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Article

Valencia's battle against floods: A cartographic review to assess water management strategies

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Abstract: The modification of the Turia River's course in the 1960s marked a pivotal transformation in Valencia's urban landscape, evolving from a flood protection measure into a hallmark of sustainable urban development. However, recent rainfalls and flooding events produced directly by the phenomenon known as DANA ((Isolated Depression at High Levels) in October 2024 have exposed vulnerabilities in the infrastructure, particularly in the rapidly urbanized southern areas, raising questions about the effectiveness of past solutions in the context of climate change and urban expansion. As a result of this fragility, more than 200 deaths have occurred, along with material losses in 87 municipalities, whose industrial infrastructure accounts for nearly one-third of the economic activity in the Province of Valencia, valued at 479.6 million euros. This paper presents, for the first time, a historical-document-based approach to evaluate the successes and shortcomings of Valencia's flood management strategies through policy and spatial planning analysis. Also, this paper remarks the ongoing challenges and potential strategies for enhancing Valencia's urban resilience, emphasizing the need for innovative water management systems, improved drainage infrastructure, and the renaturalization of flood-prone areas. The lessons learned from Valencia's experience in 1957 and 2024 can inform future urban planning efforts in similar contexts facing the dual pressures of environmental change and urbanization.

Keywords: historical cartography; Valencia; DANA; floods; water management

1. Introduction

Valencia's geographical and hydrological characteristics have made it historically vulnerable to flooding. It is a city shaped by its proximity to the Mediterranean Sea and its position within the fertile plains of the Turia River basin, playing a central role in shaping this risk. While these features have historically supported agriculture and urban growth, they also contribute to the city's heightened vulnerability to flooding. To that problem, the city's flat topography amplifies its flood risk. Low-lying and largely featureless, the terrain facilitates rapid water accumulation during intense rainfall, a hallmark of the region's Mediterranean climate. Seasonal storms often result in heavy downpours that overwhelm the city's natural and man-made drainage systems.

The intense rainfall and following flooding that affected Valencia on 29 October 2024 has reignited the debate around preventive measures for extreme weather events in the city, and also, in other areas of Spain prone to suffer heavy rainfalls. These recent episodes of torrential rain have highlighted both the strengths and limitations of the current protection and drainage systems, as well as the older plans designed for the riverbed and the city itself. The modification of the Turia River's course, carried out in the 1960s after the catastrophic flood of 1957—which caused over 80 deaths-,

serves as a key reference for understanding how Valencia has historically managed flood risks and what additional measures may be needed to address climate change and increasingly intense floods.

The modification of the river was not only an ambitious engineering project but also an initiative that would reshape Valencia's urban, social, and cultural landscape. This article explores the historical context of the city´s growth, execution of the modification of the river, and effects of this historic intervention, as well as the legacy it has left in the lives of Valencians and the city's image.

The floods of 2024, caused by a series of *gota fría* phenomena similar to the 1957 events, have had similar consequences, but now in the area where the modifications were made. Valencia experienced a year's worth of rain in just eight hours, leading to severe flash floods that caused significant damage to any kind of infrastructures. The most affected areas included the Ribera Alta, Horta Sud, and municipalities such as Chiva and Utiel, where rivers and streams like the Magro River overflowed. Some regions recorded rainfall of up to 500 mm (20 inches) in a single day, highlighting the intensity of the storm. The consequences were more than 200 deaths, along with material losses in 87 municipalities, whose industrial infrastructure accounts for nearly one-third of the economic activity in the Province of Valencia, valued at 479.6 million euros [1].

As we present here, this is not new.but these episodes, have become increasingly frequent and severe in the Mediterranean, exacerbated by climate change. This event has demonstrated that the previous land management and planning were adequate at that moment but due to the expansion of the city, other solutions need to be implemented to prevent future events from resulting in the same consequences.

Flood risk management in urban areas has increasingly moved beyond traditional engineering solutions, focusing instead on urban resilience frameworks and blue-green infrastructure (BGI) to ensure sustainable development [2]. BGI refers to the integration of natural systems (green) and water management (blue) into urban spaces to sustainably manage stormwater while delivering multiple co-benefits. Valencia's response to the catastrophic 1957 flood offers valuable lessons and allows to evaluate new approaches to the problem. Urban resilience emphasizes a city's ability to anticipate, adapt, and recover from environmental shocks while promoting long-term sustainability and inclusivity. Valencia's Plan Sur—diverting the Turia River to prevent recurrent flooding—is an early example of resilience-focused planning. Yet, it primarily addressed immediate risks through large-scale engineering, missing opportunities to integrate more systemic adaptation approaches. To deepen the discussion and align with global trends, integrating concepts such as resilient cities and BGI could elevate Valencia's urban planning model as a benchmark for future climate-adaptive strategies.

2. The legal framework for water management in Spain

The urban design in many countries today is largely influenced by 19th and 20th-centuries efforts to address water management issues. During this period, the rapid growth of cities and the increasing demand for solving problems related to water, such as spread of diseases and effective waste removal led several nations to adopt new

approaches to urban planning [3,4]. For instance, in the last third of the 19th century, England became a leader in sanitation infrastructure. During this time, strategies for managing water resources were re-evaluated, preventive measures against waterborne problems were implemented, and attention shifted from the environment to the well-being of the population [5]. In response, new urban by-laws were passed in many cities, addressing issues like sewage and drainage.

In most countries, however, water management reforms spread slowly. Spain, for example, remained behind in terms of economic, political, and social development by the late 19th century, prompting proposals to adopt the infrastructure improvements already present in other European countries [6–9]. Modernization efforts included significant sanitation upgrades, as Spanish urban areas faced severe challenges with water quality and waste management [10].

Madrid, for instance, struggled with severe water infrastructure deficiencies despite extensive public works on its sewer and drainage systems since 1856. The city still had over 3000 cesspits, while many neighborhoods lacked proper sewer traps to contain odors, and more than 4000 homes had no direct water supply [11] Likewise, between 1885 and 1893, Barcelona City Council undertook a sanitation initiative, constructing water tanks intended to circulate water through the sewer system to counteract the limited connections to residences [12]. In Seville, a dispute in 1901 between the League of Property Owners and the City Council nearly halted the expansion of drainage systems in the historic district [13].

Among Spain's cities with populations exceeding 100,000, only Zaragoza and Seville had relatively modern drainage systems, though water supply remained inadequate. In Madrid, Valencia, and Malaga, designated areas for water infrastructure were in disrepair, rendering them unusable and dangerous in case of heavy rainfalls; in Barcelona and Murcia, the facilities were also insufficient. The urgency of the water management crisis became apparent, as these infrastructure challenges contributed to high mortality rates and underscored Spain's need for immediate urban reform [14–16].

Since the 19th century, regulations have evolved to meet the specific needs of each era, addressing everything from epidemic prevention to protection against extreme weather events and earthquakes. This article outlines the key milestones in the development of Spain's legal framework for disaster management, showing how the country has moved from reactive approaches to a comprehensive, preventive system today.

In the 19th century, Spanish disaster laws focused primarily on responses to health emergencies, diseases, and large fires—serious problems in a Spain marked by urban growth and a lack of resources for crisis management. Within this context, laws were aimed at tackling cholera outbreaks that hit the country in 1833 and 1855, as well as other epidemics.

In 1855, the General Law of Public Welfare was passed, which included provisions for public health and began to introduce an assistance-based approach in crisis situations. Another notable regulation was the Health Law of 1885, which aimed to establish more coordinated responses to public health issues, laying the first foundations for health assistance during emergencies. Although "disaster management"

was not explicitly mentioned at this stage, these early efforts were pioneering steps in state intervention during emergencies.

Natural catastrophes, particularly floods, began to receive legislative attention toward the end of the 19th century. In 1866, the first Water Law was enacted to regulate water resources and prevent urban overflow, a recurring problem due to Spain's climate and geography. This regulation was an initial step toward flood control, with provisions for the construction of canals and dikes.

At the beginning of the 20th century, Spain recognized the importance of building infrastructure to prevent natural disasters. The Public Works Act of 1907 gave the state a central role in the creation and management of disaster defense infrastructure, especially dikes, canals, and hydraulic works for flood control. The Water Law of 1926 reinforced this policy and created Hydrographic Confederations; regional entities responsible for managing river basins in an integrated effort to reduce flood risks. These confederations were essential for water management and risk reduction and continue to operate today.

After the Civil War, the country's infrastructure and population were devastated, prompting the government to establish more organized measures for emergency and disaster management. In 1941, following a severe flood in Santander, a Civil Protection Law was approved, officially establishing this institution for disaster management. This law became a benchmark for the organization of state response to emergencies. It was developed further in the 1950s and 1960s, expanding to cover both natural disasters like floods, earthquakes or fire and human-induced emergencies.

The Civil Protection Act of 1985 was a milestone in disaster management in Spain, representing the first comprehensive legislation that organized emergency response levels (state, regional, and local) in a coordinated manner. This law established the modern framework for Spanish Civil Protection, organizing emergency plans into territorial (by zone) and specific (by type of disaster, such as forest fires, earthquakes, or floods) categories. It also delegated responsibilities to the Autonomous Communities, enhancing response capacity in each region [17].

Spain's incorporation into the European Union brought new standards and regulations for disaster management. In 2002, the country joined the European Civil Protection Mechanism, which provides cooperation guidelines among member states for mutual assistance in case of disasters. This mechanism enables Spain to coordinate resources and teams with other countries, increasing the efficiency of response to large-scale emergencies.

In 2015, the National Civil Protection System Law (Law 17/2015) was approved, renewing and modernizing the Civil Protection framework with a focus on prevention, planning, and risk management. This regulation also strengthens the involvement of the Autonomous Communities and establishes measures for inter-administration collaboration, focusing on adaptation to climate-related risks [15].

Today, disaster management in Spain faces new challenges. Increasingly intense phenomena, such as heat waves, forest fires, and torrential rains—such as those experienced in Valencia in October 2024—partly due to climate change, require preventive and adaptive policies that integrate both the central government and the autonomous communities. Current Climate Adaptation Plans focus on mitigating the

effects of these phenomena through a combination of infrastructure, education, and specific emergency protocols to reduce risks.

3. Previouys strategies adopted in Valencia: The reconfiguration of the river Turia after 1957

The Turia River has been a central element in the historical development of Valencia. Originating in the province of Teruel, the Turia flows for 280 km before reaching the Mediterranean Sea. For centuries, it provided water for agriculture and served as an important resource for trade and industry, though it was also characterized by its instability and tendency to overflow.

The Turia had already caused several significant floods before the catastrophic flood of 1957, including those in 1517 and 1776 [18]. These floods struck cyclically, devastating crops, buildings, and lives (**Figure 1**). Both floods clearly signaled the city's inability to manage such catastrophes due to its proximity to the river, especially as it continued to expand. This expansion is visible in 16th-century views (**Figure 2**) and the maps from the 17th (**Figure 3**), 18th (**Figure 4**), and 19th centuries (**Figure 5**), which depict the city's growth. In the 19th-century map, the historical center is highlighted with visible city walls—both the Muslim wall and the larger medieval wall ordered by Pedro the Ceremonious between 1356 and 1370. By this period, the center was already overcrowded, with buildings beginning to extend beyond the city walls.

By the late 19th century (**Figure 6**), thanks to more precise military mapping, it becomes clear that the city was gradually expanding into neighboring areas, both to the north (across the river) and to the south [17,19]. Finally, with the city's industrial development and the demolition of the walls, urban expansion became unstoppable from the early 20th century onwards (**Figure 7**).

Figure 1. View of the Puente del Mar in Valencia, ruined by the Turia River on 5 November 1776.
Source: [20].

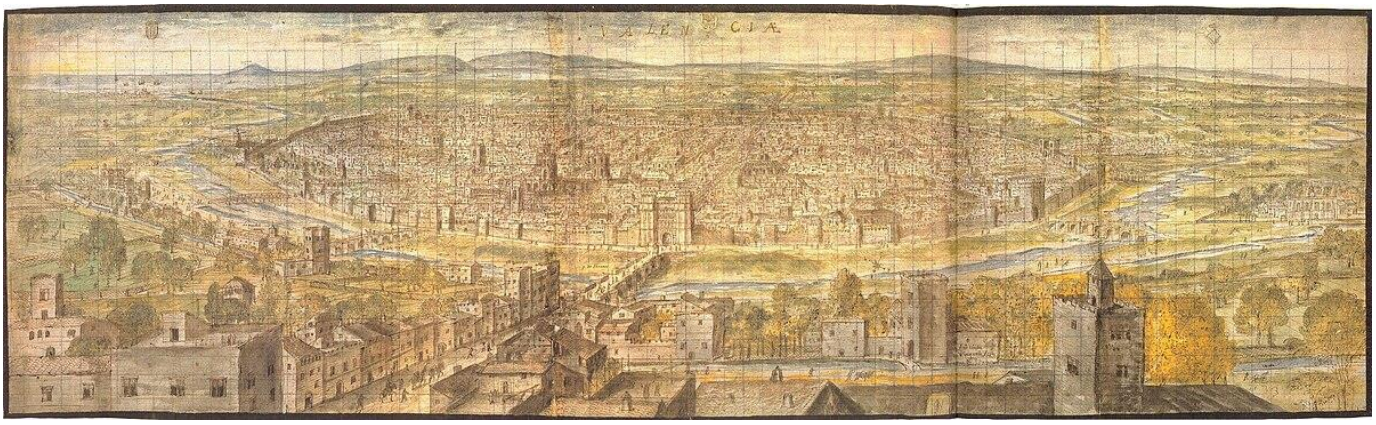

Figure 2. View of Valencia in 1563, made by Anton van der Wyngaerde.
Source: www.urbanity.es.

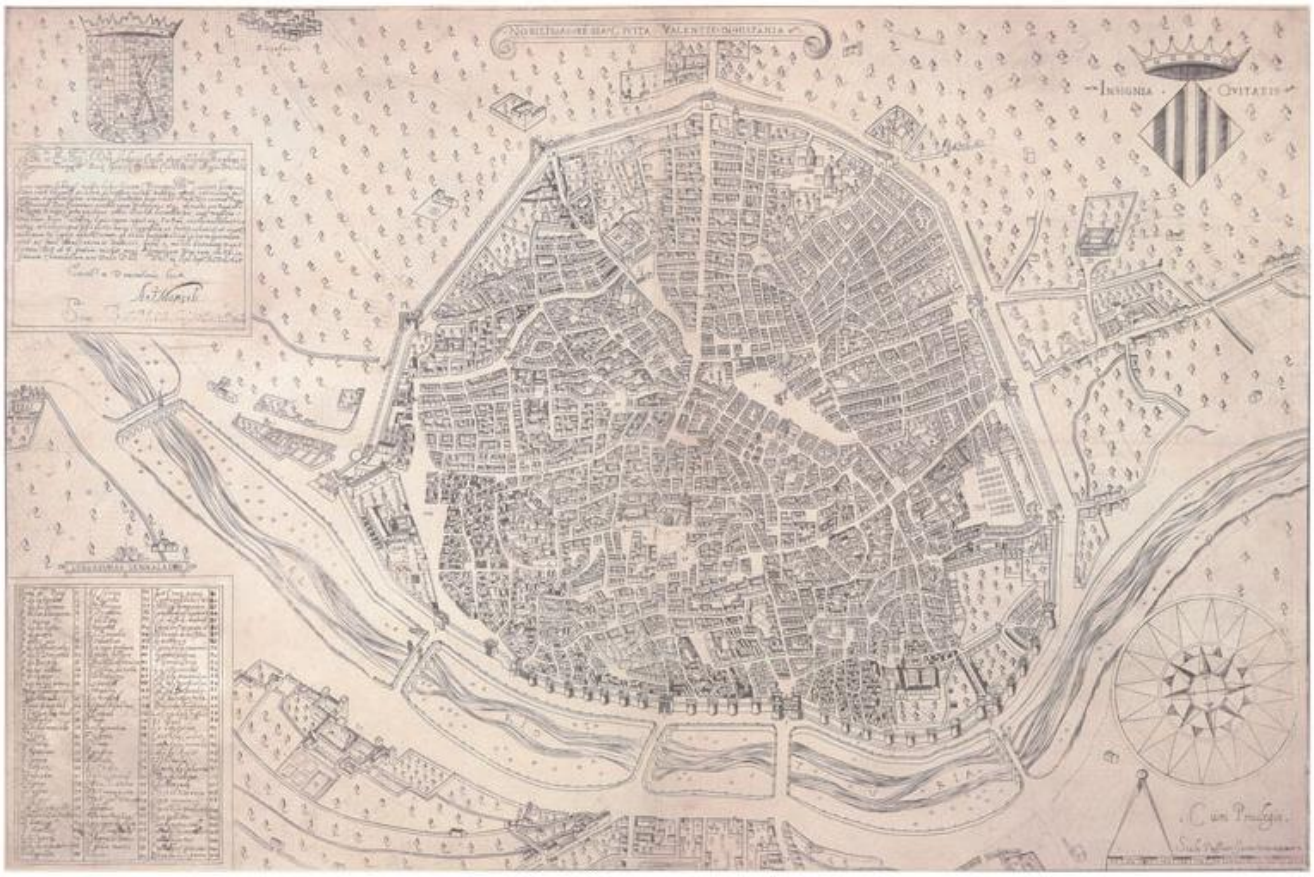

Figure 3. *Nobilis ac regia civitas Valentiae in Hispania*. The Noble and Royal City of Valencia in Spain Antonio Mancelli, 1608.

Source: Instituto Geográfico Nacional, 31-F-16.

Figure 4. *Valentia Edetanorum aliis Contestanorum, vulgo del Cid.* Valencia of the Edetani, also of the Contestani, commonly known as "of the Cid". Vicent Tosca i Mascó, 1704.

Source: Wikipedia.

Figure 5. Detail of Plan de Valence assiégée et prise le 9 janvier 1812 par l' Armeé Française d' Aragon aux ordres de S.E. Le Marechal Suchet. Plan of Valencia, besieged and captured on 9 January 1812, by the French Army of Aragon under the command of His Excellency Marshal Suchet.

Source: Instituto Geográfico Nacional, 47-K-1.

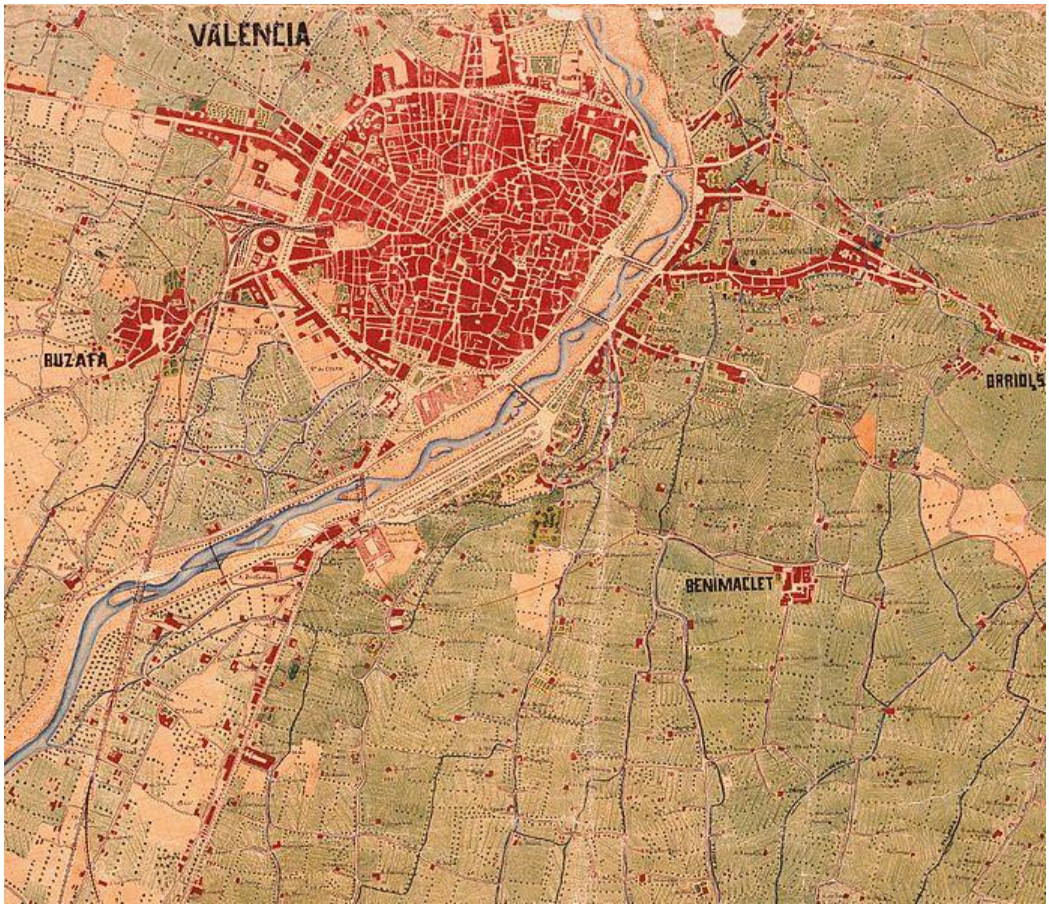

Figure 6. Detail of *Plano de Valencia y sus alrededores*. Map of Valencia and its surroundings. Francisco Ponce León, Jesús Tamarit, Pedro Bentabol. 1882–1883.

Source: Cuerpo de Estado Mayor del Ejército.

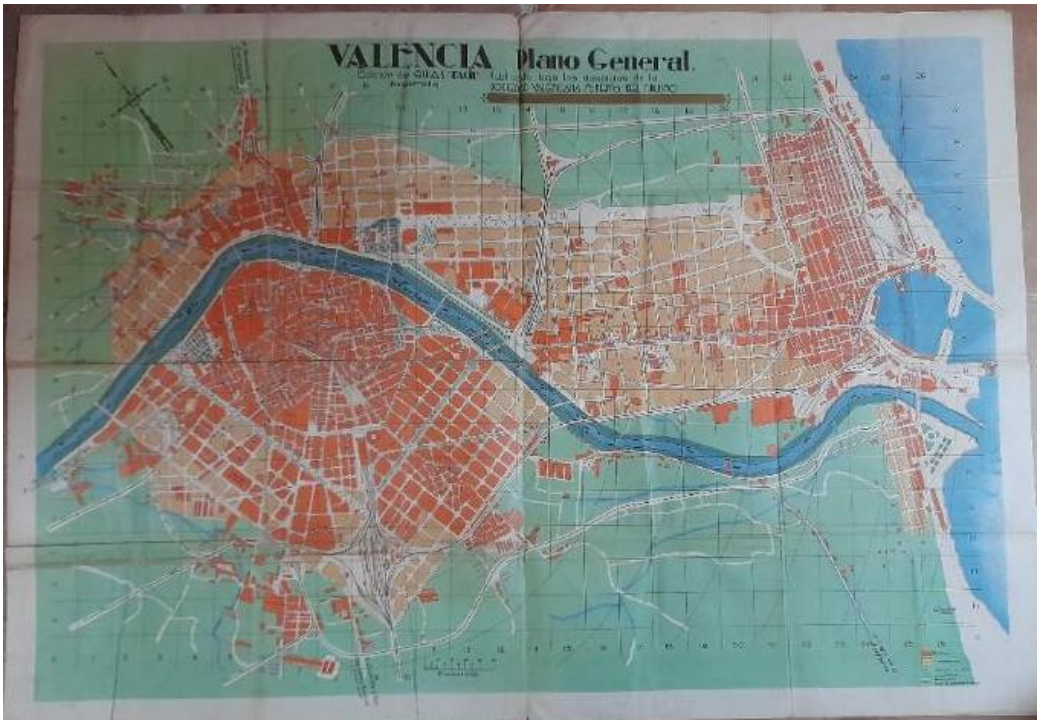

Figure 7. Valencia. Plano General. General Map.

Source: Sociedad Valenciana de Fomento del Turismo.

The 1957 flood marked a key point, far surpassing previous flood magnitudes and making it clear that the natural course of the Turia River was no longer sustainable for an expanding city like Valencia. On 14 October 1957, Valencia was hit by torrential rain resulting from an extreme meteorological phenomenon. Known as *gota fría*, this intense Mediterranean rain event caused an accumulation of up to 300 liters of water per square meter within hours. The Turia could not contain such a volume, and in just a few hours, the water breached the dikes and channels, inundating the city [21].

The resulting catastrophe devastated not only much of the historic center but also critical infrastructure, including hospitals, bridges, and transportation networks. Material damages were estimated at over one billion pesetas—like 6.010.121.000 millions uf Euros—a huge sum at the time. Local and national authorities realized that without decisive intervention, Valencia would remain exposed to future disasters.

The flood resulted in more than 80 deaths and extensive material losses, especially impacting the urban core. This event spurred the creation of the Plan Sur, an ambitious project aimed at diverting the Turia River southward, moving its course away from central Valencia. This approach followed similar patterns used by other Mediterranean cities [22–24].

The Plan Sur was a direct response to the 1957 tragedy. Valencia's mayor at the time, Tomás Trénor Azcárraga, Marqués del Turia, worked from late 1957 to find solutions to implement Valencia's adoption decree granted by Francisco Franco after the flood (issued by the Ministry of Housing on 23 December 1957), though it initially lacked funding [25].

This project became one of Spain's first major postwar urban infrastructure works, involving an investment and technical complexity unusual for the time. The execution of the Plan Sur required not only redesigning the river's course but also reorganizing road networks, irrigation systems, and connections between various neighborhoods in the city. Redirecting the Turia River altered the landscape and structure of the city, leaving a legacy in Valencia's urban, environmental, and cultural management that endures to this day. Conceived by the Spanish government in collaboration with local authorities and hydraulic engineering experts, the plan aimed to divert the Turia to protect the urban core of Valencia. A new channel was constructed south of the city's center, designed to manage large-scale flooding without impacting the population.

In 1958, García Ordóñez was appointed to oversee both Valencia's urban planning and the so-called Solución Sur, outlined in the Esquema Director, under the direction of Pedro Bidagor Lasarte, Director General of Urban Planning [26,27]. García Ordóñez, a prominent Spanish architect whose professional career focused on urban planning and infrastructure in the latter half of the 20th century, joined the Oficina Técnica de Gran Valencia alongside Valencian architects Mauro Lleó Serret (Chief Architect), Víctor Bueso Bellot, and Antonio Gómez Llopis [28]

In addition to these works, García Ordóñez was tasked by the Obra Sindical del Hogar y la Arquitectura to plan 614 social housing units near the Cabañal neighborhood. His approach reflected a strong commitment to modernizing Spanish cities during a period marked by urban reconstruction and expansion, especially after the Civil War and during Franco's dictatorship, when development and public works policies began to gain momentum toward national modernization. The Virgen del

Carmen housing group, designed as an autonomous neighborhood with typological innovations, exemplifies the highest level of volumetric composition and formal coherence among all the sets included in the "Flood Plan" [29–31]

A few weeks after García Ordóñez joined the Oficina Técnica, Mayor Trénor was dismissed, and Adolfo Rincón de Arellano replaced him. By order of the Directorate General of Urban Planning, the Administrative Corporation—whose Executive Committee was chaired by the mayor of Valencia—regained control to revise the Gran Valencia Plan. Within months, efforts to adapt the Plan intensified; it became essential to accurately position the new riverbed within Valencia's General Plan and make corrections associated with the river diversion.

The Plan Sur project, which redirected the Turia south of the city to mitigate flood risk, illustrates the scope and urban vision characteristic of the works García Ordóñez and his contemporaries promoted. Although he was not the primary author of this project, the Plan Sur aligns with García Ordóñez's ideas on urban intervention as a tool for solving complex problems and enhancing the safety and functionality of cities [29]. These ideas paralleled those emerging at the time around metropolitan development, following the example of cities like Madrid with its General Urban Planning Plan for the Madrid Metropolitan Area, dated 1961, published in 1962, and approved by a specific law on 2 December 1963 [32].

The infrastructure and urban redesign involved in the Plan Sur reflect the principles García Ordóñez valued in his projects, where the efficient organization of urban space and the integration of advanced technical solutions were paramount. This plan, which necessitated redesigning roads, irrigation networks, and neighborhood connections, also reflects a modern conception of the city as an interconnected system—a perspective fundamental to Ordóñez's urban planning vision. Also, the Southern Solution has contained the city's development towards that area (**Figure 8**).

Figure 8. Model of the 1988 General Plan of Valencia.
Source: Ajuntament de València, La Valencia de los noventa. Una ciudad con futuro. València, 1987.

The Plan Sur also demonstrated a forward-thinking approach, aimed at anticipating future challenges, such as potential flooding. This principle was essential to Ordóñez, who insisted on the need for infrastructures that would not only fulfill immediate functions but also meet future demands. Although completed in the 1970s, due to the delayed approval of the Adaptación del Plan General de Ordenación Urbana de Valencia y su Comarca a la Solución Sur (Adaptation of the General Urban Planning Plan of Valencia and its Surrounding Area to the Southern Solution) until 30 June 1966, the Plan Sur has been tested by recent rainfall events, like those of 2024. These tests highlight the ongoing relevance of the plan's original vision, which continues to protect the center of Valencia. However, they also emphasize the current challenges in urban planning—an area in which García Ordóñez would have advocated for adapting projects to urban and climatic changes to protect the now-developed areas that previously had low population density [33].

The Plan Sur was designed to safeguard the city from future floods by constructing a new riverbed that diverted the Turia's waters southward, away from populated areas. This measure has proven effective for decades, as the center of Valencia has not experienced severe flooding from the Turia since then. Nevertheless, the intense rains of 2024 have tested this infrastructure, underscoring persistent risks in areas adjacent to the diverted riverbed. The construction of the new Turia channel involved significant engineering feats, from digging large channels to constructing massive dikes and bridges. A 12-kilomkmeter-long, 175-meter-wide canal was excavated to channel the river's waters without affecting the urban core.

One of the primary challenges was ensuring that the new channel could withstand floods equal to or greater than the one in 1957. For this purpose, the project incorporated expansion zones as well as channels and gates capable of regulating water flow. The work was completed in the 1970s, becoming a symbol of Valencia's resilience through innovation and collective effort [34].

This project allowed Valencia to divert the river during heavy rains without risking overflow in the most densely populated areas. This transformation not only mitigated flood risks but also contributed to the city's aesthetic and recreational spaces. The project was essential for reducing the exposure of urban areas to floodwaters while also offering opportunities for recreational spaces and tourism, thus benefiting both urban livability and economic activity.

Regarding the capacity of the new channel, it has a length of 12,692 m and a width of 200 m. The diversion would begin between the towns of Manises and Quart de Poblet, following a straight line past Xirivella and curving with a radius of approximately 2000 m in a west-east direction near Castellar, where it would slightly turn southward. This adjustment allowed for the expansion of the port, with the river eventually flowing into the sea between Pinedo and El Saler. The drainage capacity was designed to handle 5000 m^3/s, exceeding the "maximum" flood wave recorded during the October 1957 flood by 35% (**Figure 9**)

However, recent urbanization in the southern areas of the channel has altered flood impacts. The heavy rains of 2024 have shown that, while Valencia's city center remains protected, the southern region is still vulnerable, affecting neighborhoods and municipalities that have grown in these areas.

Figure 9. Aerial image showing the exact location where the river was diverted following the implementation of the Plan Sur.

Source: Newspaper Valencia Hui: [35].

4. The results of the new configuration

One of the most important and unique aspects of this intervention was the abandonment of the Turia's former riverbed. After the river's diversion, the old channel was emptied, sparking numerous ideas for repurposing this space. The government's initial proposal was to construct an urban highway connecting northern and southern Valencia. However, residents and environmental groups opposed this, arguing that the old channel could become a green space for the enjoyment of Valencians.

After a lengthy process of debate and negotiation, the creation of an urban park in the former riverbed was approved. This decision represented a victory for the public and marked a shift in the approach to managing urban spaces, resulting in what is now known as the Turia Gardens. The design of the Turia Gardens began to take shape in the 1980s. Today, this park spans over 110 hectares, being one of the largest urban parks in Spain and a model of urban revitalization and environmental management. Highlights include the Gulliver Park, the City of Arts and Sciences, and the Palau de la Música, each a testament to Valencia's cultural and architectural richness(**Figure 10**).

Figure 10. Aerial photo of Valencia in the mid 70 s.

Source: [36].

Economically, the park has boosted tourism and stimulated sectors such as hospitality, commerce, and services. The City of Arts and Sciences, situated within the gardens, attracts visitors from around the world, generating revenue and employment for city residents. This park has significantly enhanced the quality of life in Valencia, improving the city's image and providing a space for recreation, sports, and culture. (**Figure 11**).

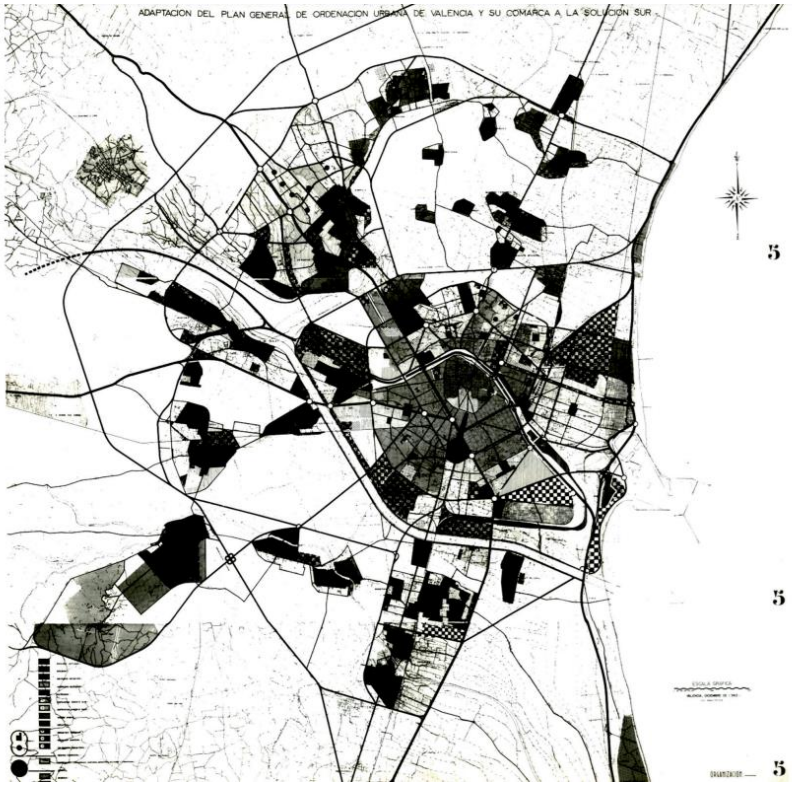

Figure 11. Adaptation of the General Urban Development Plan of Valencia and its Region to the South Solution. Photographic reproduction of Plan 5. Organization (Green Areas). December 1963.

Source: Archivo de Planeamiento del Ayuntamiento de Valencia.

On a social level, the park has become a gathering place for Valencians, who use it for sports, cultural, and recreational activities. The accessibility and connectivity offered by the former riverbed have enhanced mobility and integration between neighborhoods, fostering greater social cohesion.

Today, the old Turia riverbed is a model of urban planning that prioritizes sustainability and quality of life. The Turia Gardens are considered an example of how a city can transform an abandoned infrastructure into an ecologically and socially beneficial space [37]. Additionally, the park contributes to urban temperature regulation and air quality, helping to mitigate the heat island effect in Valencia. Once a source of risk for the city, the Turia River has become the green heart of Valencia, with its success inspiring similar projects in other Spanish and European cities. However, the recent 2024 floods have exposed that the previous plan was useful at that moment but maybe not any more. Floods have affected former flood-prone areas south of the city, like Pinedo and El Saler, which saw urban expansion and infrastructure improvement after the transformation of the Turia. Also, new residential and industrial zones were established, particularly along the newly created flood-free zones. The cartographic comparison between 1956 and 2023 showcases these dramatic changes, emphasizing the shift from a flood-prone river basin to a more controlled and urbanized landscape (**Figures 12** and **13**). Also, because of the huge growth of population in this area—75 municipalities with a resident population of 1.8 million people [38,39], road and rail infrastructure systems were improved, including bridges over the new riverbed and strengthened connections between southern municipalities like Quart de Poblet, Xirivella, and central Valencia.

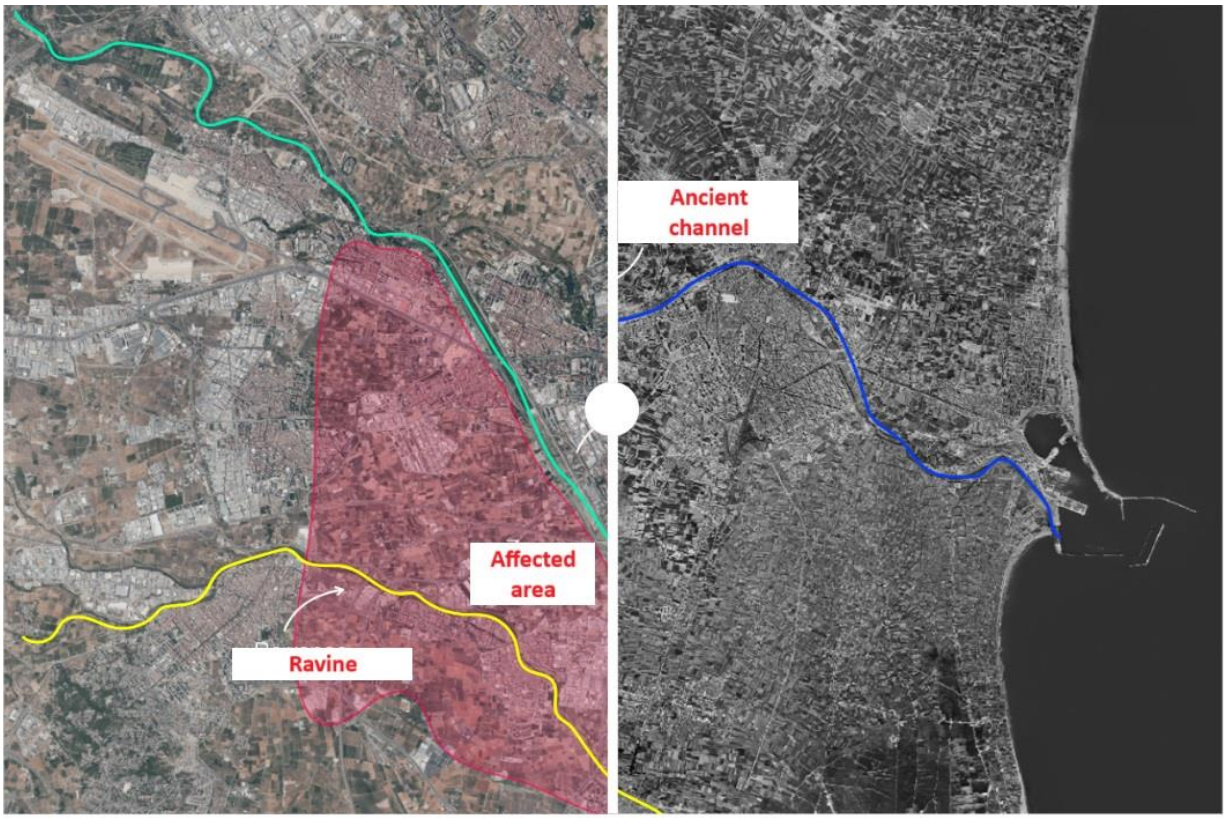

Figure 12. 1956 Photograph, 2023 Photograph.
Source: Cartographic Viewer of Valencia.

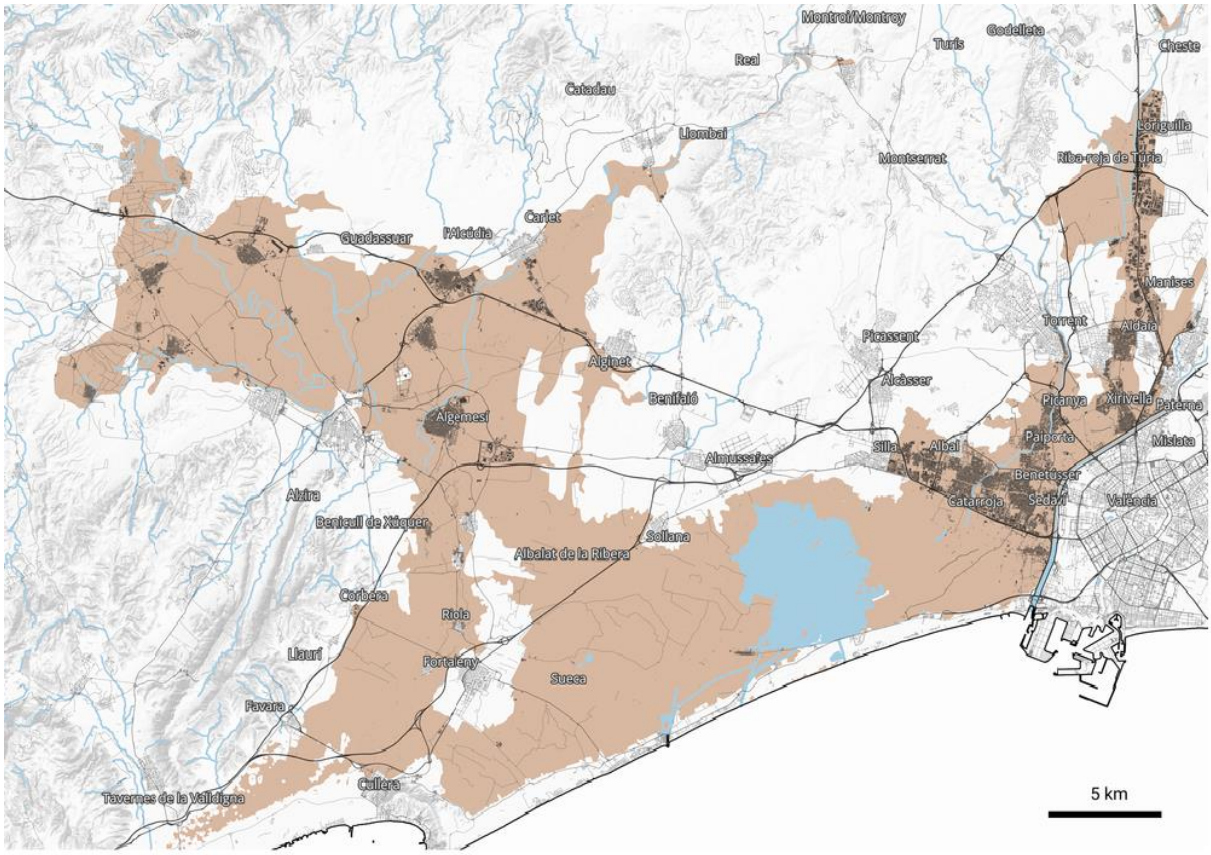

Figure 13. In orange, flooded areas.
Source: Universitat de València, Copernicus EMS, IGN.

5. Reflections about the problem and future directions

Due to all these elements, experts consider whether the old reconfiguration is still useful, in other words, if the park's current use might be adapted to better retain and manage rainwater during the increasingly frequent intense rains in the Mediterranean, driven by climate change or if the changes implemented at that time are enough or which strategies can be implemented regarding the blue-green infrastructure (BGI). Valencia's Turia Gardens, repurposing the old riverbed as a green corridor, embodies the potential of BGI. However, expanding BGI's scope could bolster Valencia's flood resilience and urban sustainability

Since the 1957 flood, Valencia's urban planning incorporated advanced flood management infrastructure such as retention basins, levees, and improved drainage systems. The city's stormwater management system has been enhanced to handle larger volumes of water, with a focus on sustainable urban drainage systems (SUDS). These systems aim to not only divert water but also promote natural water infiltration, reducing urban heat island effects and improving ecological health. However, it seems that some improvements are necessary. Regarding other European cities with similar historical problems—such as Amsterdam, Venice, Paris, London or Copenhagen -, Valencia has a lot of possibilities to enhance the problem to prevent future flooding situations [40].

Amsterdam is often seen as a global leader in flood management [41–43]. Due to its location below sea level, the city has implemented extensive water management

strategies for centuries. Amsterdam's approach focuses on integrated flood risk management, using a combination of dikes, storm surge barriers, and flood retention areas. Notably, the city's Room for the River program is a standout strategy, where water is allowed to flow into specially designated floodplains during extreme weather events, reducing the pressure on urban infrastructure. This contrasts with Valencia's river diversion strategy but shares a common focus on land use adaptation and water retention.

Venice, another city vulnerable to flooding due to its low-lying position, has faced growing challenges with sea level rise and increased flooding. The city is implementing the MOSE project, a series of movable barriers designed to protect the Venetian Lagoon from high tides [44]. While this strategy is more focused on protecting the city from tidal surges, it shares similarities with Valencia's flood barrier strategies, such as protecting vital urban areas from inundation [45,46]. However, Venice's challenges are different from those in Valencia, which faces flood risks from inland rivers rather than sea surges. Both cities, however, demonstrate a strong focus on technological innovation in flood risk mitigation.

Paris has employed a more natural approach in managing flood risks, particularly through urban green spaces and floodplain restoration. After the catastrophic floods of 1910, Paris implemented a comprehensive flood management plan that includes levees, locks, and water retention basins [47–50]. The city has increasingly focused on green infrastructure, such as permeable surfaces, which help manage runoff and reduce flood risks [51]. This approach contrasts with Valencia's heavy reliance on engineering solutions like the Plan Sur but reflects a growing European trend towards sustainable and nature-based solutions in flood management.

London's flood management strategy involves the Thames Barrier, which protects the city from tidal surges. The city's flood risk management is integrated into the Thames Estuary 2100 Plan, which takes into account future climate change predictions [52,53]. London also uses a combination of levees, flood defenses, and land use planning to manage river flooding. Similar to Valencia, London has recognized the need for multifaceted solutions, combining hard engineering solutions with better urban planning, though London's focus is more on tide and surge protection compared to Valencia's emphasis on river flooding [54].

Inspired by other cities like Copenhagen [55,56], Valencia could design floodable parks or wetlands that temporarily store stormwater, preventing urban inundation while supporting biodiversity. Also, encouraging green roofs, rain gardens, and permeable pavements across urban developments would enhance water infiltration and reduce runoff, mitigating the impact of extreme precipitation events

The recent events have shown that even with sophisticated flood management strategies, challenges remain. Municipalities along the southern area of Valencia, particularly in areas like Albufera and L'Horta Sud, were still heavily impacted by floods. This highlights the need for continuous updates to flood risk assessments and the further adaptation of urban spaces to a changing climate. It is essential to continuously improve resilience strategies, ensuring that newer urban developments incorporate flood-prone area considerations.

Learning from Amsterdam and Paris, Valencia could enhance its approach by expanding nature-based solutions, such as creating more permeable surfaces and

expanding green spaces to manage runoff more effectively. Or, as seen in London, flood management is increasingly focused on long-term climate change scenarios. Valencia could benefit from incorporating more adaptive measures to handle the anticipated impacts of climate change, particularly sea level rise and changing precipitation patterns.

Also, there is a significant focus on public engagement and education about flood risks and prevention. Valencia could enhance public awareness of flood risks and encourage community involvement in flood preparedness.

6. Conclusions

The modification of the Turia River's course in the 1960s marked a turning point in Valencia's history. What began as a protective measure against flooding transformed into one of the most significant and positive urban transformations in the city. Today, the Gardens of Turia, which run through the city, symbolize not only Valencia's resilience in the face of adversity but also its ability to reinvent and adapt itself, seeking a balance between urbanization and sustainability.

This project, which arose in response to a tragedy, has become an example of how cities can be redesigned to protect their inhabitants and improve their quality of life. The transformation of the Turia River has left an indelible mark on Valencia's identity and continues to serve as a model of urban planning for other cities around the world.

However, with the floods that occurred in 2024, Valencia's infrastructure, designed decades ago, is being put to the test, especially in areas where urban growth has been more rapid, such as the south. This area is the most affected during heavy rains, as the diversion of the Turia River in the Sur Plan shifted the flood risk from the center to the south. Although the new course is designed to withstand large floods, it is not equipped to efficiently drain in the nearby urbanized areas. Urbanization has reduced the natural spaces that absorb water, making these areas prone to flooding in the event of heavy rainfall.

In 2024, the rapid runoff from urbanized areas exacerbated the flooding, particularly in locations where the infrastructure is insufficient to handle such volumes. This situation has sparked debates about the need to redesign these infrastructures and add new containment measures.

While the Sur Plan has effectively protected the center of Valencia, the 2024 floods have highlighted the limitations of its effectiveness in the context of climate change and accelerated urbanization. The drainage infrastructure and water containment systems need to adapt to current conditions to reduce the risk in the southern area and in regions close to the new river course.

The river diversion model, which was innovative in the 1960s, should be complemented with more modern solutions, such as water capture and retention systems in the old course, to prevent excess water from flowing into urban areas. The modification of the Turia River in the 1960s was an innovative solution that protected central Valencia from future flooding, but the recent events of 2024 have shown that it is necessary to update infrastructures and water management strategies in the city. Valencia finds itself at a crucial moment to apply a forward-looking vision that

combines the effectiveness of the Sur Plan with innovations that reduce flooding risks throughout the territory, including the southern area. The recent floods of 2024 should be seen as a wake-up call to invest in resilient urbanism that prioritizes both the safety of the population and environmental sustainability. In the face of the growing threats posed by climate change, Valencia could implement a series of additional measures, such as retention infrastructures in the old course, drainage and absorption systems in the southern area, that implies improving the sewage and drainage systems in the neighborhoods and municipalities of southern Valencia or the renaturalization of floodable areas.

Valencia's flood management history is a testament to the potential of large-scale engineering solutions. However, as climate challenges intensify, adopting resilient city frameworks and blue-green infrastructure strategies can provide a more comprehensive, sustainable approach. Cities like Paris, Copenhagen, Venice or London offer valuable lessons, underscoring the importance of integrating water management with urban development. Valencia stands at a crossroads to evolve its legacy into a model of 21st-century flood resilience, demonstrating how to balance protection, sustainability, and urban vibrancy.

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