento della Protezione Civile*. Retrieved 10.27.2025, from https://rischi.protezionecivile.gov.it/
17. Directorate-General for Environment. (2025, September 23). *How do we boost flood resilience in cities? Addressing social vulnerability is key, a new study finds*. European Commission. https://environment.ec.europa.eu/news/how-do-we-boost-flood-resilience-cities-addressing-social-vulnerability-key-new-study-finds-2025-09-23_en
18. DIRETTIVA 2007/60/CE DEL PARLAMENTO EUROPEO E DEL CONSIGLIO del 23 ottobre 2007
19. Explore Kazakhstan. (n.d.). *Ishim River Embankment*. Retrieved [11.12.2025], from https://explorekazakhstan.com/destination/astana/ishim-river-embankment/
20. European Commission. (2025, September 23). *How do we boost flood resilience in cities? Addressing social vulnerability is key, a new study finds.* Directorate-General for Environment. https://environment.ec.europa.eu/news/how-do-we-boost-flood-resilience-cities-addressing-social-vulnerability-key-new-study-finds-2025-09-23_en
21. FIDE. (n.d.). *Women's Grand Prix – Astana*. Retrieved [11.13.2025], from https://womengrandprix.fide.com/info/astana
22. Forno, M. G., & Gianotti, F. (2021). The Turin fluvial terraces as evidence of the new Holocene setting of the Po River. *Journal of Maps, 17*(4), 75-85. https://doi.org/10.1080/17445647.2020.1768447
23. Government of the Republic of Kazakhstan. (2019). *State Program on Emergency Risk Management for 2020–2025 (Decree No. 1029)*.
24. Great Runs. (n.d.). *Po River Path — Turin, Italy*. Retrieved 11.13.2025], from https://greatruns.com/turin-po-river-path/
25. IdroGEO. (n.d.). Retrieved on 10.25.2025, from https://idrogeo.isprambiente.it/app/ — A web-application by ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale).
26. Inz, A. (2025). *Resilient infrastructures: managing risks from water-related hazards. The Storm Alex case study* (Master's thesis, Politecnico di Torino). Retrieved from on 10.25.2025 https://webthesis.biblio.polito.it/36054/1/tesi.pdf
27. Kazhydromet. (2020). *Hydrological monitoring and flood risk reports*.
28. Komissiya.kz. (2024). *Flood hazard maps for Astana regions*. https://komissiya.kz
29. Kudaibergenov, A. (2024, April 16). *Река вышла из берегов*. informburo.kz. https://informburo.kz/tags/reka-vyshla-iz-beregov Accessed 15 October 2025.
30. Luca Coppolella, Luca. (25 October 2004). https://torinotechmap.it/en/news/turins-commitment-to-climate-neutrality-rewarded-with-eu-mission-label/ . Accessed 10 October 2025.
31. *Map of Kazakhstan (Astana).* getamap.net. (n.d.). https://www.getamap.net/maps/kazakhstan/

32. M., Gabriella Forno, and Franco Gianotti. "The Turin fluvial terraces as evidence of the new Holocene setting of the Po River." *Journal of Maps*, 2020. Accessed 10 October 2025.
33. Metych, Michele. "Turin | History, Map, & Facts." *Britannica*, (9 September 2025). https://www.britannica.com/place/Turin-Italy . Accessed 10 October 2025.
34. Ministry for Emergency Situations of Kazakhstan (МЧС РК). (2023). *Annual report on flood preparedness*.
35. Novikov, A. M. "Статьи - Что такое методология и почему необходимо учить студентов ее основам." *МЕТОДОЛОГИЯ*, (2007). http://www.methodolog.ru/artikle/ob_met.htm . Accessed 21 September 2025.
36. *Nurlan Ongdas*; *Farida Akiyanova*; *Yergali Karakulov; Nurlybek Zinabdin,* (2020). *Map of the sensitive land-use types present in the study area*. In Title of article. Publisher/Journal. https://www.researchgate.net/figure/Map-of-the-sensitive-land-use-types-present-in-the-study-area_fig5_345484902
37. Participedia. (n.d.). *Participedia: a global network and crowdsourcing platform for public participation and democratic innovations*. Retrieved 10.25.2025 from https://participedia.net
38. "Po River | Italy, Map, Facts, & History." Britannica, (1 October 2025). https://www.britannica.com/place/Po-River . Accessed 10 October 2025.
39. Popov, N. V., Plekhanov, P. A., Medeu, N. N., & Nikiforova, L. N. (2020). *Identification of flood zones for settlements in the upper part of the Ishim River basin during high water periods. Issues of Geography and Geoecology,* (1), 43–50. Retrieved from https://cyberleninka.ru/article/n/vyyavlenie-zon-zatopleniya-dlya-naselennyh-punktov-v-verhney-chasti-basseyna-reki-esil-pri-vysokom-polovodie
40. Republic of Kazakhstan. (2003). *Water Code of the Republic of Kazakhstan* (as amended in 2021).
41. Regione Piemonte. (n.d.). *Sito istituzionale*. Retrieved 10.27.2025, from https://www.regione.piemonte.it/
42. Regione Piemonte. (n.d.). *Piemonte Parchi*. Retrieved 10.27.2025, from https://www.piemonteparchi.it/
43. Regione Piemonte – Difesa del suolo. (2024, February 20). *Piano gestione rischio alluvioni – PGRA – Nuova visualizzazione sul geoportale regionale*. https://www.regione.piemonte.it/web/temi/protezione-civile-difesa-suolo-opere-pubbliche/difesa-suolo/strumenti-per-difesa-suolo/piano-gestione-rischio-alluvioni-pgra-nuova-visualizzazione-sul-geoportale-regionale
44. Rentschler, J. (2022). *Rapid urban growth in flood zones* (World Bank Publication No. 6f976b10-9b7d-5743-a9e2-69e1a40f5ede). World Bank. https://openknowledge.worldbank.org/entities/publication/6f976b10-9b7d-5743-a9e2-69e1a40f5ede
45. "River floods." *ClimateChangePost*, https://www.climatechangepost.com/countries/italy/river-floods/. Accessed 10 October 2025.
46. Shashkina, A. (2024, May 25). *Astana "flooded" due to heavy rain – video.* Tengri News. https://tengrinews.kz/kazakhstan_news/astana-poplyila-iz-za-silnogo-dojdya-video-536315/

47. State Institution "Department of Architecture, Urban Planning and Land Relations of the City of Astana" and LLP "AstanaGenPlan" (2023)
48. The JICA Study on the Master Plan for the Development of the City of Astana
49. United Nations Development Programme (UNDP). (2021). *Sustainable water management and climate adaptation in Kazakhstan*.
50. Vandecasteele, I., & Lavalle, C. (2015). UDP – Urban flood risk, 2010–2050 (JRC LUISA Reference Scenario 2016). European Commission, Joint Research Centre. https://data.europa.eu/89h/jrc-luisa-udp-floodrisk-reference-2016
51. *Yearly & Monthly Weather - Astana, Kazakhstan*. Weather Atlas. (n.d.). https://www.weather-atlas.com/en/kazakhstan/astana-climate
52. World Bank. (2022). *Enhancing flood resilience in Central Asia through digital mapping and risk modeling*.
53. Геоинформационный центр города Нур-Султан. (n.d.). https://gis.esaulet.kz/portal/apps/experiencebuilder/experience/?id=b9f6d12fcdc644f6944a96d5c42b915f&page=page_17