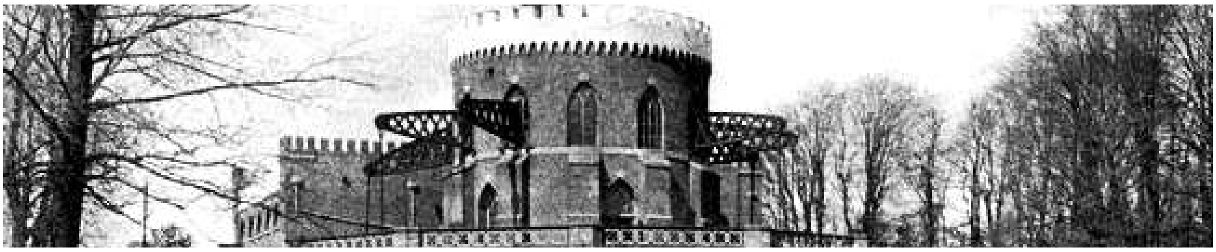
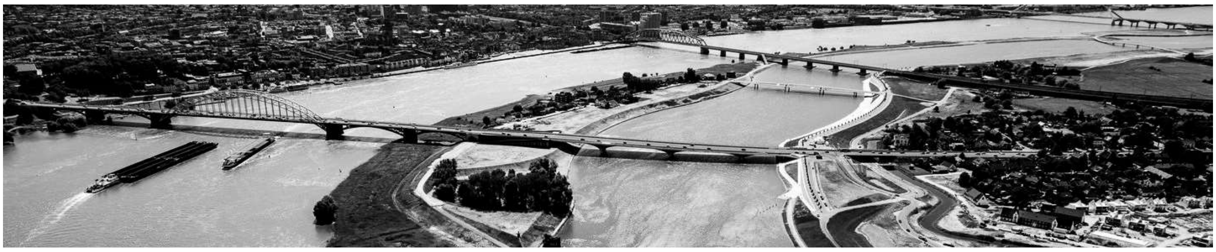
AR2A011 - Architectural History Thesis
2023/2024

Living with Water

A Historical Exploration of **Dutch Architectural Responses** to **Rising Water Levels** within its **borders**





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*“From keeping the **water out** to learning to live **with** the **water**“*

Contents

Abstract

Keywords

Rising sea-and river levels, Watermanagement, Historical architectural adapation of water, Living with water, Strategies, Technological architectural advancements

The world is warming up, causing a rise in water levels. The Netherlands has a rich history in the field of water protection: throughout the centuries, the country has increasingly improved its defenses with the help of new techniques, technological advancements, and better regulated management. However, since the end of the previous century, there has been a shift in the way water is dealt with. No longer is the motto "keeping the water out," but rather "learning to live with water."

This thesis investigates the reasons behind this change in Dutch policy by answering the following question: *'What are the historical architectural adaptations of the Netherlands before 1953 to effectively handle water within the face of rising water levels and why did this strategy change after 1953 from 'keeping the water out' to 'learning to live with water?'* To answer this question correctly, two periods, each with sub-periods, have been examined: before the flood disaster of 1953, and from 1953 to the present.

When examining the sub-periods, the relationship between catastrophic events, water management, and technological advancements was looked at. By addressing architectural cases, this relationship could be clearly defined. The results indicate a correlation between when these events occur and how they are responded to with technology and water management. Another correlation was observed in how technological progress also led to better organization: improved technology enabled larger projects, which in turn required larger forms of water management.

However, the flood disaster of 1953 revealed that there is a limit to protection against water. The floods of 1953, 1993, and 1995 made the Dutch realize that merely protecting against water is not sufficient; a new strategy of water management was needed, one in which we also learn to live with water. This strategy must ensure that the Netherlands remains safe from water in the future, even with the expected rise in sea-and river levels.

1. Introduction

Our world is warming up, causing a rise in water levels. To determine how fast the water levels are going to rise is nearly impossible due to processes within ice caps. However, the IPCC (2021) does not rule out an increase in sea-levels of 2 meters by 2100 and 5 meters by 2150. Deltares (2019) has outlined four different solutions for the Netherlands to protect itself against water: closed protection, open protection, seawards and accommodating. This thesis will focus on two different time aspects: The Netherlands from 500BC – 1953AD, in which the Dutch have learned throughout the ages how to keep the water out of its borders, and the Netherlands after 1953, where they slowly developed a new strategy to learn how to 'live with water'. The focus lies on how Architecture is influenced or influences the different time periods and what the characteristics of these periods were.

First, it is relevant to look at how the Dutch have learned to keep their feet dry throughout the ages. How did they protect themselves and what was the setting of that time period? In the first chapter the first part of the thesis question will be examined: *'What are the historical architectural adaptations of the Netherlands before 1953 to effectively handle water within the face of rising water levels?'.* To answer this question, four representative time periods are distinguished each with a case study of a typical architectural project for that time:

• 500BC – 1250AD: Historical mounds / De terp van Ezinge
• 1250AD – 1798AD: Polder Mills / De Beemster Molens
• 1798AD – 1916AD: Steam Pumping Stations / Steam pumping station Cruquius
• 1916AD – 1953AD: Zuiderzeeproject / Afsluitdijk

To create a complete overview, the case studies focus on three different aspects: water management, water-related events and (landscape)architecture. The architectural project serves as a characteristic example for that time period. The periods are chosen according to the paper of van Koningsveld (2008) and the book by van de Ven (1993) of key moments that changed the way we approached handling water. Often, catastrophic events have led to changes in politics or were the emergence of technological advancements within architecture. After the case studies, a general conclusion of the period before 1953 will be given in which correlations and differences of the time periods will be made.

In the second chapter, this thesis will focus on answering the second question of the thesis: '*why did the strategy change after 1953 from 'keeping the water out' to 'learning to live with water?'.*' Working with this question provides insights on how the Dutch view about water has changed over the years and why the landscape looks like what it is right now. The shift at how the Dutch approach water from 1953 after the Watersnoodramp marks the beginning of a new politics and strategies that are further developed throughout the last 50 years. There is more room for working together with nature than solely defending against it (Saeijs et al, 2004). This strategy also influences the way architects changed designs close to water, which is visible within more recent projects. To examine how the Dutch architecture learns to work with nature two new case-studies and one new period will be examined:

• 1953AD – 1993AD: The Deltaworks / Oosterscheldekering
• 1993AD – 2007AD: The New Delta Plan / Ruimte voor de Waal
• 2007AD – present: Working together with water

After answering both questions, a general conclusion will be written in which the two sub questions will be merged into the main thesis question: *'What are the historical architectural adaptations of the Netherlands before 1953 to effectively handle water within the face of rising water levels and why did this strategy change after 1953 from 'keeping the water out' to 'learning to live with water?'.'* By combining the questions into one, a clear shift or difference between the two periods can be made more easily.

For this thesis, the hypothesis is that the Netherlands is moving towards becoming a country where they will need to learn on how to live with designated areas that are occasionally going to be flooded. The Dutch have a rich history with water that contains enough examples that are still applicable nowadays. The way they approach water is an ever-ongoing process due to new strategies and/or technological developments. This is also visible in the related architecture.

The definition 'architecture'

During this thesis, the term architecture does not solely apply to buildings, but will be looked at in the broader sense as defined by Encyclo (Architectuur (Vakgebied) - Definitie - Encyclo, n.d.):*' The art or science of designing and constructing, especially habitable structures, in accordance with principles determined by aesthetic and practical or material considerations.'*

2. Historical adaptations before 1953

Four case-studies throughout the ages dating back to 500BC to 1950AD

In this chapter, four case studies from different time periods in the Netherlands will be examined. Each case study describes the historical background of water-related events, politics, general background, and architectural adaptations. Preceding the case studies is the time period from the beginning of the Holocene until 500 BC, which explains how water shaped the Netherlands into its current coastal plain and river system.

2.1 Before 500BC

The Dutch coastal plain can be viewed as a sediment-imported system dating back to the last ice age, also known as the end of the Pleistocene (Nieuwhof et al., 2018). During the Holocene (our current geological period, starting 11,500 BC), the ice from the Pleistocene began to melt and was collected in what is now the North Sea. During this melting period, loads of sand and clay were transported from Scandinavia towards the Dutch coastal plain. Initially, this resulted in a transgressive coastal system in which the rivers acted as barriers for sediment. As sea levels rose, the rivers flooded, leading to meandering. Due to this phenomenon, the riverbeds cut deep into the shapes they are today (Berendsen, 2002).

Around 5000 BC, there was a shift in the coastal system. The rising sea level couldn't keep pace with amount of the sediment, resulting in the formation of sand plates (Beets, van der Valk, and Strive, 1992). The transgressive coastal system changed into a regressive coastal system. Despite the continued rise in sea level, vegetation grew during non-flood periods, retaining sediment and causing land expansion seaward. These areas, with rising tides and salt-tolerant vegetation, are known as salt marshes, or 'kwelders' (Kwelders, n.d.). Kwelders are particularly suitable for agriculture, which attracted farmers to settle in these regions.

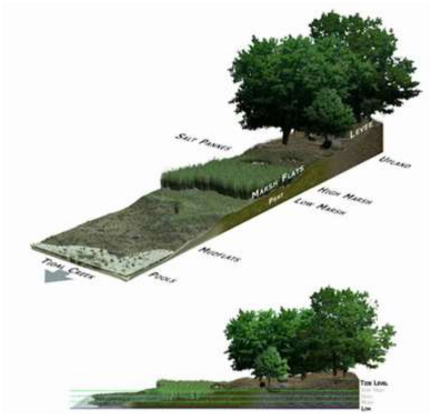


Figure 1: Animation of a salt marsh during low tide, main, high tide and very high tide. (Wikipedia-bijdragers, 2023).

2.2 Historical Mounds / Mound of Ezinge

500BC – 1100 AD

During the regressive coastal system and the emergence of salt marshes, farmers were drawn to the north of the Netherlands. However, the salt marshes occasionally flooded during winters or storm surges, necessitating higher ground for farmer dwellings (Betten, 2018). The need for elevated terrain in areas with salt marshes led to the creation of mounds, known as 'Terpen.' Mounds are artificial hills constructed from clay, manure, and sod to enable farming in the salt marshes as seen in 'Figure 3. The earliest mounds accommodated one or a few farms and were only occupied during the summer months. During winter, farmers relocated to higher ground (Betten, 2018). Over time, the mounds grew bigger into so-called mound-villages, which were permanently inhabited.

During this period, there was no regional or national policy for water protection. The mounds were self-sustaining and responsible for their own reinforcement and maintenance.

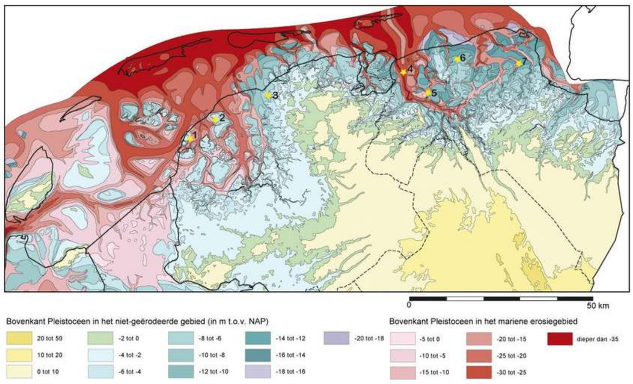


Figure 2: Pleistocene height map of North-Netherlands that show how deep the sand lies w.r.t. the NAP. Star 5 shows the location of Ezinge. (Vos, 2015, p.56)

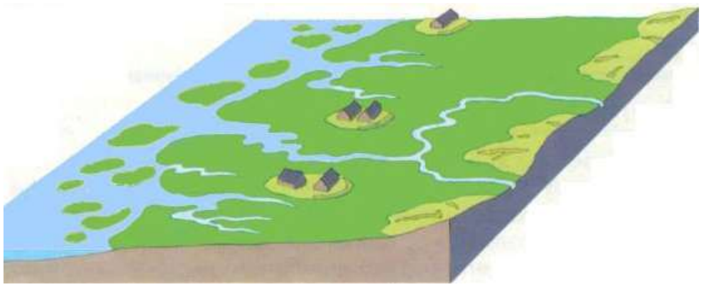
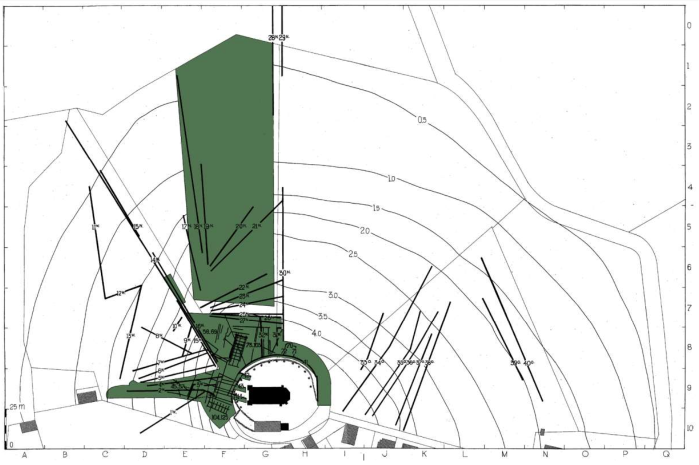


Figure 3: The forming of mounds in salt marshes (de Vree, n.d.)



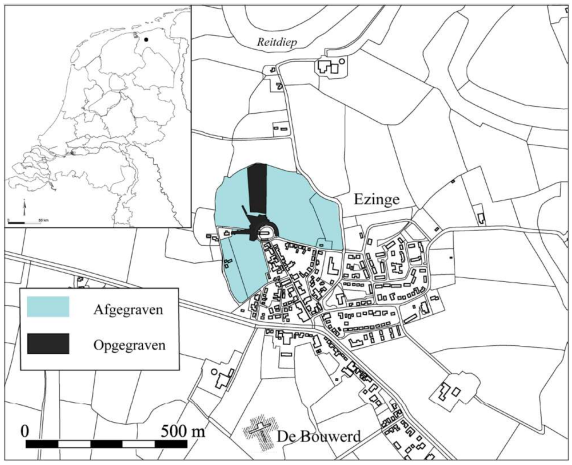
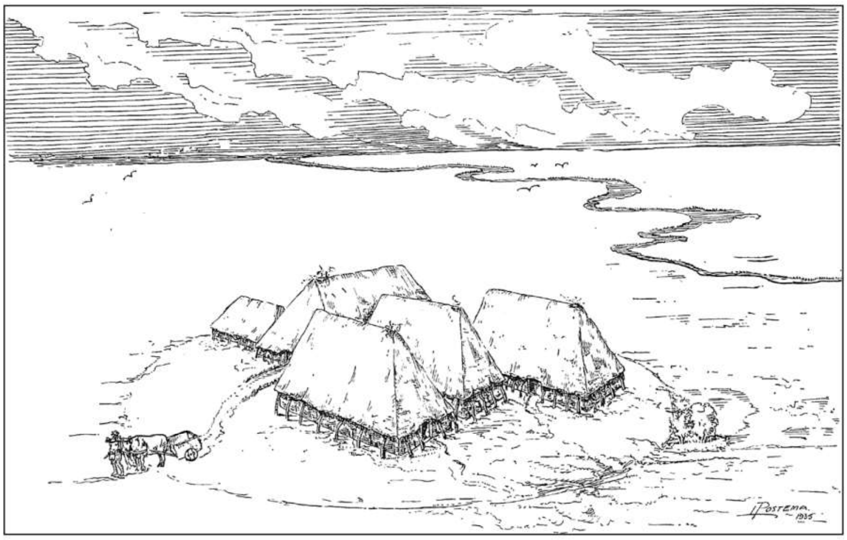


Figure 4 (left): location of Ezinge (blue what is excavated, black wat is dug up) (Nieuwhof, 2014)
Figure 5 (right) : Plan area with height lines w.t.r. NAP with in green the excavation work pits. (Nieuwhof, 2014)



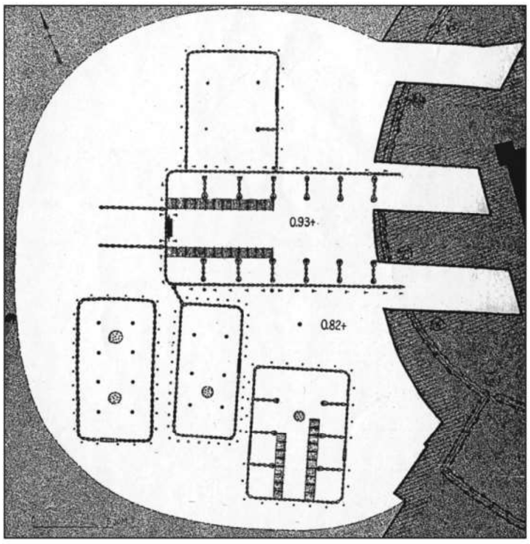


Figure 6: Reconstruction drawing of the settlement on the mound in the salt marsh landscape. (Van Giffen, 1936)

Mound of Ezinge

Archaeological findings of the earliest mounds, known as 'Terpen,' date back to 500 BC. The village of Ezinge in Groningen is the oldest of these mound villages. The paper of Nieuwhof (2014) mentions that materials unearthed during excavations conducted by archaeologist Professor A.E. Van Giffen between 1923 and 1934 in Ezinge do not only demonstrate that farmers were constructing mounds 2500 years ago but also reveal that they had sizable farms capable of accommodating both people and cattle, rather than primitive huts, as seen in 'Figure 6.

The mound, as shown with height lines in figure 5, was laid during 500BC. Typical for these mounds are there round forms that gradually phase out. The height of the mounds variate between 2 to 8 meters. Doesburg & Stöver (2018) state that as by now that in total there are more than 1300 mounds in the Netherlands.

The mounds are the most primitive and early adaptations within architecture that show a direct example on how people tried to protect their houses against rising water tides. Ezinge is the oldest, but certainly not the only mound of the Netherlands. Even now, new mounds are being built to provide new places for dwellings and can thus be seen as a valid tool to handle water.

2.3 Polder Mills / De Beemster Molens

1100AD – 1798AD

In 1255 AD, a shift occurred in the Dutch approach to water management. In the 12th century, there were three major floods: one in 1134, one in 1164, and the largest in 1170 (van de Ven, 1993). Following these disasters, the Dutch were forced to collectively take safety measures. As mentioned in the book by the Historisch Genootschap & Van der Linden from 1988: *"The very severe storm surge of 1134 caused so much havoc in southwest Netherlands that people were forced to take collective safety measures. They began constructing water barriers that had to protect not just one local community but sometimes entire islands from extremely high sea water levels."* (p. 537). This marked the first instance of collective water management on a regional scale. However, the organizations that resembled water boards at this time were primarily locally organized. This changed in 1255 when Count Willem II of Holland established the first water board: De Heemraden van Spaarndam (Van Rijnland, 2021). This marked the beginning of the Waterschappen, an institutional entity of the Dutch government solely responsible for protecting against water.

In the late Holocene, sand dunes and the regressive coastal system were forming, resulting in the drying of land behind the beach ridges. The salt marshes behind the new beach ridges became increasingly fresh with the influx of rain and river water. Due to the increase in fresh water, extensive swamp forests were able to develop in these wet conditions (Bierma et al., 1988). This led to the formation of what is known as Hollandveen i.e. Dutch peat. This peat is composed of the remains of various types of plants and can be used as fuel.

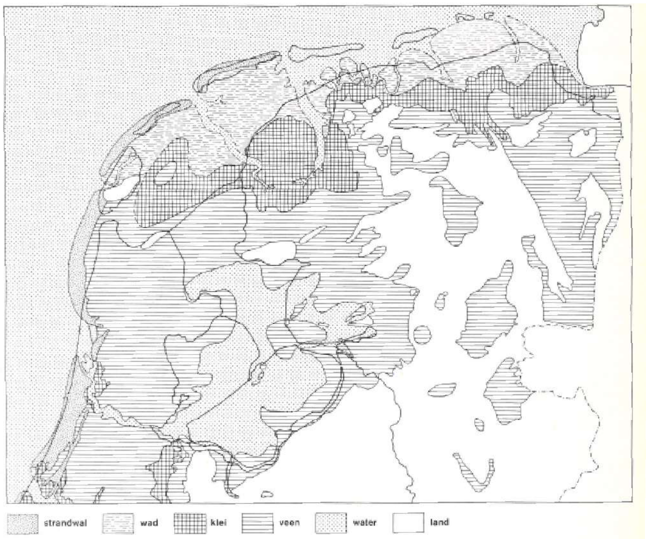


Figure 7: the forming of peat behind the beach ridges. (Bierma et al., 1988, page 11)

Around 1100, cities in the Netherlands began to expand, leading to increased agricultural needs. More land was required, which led to farmers digging ditches to drain water from the peat (van Beusekom, 2007). The then drained peatlands were transformed into agricultural areas, resulting in a decline in the elevation of the meadows. This process of winning peat and converting meadows into agricultural fields, known as 'polderen' in Dutch, lasted for several centuries.

Later, the lower grounds were protected by dikes until the grounds were too low for the water to flow away. The solution for this problem presented itself around 1400 with the invention of windmills capable of pumping water from lower to higher ground. These so-called polder mills allowed for the drainage of larger areas. One of these polder projects is The Beemster Molens.

The Beemstermolens

In 1608, during the Dutch Golden Age, a group of businessmen formed a new company: De compagnie der Bedijkers to realise the reclamation of de Beemster. (Leeghwater, 1973). The reason for the reclamation: making profit with the land that comes free for agriculture, as seen in 'Figure 8 and 'Figure 9: The Beemster before and after the reclamation. Although the process of polderen had been ongoing since the 12th century, the Beemster project was unique in its scale. It involved reclaiming a total of 7,650 hectares of land and pumping away 140,000,000 cubic meters of water.

In 1608, the company ordered 16 windmills for the Beemster project. By 1612, a total of 42 windmills had been installed. However, a problem arose with the Beemster reclamation: the need to lift water over a total height of 4.5 meters, while the polder mills were only capable of lifting water up by 1.5 meters due to the design limitations of the paddle wheel, as seen in 'Figure 10 (Schultz, 1992). The wind set the wheel of the mill in motion, which in turn motioned the paddle wheel to pump water upwards. To pump the water 4,5 meter in height, multiple canals and basins had to be dug, as shown in Figure 11. The water pumped up from the polder into a low basin, then further pumped into a middle basin, and finally into a ring canal with a total distance of 42 kilometers around the Beemster. Within 4 years, entire Beemster was laid dry and the land could be sold to farmers. The project was a success (Leeghwater, 1973).

Even though the Beemster project was completed in 1612, it continues to stand as a prime example of how the Dutch advanced in implementing water management on a larger scale from 1100 to 1798. Investors worked together throughout different companies to reclaim a total of 7,650 hectares of land and pump away 140,000,000 cubic meters of water. Additionally, a dike with a span of 42 kilometers was constructed. Remarkably, all of this was achieved within four years, an achievement that remains remarkable even by today's standards In 1999, the Beemster is listed on the UNESCO world heritage list (Droogmakerij De Beemster (Beemster Polder), n.d.).

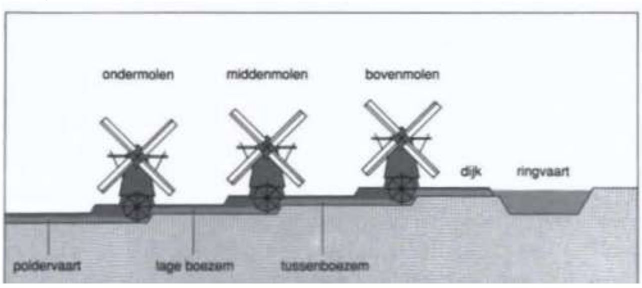


Figure 11: principle of pumping up the water via multiple canals into the ring canal. (Schultz, 1992)

Figure 8: De Beemster before it was reclamated. (Noorderkwartier, 2023)

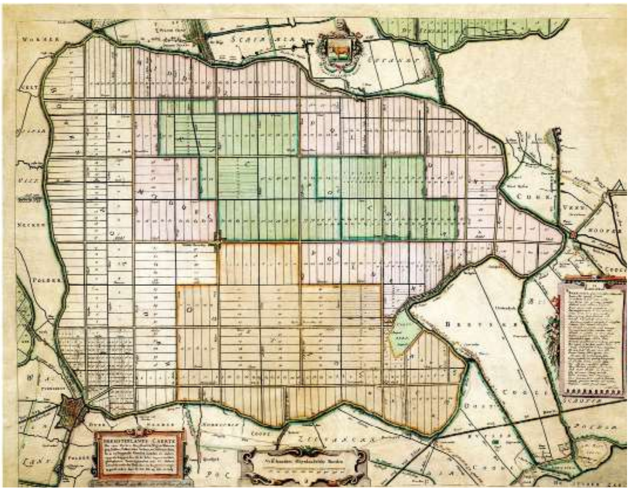


Figure 9: De Beemster after reclamation, drawn by Lucas Sinck in 1625 (Noorderkwartier, 2023)

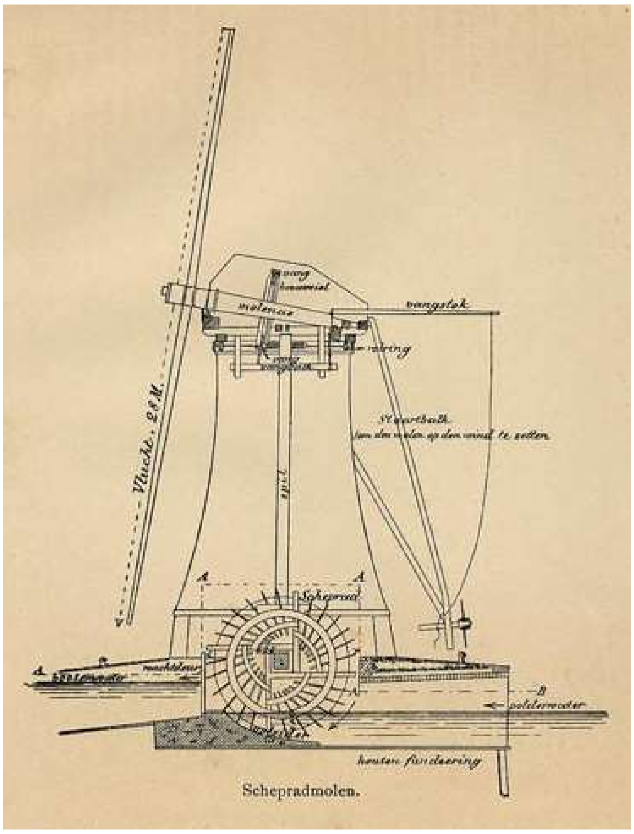


Figure 10: paddle wheel mill as used by the Beemster to pump the water. (Gardien, n.d.)

Figure 25: Painting of Schermer mills that show a similar sight on the Beemster mills must have looked like. (Alphenaar, n.d.)

2.4 Steam Pumping Stations / Steam pumping station Cruquius

1798AD – 1918AD

1798 marks the year of the founding of the Rijkswaterstaat, under the name of Bureau for Water Management (Ministerie van Infrastructuur en Waterstaat, 2024). Over the centuries, the condition of the dikes and riverbeds were neglected and weakened, which led to disastrous floodings in the 17th and 18th century. Van Koningsveld (2008) states in his paper: "*The seventeenth and eighteenth centuries were not without problems, as storm surges occasionally still had disastrous consequences (e.g., 1625, 1686, 1717, 1775/76, and 1776/ 77). Equally severe river floods occurred in 1608, 1651, 1725, 1741, 1757, 1784, and 1799.*"(p. 372). Due to the large amount of damage, a national approach was needed. In 1799, the parliament passed an instruction which made the Minister of Internal Affairs in charge of the management of the dikes, roads, water and supervision over the waterboards (Lintsen et al., 1998). In 1848, during the constitutional revision of 1848 led by Thorbecke, the Board of water management was changed into Rijkswaterstaat (Lintsen et al., 1998).

The 18th and 19th century also mark the time period in which the Industrial Revolution took place. This influenced the way the Dutch were able to approach the water. Technical innovations like steel, steam and electricity resulted in new possibilities for water management. Infrastructure, mechanics and advanced technologies were introduced to protect and improve water management (Linsen et al., pp: 97-128).

Reclamation of The Haarlemmermeer by the Steam pumping station in the Cruquius

One of the initial projects of the water department was the reclamation of the Haarlemmermeer. The lake, with its enormous size of 18,000 hectares, posed a hazard to its surroundings. In 1813, the department became involved for the first time with plans to reclaim the lake (Lintsen et al.). However, as is often the case in water management, it took a catastrophic event to take action. In 1836, two major floods occurred, which led King William I to initiate the Haarlemmermeer drainage (Van Der Pols & Verbruggen, 1996).

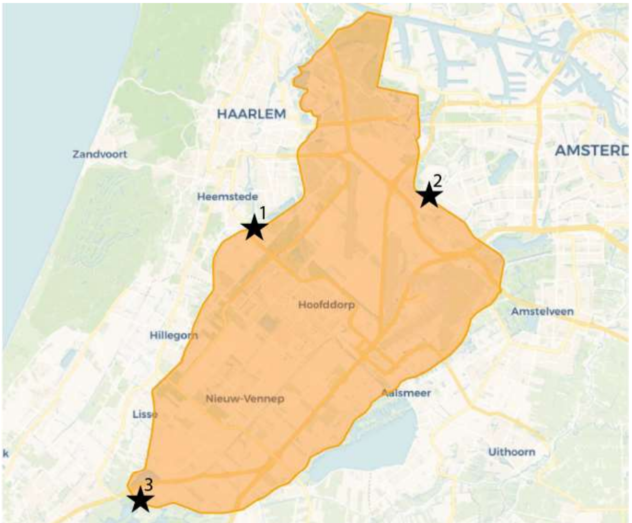


Figure 12: Waterschap Groot-Haarlemmermeer with the location of the steam pumping mills, with 1: Cruquius, 2: Lynden and 3: Leeghwater. (Buurtje.nl, n.d., edited by: Pim Braakhuis, 2024)

In May 1840, thousands of workers began digging the ring canal of the Haarlemmermeer. Over 60 kilometers of dikes and canals were dug and built (Gevers Van Endegeest, 1843). By 1848, the canals were completed, and the construction of the mills commenced. Due to the industrial revolution, steam emerged as an alternative to wind power. Although there was still debate within the Rijkswaterstaat regarding the use of wind versus steam, the Rijksbouwmeester ordered the Haarlemmermeer to be drained by three steam-powered pumping stations. One of these stations was the Cruquius, named after one of the project's initiators, Nicolas Samuel Cruquius (Hoeksema, 2007).

The Cruquius, made in 1849, was the second pumping station of the three in total. The first station, the Leeghwater, used 11 cylinders which pumped the water into the ring canal. The Cruquius station and Lynden station only used 8 cylinders. The Cruquius houses the world's largest steam engine with its main cylinder having a diameter of 3,66m (Geschiedenis Van Het Gemaal, 2020). The building is made in neogothic style, which is still original today. Each of the 8 pumps were able to lift up 8000 liter water to 5m per stroke and were able to perform 5 strokes per minute which meant that it was able to pump up 320.000 liter of water per minute (Hoeksema, 2007). As seen in figure 13, the water flowed into the the building, which was then lifted up 5meters by the pumps. If the water was lifted up, the locks opened which allowed the water to flow into the ring canal.

It took the three pumping stations a total of 39 months to lay the lake dry (Hoeksema, 2007). In 1933, the building was put out of operation. As by 1973, it was converted into a museum of drainage.

The establishment of Rijkswaterstaat in 1798 marked a turning point in Dutch water management, forcing the Dutch into a national approach due to disastrous floodings. The Industrial Revolution of the 18th and 19th centuries brought technological advancements, enabling larger projects like the reclamation of the Haarlemmermeer. Initiated in response to major floods in 1836, the project utilized steam-powered pumping stations, including the iconic Cruquius, to drain the lake by 1849. Today, the Cruquius symbolizes the Dutch ingenuity and serves as the museum for Dutch drainage.

Figure 13: functioning of the Cruquius pumping station. (Cruquius-Gemaal | Jan Egas, n.d.)

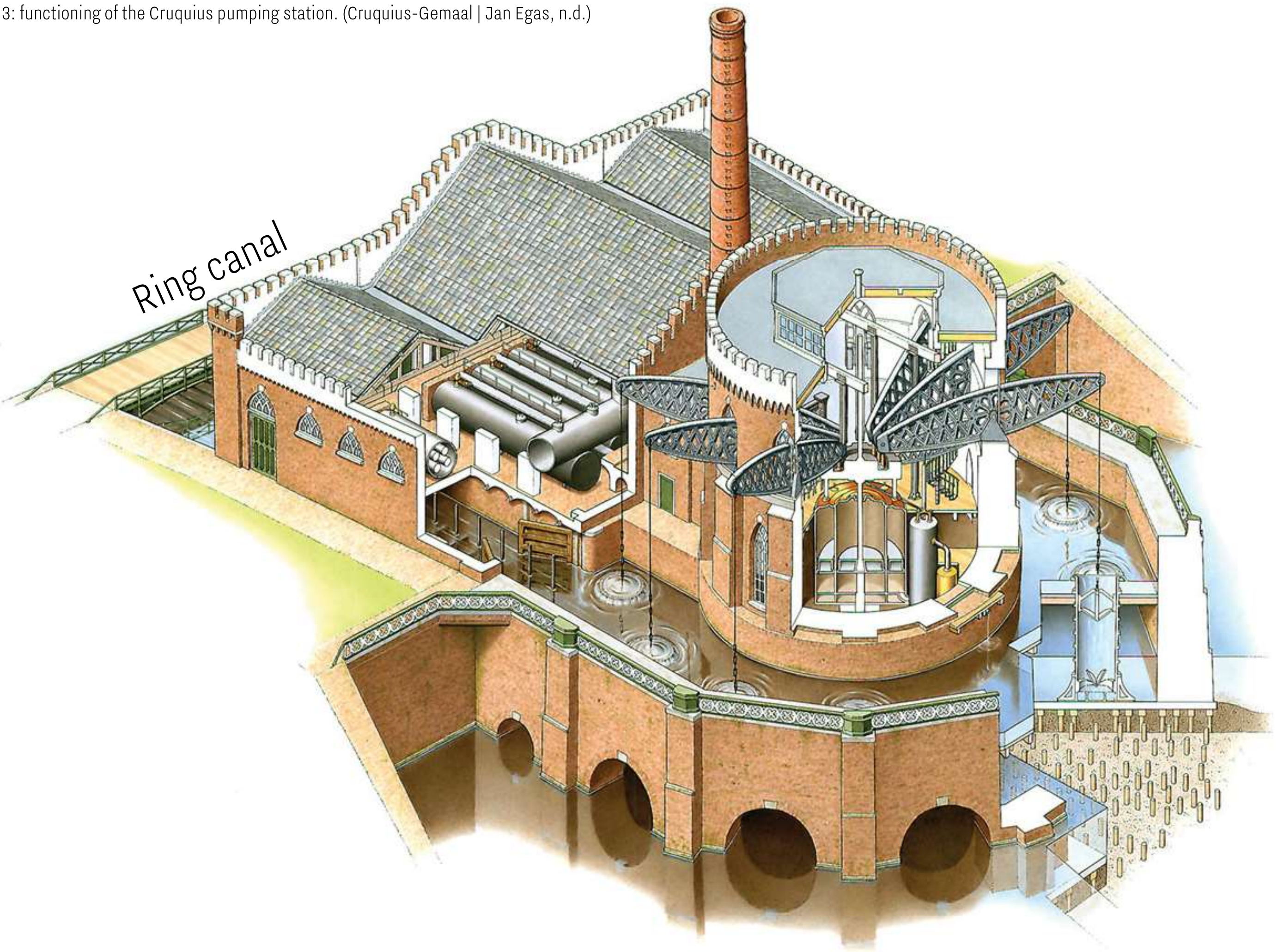
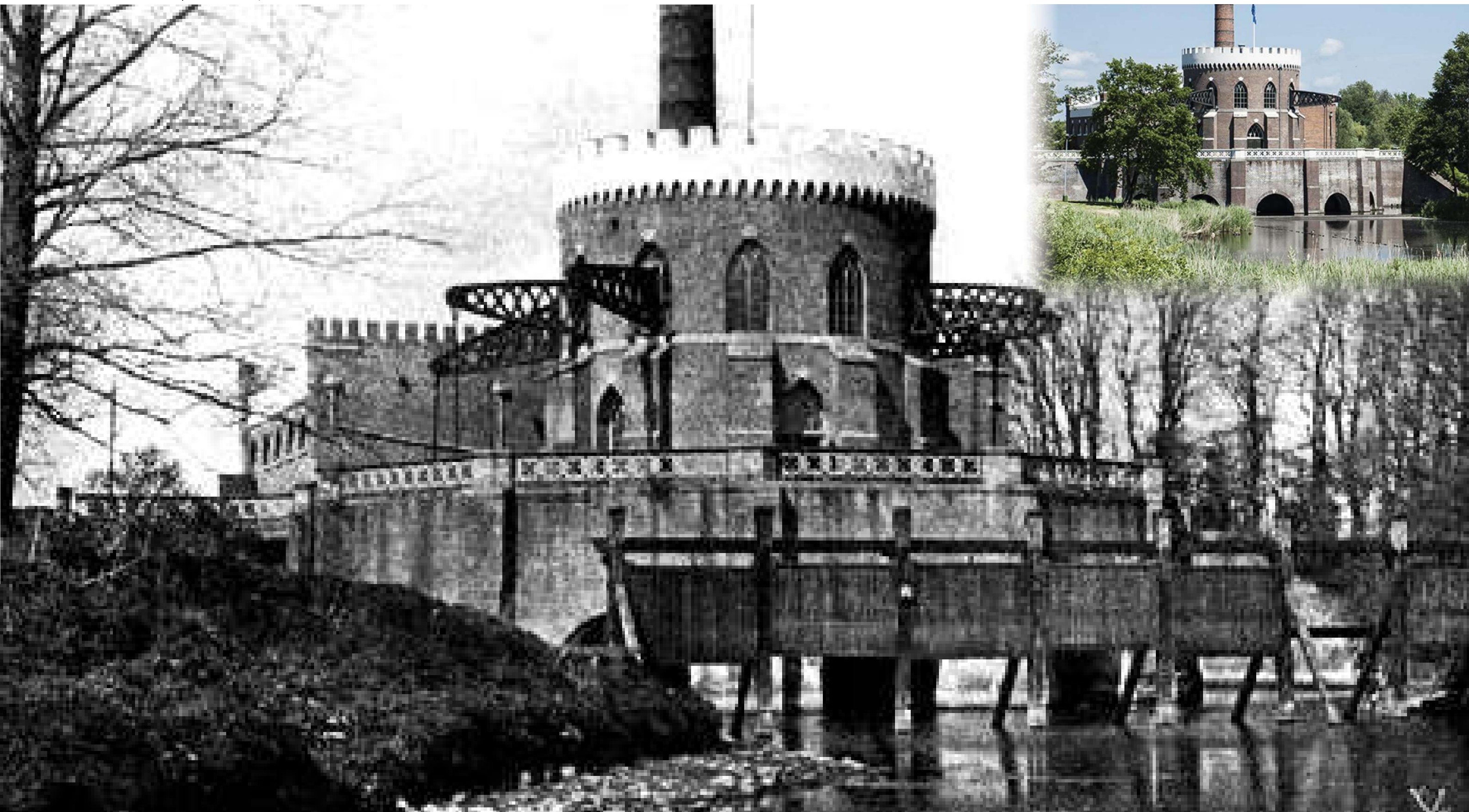


Figure 14: Comparison of Cruquius in 1933 and now. (De Werktuigen Van Het Stoomgemaal Cruquius Van De Haarlemmermeer Door Prof. Ir. J.C. DIJXHOORN, n.d.) (Vereniging Vrienden Van De Cruquius, 2023)



2.5 Zuiderzeeproject

1916-1953AD

The twentieth century is known as the era of technology. With the reclamation of the Haarlemmermeer, the Dutch were convenient they had the control over the water (Berendse, M. J., & Brood, P. 2022). Since the 17th century were there plans to reclaim the Zuiderzee due to its constant hazard of floodings (Ministerie van Infrastructuur en Waterstaat, 2024c). In the late 19th century, concrete plans began to take shape under the leadership of engineer Cornelis Lely. In 1913, Lely succeeded in elevating the Zuiderzee project to a cabinet policy (Berendse, M. J., & Brood, P. 2022). Armed with technological advancements and knowledge gained from previous projects such as the Haarlemmermeer, the Dutch were convinced to succeed with the largest reclamation in the history of the Netherlands.

Like the Haarlemmermeer, the reclamation of the Zuiderzee was accelerated by the government in response to catastrophic events. The storm surge of 1916, known as the Stormvloed van 1916 or de Zuiderzeevloed, resulted in numerous breaches of dikes along the edge of the Zuiderzee. Additionally, the implications of the First World War, which created a demand for more agricultural land due to food shortages, triggered the government to approve the Zuiderzeewet (van Koningsveld, 2008). This framework law, passed in 1918, had two main objectives: the closure of the Zuiderzee and the conversion of parts of it into agricultural land. To carry out these objectives, an institute called the Dienst van de Zuiderzeewerken was established (Ministerie van Infrastructuur en Waterstaat, 2024c).

De Afsluitdijk

One of the projects of de Zuiderzeewerken was the Afsluitdijk: an enclosing dam between the Wadden sea and the Zuiderzee to create a new lake: het Ijsselmeer. In essence, the function of the Afsluitdijk was to protect the Dutch against floodings (Ministerie van Infrastructuur en Waterstaat, 2024c). Besides protection, the dike was of importance for freshwater supply, ecology, traffic and transport by road and water. The location of the Afsluitdijk was not determined within the law and was thus interpretable for architects and engineers. In the 19th century multiple plans were presented, as seen in figure 15.

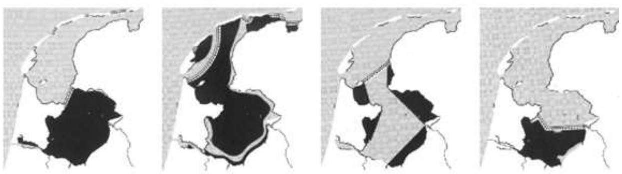


Figure 15: designs for the afsluitdijk. From left to right: 1848. Kloppenburg en Faddegon, 1849. Van Diggelen, 1865. Beijerink, 1870. Opperdoes Alewijn en Kooy. (Afsluitdijk, n.d.)

Figure 16: Plan-Lely in 1891. (Ontwerp Tot Afsluiting Der Zuiderzee, 1892)

None of the previous plans managed to gain government approval, and the idea of closing off the Zuiderzee was set aside. This changed with the arrival of Lely. As illustrated in 'Figure 16, Lely expanded on Beijerink's design, particularly focusing on the location of the Afsluitdijk. His plan differed from Beijerink's in terms of the reclamation of land within the Zuiderzee.

The plan consisted of different stages for reclamation, beginning with the construction of the Afsluitdijk. Although the operation to close off the Zuiderzee officially commenced in 1920, actual construction of the Afsluitdijk didn't begin until 1927 (Afsluitdijk, n.d.). The project consisted of two main components: a 2.5km dike connecting North-Holland to the island of Wieringen, and a 30km dike extending from Wieringen to the Frisian town of Zurich. The project marked a significant engineering project, given the absence of technical precedents. Due to its enormous size, technological developments were needed.

One of these novelties within the project was the use of a new material: boulder clay i.e. Keileem, founded by the Rijks Geologische Dienst by a dam build in 1920 (Afsluitdijk, n.d.). Boulder clay contains rocks that enable the material to withstand high flow rates. Figure 17 illustrates a cross-section depicting the construction of the dike with this material.

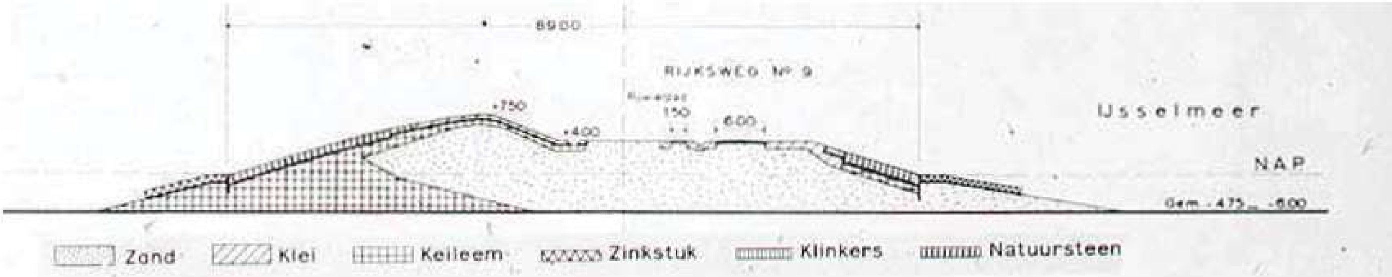


Figure 17: profile of an average section of the Afsluitdijk like it was built (Feddes/Olthof landschapsarchitecten bv et al., 2013)

In addition to the innovative material used in the dike itself, locks and drainage sluices were constructed along the dike. A total of 25 sluices were built, divided into 5 complexes, with one of the most famous being the Stevinsluizen, designed by architect Dirk Roosenburg. The purpose of these sluices is to discharge water from the Ijsselmeer into the Wadden Sea during low tide if the water level becomes too high. Along the sluices are also other buildings: There is a monument, designed by M.W. Dudok, at the location where the dike closed and multiple bunkers due to the military importance of the Afsluitdijk.

On May 28, 1932, the last closing hole, the Vlieter, was closed. The closure was a fact, the Zuiderzee was now referred to as the Ijsselmeer (Ministerie van Infrastructuur en Waterstaat, 2024c). It took another year to finish up on the roads and strengthen the dike. In 1933, the regional road over the dike was opened for the public.

The completion of the Afsluitdijk symbolized the Netherlands' mastery of water management and engineering expertise. With its closure, the Dutch demonstrated their capability to regulate tides and reclaim land from the sea on an unprecedented scale. Led by Cornelis Lely, the project was not only unique in size but also in the Dutch approach to water management. Unlike previous endeavors, the Afsluitdijk became a national project. Arranged from within the Rijkswaterstaat, an extra implementing organization was set up, solely for completing the Zuiderzee projects. This illustrates the depth and organization of water management within the Netherlands' governance structure.

The architecture of the Afsluitdijk represents centuries of knowledge in water management. With innovative materials and features such as locks and drainage sluices, the Afsluitdijk not only served as a barrier against floods but also provided a crucial source of freshwater and a new transportation route from North-Holland to Friesland, holding significant cultural value for the entire lowlands.

Figure 26: The building of the Afsluitdijk in process. (Historiek & Redactie, 2024)

2.6 Conclusion

Within this chapter, four different cases throughout the history of the Netherlands, dating from 500BC until 1953AD, were examined. Every case symbolizes a certain period that is relevant for understanding how the Netherlands have changed their landscape and water management over the ages. The cases focused primarily on what the background for that time-period was, and how events led to changes within water management. The architectural cases were the results or novelties of the decisions made within water management.

Beginning with the earliest case, the formation of mounds in salt marshes around 500BC, exemplifies the connection between the Dutch landscape and its inhabitants. As farmers were drawn to the fertile salt marshes of the north, they adapted by constructing mounds to protect against flooding, laying the groundwork for a culture of water management. In this period there wasn't a regional or national policy for protecting against water during this period. The mounds were self-sufficient and responsible for reinforcing and repairing the mounds. The case of Ezinge serves as a prime example of an architectural innovation of that period. The project is one of the oldest mound villages in Groningen and reveals how the inhabitants protected themselves against rising tides.

Moving forward to between 1100AD and 1798AD marked the beginning of water management on a larger scale. With the technical innovation of windmills, the Dutch found a way to use wind power to drain water from reclaimed land. This resulted in that the Dutch were able to reclaim land from the water and explains how the system of polders, agricultural development and urban growth was forming within the borders. The Beemster represents this development of water management and land reclamation. Initiated during the Dutch Golden Age, the reclamation of the Beemster exemplifies how the Dutch were combining their strength and management on a larger scale, with a network of multiple windmills working together to drain larger areas of land for agricultural use. Even though the project was finished in 1612, it still serves as a prime example on how the Dutch were advancing in implementing water management on a larger scale during the period from 1100 to 1798.

The period from 1798 to 1916 marks the beginning of water management on a national scale in combination with even more technological advancements. Unlike earlier cases where water management was primarily locally arranged, the involvement of Rijkswaterstaat was an huge shift towards a more centralized approach to water management. As the Dutch transitioned from wind-driven polder mills to steam-powered pumping stations, the need for a centralized organ became increasingly important. This led to the establishment of Rijkswaterstaat in 1798.

The Cruquius pumping station, built in 1849, represents this development in Dutch water management, and is a symbol for technological innovation in architecture. What sets the Cruquius apart from earlier cases is its steam power, marking a shift from traditional wind-driven methods. The steam allowed for greater efficiency and scalability within reclamation. The Cruquius pumping station serves as a great example for the Dutch commitment to innovation and new technologies and possibilities within scalability.

Similar is the period from 1916 to 1953, which further illustrates how deep and well-organized water management had grown into the governing body of the Netherlands. New institutes and even laws were getting surpassed by the Dutch authorities. In response to the Stormvloed of 1916 and growing concerns over flooding and land scarcity due to the first world war, the Dutch government passed the Zuiderzeewet in 1918, freeing up the way for the establishment of the Dienst van de Zuiderzeewerken.

Symbolic for this period is the construction of the Afsluitdijk, finished in 1932. A monumental achievement in Dutch water management on a national scale. Unlike the earlier more local projects, the project aimed to get control over an entire sea. The Afsluitdijk, a 32-kilometer-long dike, symbolizes the knowledge and expertise that the Netherlands gotten throughout the centuries. By enclosing the Zuiderzee and creating the Ijsselmeer, the project not only protected against flooding but also facilitated land reclamation and freshwater supply for agricultural and urban use.

Across these four cases, a connection between them is seen: the relationship between events, water management strategies, and architectural innovations, as seen in the timeline on page 17. The Dutch have a rich history concerning water management. It is full of events, innovation, and adaptation. From ancient mounds to a 32km long dam, each architectural intervention reflects a never-ending effort to protect its land and control the water. Each period represents a response to environmental factors, where the technological advancements required a scale up in water management. All this combined explains the Dutch landscape and identity.

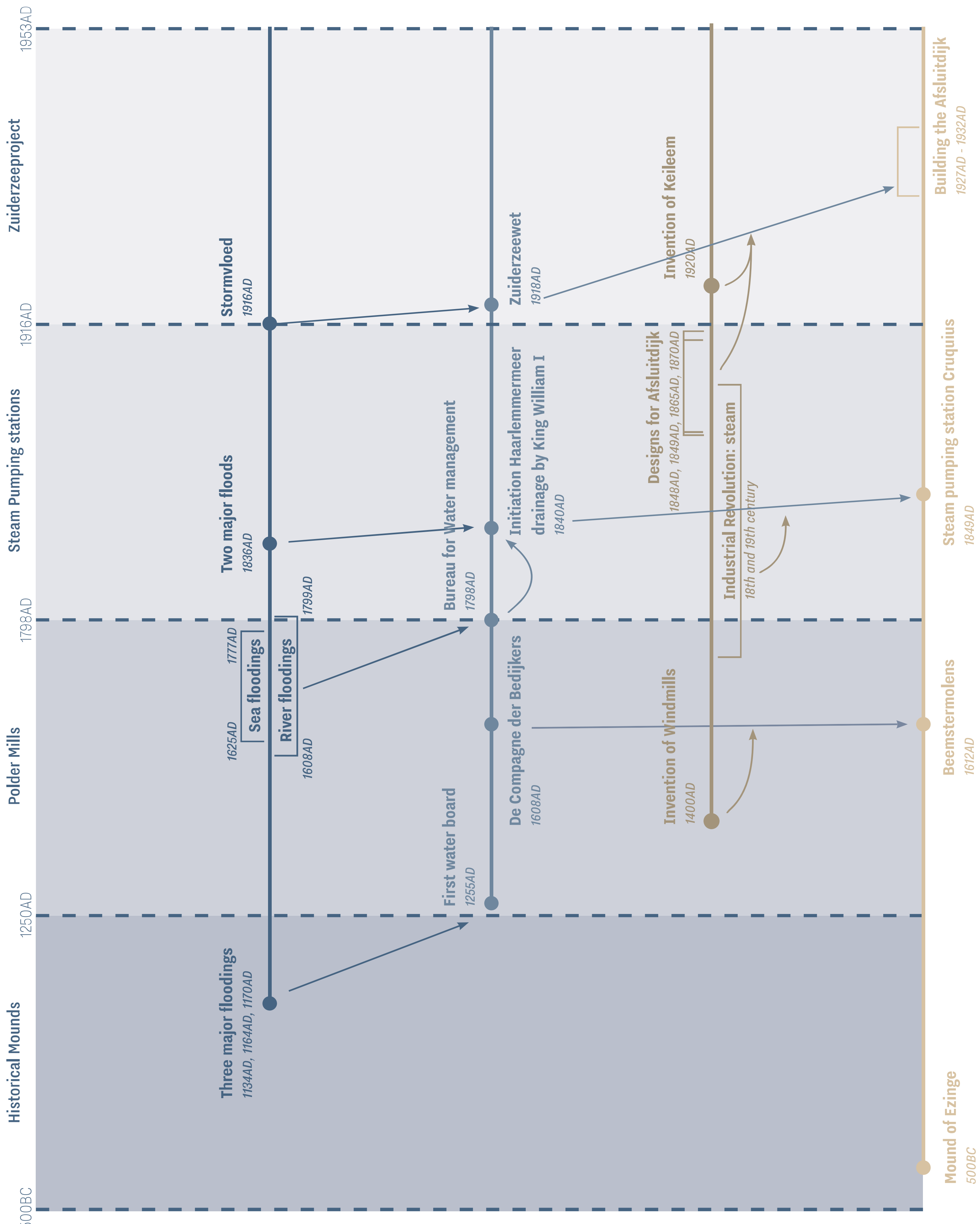


Figure 28: Timeline of events, water management, and architectural innovations before 1953 (Own source)

3. Historical adaptations after 1953

Two case-studies with a shifting focus to accommodate water after 1953

In the previous chapter, a compact overview was provided of how the Dutch learned to live with and protect themselves against water until 1953. When comparing the cases, a clear correlation between water-related events, water management practices, and architectural innovations was found. had developed into a world leading example with even governmental institutes on how they could impose the water to their will, or so they believed. However, this newfound, somewhat arrogant, self-image as masters over water was shattered in 1953 with a new flooding (Berendse & Brood, 2022).

In the night of 31 January to the first of February 1953, the biggest Dutch national disaster of the 20th century takes place. Within one night, the seawater levels pushed up 4 meters above average which caused over 150 dike breaches divided over the provinces of Zeeland, South-Holland, and North-Brabant. Over 150.000 ha ground gets flooded and 1836 people drown (Berendse & Brood, 2022). The damage is enormous with a total cost of 1.5 million Dutch guilder. It takes until November 1953 to close the last breach. How could it be that, with all their knowledge, the Dutch were unprepared for such circumstances?

This chapter will examine the second part of the main question of this thesis: "*why did the strategy change after 1953 from 'keeping the water out' to 'learning to live with water?".* Two new case-studies will be introduced: De Oosterscheldekering (1976) and Ruimte voor de rivier (2007). Both studies explore how the strategies of the Rijkswaterstaat evolved since 1953 and what drove the Netherlands into accommodating the water back into their borders after centuries of reclamation. Before delving into these case studies, a comprehensive overview of the Delta Committee and its role in water management is made.

3.1 The Deltaworks

1953AD - 1993AD

The Watersnoodramp of 1953 was such a catastrophic event that, as seen in Dutch history before, it acceleration of changes within the government (Lintsen et al., 1998). Less than three weeks after the storm, Waterstaat Minister J. Algera established a new committee: the Delta Committee, i.e. Deltacommissie. Consisting of experts, this committee was tasked with advising the ministers of Rijkswaterstaat. As described in the inventory in 1974 by the Delta Committee itself: *"The work of the Delta Committee mainly concerned the design of plans to protect against high storm surge levels and the improvement of the freshwater supply in the large river basins"* (Misérus, 1974, p.8). Over a period of eight years, the committee worked on a comprehensive plan aimed at ensuring that the Watersnoodramp would never occur again, resulting in the Delta Act.

The Delta Act consisted of five interim pieces of advice and one final advice, presented to the government in 1960 (Misérus, 1974). Within the Delta Act were the Delta Works, i.e. Deltawerken: 14 interventions that collectively formed the strongest defense system of the Netherlands against high sea water levels (Ministerie van Infrastructuur en Waterstaat, 2024a). These flood defenses consisted out of five storm surge barriers, two locks, and six dams, designed to reduce the probability of flooding to 1 in 4000 per year (Ministerie van Infrastructuur en Waterstaat, 2024a). In 1958, a law similar to the Zuiderzeelaw was passed to formally record the Delta Act: the Deltawet.

The committe was successfully disbanded in 1961, but the work was far from over. In total, it took over 40 years to realize the Delta Act, with the Maeslantkering and Hartelkering being the last two projects completed in 1997 (Ministerie van Infrastructuur en Waterstaat, 2024a). During these 40 years, the Deltadienst, a division within the Rijkswaterstaat, was responsible for implementing and overseeing the projects.

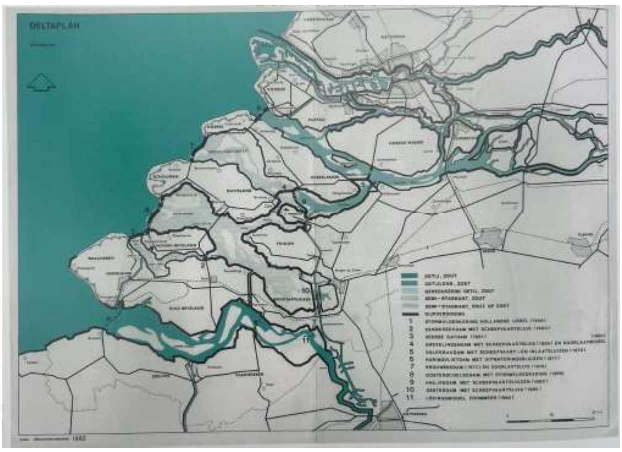


Figure 18: Map of Southwest-Netherlands, with mention of tides in the different waters and with the planned and realized Delta projects in 1982. (Berendse & Brood, 2022, p. 194)

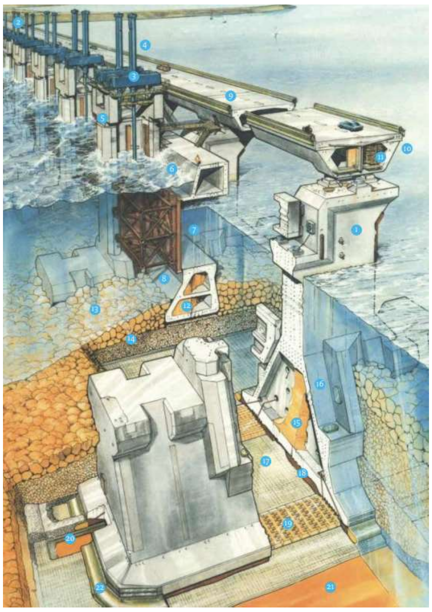
Oosterscheldekering (1976)

The Oosterscheldekering, completed in 1986, stands out as the most renowned Deltawork due to its size and strategic significance in defending against water (Ministerie van Infrastructuur en Waterstaat, 2024d). Originally, the Oosterschelde is a nature reserve unique in the Netherlands. It functions as an estuary where nature can flourish: fish use it as a nursery, while oysters and mussels grow there in large numbers. Swallow, gulp, and sandbanks provide habitats for birds (Rijkswaterstaat Zee en Delta & K. Steenepoorte, 2016). Closing off the estuary with a dam would have resulted in the disappearance of this nature reserve, leading to public resistance. Under pressure from this resistance, the Dutch government was compelled to conduct new studies on the feasibility of keeping the Oosterschelde open with a closable storm surge barrier. In 1979, parliament decided to proceed with the construction of the storm barrier, reaching a compromise between left- and right-wing parties (Van De Ven, 1993).

The Oosterschelde barrier is unique, requiring specialized approaches in every aspect of its construction. Before the start of the barrier itself, the seabed was completely transformed into solid ground using new techniques (Rijkswaterstaat Zee en Delta & K. Steenepoorte, 2016). Subsequently, 65 colossal concrete pillars were fabricated in a factory specifically built for the Oosterscheldekering. These pillars ranged in height from 30 to 40 meters and were transported to the construction site using specially developed ships. Upon arrival, they were installed by other specialized ships, which placed enormous stones against the concrete to enhance stabilization. In total, over four years, five million tons of rocks were placed.

Once the main part of the storm surge barrier was completed, the final phase of the project involved the installation of traffic tunnels and gates. The gates varied in height from 6 to 12 meters, with the largest gate weighing a total of 480 tons. Closing this gate takes 82 minutes (Rijkswaterstaat Zee en Delta & K. Steenepoorte, 2016). A complete overview on the different parts is seen in the section of Figure 19.

The installation symbolizes how enormous and long-lasting the Deltaworks were to prepare and develop. With the completion of the Oosterscheldekering, Queen Beatrix declared in 1986 that the Deltaworks were finished (Ministerie van Infrastructuur en Waterstaat, 2024d). In total, 12 billion guilders were spent on all the works combined by Dutch society. The works brought enormous changes for people, but also for the flora and fauna. With the placement of all the new defense mechanisms, the natural rhythm and environment of the area were drastically changed. That is why the Oosterschelde is such a unique work: besides focusing on protecting the land, it also emphasizes learning to live with the water and respecting the flora and fauna, even if it costs more.



1. Pillar
2. Rubble mound dam
3. Beam for suspension of moving parts
4. Hydraulic cylinders
5. Extension piece
6. Top beam
7. Gate
8. Threshold beam
9. Traffic road
10. Traffic tunnel
11. Pipe gallery
12. Sand fill
13. Top layer of threshold
14. Core of threshold
15. Sand fill at pillar base
16. Stops/supports for threshold beam
17. Superstructure
18. Grout filling
19. Tile mat
20. Sub-mat
21. Compacted sand from the bottom of the Eastern Scheldt
22. Gravel bag

Figure 19: a section of the Oosterscheldekering with all different elements. (Rijkswaterstaat Zee en Delta & Steenepoorte, 2016)

Figure 27: One of the movable barrier sections of the Oosterschelde during a storm. (Rens Jacobs / Beeldbank V&W)

3.2 The New Delta Plan after the almost disasters of 1993 and 1995

1993AD – 2007AD

In 1993 and 1995, two floodings events occurred, almost repeating the dramas of the past. However, this time, the danger didn't come from the sea. In December 1993, water levels in the Rhine and Meuse rivers began to rise strongly (Berendse & Brood, 2022). Over 12,000 inhabitants had to be evacuated, and 18,000 hectares of land were flooded (Ministerie van Infrastructuur en Waterstaat, 2024f). Investigative committees concluded that the solution lay in widening and deepening the rivers. Before a definitive plan could be made, a second flooding occurred in 1995. This time, 250,000 inhabitants had to be evacuated (Berendse & Brood, 2022). There were no fatalities due to timely responses, but the fear was reawakened.

Two weeks after the second flooding, the parliament addressed the House of Representatives, resulting in the formation of a new Delta plan: the Delta Plan for the Major Rivers, or het Deltaplan van de Grote Rivieren (Berendse & Brood, 2022). There were two crucial aspects of the plan: 1. reinforcing the dikes along the Rhine and Meuse rivers, and 2. significantly expanding water storage in undiked areas (Ministerie van Verkeer en Waterstaat, 1995). While the first solution aligns logically with the Dutch long history of defending against water, the second represents a shift in strategy. No longer were they solely focused on strengthening and improving defense mechanisms; they were also considering returning land (controlled) to the rivers during flood events. This marked a significant departure from historical approaches.

Ruimte voor de Waal (2010)

Following the new Deltaplan was the key planning decision: Room for the Rivers in 2006 (Ministerie van Infrastructuur en Waterstaat, 2024f). The intention of the program was to prepare the Netherlands for extreme water levels, including higher levels in the winter and lower levels in the summer (Berendse & Brood, 2022). Due to global warming, increased meltwater from the Alps will heighten pressure on the rivers, while summer droughts will rely on sufficient water availability. Rijkswaterstaat proposed creating more "natural" water storage solutions (Ministerie van Infrastructuur en Waterstaat, 2024f). In total, 34 projects were undertaken within the program, employing various measures as shown in Figure 21. The projects aimed at creating safer and more spacious rivers, with an overview in Figure 20.

One of these measures was the dike relocation project in Lent, located in the city center of Nijmegen, where the Waal forms a narrow bend creating a bottleneck shape (Royal HaskoningDHV, 2014). During the floods of 1993 and 1995, it became evident that the bend at Nijmegen formed a vulnerable spot for the inhabitants living there. Plans were

Figure 20: Overview map of all the measures taken in the program Room for the River. (Ministerie van Infrastructuur en Waterstaat, 2024f)

made within the municipality of Nijmegen to reinforce this vulnerable area. In 2010, the municipality presented the final spatial plan, which necessitated the relocation of the dikes. In total, the dikes were moved 350 meters inland (Royal HaskoningDHV, 2014).

The relocated dike near Lent has been constructed in the form of a buildable quay. Within the 350 meters, a new secondary channel was dug, connecting downstream with the Waal again. Between the new channel and the Waal lies a peninsula with a unique river park that accommodates housing and natural spaces (Royal HaskoningDHV, 2014). Due to this newly dug channel, which is 200 meters wide, the water level decreased by a total of 34 centimeters, and the channel now handles one-third of the entire water discharge in the bottleneck area.

Similar to the Oosterscheldekering, the Cabinet was aware of the impact of the project on the inhabitants and nature. However, the municipality chose dike relocation because implementing the measure now prevents the need for a second intervention in the area later. If a further decrease in water levels on the upstream section is required in the long term, it can be achieved through various other measures outside the area of dike relocation (Royal HaskoningDHV, 2014). What is new in the relocation of Lent is the attention to the special quality of nature. One of the main objectives was to realize the potential that the nature around the Waal had to offer. This goes further than the Oosterscheldekering. The relocation of Lent purposely focuses on improving and creating water-related nature instead of merely preserving it, as seen in the Oosterscheldekering.

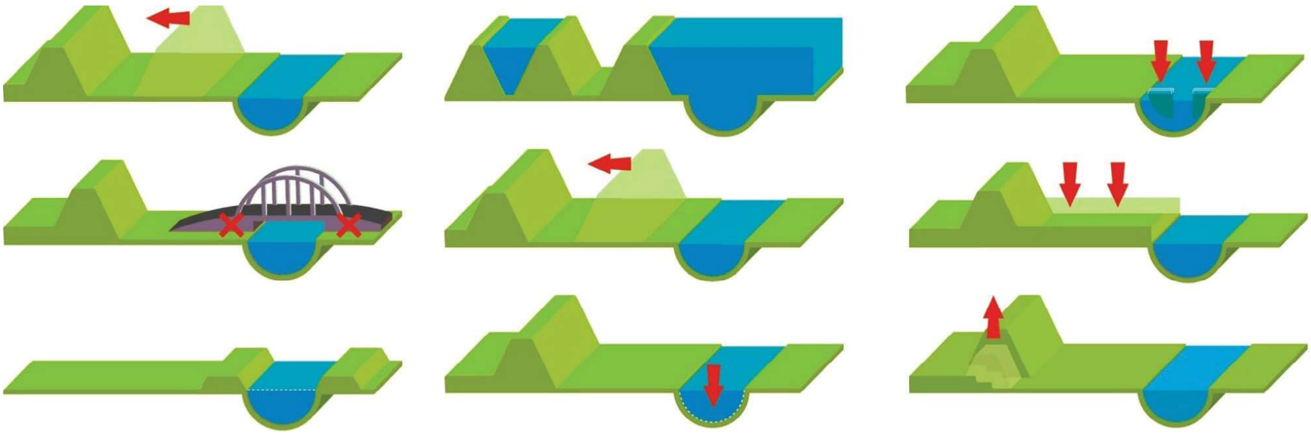


Figure 21: methods to increase safety and widen the rivers. 1. Dike relocation 2. High-water channel 3. Groyne reduction and longitudinal dams 4. Obstacle removement 5. Depoldering 6. Floodplain excavation 7. Water storage 8. Summer bed lowering 9. Dike improvement. (Ministerie van Infrastructuur en Waterstaat, 2024f)

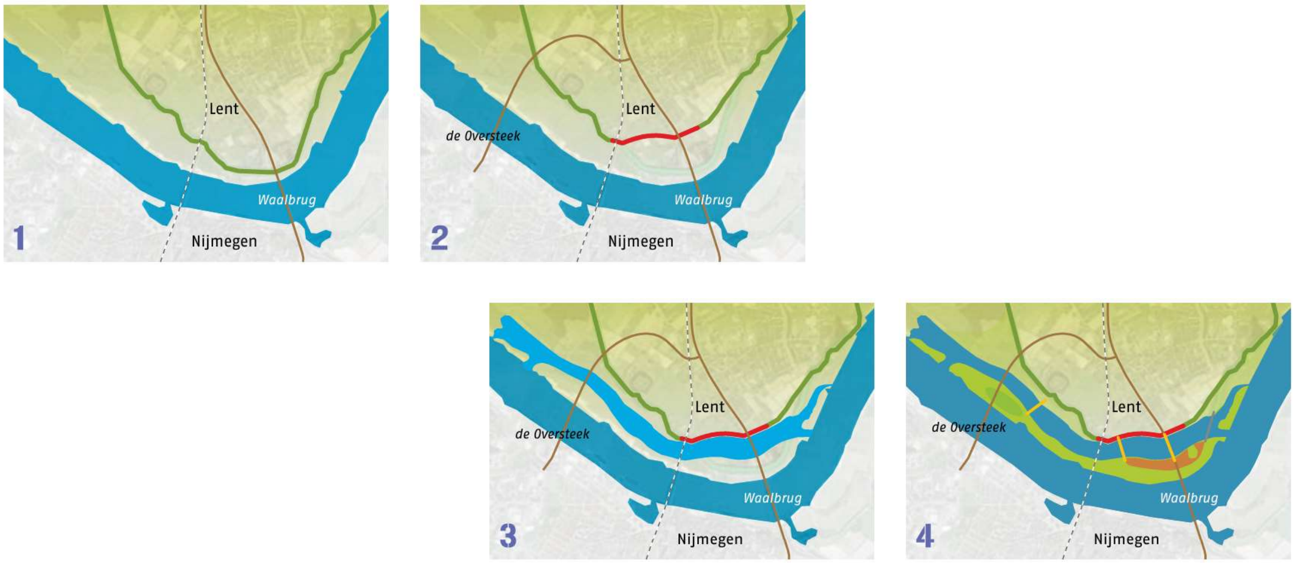


Figure 22: the four different stages of the municipality plan. (Gemeente Nijmegen et al., 2013)

Figure 23: Overview of the realised dike relocation of Lent. (Archined, n.d.)

3.3 Working together with water

2007AD – present

In 1953, the first Delta committee was installed in response to the biggest flood disaster of the 20th century. In 2007, a new Delta Committee was commissioned by the government to address the consequences of climate change (C. P. Veerman & Deltacommissie, 2008). Rising sea levels and increased river discharges force the Netherlands to prepare for extreme flooding and droughts on an unprecedented scale. Unlike the first Delta committee and other past examples, the second committee was not formed in response to an acute disaster. Are the Dutch finally learning that prevention is better than cure?

Figure 24: Areas within the Netherlands for which the committee made recommendations. (C. P. Veerman & Deltacommissie, 2008, p.18)

Both Delta committees had a common purpose: giving advice on protection for the Netherlands against rising water-levels with strategies and measures. Misérus (1974) & C. P. Veerman & Delta commissie (2008) shared a common purpose: providing advice on protecting the Netherlands against rising water levels through strategies and measures (Misérus, 1974)(C. P. Veerman & Deltacommissie, 2008). What sets the new committee apart is its additional focus on the interconnectedness of water management and its surroundings. "Where there is water, there is life" is the new crescendo of the committee. Sustainability and safety are now regarded as equal pillars for the strategy of the coming centuries (C. P. Veerman & Deltacommissie, 2008). There is also a noticeable shift in attitude towards water. Instead of viewing water as an enemy or intruder, the committee sees the possibilities that adapting to water brings:

"Adapting the layout of the country to the consequences of climate change creates new opportunities, and working with water offers excellent chances for innovative ideas and applications." (C. P. Veerman and Deltacommissie 2008, p.7)

For the implementation of the advice for a climate-resilient layout of the Netherlands, the Delta Commission developed the Delta Program, which provides concrete recommendations for the year 2050 and a clear vision for the year 2100 (C. P. Veerman & Deltacommissie, 2008). Unlike the Delta works of the first committee, no concrete plans are made. However, research findings within the advice conclude that the Netherlands are lagging current standards. Moreover, these standards are outdated, and there is a real chance that water levels will rise faster than expected. Twelve recommendations for the future were outlined in the report, and new projects must adhere to these recommendations to be approved by the authorities.

3.4 Conclusion

In this chapter, two cases were examined to look at how water management has changed after 1953. The main goal of looking into these two cases was to answer the second part of this thesis question: *"why did the strategy change after 1953 from 'keeping the water out' to 'learning to live with water?'"*. The period following the Watersnoodramp of 1953 marked a significant shift in Dutch water management strategies, moving from a focus solely on keeping water out to a more balanced approach of learning to live with water. Two case studies, the Oosterscheldekering and the Dike relocation of Lent, illustrate this transition and the evolving relationship between the Dutch and water.

The establishment of the Delta Committee in response to the Watersnoodramp led to the development of the Delta Act, which resulted in the Delta Works: a series of engineering projects aimed at protecting the Southwest of the Netherlands. However, the realization of the Oosterscheldekering (1986), with its innovative approach of combining flood protection with preserving the unique natural environment of the Oosterschelde estuary, marked a turning point towards more nuanced water management strategies with eye for nature.

Even more shifting was the Dike relocation of Lent in (2010), a project that was part of the Room for the River program. It exemplifies a shift towards accommodating water within urban landscapes while enhancing natural habitats and recreational opportunities. By relocating the dike inland and creating a secondary channel, the project not only took on flood risk but also improved the cultural value of the area and biodiversity along the river.

Both these case studies highlight a broader shift in mindset from viewing water as a threat to embracing it as a resource and opportunity. The Dutch approach to water management has evolved from a focus on defense to one of adaptation and collaboration with nature. This mindset is further emphasized by the recommendations of the second Delta Committee (2007) in a new advice called: 'Samenwerken met water'. The advice emphasizes sustainability, innovation, and a better understanding of water management in the face of climate change.

In conclusion, the shift in water management strategy after 1953 from "keeping the water out" to "learning to live with water" is related to the limitations of traditional defense approaches in the face of rising water levels. The devastating impact of the Watersnoodramp forced the Dutch authorities to once more look at their approach to water management to find more sustainable and integrated solutions. The case studies of the Oosterscheldekering and the dike relocation of Lent exemplify this shift in strategy, showcasing a move towards nature-based solutions while preserving ecological value. Finally, the transition reflects a broader understanding of the connection between water, nature, and safety. No longer do the Dutch see water solely as a threat, but also as an opportunity for a more sustainable Netherlands where we work together with the water.

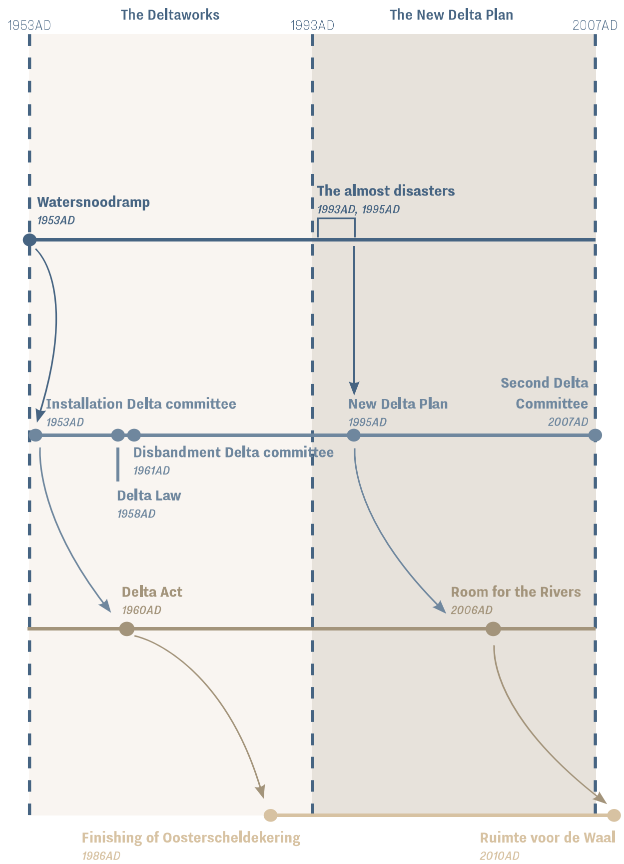


Figure 29: Timeline of events, water management, and architectural innovations in the period 1953-2008 (Own source)

4. Thesis Conclusion

This thesis aimed to reveal the history of the never-ending battle between the Netherlands and water and how architecture, disastrous events and water management led to a shift in the strategies after the big flood of 1953. Through a comprehensive case study research of historical architectural adaptations in the Netherlands before 1953 and a shift in water management strategies after 1953, this paper tried to answer the question: *'What are the historical architectural adaptations of the Netherlands before 1953 to effectively handle water within the face of rising water levels and why did this strategy change after 1953 from 'keeping the water out' to 'learning to live with water'?*

To give a complete answer on that question, the thesis was divided into two parts: The case studies before 1953 answering the sub-question: '*What are the historical architectural adaptations of the Netherlands before 1953 to effectively handle water within the face of rising water levels?'* and the studies after 1953 answering the sub-question: *'why did this strategy change after 1953 from 'keeping the water out' to 'learning to live with water?.'*

The case studies before 1953 show a clear correlation in the Dutch approach to water management and the relation to its environment and disasters. Dating all the way back to 500BC with historical mounds in salt marshes to the reclamation of the Zuiderzee in the 20th century, each architectural intervention illustrates the relation of environmental problems, technological advancements, and level of water management. Answering the first sub-question: The historical architectural adaptations lie in the technological advancements that came with: the invention of the windmill and steam-powered mills for example allowed the Netherlands to work on bigger projects then the period before that. Due to these larger projects, better organization was needed which resulted in shifts within water management.

However, the devastating Watersnoodramp of 1953 marked a turning point in Dutch water management strategies. With the governmental instalment of the Delta Committee and the development of the Delta Act, a change towards more sustainable water defense mechanisms was made. Realization that there was a maximum on protection possible without permanently damaging the environment was getting more and more accepted within the institutes, emphasizing the coexistence of flood protection with ecological preservation and societal well-being. The acceptance of reintegrating and learning to live with water started to come up as an alternative solution.

Case studies of the Oosterscheldekering and the dike relocation of Lent are good examples of this transition, showing a shift from traditional defense mechanisms towards nature-based solutions and collaborative strategies. The projects symbolize a broader understanding of the interconnectedness between water, nature, and safety, with a need for sustainable and integrated solutions. Answering the second sub-question: The shift from "keeping the water out" to "learning to live with water" reflects a recognition of the limitations of traditional approaches in the face of climate change and rising sea levels.

In conclusion, the historical architectural adaptations of the Netherlands led to a country that is specialized and globally known for their tremendous expertise within water protection and management. However, there is a maximum in the possibilities within solely protecting yourself against water without destroying nature. That is why after the floods of 1953, 1993 and 1995 the Dutch started to realize that working together with the water instead of solely fighting against it was more beneficial for the country and well-being of the inhabitants. This changing strategy in water management showcases the country's ability to adapt and innovate in the face of rising water levels. By embracing water as a resource rather than solely as a threat, the Dutch can once again serve as a global example on how to handle rising water levels for the near future.

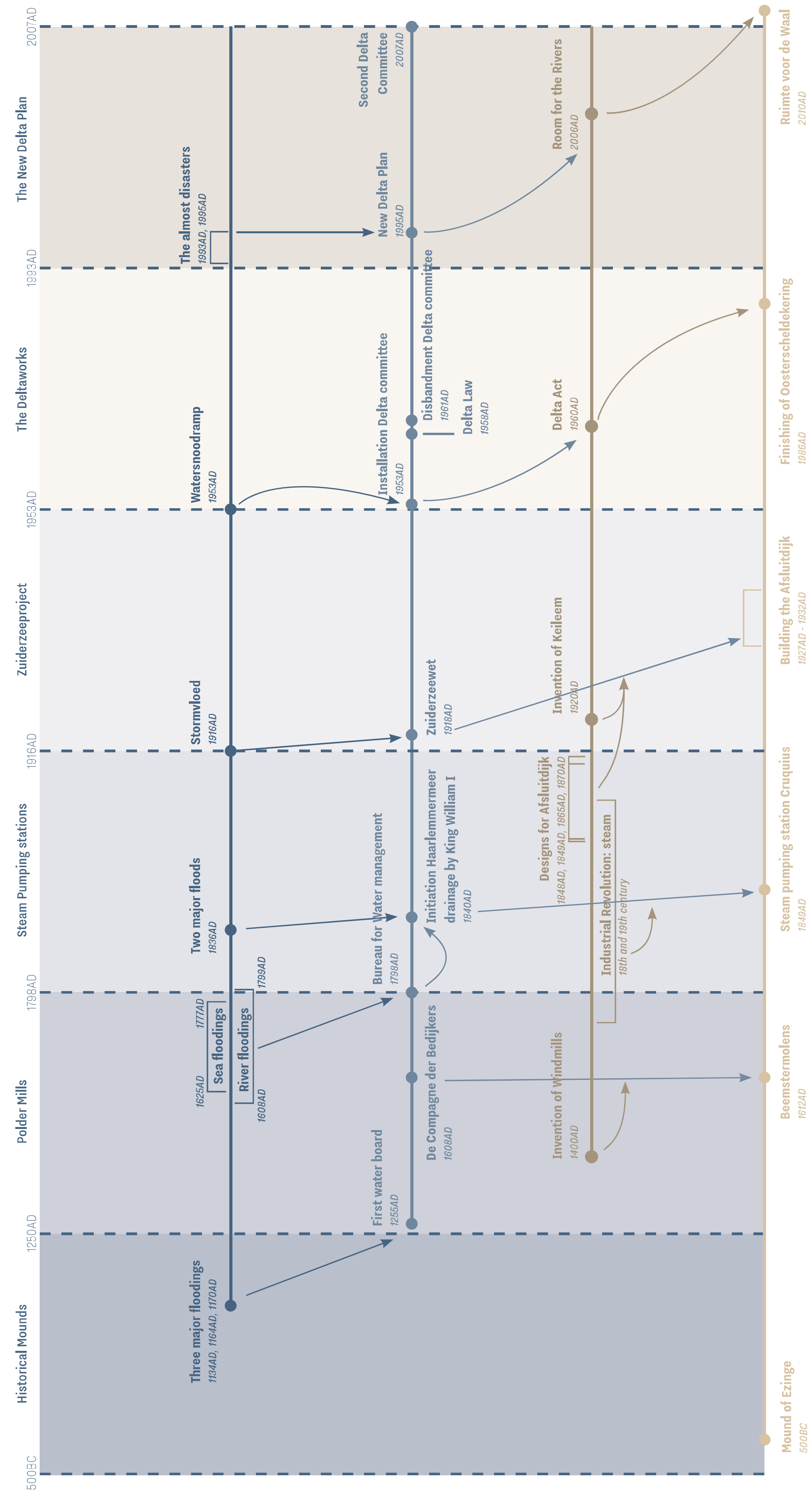


Figure 30: Timeline of events, water management, and architectural innovations from 500BC to present (Own source)

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