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GIS-Based Risk Assessment on Sea Level Rise and Flooding in Alsancak Harbour Behind Area

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Abstract

According to climate change projections outlined in the Intergovernmental Panel on Climate Change 6th Assessment Report, sea levels are expected to rise between 0.37 and 1.88 meters by 2150. The rise in sea level poses a significant threat to coastal areas, including industrial heritage zones frequently developed around ports. Alsancak Harbour Behind Area is a significant location due to its essential industrial heritage. The main objective of the research is to evaluate the potential risks related to floods and long-term sea level rises in the Alsancak Harbour Behind Area. Thus, the research aims to assess the potential risks associated with flooding and long-term sea level rise in the Alsancak Harbour Behind Area within the context of industrial heritage. It also measures the area's resilience to these risks and discusses planning decisions. The 'Coastal Risk Screening Tool' was used to create a coastal flood map according to determined three different scenarios. The result shows that the valuable industrial heritage buildings such as the Coal Gas Factory, Old Flour Mill-II and Tariş Alcohol Factory, new high-rise residential areas, port facilities and transportation arteries are at high or medium risk, especially in 2100 and 2150.

***Keywords:** Flooding, Izmir, industrial heritage, urbanization.*

Alsancak Liman Arkası Bölgesine Yönelik Deniz Seviyesindeki Yükselme ve Sel Baskınının Olası Etkilerinin CBS kullanılarak Analizi

Öz

Hükümetler arası İklim Değişikliği Paneli 6. Değerlendirme Raporu İklim değişikliği senaryolarına göre su seviyesinde 2150'ye kadar 0,37 ile 1,88 m arasında bir artış beklenmektedir. Su seviyesindeki yükselme özellikle kıyı alanlarını dolayısıyla genellikle liman çevresinde gelişen endüstriyel miras bölgelerini tehdit etmektedir. Alsancak Liman Arkası sahip olduğu yapılar itibari ile içerisinde endüstriyel kültür varlıklarının kümelendiği önemli bir alandır. Araştırmanın temel amacı İzmir'de Alsancak Liman Arkası Bölgesindeki taşkın ve uzun vadeli deniz seviyesi yükselmesi ile ilgili potansiyel riskleri endüstriyel miras kapsamında değerlendirmek, bölgesinin bu risklere göre dayanıklılığını ölçmek ve planlanmasına dair kararların bu kapsamda tartışılmasına imkan sağlamaktadır. *Araştırma belirlenen üç farklı senaryoya göre sel baskını haritası oluşturmak için 'Kıyı Riski Tarama Aracı' kullanılmıştır. Araştırmanın sonuçları Havagazı Fabrikası, Eski Un Değirmeni-II ve Tariş Alkol Fabrikası gibi değerli endüstriyel miras yapılarının, yeni yüksek katlı yerleşim alanlarının, liman tesislerinin ve ulaşım arterlerinin özellikle 2100 ve 2150 yüksek veya orta risk altında olduğunu göstermektedir.*

***Anahtar kelimeler:** Su baskını, İzmir, endüstriyel miras, kentleşme.*

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1. Introduction

Coastal areas have fragile ecosystems due to many factors such as floods, storms, coastal erosion, sea level rises and often the interaction of several of them (Hsiao et al., 2021; Satta, 2014; Zellou & Rahali, 2019). However, these areas host a large part of the world's population. Currently, approximately 2.75 billion people worldwide inhabit within 100 km from the coast (Reimann et al., 2023; United Nations, 2008, 2017). Areas located around the coast experience potential dangers that can lead to negative consequences due to the dense concentration of people and valuable assets stead in vulnerable areas (Reimann et al., 2023). Although the rapid urbanisation of coastal areas brings economic benefits and provides the region with transportation and development opportunities, it raises concerns about the environmental deterioration of the coastal areas (Liz Creel, 2003). Human activities have been one of the biggest threats to the destruction of coastal and ocean ecosystems due to this increase in the number of people living in these regions and their needs (Gattuso et al., 2015; Hinrichsen, 1999; Sharma & Chatterjee, 2017; Zhai et al., 2020). Urban expansion, agricultural production, industrial activities, mining (Zhai et al., 2020) and microplastics (Sharma & Chatterjee, 2017), threaten oceans and seas as human activity. Gattuso et al. (2015) highlight the increase in CO2 during the industrial era and report that increases in atmospheric carbon dioxide (CO2) have consequences such as global warming, melting glaciers, ocean acidification, and sea level rise.

This concentration of population in coastal areas and the economic dependence on them caused the expansion of the coastal regions towards the sea through land reclamation (Sengupta et al., 2023). Land reclamation refers to the process that involves altering the natural coastline and converting underwater areas into usable land for various purposes. The reasons behind these reclamation processes are the necessities of coastal cities for agricultural, industrial, commercial, recreational and residential areas (Martín-Antón et al., 2016; Sengupta et al., 2023). The coastline of Turkey is more than 8000 km long (Samsunlu et al., 2000) and there are 28 coastal cities, along with 191 districts and 181 villages or towns situated below the 10 m contour line Türkiye, resulting in areas vulnerable to sea level rise (Kuleli, 2010). In alignment with the global pattern, the populations of 28 coastal cities in Turkey in 2000, 2010 and 2020 were approximately 34, 39 and 46 million (Kocadağlı, 2022) respectively, which is slightly more than half of the country's total population and is in a constant increase throughout the period. Due to intensive migration from Turkey’s eastern and south-eastern parts (Karaca & Nicholls, 2008), the population density in coastal cities is relatively high compared to the hinterland, considering that coastal cities constitute 28% of Turkey's total surface area (Kocadağlı, 2022). As a coastal city, Izmir ranks third in population and holds second position in population density (Baser, 2020).

Izmir's population, approximately 1.2 million in 1965, has almost quadrupled, reaching about 4.5 million in 2022 (TUIK, 2022). One of the most important factors affecting this rapid population growth is the migration movement that started in Turkey in the 1950s. After Izmir gained more strategic importance, especially after the 1960s, it became one of the provinces that received the most immigrants from rural areas of Turkey (Işık, 2017).

As a result of the increasing population and urbanisation pressure on the coasts of the Izmir Gulf, the city has expanded incrementally towards the sea since the 1970s through reclamation for mostly recreational, industrial and infrastructural purposes (Kösenciğ & Güneş, 2023).

However, this expansion towards the sea has destroyed Izmir's coastal ecosystem, making the city more vulnerable to floods (Ak, 2021). Green areas along the Gulf of Izmir through land reclamation have caused the degradation of coastal habitats (IZM et al., 2017). For example, 1258.57 hectares of vegetation in the salt plain in the Gediz Delta was reclaimed, decreasing by more than 40% between 1963 and 2005. Reclamation was seen as an opportunity to increase the available land area, but environmental impacts of land reclaimed from the sea were not considered (Hepcan et al., 2012). One of the primary environmental threats facing coastal areas is climate-induced sea level rise (Reimann et al., 2023) and its resultant effects on the cities (Neumann et al., 2015). Although the land reclaimed

from the sea meets the land demand in the city, it exposes these areas to coastal floods due to storms and rising water levels (Xu et al., 2021). The research aims to reveal the lands obtained through land reclamation for port and infrastructure purposes in the Alsancak Harbour Behind Area. It is also intended to assess the risk of possible flooding and long-term sea level rises to see the effects on the district.

2. Alsancak Harbour Behind Area

2.1 Study Area

The geographic extent of the Alsancak Harbour Behind Area is shown in Figure 1. The study area is located within district of Konak in Izmir, encompassing the distinctive neighbourhoods of Umurbey and Ege. The study area consists of large industrial buildings that are still operational, have been repurposed, or are currently vacant., areas created by the demolition of industrial buildings, small and medium-sized commercial units, and large port and warehouse buildings. These buildings are the main spatial characteristics of the area. The Turkish Railways facilities also cover a huge space in this area and are an important characteristic of it. The study area also comprises of current residential buildings, high-rise residential building projects, and an urban transformation project by the İzmir Municipality.

Figure 1. Study area map.

While the Umurbey neighbourhood includes primarily commercial areas, the Ege neighbourhood covers mostly residential area. Ege and Umurbey had a population of 2238 people in 2021 (TUIK, 2022), 1025 buildings (IBB open data portal), 2975 dwellings, and 812 workspaces (Konak Municipality, 2023) (Table 1).

Table 1. Existing dwelling, workspace, and population in the research area.

Neighbourhoods	Population (2021)*	Number of buildings**	Number of dwellings ***	Number of private workplace(2)***	Number of IHB ****
Ege neighbourhood	1929	467	1887	257	0
Umurbey neighbourhood	309	558	1088	555	13
Total	**2238**	**1025**	**2975**	**812**	**13******

*Population data will be obtained from TUIK 2021 Sonuçları
**Number of buildings (data was obtained from Izmir Metropolitan Municipality Open Data Portal)
***Number of dwellings and workplaces (data were obtained from Konak Municipality)
****IHB: Industrial Heritage Building (IZKA, 2021). Data was obtained from the Izmir Industrial Heritage Inventory. Please see Figure 3 for identification of the buildings.

2.2 History of the study area

Industrial investments gained momentum with the Industrial Incentive Law in 1927 in Turkey, according to Izmir Province Yearbook (1929). The number of industrial investments, with more than ten labourers, increased approximately from 289 to 936 in İzmir between 1950 and 1961 (Tümertekin, 1961). İzmir is a metropolitan city with 10% of the industrial establishments in Turkey and nearly half of the industrial establishments in the Aegean Region (Ünal, 2019). These investments in İzmir are concentrated mainly in the post-harbour area which is called “Alsancak Harbour Behind Area” located between Halkapınar-Basmane, Çınarlı-Bayraklı and Bornova (Figure 1) within the central region of the city between 1950 and 1960 (Karadağ & İncedere, 2020).

Izmir has played a significant role in the industrialisation process, meeting the industrial needs of Turkey since the beginning of the industrial era due to its geographical privilege. On the other hand, this industrialisation process affected the urban development of Izmir. According to Tümertekin, while residential and industrial areas are integrated into Istanbul, these areas are separated in Izmir (Tümertekin, 1961). One of the most important reasons behind this segregation is the boundaries of Alsancak Harbour Behind Area. This district is pretty unique in terms of its industrial heritage, land use pattern, and urbanisation policies. This area, which consists of Ege and Umurbey neighbourhoods, was separated from its vicinity by distinctive physical boundaries. The triangular-shaped area is surrounded by the railway line reaching Alsancak train station, Alsancak port, and Meles Stream.

In terms of industrial heritage, the Alsancak Harbour Behind Area holds paramount significance. The Darağaç axis, starting from the Punta (Alsancak) Train Station and continuing towards Bayraklı, stands out as the areas where food activities are concentrated, and the Basmane Train Station and Halkapınar Water Factory axis are the area where leather enterprises and oil factories are concentrated (IZKA, 2021). However, changes in Turkey's macroeconomic policies after 1980 and the decisions taken regarding the relocation of urban industrial areas led to the end of production of many factories in the Alsancak Harbour Behind Area (Ayik & Ögel, 2022). The preservation of industrial heritage in Turkey began to be discussed in the 1990s (Karadağ & İncedere, 2020). Thus, it led to the re-functioning of factories in this district from the 1990s to the present day.

While part of the factory area of Sümerbank is operated by the Ministry of National Education, Soil Crops Office Silos (Figure 2) and Railway Campus are still in the same function today. The Railway Maintenance and Repair Shops were established to provide maintenance and repair locomotives, encompassing an area of 50,393 square meters. The second-largest industrial complex in the district, the Sümerbank textile industry, was officially registered as a "Cultural Heritage to be Protected" on March 29, 2001, under the provisions of Laws No. 2863 and 3386. In the same decree, the necessity of preserving the production equipment reflecting the manufacturing process of the İzmir Sümerbank Textile Industry for transformation into an industrial museum was also underscored (IZKA, 2021).

Figure 2. TMO silos.

Coal-Gas Plant, one of the iconic industrial structures of Alsancak Harbour Behind Area, has maintained its original function from 1867 until 1995 and was restored after being used as a bus depot for a while. It was re-functioned as a cultural centre in 2008. The building is currently located in a medium-risk area in case of a possible water rise (IZKA, 2021).

Old Flour Mill I, which functioned as a factory until the 1980s, was transferred to the Yaşar Education and Culture Foundation in 1996, and in 2002, it took over the educational function as the Alsancak campus of this university (IZKA, 2021). Afterwards, the foundation converted this building into a museum (Figure 3) completing the restitution and restoration works in 2021. This museum encompasses an enclosed area of roughly 6000 square meters, consisting of temporary and permanent exhibition areas, a library, offices, a conference hall, a cafeteria and sales units (YEKV, 2018, 2022). Tuzakoğlu Flour Mill was converted into an IBB vocational training. In addition, the Tekel Maintenance Supervisor's Office and guesthouse in the research area have been converted into the Architecture Center (IZKA, 2021).

Figure 3. Photos of Selcuk Yasar Museum (Old Flour Mill I) from Liman Street (left) and Şehitler Street (right).

2.3. Development of Residential Areas in Study Area

The process that started with the international competition announced by Izmir Metropolitan Municipality in 2001 was effective in this change of land use in this region. The competition aimed to encourage the generation of ideas for creating a new city centre between Turan and Alsancak by assuming the function of the existing city centre. In 2003, Izmir Metropolitan Municipality produced a master development plan at a scale of 1/5000, based on the data obtained from the projects that won places in this competition (Erdik & Kaplan, 2009). This plan envisages the use of land for tourism, trade and cultural purposes behind the Alsancak harbour. However, it can be said that this process, which started in 2001, has paved the way for the rise of skyscrapers in this area today, due to the uncertainties regarding floor heights both in the competition and in the master development plans.

Large residential construction projects such as "Pekerler İnşaat, Allsancak," "Teknik Yapı, Evora İzmir" and "Teknik Yapı, Divan Residence" have started in this district pointed out by (Peker, 2019) as demolished area for the construction. According to the Izmir Municipality public reports and the information on their website, the total number of existing dwellings will double in the following years (Table 2).

Table 2. Planned dwellings and workspaces in the research area.

Projects	Neighbourhood	Number of dwellings	Number of private workplaces	Source
Allsancak-Pekerler İnşaat	Ege	1069	37	(Emlak Konut, n.d.)
Evora İzmir-Teknik Yapı	Umurbey	1057	41	(Teknik Yapı, n.d.-b)
Divan Residence-Teknik Yapı	Ege	670	4	(Teknik Yapı, n.d.-a)
Urban Transformation Project-IBB	Ege	784	244	(IBB, n.d., 2023)
Total		3502	326	

In addition to new residential projects within the borders of Alsancak Harbour Behind Area, the construction of similar mega-residential complexes continues just on the east side of Meles Stream (Figure 4). This district, known for its industrial identity, is evolving into an area with a different identity due to the construction of these mixed-function skyscrapers and this construction trend that is expected to continue in the future.

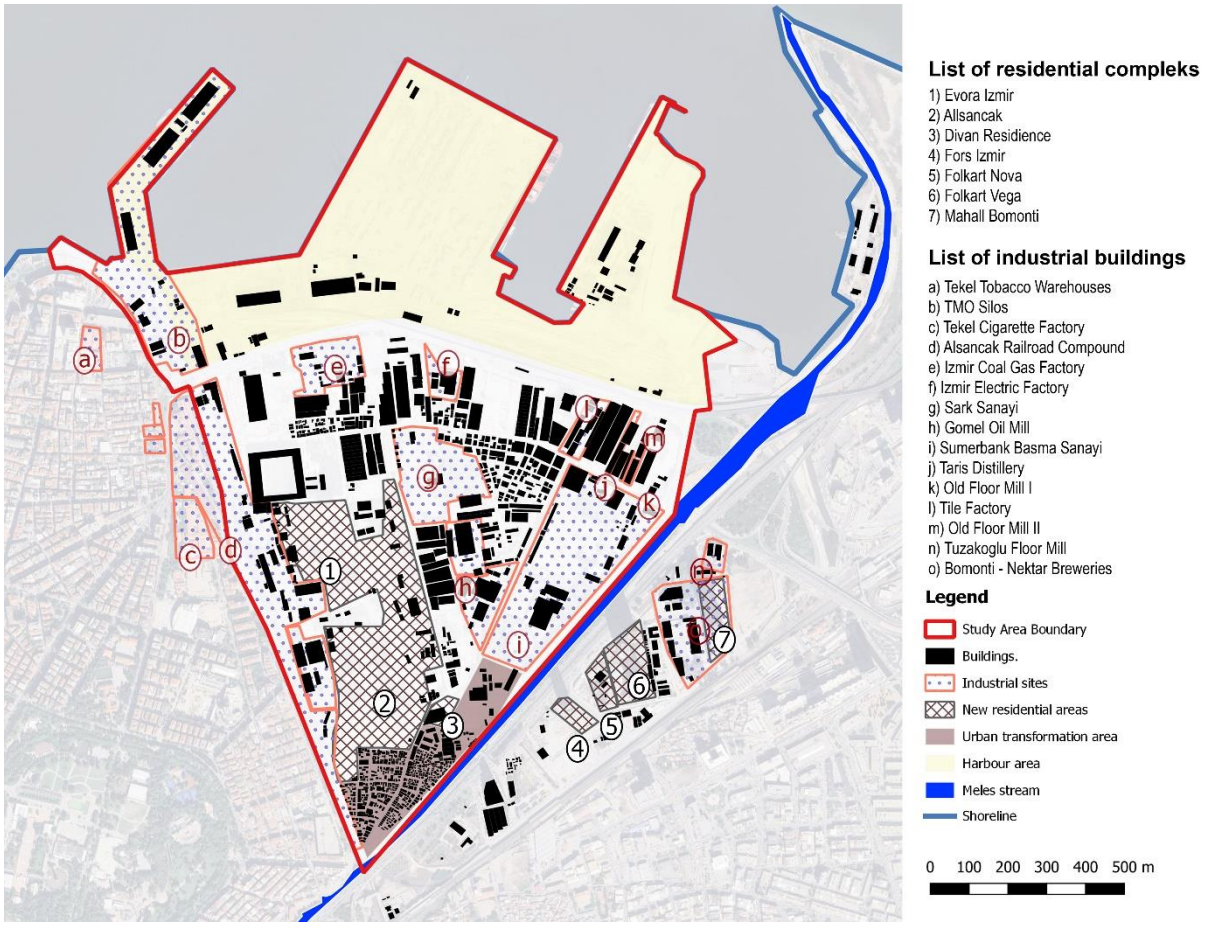

Figure 4. Map showing industrial, new residential complexes* and urban transformation area** in Alsancak Harbour Behind Area.

Note: * Boundaries of new residential complexes were identified through their websites and catalogues of the relevant projects (Teknik Yapı, n.d.; Pekerler İnşaat, 2020; Teknik Yapı ve Halk GYO, n.d.; Güçsan Yapı, 2021; Saya Grup, 2021; Türkerler, n.d.). ** The Izmir Industrial Heritage Inventory published by IZKA was used to determine the locations of industrial sites (IZKA, 2021).

Figure 5. View of Evora Izmir project rising on the land of Tariş (left) and Allsancak project from Ege Neighbourhood (right).

Two high-rise residential projects (Figure 5) are currently under construction in the Alsancak Harbour Behind Area. Both projects contrast in height, scale and form with the fabric of the two neighbourhoods in the region. The existing fabric consists of Umurbey Neighbourhood with the sparse

gross density, where industrial areas are located, and Ege Neighbourhood transformation area with medium gross density, which is mainly composed of low-rise residential buildings (Table 3).

Table 3. Neighbourhoods' surface areas and gross densities.

Neighbourhoods	Area (hectare)	Gross density* (population/hectare)	Urban Transformation area *** (hectare)	Gross density in urban transformation area (population/hectare)
Ege neighbourhood	23.49	82.12	7	274.8
Umurbey neighbourhood	160.44	1.92	-	-
Total	**183.93**	**-**		**-**

*The research utilised the density rating as determined by the Master Development Plan. In calculating the density, the populations of the neighborhoods for 2021 were taken into account.
** Urban transformation boundaries were obtained by transferring the boundaries to QGIS environment in the project prepared by IBB (IBB, n.d.). See Figure 4 for the boundary.

2.4. Climatic Features and Reclamation Works in Alsancak Harbour Behind Area

Alsancak Harbour Behind Area, which is situated close to the historical port of Izmir has a direct correlation with the Aegean Sea, which has played a pivotal role as a crucial conduit for trade and transportation throughout history. This advantageous coastal location has notably influenced the growth and evolution of maritime-related industries within the district, thereby contributing to its distinctive industrial heritage. To meet the demand for trade, this harbour area was formed by a land reclamation throughout history and eventually attained its present form.

Alsancak Port is a natural harbour that is the centre of Izmir's industrial and commercial activities. It consists of both Passenger Port and Freight Port areas. In Alsancak Harbour, which is still operated as a public enterprise today, there are docks for passenger, cargo and container purposes and various storage areas and service buildings such as warehouse, dock master, passenger hall, port operation building, protection and security chief, fire brigade, warehouse workshops, technical manager, closed shed, CFS, Flammable material, Social building, Arkas building, old container washing agency offices, office, and Container Operation Building (IZKA, 2019).

Izmir is impacted by river floods in three key river basins: "Küçük Menderes", "Gediz" and "Kuzey Ege" Basins (AFAD, 2021). 54%, 24.91% and 16% of Izmir province are located on the borders of the "Küçük Menderes", Kuzey Ege and Gediz basins, respectively (SYGM, 2019b, 2019a, 2019c). Additionally, the district shares a significant association with the Meles streams, which traverse the city of Izmir. The Alsancak Harbour Behind Area presents hydrological and geographical features that make it prone to flooding. These features include its proximity to sea level and the presence of Meles Stream. Therefore, the region's hydrologic cycle dynamics; the precipitation, run off, evaporation, infiltration and basin storage capacities are crucial. The "Küçük Menderes Havzası" Flooding Management Plan (SYGM, 2019b) indicates that the flood risk of the Meles Stream is categorised as a medium, while the Meles Stream Side is considered to have high flood risks. It is important to note that these risk levels are not static and are subject to change due to the rapid urbanisation process (Miller & Hutchins, 2017) in the district. The expansion of urban areas and associated modifications to land use patterns contribute to an increase in the overall flood risk potential of the area.

Due to climate change, sea levels are increasing in coastal cities and this increase is expected to continue in the future (NASA, n.d.-b). There are studies that reports the global mean see level rise in between 0,2 m and 2.0 at 2100 (Hall et al., 2016; Parris et al., 2012; Sweet et al., 2017). Predictions regarding sea level rise are critical for understanding its impact on cities. NASA has developed one of the most important studies for this purpose. They make predictions about the increase in sea level for

certain major cities in the future under different scenarios, using the Sea Level Projection Tool, which they developed based on the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report (NASA, n.d.-b).

The Shared Socio-economic Pathways (SSPs) were developed according to different climate mitigation scenarios due to the climate policy. Lee (2021) states that "SSP-1-2.6 for sustainable pathway, SSP-2-4.5 for middle-of-the-road, SSP-3-7.0 for regional rivalry, SSP-5-8.5 for fossil fuel-rich development." and SSP-1-1.9 scenario for "the assessment of the 1.5 C Paris Agreement goal". SSP-1-1.9 is the lowest then SSP-1-2.6, SSP-2-4.5 and SSP-3-7.0 follows, then SSP-5-8.5 is very high scenarios according to Greenhouse Gas Emissions (NASA, n.d.-b). According to these scenarios, the expected increase specifically for Mentes, Izmir under different scenarios is listed below for the years 2050, 2100 and 2150, respectively (Table 4).

Table 4. Sea level rises for Izmir under five scenarios (NASA, n.d.-b).

Scenarios	2050	2100	2150
SSP1-1.9	0.20 m	0.41 m	0.61 m
SSP1-2.6	0.23 m	0.50 m	0.74 m
SSP2-4.5	0.24 m	0.60 m	0.97 m
SSP3-7.0	0.25 m	0.70 m	1.18 m
SSP5-8.5	0.27 m	0.79 m	1.35 m

This study ignores the impact of floods and only calculates the water level that changes due to climate change. However, even in this case, a water level increase is expected to vary between 0.58 m and 1.34 m by 2150 which is evidence that a large majority of the area will be submerged. The research aims to produce scenarios for situations where sea level rise due to climate change and flooding occur together in the Alsancak Harbour Behind Area and argues that these factors should be considered holistically.

3. Methodology

This research aims to evaluate the area called Alsancak Harbour Behind Area according to risk levels in case of possible sea level rise and flood in specific periods in the future: 2050, 2100, and 2150. To accomplish this, research was designed as three stages: (1) data collection and creating base maps for the case study area, (2) creating risk zones, and (3) performing holistic risk assessment analyses by overlapping the data collected in the first two stages.

3.1 Case Study Selection

Alsancak Harbour Behind Area contains significant industrial heritage, both large and small-scale, that holds historical, cultural, and industrial value. Therefore, it is of great importance to the city of Izmir and its citizens. After most of the factories in this region lost their functions, the Liman Arkası area has become a construction site for high-rise residential buildings. However, this district behind the port is susceptible to flooding, having experienced numerous floods in the past and more frequently in recent times (Table 5). This research has chosen this region as a case study to measure the potential damage caused by a flood disaster and sea level rise and to determine the extent to which important historical structures in the area may be affected.

Table 5. Flood events occurring in the immediate vicinity of the Alsancak Harbour Behind Area

Date	Region affected	Source
20.02.1965	Mersinli, Halkapınar	
11.26.2000	Konak	(AFAD, 2021)
14.11.2001	Konak	
04.12.2012	Kordon, Alsancak	
21.09.2015	Cumhuriyet Squares, Konak	
18.01.2018	Kordon, Alsancak	(Ak, 2021)
23.12.2019	Kordon, Gundogdu	
05.02.2020	Cumhuriyet Squares	
26.02.2023	Alsancak	(IBB, 2023; Konak Municipilaty, 2023)

3.2 Data collection and preparation of base maps

The first phase of the research involves geospatial data collection. Maps were produced showing roads, numbers of buildings, industrial sites, and housing complexes that have recently been built, are being built, or are planned, urban transformation area (Table 6). These maps were generated according to the Open Street Map and Google Satellite Map 2023 data at the QGIS environment.

Table 6. Data types collected at QGIS environment.

Geo-spatial data	Type
Transportation axes Shoreline	Line
Buildings Industrial sites New residential sites Uban transformation site Harbour area Meles stream	Polygon

3.3. Identification of Risk Scenarios

The second stage holistically identifies risk zones against sea level rise and floods. Research uses tool was developed by 'Climate Central' and usable as an open web source. This tool called the Coastal Risk Screening Tool, was developed to make predictions based on the 2022 Sea Level Rise Technical Report (U.S. government) and the IPCC 6th Assessment Report (NASA, n.d.-a). This tool enables to see the change in water level caused by flooding and the increase in sea level caused by climate change. The assessment of sea level rise is based on the elevation of the sea surface in this tool. Flood, as a separate factor, affects the rise in sea levels and its effect can be in two ways: annual or moderate. Another setting examines sea level rise based on the luck factor (from good to bad luck), resulting from the

effects of heat-trapping pollution and global warming. Scenarios regarding the risk situations identified by the research are as follows (Table 7):

Table 7. Scenarios identified in the research for Alsancak Harbour Behind Area based on the coastal risk screening tool.

Risk	Scenario*
Highest	Sea Level + Annual flood + good luck
Medium	Sea Level + Moderate flood + medium luck
Lowest	Sea Level + Moderate flood + bad luck

* Pollution Pathway is determined as the Current Trajectory (SSP3-7.0) for all scenarios.

The Climate Central Tool uses the local annual flood data of Muis et al. (2016) for Türkiye. It uses sea level, annual, and moderate flood data to generate different scenarios. The tool utilizes data from the IPCC's Sixth Assessment Report and follows the IPCC's Fifth Assessment Report model. According to this model, these values depend on the geographical location, the trajectory of climate pollution, and the responsiveness of temperatures and sea levels to pollution and warming. The coastal flood map simulation uses CoastalDEM elevation data (NASA, n.d.-a). The tool utilizes the sea-level projections of the IPCC Report, and this research determined the pollution pathway to be SSP3-7.0.

The elevation data has limitations because of vertical measurement errors, such as in buildings, vegetation, and random noise. Furthermore, (NASA, n.d.-a) reports that "These maps are not based on physical storm and flood simulations and do not take into account factors such as erosion, future changes in the frequency or intensity of storms, inland flooding, or contributions from rainfall or rivers." as a limitation for the tool (Table 8).

Table 8. Data and data constraints

Data Sources		
Elevation Data	CoastalDEM	Climate Central
Soil Infiltration Data	NA	
Pollution Trajectory	IPCC (AR 6)	
Erosion Data	NA	
Storm Data	NA	
Inland Flooding Data	NA	
Rainfalls Data	NA	
List of Current Residental Buildings	Open Street Map, Google Satellite Map	
List of Residential Building Projects	Web Pages of related firms and IBB	
List of Industrial Buildings	IZKA, 2021	
List of Port Buildings and Facilities	IZKA, 2019	

3.4. Risk Assessment Analysis

At this stage, risk analysis was carried out based on three primary risk zones determined through geospatial data collected during the field study. The damage that will occur in case of possible flood and water level rise has been presented in three different periods (2050, 2100, 2150) and future projection scenarios. It was examined under three headings: the number of buildings, industrial areas and infrastructure.

4. Findings

This research developed a hazard map that holistically shows the impact of sea level rise and flooding using three criteria: Flood intensity, luck factor and pollution pathway Thus, risk zoning was obtained

for the district, representing different scenarios under three layers: Highest, Medium and Lowest. Figure 6, 7 and 8 shows that the most important factors in determining flood-prone areas in Alsancak Harbour Behind Area are the geographical and hydrological elements of the area. This triangular-shaped district has the risk of being exposed to water flow from both the Aegean Sea and the Meles Stream. Its proximity to water resources and location in low-lying lands increase the risk of these areas being flooded in the future.

The research also shows that in addition to the human activities that cause sea-level rise, the activities such as land reclamation and rapid urbanisation process on these areas are another crucial factor affecting the flood and sea level rise risk assessment for the district. Alsancak Harbour Behind Area, which has been incrementally expanded towards water throughout history through land reclamation as a result of human activities, is at high risk. From an urban development perspective, new residential areas rising next to the Meles River increase the potential damage from floods and sea-level rise. Furthermore, these buildings decrease the soil's infiltration capacity, which increases the risk of flooding. This research developed coastal flood maps and assessed potential damage for the area based on future projections for 2050, 2100, and 2150. However, it did not consider changing soil infiltration capacity as a factor for flooding.

According to the risk map of 2050 (Figure 6), the 'Passenger Port' section on the left side of the harbour obtained through land reclamation is at high risk. This area is important in terms of being one of the important industrial areas containing TMO Silos and also being a key transfer point connecting the 'Freight Port' and Liman Street. In case of a possible rise in water level, there is a high probability that the passenger hall and other buildings located on the platform in this area will be damaged. Also, the possibility of Passenger Port being disconnected from the rest of the harbour is considerable. In addition, Altınyol, Halkapınar Junction and Liman Street, which connect the Port area to Bayraklı and other districts of Izmir, are at medium risk.

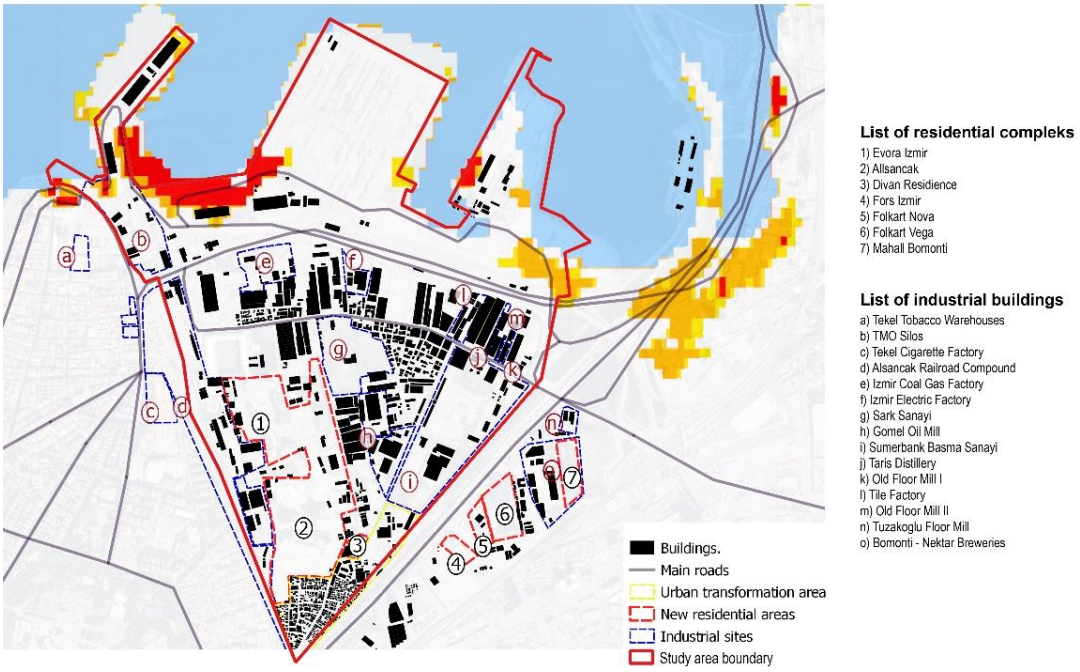

Figure 6. Flood and sea level rise risk assessment of Alsancak Harbour Behind Area for 2050.

The risk assessment map dated 2100 (Figure 7) shows that transportation arteries are at serious risk. It is estimated that the promenade between Ataturk Street and Kordon, the roads between Passenger Port and Freight Port, the connection point of the D gate of the Port with Halkapinar junction, Altinyol and Liman streets will be at very high risk in 2100. In addition, some of the important industrial sites in the area between Liman Street and Sehitler Street may be at risk of flooding. Old Flour Mill I, built

in 1895, is located in a medium-risk area. In case of a possible water level rise, all open, semi-open and closed areas of the museum with different functions are expected to be submerged. It is seen that there is a tendency for flood-prone areas to spread along the Meles River until 2100. The risk of flooding due to the flow and capacity of the river is effective in this pattern. These areas along the Meles River will be at risk, albeit low.

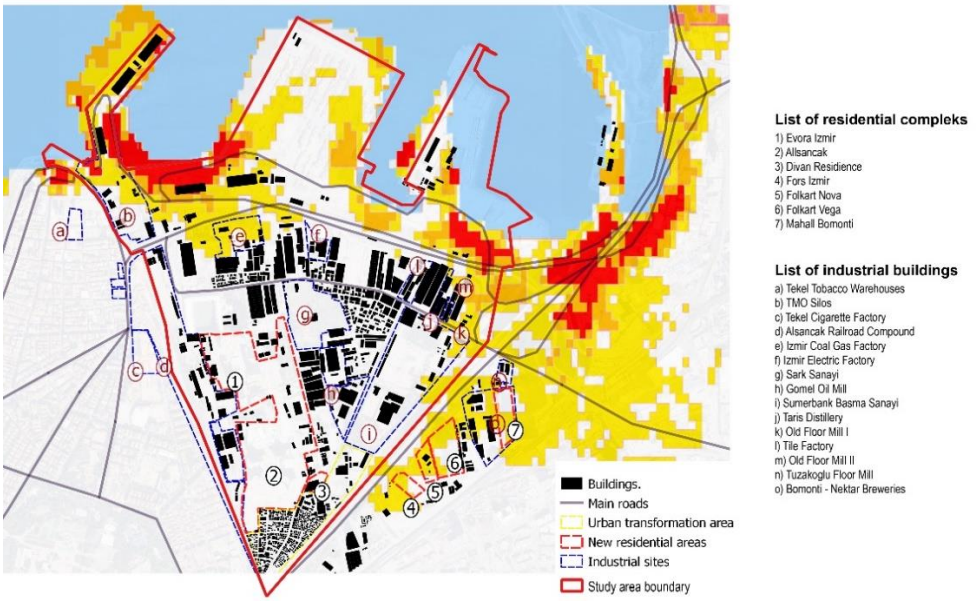

Figure 7. Flood and sea level rise risk assessment of Alsancak Harbour Behind Area for 2100.

According to the risk assessment map dated 2150 (Figure 8), high and medium-risk areas stand out in both passenger and freight ports. Unlike other maps, this assessment shows that medium-risk areas leak into the inside of triangular-shaped district where important industrial sites are located. Coal-Gas Plant, which occupies an area of 23,250 square meters with a cafeteria, reading room, sales units, restaurant and exhibition halls (IZKA, 2021) at medium risk of being damaged by this situation. Other important buildings at medium risk are Old Flour Mill-II and Tariş Distillery. The first building is currently used as an office while the second one functions as a parking area (IZKA, 2021).

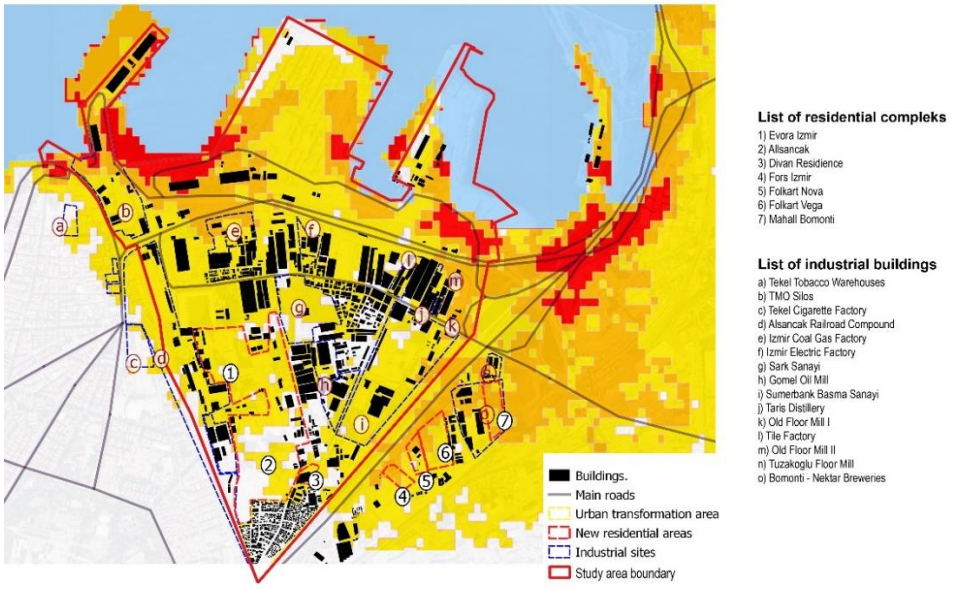

Figure 8. Flood and sea level rise risk assessment of Alsancak Harbour Behind Area for 2150.

5. Conclusion and Recommendations

The research reveals that transportation arteries will be at medium risk in 2050 and at high risk in 2100 and 2150. This means that the physical linkages of the district with its immediate surroundings will be in jeopardy. This research also shows that some of the buildings that have an important place in the industrial identity and urban memory of the city are located in flood-prone areas. While the Old Flour Mill I is at medium risk by 2100, the Coal-gas Plant, Old Flour Mill-II, and Tariş Distillery are at medium risk by 2150.

According to the tendency of flood-prone areas to spread along the Meles River, a large part of the new planned urbanization areas will be at medium risk by 2100. Allowing the construction of high-rise buildings due to current planning decisions causes a great risk considering the geological and hydrological characteristics of the area.

Based on the identified risks, the study recommends that settlements be located in less risky areas, particularly away from the Meles Stream. Although the location of the urban transformation project, which is currently ongoing next to the Meles Stream, may remain the same due to the rights of previous stakeholders, urgent action must be taken to prevent damage before construction begins. The initial step should be safeguarding current green spaces for soil infiltration, establishing new green spaces, or implementing permeable surfaces to enhance natural drainage. To preserve natural drainage and prevent population growth in areas vulnerable to sea level rise, it is advisable to refrain from constructing new residential buildings.

Additionally, it is crucial to assess the risks of sea level rise before repurposing industrial buildings that may be susceptible to damage, such as Old Flour Mill I and II, Coal Gas Plant, and Tariş Distillery. It is recommended that the sea walls surrounding the coastal filling area be raised, as this is the area that is most at risk. Furthermore, in order to protect the region against flood risk, it would be beneficial to increase the existing green areas and facilitate the discharge of flood water by utilising floor coverings made of permeable materials. The municipality should implement adaptation strategies, such as raised foundations and flood barriers, to mitigate the impact of sea level rise. Additionally, the Old Flour Mill II, which is currently a museum, could be repurposed as an attraction to raise awareness about the effects of sea level rise on coastal heritage. Furthermore, transportation arteries should be re-evaluated before 2100 to ensure the safety of harbour activities in light of sea level risks. Furthermore, the deployment of early warning systems for the region is also recommended.

Urban planning is one of the most important tools in demanding alternative futures of Alsancak Harbour Behind Area. This research has the potential to be used as a guide for the urban policies regarding the Alsancak Harbour Behind Area, which is a critical region in terms of its industrial heritage and being a commercial centre. This research draws attention to the problematic aspects of the current planning decisions of this region, which is under rapid urban transformation. In addition, it presents a realistic and unique methodology, addressing sea water rise and annual flooding situations. This methodology can help planners, decision-makers and architects in making decisions about this district, showing flood-prone areas in the future.

This research aims to aid policymakers in estimating the spatial impact of increasing coastal sea levels. However, it is recognized that such estimations require a comprehensive approach that encompasses soil infiltration, storms, and precise elevation data to generate accurate results. Therefore, this study has yet to introduce a new tool. Instead, it provides a unique analysis of the case area and its results, which is crucial for local authorities. This study's existence, despite its limitations, will be a valuable contribution to this fast-developing region.

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Author Contribution and Conflict of Interest Declaration Information

1st author contributed 40%, 2nd author contributed 40%, and 3rd author contributed 20% to the research. There is no conflict of interest.

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