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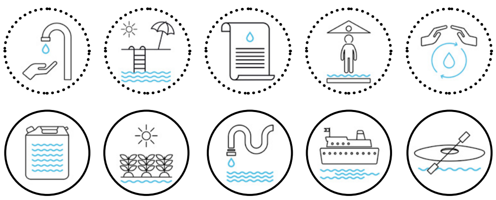
# Looking Back Paves our Way Forward: The Delta City of Amsterdam

**Sannah Peters, Maarten Ouboter and Jeroen Oomkens**
Regional Public Water Authority Amstel, Gooi and Vecht

*As one of the most famous delta cities in the world, Amsterdam exemplifies how decisions and narratives from the past can be the driving force for present-day actions and more effective design principles for future city planning. Water management in Amsterdam has often been, and frequently still is, reactive in response to water hazards, flooding, droughts, pollution and disease. While contemporary pressures urge water managers to redesign the living environment in harmony with changing water cycles, the centuries-long history of water awareness, cumulative knowledge and long-term spatial planning has led to gradual improvement throughout Amsterdam. Many solutions are still relevant today and are essential in decision making as we design a new climate-resilient future and deal with challenges such as sea-level rise and demographic change. Despite residing below sea level, the people of the delta city of Amsterdam exhibit a profound sense of confidence and security against flooding. Moreover, the material and immaterial dimensions of the water network serve as a tangible reminder of our ancestors' deltaic identity, highlighting their contributions to our current living environment. Therefore, the water system plays a vital role in preserving Amsterdam's urban landscapes, cultural heritage and historical significance, which also helps strengthen this delta city's future water management and urban planning.*


KEY THEMES



CLIMATE

A B **C** D E

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***Temperate oceanic climate***


< Fig. 1 The Amstel Locks (1673) protected the Amstel River's upstream areas, which are important for food production, from poor water quality by flushing water. The locks still play an important role in Amsterdam water management (Source: Albert Jan Perier).

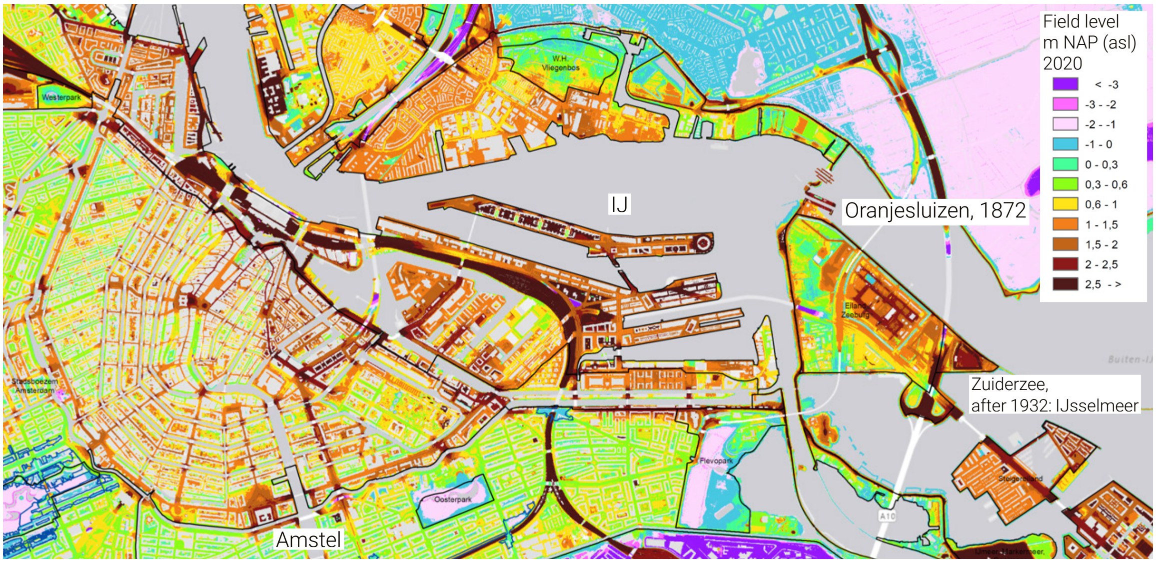
**The Delta City of Amsterdam and its Water Management Challenges**

Amsterdam, the capital city of the Netherlands, has been strongly influenced by water for more than 700 years. From a settlement at the edge of the Amstel River, it has become a city with over 800,000 inhabitants, built on, in and with water (van Leeuwen and Sjerps 2015). Amsterdam's connection with water is ubiquitous and even the city's name is a direct reference to its origin. A levee – dam – built on the intersection of the Amstel River and former Zuiderzee created space for a trading center. The established canals are artificial multi-purpose extensions of the Amstel, combining protection, transport of trading goods and groundwater drainage with an essential connection to the catchment of Amstelland. Investments in flood risk management, water quality and robust water infrastructure turned Amsterdam into an attractive, economically healthy and safe city (IWA 2016; Koop et al. 2017).

People shape, reshape and adapt urban spaces to sustain human life and its living environment. Today, natural water systems are increasingly impacted by human factors in ways that affect water availability and quality (Khatri and Tyagi 2015). Pressures on water systems create challenges for cities related to housing, drinking water, solid waste, drainage, wastewater, groundwater and surface water. For cities to remain livable, adequate water management is an essential and continuous task. To meet its future challenges, the Amsterdam region invests constantly in developing and maintaining its water system. Sustainable investment decisions for water management demand consideration of historic developments that proved valuable for the regional water board and the City of Amsterdam. Therefore, the development and the preservation of a solid knowledge base regarding the water system and environment is a critical priority in the decision making process and contributes to the legitimacy of water governance in the region.

The world-famous water system of Amsterdam earned its legacy over the course of six centuries in response to crises by balancing opportunism, entrepreneurial spirit and societal pressures. Praised as unique, history shows how water management in Amsterdam has often been, and frequently still is, reactive in response to water hazards, flooding, droughts, pollution and disease. Moreover, to this date essential steps in good decision making still require efforts to raise awareness of water issues (Peters et al. 2021). Politicians and water managers have a centuries-long track record developing a variety of solutions to prevent disasters. Enhanced knowledge and long-term spatial planning have led to gradual improvement throughout Amsterdam, and many of the solutions are still relevant. In terms of prospects for the Amsterdam of the future, they involve both hindrances and inspiration. Contemporary pressures urge water managers to reconsider and redesign the living environment in harmony with changing water cycles. Practitioners and society at large are confronted with the monumental opportunity and challenge of addressing sea-level rise and demographic change to invent a climate-resilient future.

A typical delta city faces four challenges: transmission of hinterland runoff, high water levels outside the city (high tides), water quality issues connected to wastewater production, and the city's spatial planning together with its water infrastructure design to manage rainfall and groundwater. These are among the challenges Amsterdam has faced in the Dutch delta within the city territory and its adjacent areas inland and along the shore. The city was designed




^ Fig. 2 Field level, Amsterdam. The city center has been artificially elevated to above average sea level (NAP). The city is protected against flooding by a dike with an altitude of +2 mNAP (in brown). IJ was part of the tidal area until 1872 (when the Oranje Locks closed). Zuiderzee, east of the Oranje Locks, became IJsselmeer in 1932 (Source: Wessel de Meijere, Waternet. Data: ESRI Nederland).

considering the water geography of its surroundings and constrained by fluctuating water levels in both the catchment area and in its connection to the sea.

## Past: Decisions that Shaped the Natural Environment in the Process of Developing a Delta City

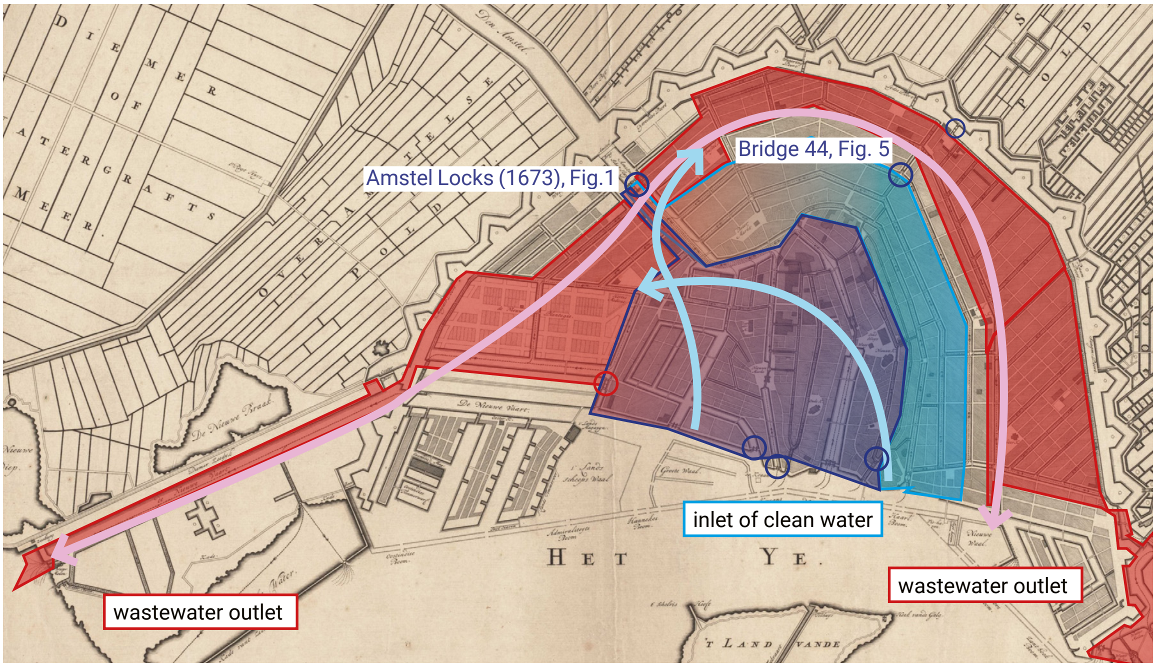
Before the original settlement that became Amsterdam, the sea intruded into the central part of the delta (1170). Protection against flooding was crucial and sea dikes were built. The sea dike has been reinforced over time in line with the highest flood level. After the big flood of 4 November 1675, the highest tide in Zuiderzee prior to the twentieth century, the level of the sea dike protecting Amsterdam from the sea was 9 feet, 5 inches, which is, following Amsterdam metrics, around 2.6 meters above sea level. Managing the tidal variability through the Oranje Locks (Orangesluizen) in 1872 reduced the risk of flooding in Amsterdam. In 1932 the distance of the city to the sea was further increased due to the construction of the Afsluitdijk. The Afsluitdijk is a sea-dividing levee that changed a brackish lagoon (Zuiderzee) into a freshwater lake (IJsselmeer). The IJsselmeer is now of great importance for the freshwater supply of the Northern Netherlands. In the future, regarding sea-level rise, the lake might have an important function connecting the Rhine to the North Sea.

Within the Netherlands, flood risk protection in urban areas is not solely dependent on the construction of levees. Another important measure is to increase field levels. It is common delta practice to raise the land, bringing in sand or other substrate materials before construction. In addition, elevated entrances to domestic housing will also mitigate flood risk. Basically, before urban development, Amster-


^ Fig. 3 1767 map Nieuwe Ambagtsheerlykheden der Stad Amsterdam waarin ook de Groote Ring van Amstelland. The area indicated in blue is the catchment directly connecting to the Amsterdam canals (Source: Historisch archief van Waterschap Amstel, Gooi en Vecht, NL-AsdWAGV_010140).


dam structurally raised land using soil, so that the city center is an artificial high point in the landscape. Outside the dike, in the tidal waters, street levels were raised up to 2.0m above sea level. In the protected area near the city center, street levels are typically raised between 0.5m and 1.0m above sea level (fig. 2).

Another layer of protection was added by the city's decision to restrict the discharge of the Amstel River draining into Amsterdam by managing the size of the catchment area. The city extended its influence over adjacent territories by acquiring new land while actively participating in local regional water authorities in the Amsterdam hinterlands. After a century of struggle and a decision from Holy Roman Emperor Charles V in 1525, it finally became clear which areas would be allowed to drain via Amsterdam (Zwaan 1984). The 1767 map in figure 3 shows the perimeter of the Amsterdam catchment in blue. The sinking peat land south of Amsterdam is divided into so-called polder areas, which are intentionally kept dry by pumping the rainfall surplus to a primary channel system known as the *boezem*. The Amstel River and city canals are part of the boezem designed for transporting rainfall surplus to the Zuiderzee. The Dutch name for this transport system is *boezem*, because it reflects the movement of the human chest in breathing. The periodic increases in water level, naturally occurring through small water level variations "breathe" rainfall surplus into the sea. However, after finishing the development of the port of Amsterdam, the installed Oranje Locks closed the – until then – permanent open connection between the Zuiderzee and the IJ in 1872. Since then, the initially steam-driven pumping stations complemented the natural flow at low tide in the sea and regulated the transport of catchment water to the Zuiderzee, with exceptions in 1942, 1975 and 2005.




^ Fig. 4 Flushing scheme in the second half of the seventeenth century until 1872. The blue arrows indicate the clean inlet water, and the red arrows indicate wastewater-enriched outflow. Locations of fig.1 and 5 are indicated. (Source: Map: Stadsarchief Amsterdam, KOKA00125000001).

The most significant impact from closing the Oranje Locks was the change in intensity of tidal variability and its inlet location, which directly affected the water volume available for flushing. It effectively prevented the system from flushing clean the Amsterdam canals with the required volume of water (Fig. 4). This prompted a streak of water quality issues and public turmoil and eventually the necessity of a proper sewage system became apparent. Water managers and city officials decided to build a sewer, transporting wastewater to the Zuiderzee. After a century of discharging untreated Amsterdam effluents, wastewater treatment started after 1982, dramatically improving the IJsselmeer's water quality. It took over 115 years, until 1987, to finish the sewerage system in the older city quarters. Nowadays, the water quality in Amsterdam canals has significantly improved and is even suitable for swimming.

**Present: The Pressures that Drive Actions in Perspective**

Due to the earlier adjustments to the water system, the city is located in a large polder. Water levels in the polder areas tend to rise due to limited pumping capacity. Which is why the increased risk of heavy rainfall forced Amsterdam to expand its storage capacity. In urban areas, blue and green solutions offer water-storage capacity on rooftops and gardens, in the public spaces of parks, and underneath streets. The lowest sections of polders act as natural floodplains. Floodplains are an important flood risk protection measure in spatial planning as water drains with the fewest obstacles. Floodplains nowadays also double as recreational space.

The present-day discussion is characterized by a sense of urgency about expanding pumping capacity to transport water outside the city area, namely to the North Sea and the Markermeer and IJsselmeer lakes. The primary channel system comprising the IJ and Amsterdam canals developed as a typical transport system, that is, a system helping to discharge water from the low-lying areas. The area around Amsterdam has been designed and developed in such a way that the water levels cannot fluctuate strongly, therefore the water level must remain stable and excess water is pumped out.

There are also many tangible and intangible developments and pressures in the delta. The Dutch population is rapidly growing, demanding fresh water and seeking leisure on and along the canals, resulting in an overall exacerbation of pressures on the Amsterdam water system. The fact that Amsterdam is already a densely populated area also presents immense challenges for spatial development. Fortunately, a new national law, the Environment and Planning Act (Omgevingswet), will supply us with legal instruments for enforcing environmental values and principles, leaving the regional water authorities better equipped for their tasks. The impending law establishes quality requirements and values for many types of activities that affect assets like water and soil. These environmental values are designed to be adaptive to changing environments and societal needs in the future. Examining these values in relation to the past, including detrimental decisions that often irreversibly shaped the Amsterdam landscape, could offer new solutions to problems of the present and future. That process of reflection is in the spirit of the new law.

The delta region of Amsterdam faces significant pressures, leading to dynamic spatial developments and prompt governance actions that have shaped a distinctive environmentally conscious identity and behavior among the city's citizens. Additionally, the heightened awareness has induced societal unease, leading to demands for engagement and cooperation between governments and the people of Amsterdam to improve decision making. Citizens' concerns regarding their living environment have resonated with policymakers and institutions, which similarly prioritize ecological considerations, nature-based solutions, and water quality. Despite residing below sea level, the people of the delta city of Amsterdam exhibit a profound sense of confidence and security against flooding.

Water is regarded as the delta city's crown jewel. Less visible are the democratically elected water authority boards and their taxation system, which are crucial in maintaining and developing the intricate water network in urban landscapes. This comprehensive water system encompasses many physical structures, including canals, sluices, locks, quays, ports, water-related buildings and hidden infrastructures. Moreover, this network's tangible and intangible dimensions serve as a reminder of our ancestors' deltaic identity, highlighting their contributions to our current living environment. The water system will play a vital role in preserving the cultural and historical significance of Amsterdam's urban landscapes.

**Future: Design Principles for Water Management in Amsterdam**

The decisions of the past and the narratives we develop about them in the present in connection to citizens, or in a broader sense society, provide frameworks and insight for future water management and urban planning. Best practices and mistakes offer principles. The following principles are important to consider when shaping water management in the future:

^ Fig. 5 Bridge 44, Leidsegracht, where the platforms show traces of a lost function: closing doors were operated to force flow in the flushing scheme between 1663 and 1872 (Source: Stadsarchief Amsterdam, B00000024728).

1. Amsterdam should maintain an open water system to prioritize natural water movement connecting the catchment to the sea. The heritage of the water system formed in the past, integrated with the surrounding environment, forms a sound foundation for future functioning. Minimizing obstructions in the water, such as floating parks and houses, also maintains water quality and supports the system's active role in the ecosystem.

2. We need to develop adaptive strategies, such as increasing pumping capacity and backup systems, to address future sea-level rise. The *boezem* is a transport system and the space for storage is limited. We need to incorporate and extend water storage within the urban environment, utilizing rooftops, gardens, streets and parks. Polder areas can form floodplains. Continued and enforced collaboration with neighboring catchments is crucial for effective water management.

3. We need to ensure the open character of the IJmeer, which is important for the freshwater supply of the Northern Netherlands. Refrain from further development and consequent reduction in freshwater storage. In addition, it may be necessary in the future to be able to discharge more of the water from the Rhine via Ijmeer/Ijsselmeer as sea-level rise limits the ca-

pacity for outflow of the Rotterdam area.
4. We need to design water management systems that prioritize the governance, knowledge and heritage of Amsterdam. Strategies should aim to ensure the sustainability of the water system while balancing the cultural and economic significance of the city. Prioritize stakeholder engagement and cooperation among different institutions, including those responsible for heritage preservation, to ensure that spatial and water planning respects the city's unique cultural and historical characteristics.

5. Design strategies are needed to retain and store precipitation in polders and cities to ensure gradual drainage during heavy rainfall and to provide water during drought.

6. We need to improve water management systems in Amsterdam to enhance the protection of the city and its hinterland from floods resulting from rising sea levels. We should prioritize the conservation and functionality of existing dikes and heritage structures by ensuring that they are maintained and strengthened to withstand future challenges. Strategies should focus on enhancing the ability of existing dikes to protect the city and its inhabitants against dynamic water levels in IJ/Noordzeekanaal and beyond.

7. Water management systems need to be designed to prioritize elevated field levels in new construction and infrastructure. Given the threat of flooding and changes in ground level, it is essential to raise the field levels of urban areas to limit potential damage caused by flooding.

8. There is a need to reconsider Amsterdam's water management systems to prioritize cooperation and the balance between saltwater intrusion and freshwater use. Development of the harbor has historically disrupted water management, and sea-level rise will put additional pressure on this balance. Therefore, improving cooperation and coordination is crucial to ensure the sustainability of water management in the face of future challenges.

9. We need to design water management systems to obligate a priority for water quality and ecology. It is important to reduce pressure on the water system and waste management to ensure and improve water quality. If, in any case, reducing pressure on the water system is not in the capacity of the regional water board or municipalities, we should focus on more local reduction of pressures to improve water quality.

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**Sannah Peters** is an asset manager of water infrastructure responsible for the drinking water supply and wastewater transport in the city of Amsterdam and the surrounding area. Her career started with a thesis and publication at Waternet and KWR Water Research Institute, where she conducted a historical analysis of water management and governance in Amsterdam. Sannah explored how past experiences offer opportunities to address present and future challenges in Amsterdam and other cities across the globe. As a water and innovation technologist, she has contributed to projects on the energy transition and circular economy and on water quality in the water cycle. Sannah participated in the Dutch National Watertraineeship, which allowed her to gain experience at various water organizations. During the traineeship, she founded Youth for Drinkable Rivers, supporting the Drinkable Rivers initiative. She is also committed to water heritage, in which the past connects to the present.

**Contact: sannah.peters@waternet.nl**

**Maarten Reinier Lemme Ouboter** has a background in earth sciences, specializing in hydrogeology and geochemistry. He started his professional career at Delft Hydraulics, where he developed a strong foundation for integrated system analysis. Since 2001, Maarten has become the public voice – ambassador – of water at the Regional Public Water Authority of Amstel, Gooi and Vecht. His comprehensive knowledge of greater Amsterdam is essential in regional water, environmental and cultural developments. Securing this voice and its intrinsic values in investment plans makes Maarten instrumental for future challenges of the region. He advocates for more integrated approaches that include historical perspectives, particularly of the landscape, natural processes, culture, governance and its people. The outcome of all equations is ecology: can plants and animals sustainably co-exist in a water system with people and their ambitions?

**Contact: maarten.ouboter@waternet.nl**

**Jeroen Oomkens** is a senior legal policy advisor responsible for future-proofing regional legislation in the Netherlands. For 10 years, he has coordinated and led the development of tailored water, climate and environmental solutions to support the transition of (inter) national organizations and institutions. For the Dutch Ministry of Foreign Affairs, he participated in a study on the political economy of water infrastructure investments in South Africa, Kenya, Indonesia and the Philippines. And for Cabo Verde he co-authored the National Adaptation Plan. Jeroen also contributed to policy developments for the European Green Deal, where among other projects, he led the impact assessment for the new EU Adaptation Strategy, inspiring a clear call for action. He is chairman of the Dutch committee of ISO standards on climate change adaptation and the Dutch Head of Delegation for the CEN/TC on climate change. Jeroen also volunteers within the SDSN Youth Network as a coach and expert. He holds a master's degree in earth sciences and environmental management from the University of Amsterdam and a mechanical engineering degree from the University of Applied Sciences in Utrecht.

**Contact: jeroen.oomkens@waternet.nl**