The Importance of History for Modern Climate Adaptation Strategies.

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The Netherlands form a part of the northwest European river delta, where almost all the major European rivers drain onto. Therefore the country is very prone to flooding. Dikes and polders have been constructed to manage the water and reduce this risk. An elaborate organisational system was set up for their maintenance: the water boards. Next to these administrative bodies, the Dutch cities of Holland often had their own policies on water management.

Modern research into historical maps and archives on water management shows how an integrated policy connecting urban and water board administrations in the past has led to a safe (living) environment. In contrast, places where this integrated policy was abandoned in favour of new developments without historical knowledge are often characterized by persisting flooding and subsidence problems. This underlines the importance of knowing old policies and visions, since they still have a clear influence on the present-day landscape. Consequently, better understanding of these systems might provide solutions to future problems we face regarding amongst other climate change, soil erosion and subsidence.

In this paper we present the development of a historical GIS on water systems, which is currently conducted at the Cultural Heritage Agency of the Netherlands. The focus of this paper will be on the methodology of integrating maps, archives and historical solutions into one GIS. This new integral historical landscape GIS will not only guarantee the preservation of cultural heritage in present-day dynamic environments, but can also give recommendations for climate-adaptation policies, demonstrating the importance of historical data for modern challenges.

Key words:
Heritage data for climate change adaptation strategies, Historical GIS, Water management.

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INTRODUCTION

Located in north-western Europe, the Netherlands are part of the Rhine-Meuse-Scheldt-Weser delta. The majority of the country is low lying and thus prone to flooding. (Fig. 1) For centuries dikes and polders have been constructed in order to manage and contain the water and regulate the changing rivers. Around AD 1300 all the major rivers were diked in, and some of the minor rivers were dammed off. [Vos et al. 2011] An elaborate organisational system was set up for their upkeep and maintenance: the water boards. Next to the water boards, the individual cities of Holland had their own political needs, strategies and ideas, and not only for water quality and safety. These several governmental bodies sometimes even had opposite interests.

During the 17th and early 18th century the Netherlands knew a period of great prosperity, the so-called Dutch Golden Age. Especially the cities in the western parts of the country, the provinces of Holland and Zeeland capitalized on this economic boom and grew incredibly. With this growth came a huge increase in energy need. For

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industrial purposes this energy mainly came from windmills, but in urbanized context peat was the main source of fuel. Peat extraction, however, causes land erosion and subsidence, and consequently increased risk of flooding. Most cities and water boards therefore had strict rules regarding extraction activities in order to keep the land safe from flooding.

Fig. 1. The Netherlands as part of the north western European river delta between the Rhine, Meuse, Scheldt and Weser rivers. The light red line depicts the 50m. contour line. Below this contour is the northwest European delta. The red rectangle is the research area.

In modern times the water boards are still responsible for the regional water protection policies, while the state is responsible for the larger rivers and sea barriers. (Fig. 2) However, fueled by problems like climate change, these traditional policies are changing. At first, the likelihood of flooding was conventionally met with the construction of higher and stronger dikes. Newer plans such as 'Ruimte voor Rivieren' ('Space for Rivers') and the 'National Climate Adaptation Strategy 2016 (NAS)' [Rijkswaterstaat 2016] promoted an adaptation of the landscape to accommodate water fluctuations. Dikes should be strengthened on the basis of a risk analysis for exceptional floods, while peak waters should be countered by temporal storage. Currently, new models are being developed to calculate flood risks instead of flood probabilities. [Bomers et al. 2018] These models take all kinds of hydrological variables into account, as well as geological and geophysical aspects, but only a very limited amount of historical data. This is best explained by the fact that these models are basically quantitative models, whereas historical data are generally more of qualitative nature, i.e. records describing the situation or event. However, as already stated, the Netherlands know a long history of water management and therefore quite some measurements have been taken throughout history. For example, relatively detailed information is available on water levels and floods in the North Sea at Katwijk, the IJ river and the water level in the boezem (the drainage of the polders) of the Rijnland water board area (mainly the area north of the current city of Delft, west of Woerden, the Haarlemmermeer and the North Sea) for July 1737 till June 1740. [Bolstra 1740]

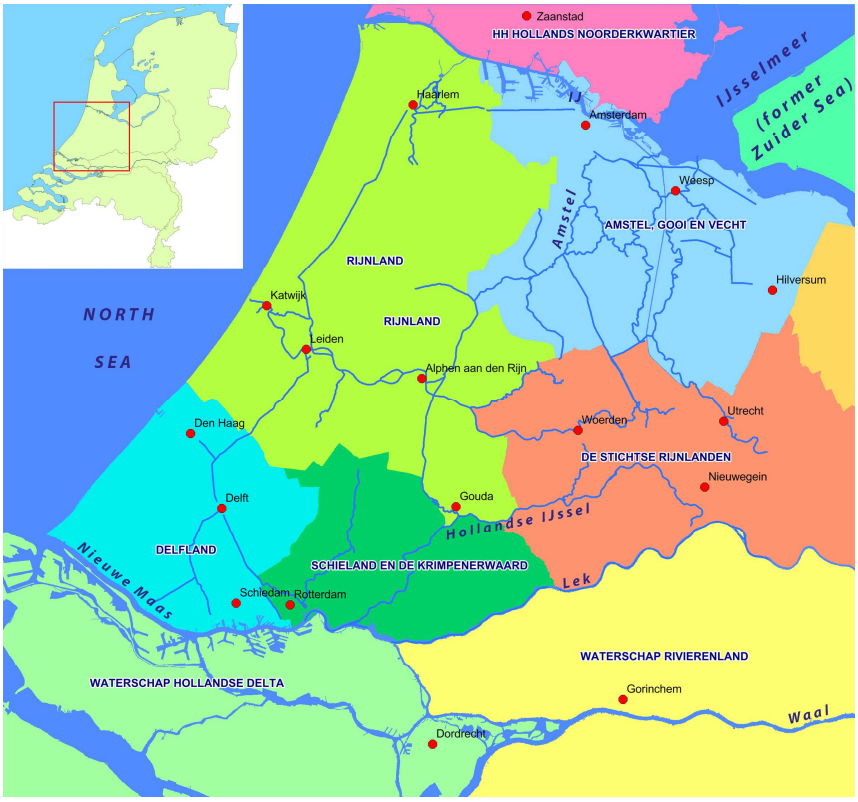

Fig. 2. The research area with the most important toponyms and the water boards.

Another important source of historical information is the so called 'Waterstaatskaarten'. From 1850 onwards the whole of the Netherlands was uniformly mapped with all data necessary for the upkeep of the elaborate water management system (e.g. polder levels, mean sea level, drainage capacity of sluices and canals etc.). These 1:50.000 scale maps were published and regularly updated from 1865 onwards and came with a complete descriptive book on polder levels, water management systems and hydrological engineering works. [Ministerie van Verkeer en Waterstaat 1983]

This kind of information from historical sources does not only provide essential data for modern hydrological modelling, but also gives valuable insights into the superregional water management systems. This superregional approach also facilitates more integrated multi-disciplinary research. Allowing to assess not only problems like flooding, peak rain showers or soil subsidence in a specific region, but also integrate river water influx from other regions, alternative drainage and agricultural, urban and economic land use. To access and adequately use these historical sources we will develop a new GIS model and approach. This paper will give a first impression on the research project that will lead to such an integrated historical landscape GIS and will present some preliminary outcomes.

METHODOLOGY: BASIC DATA AND GEOMETRY

Most GIS databases are specifically developed for present-day situations. And although there are very good examples of historical GIS datasets, they mainly focus on one specific period. Making diachronical comparisons between numerous datasets is often challenging. For a GIS integrating water management, energy, agricultural and urbanistic landscape characteristics, the first problem to be tackled is what to use as a geographical and geometrical base map. Since the objective of the GIS is to inform modern planners and integrate historical data into modern models and processes the geometry of the GIS should comply with modern cartographical standards. Therefore the basic geometry was taken from the modern standard 1:10.000 Dutch topographical map. From this map the centre

line of the relevant waterways was taken as the base for the GIS geometry. To establish what the relevant waterways are, the data on water type was used as given by the 'Planbureau voor de Leefomgeving' (PBL Netherlands Environmental Assessment Agency) in their GIS dataset 'Basiskaart Aquatisch: De Watertypenkaart' (Aquatic base map of the Netherlands; map of water types). [Planbureau voor de Leefomgeving 2010]

Even with this elaborate dataset creating a GIS covering the entire country will prove challenging. The majority of historical information on water management originates from the western and central parts of the Netherlands, most notably the provinces of Noord-Holland, Utrecht and Zuid-Holland. These provinces are also the areas with most water-safety related problems, soil subsidence and land-use changes (i.e. new methods for agriculture in peat meadows). In order to ensure the best data comparison and integrity our research area covers the lower central Dutch river area, basically the drainage of the old Rhine system. (Fig. 3) The boundaries of the GIS are in the west: just east of the city of Utrecht, in the north: the former Zuiderzee and IJ river, in the south: the rivers Lek and Nieuwe Maas and in the west: the North Sea. Subsequently, this area covers the present day water boards of Rijnland, Amstel, Gooi en Vecht, Delfland, Schieland en de Krimpenerwaard and De Stichtse Rijnlanden. Historical data from these water boards or their predecessors are available via their archives. Therefore we can say that the historical data coverage of the research area is the highest in the Netherlands.

One of the data fields in the Aquatic base map dataset is whether a specific watercourse at present is in use as a main or a secondary drainage or has no active drainage function today. This information is provided by the water board governing this waterway. We only included the main and secondary drainage waterways into the new GIS. Besides drainage information the Aquatic base map also provides insights in whether that specific watercourse is of natural origin or whether it is man-made. This information was also included in the GIS. Based on the drainage information and the boundaries of the present-day water boards the direction of drainage, or rather where a specific waterway drains to, was also added to the database. At a later stage in the project these data will be recorded more precisely based on information on hydrological engineering works like sluices, dams and culverts. Since these will be point elements in the GIS, they require a different geometry than the waterways themselves, who are represented as line elements. This point element table will be included into the GIS at a later stage.

In order to ensure diachronical comparisons, other information stored in the Aquatic base map was not included into the GIS since the historical sources did not give a same level of information. Details on salinity, amount of change or rate of flow, for instance, were not included into the GIS. However, these extra details will not be disregarded since they can give more insights into the precise course of waterways not only in the present but also in the past. Therefore these data allow us to add and reconstruct waterways which are no longer present in the current drainage system, but might have been in the past. Consequently, regular checks against the source datasets while reconstructing the historical geometry is very important.

METHODOLOGY: HISTORICAL DATA AND GEOMETRY

As already stated the Netherlands have had an elaborate mapping on hydrology and water management from 1865 onwards with the 'Waterstaatskaarten'. Although these maps are all in a modern projection and have a rather precise geometry, the data on them are mainly on administration of water systems. So while all the engineering works, including their specifications, are mapped, specific drainage systems and directions are not. Therefore the 'Waterstaatskaarten' are highly useful for reconstructing point locations of e.g. sluices, but are of less use for the reconstruction of the watercourses. However, for our research area a highly-detailed water system map is available, the 1910 Hoekwater map. [Hoekwater 1910]

This 1:50.000 scale map depicts the polders, polder water levels, drainage canals, drainage direction and engineering works for the area between the rivers Meuse and IJ and the city of Utrecht and the North Sea, generally matching our research area. Contrary to the 'Waterstaatskaarten' the Hoekwater map was not meant to be geometrically correct, but only clearly readable for the polder water drainage systems. This is underlined by its beautiful, almost art deco design, further hampering geometric comparison. So while the information about primary and secondary drainage water and the relevant engineering works are very legible and understandable, georeferencing the map into a GIS is challenging. In order to overcome these challenges we started with the modern geometry. Instead of exactly georeferencing the Hoekwater map, we roughly placed it whereupon the relevant waterways could be compared with those from the Aquatic base map dataset and allocated to the right geometry. In cases where the discrepancy was too big, or the waterway was obviously altered, the 'Waterstaatskaarten' could be used for the exact geometry.

This way the GIS line geometry was extended with some new lines, but mainly enriched with turn-of-the-century data, still matching the modern geometrical standard.

Although the water boards had and have a very good administration and very accurate maps, spatial data predating the nineteenth century are often more difficult to georeference precisely. The first obstacle is that these pre-cadastral maps do not have a modern, or even standard, projection system. However, the specialist water board maps do have something in common; they were all made for water management purposes, so the waterways and engineering works were meticulously mapped. Given the modern GIS structure we could, in the same way the Hoekwater map was digitized, approach the seventeenth century maps, i.e. roughly georeference the water board maps and then appoint the waterways to the modern geometry. To place the maps the most accurate way, the chosen georeferencing points were all water related. Not only the main canals as mapped in the Aquatic base map were chosen, but also the elaborate canal system within the cities. Since the digitalization by the Cultural Heritage Agency of the Netherlands of the Jacob van Deventer maps from the late Middle Ages a few years earlier [Kosian et al. 2016] there was already a good base geometry for the medieval city centres. With the help of the first cadastral maps of the Netherlands later canals could be accurately added. Although these cadastral maps date from the 1830s most of the cities were not extended very much after their Golden Age growth. [Rutte and Abrahamse 2016] With this dataset all the canals, bridges and dams within the cities could be used to georeference the water board maps.

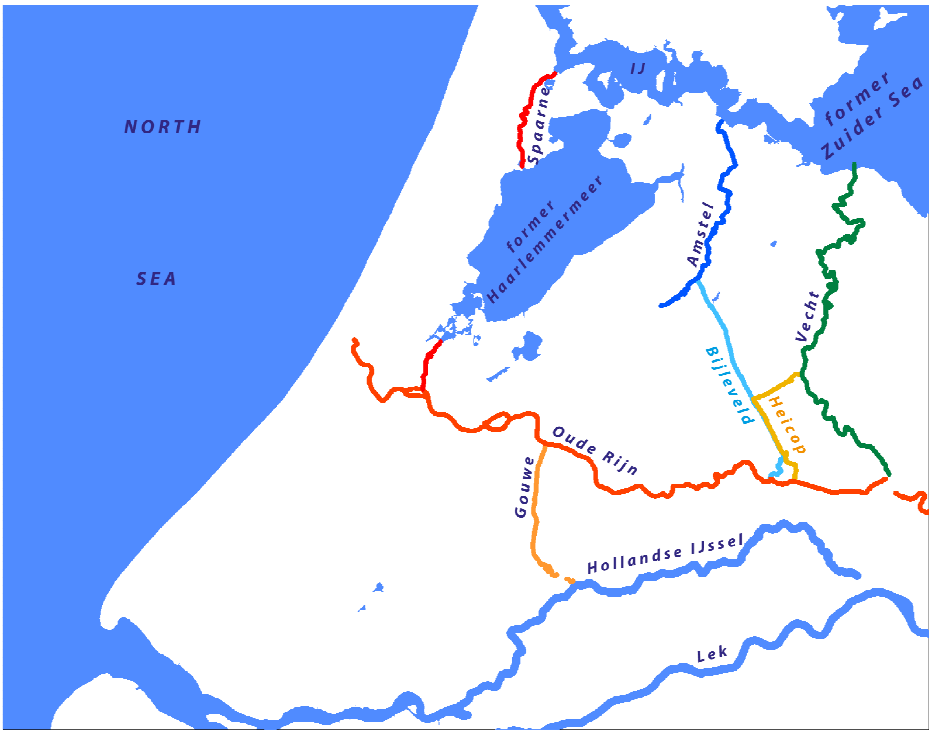

Fig. 3. Drainage system of the Oude Rijn River during the Dutch Golden Age. Direct west of Utrecht the canals Heicop and Bijleveld drain respectively to the Vecht river and Amstel river reducing water influx into the lower Oude Rijn system which drains either into the IJ via the Haarlemmermeer and Spaarne or the Hollandse IJssel via de Gouwe.

Another very helpful source was the PhD research by R.J. van Lanen into patterns of connectivity and route networks in the late Roman and early medieval period in the Netherlands. [Van Lanen 2017] One of the main research topics in this dissertation was the possible persistence of route networks and connectivity patterns over a longer period of time. For this research topic the known road network from around AD 1600 was digitized. This meant that, next to the waterways, there was also a geometry for the main roads available. With this double geometrical pattern even the older maps could be reliably placed, after which the relevant rivers and canals could be allocated to the modern water geometry or newly digitized where major changes have been made.

Following this method all the relevant water board maps for the research area could be included into the line geometry table of the GIS. The direct surroundings of the city of Utrecht as well as the regions east of the river Vecht were taken from the Nieuwe Caerte vande Provincie van Utrecht (New Map of the Province of Utrecht) by Bernard de Roy [1696]. Several cross checks with contemporary regional maps by for instance Joan and Willem Blaeu from [1649] and Nicolaas Visscher from [1670] were made to ensure the choice of waterways.

FIRST PRELIMINARY RESULTS

Since the project to make an integrated GIS for the historical water system, as presented in this paper, has just started, we can only give some preliminary first results. On the other hand, the first geometries are now included into the GIS and all the basic historical maps are prepared and georeferenced to complete the presented line-geometry table. Through this table we already are able to see some interesting patterns appear. In the very early beginning of water management in the western Netherlands all the individual polders had their own polder boards (heemraden). From the medieval period onwards these boards were organised into coordinating governing organisations, the water boards (hoogheemraden). The borders between these water boards were therefore often the polder dikes or adjacent drainage canals. These drainage canals formed not only the border between the juridical areas of the water boards, but also the actual watersheds for their respective drainage. Where waterways crossed the boundaries of the water boards locks, sluices or even actual dams were constructed to control the flow and direction of drainage. This way an elaborate system of water management gradually grew. The historical GIS for the period of the Dutch Golden Age locates six main water systems: (1) the Oude Rijn system (the former lower reaches of the river Rhine, from the city of Utrecht to the west), (2) the Vecht system, (3) the Amstel system, (4) the Rotte system, (5) the Westland system and the (6) Krimpener- and Lopikerwaard system. (Fig. 4) In order to relieve the western polder areas, the polders west of the city of Utrecht and around the city of Woerden were connected to either the Amstel system, draining to the IJ River near Amsterdam, or the Vecht system, draining to the Zuiderzee. These connections were established by digging two large canals, the Heicop and the Bijleveld, divided by a strip of land. (Fig. 3) The rest of the Oude Rijn system drained via the Haarlemmermeer and Spaarne River onto the IJ near Haarlem. This system also had a second drainage via the Gouwe River onto the Hollandse IJssel River near Gouda. The GIS shows that this complex system still functioned at the end of the nineteenth century, although there were less main drainage canals than in the previous periods. This was due to an increased capacity of steam-powered pumping stations that could serve a larger hinterland. Especially the Heicop and Bijleveld relief system was still functioning. At the present day, however, the building of the new town of Leidscherijn disrupted this old system, increasing the influx of polder water into the Oude Rijn system, putting more stress onto the Spaarne and especially the Gouda discharges. Locating and understanding these systems and their historical roots give an important input for engineering modern solutions for the integrated adaptation strategies against for example climate related water problems.

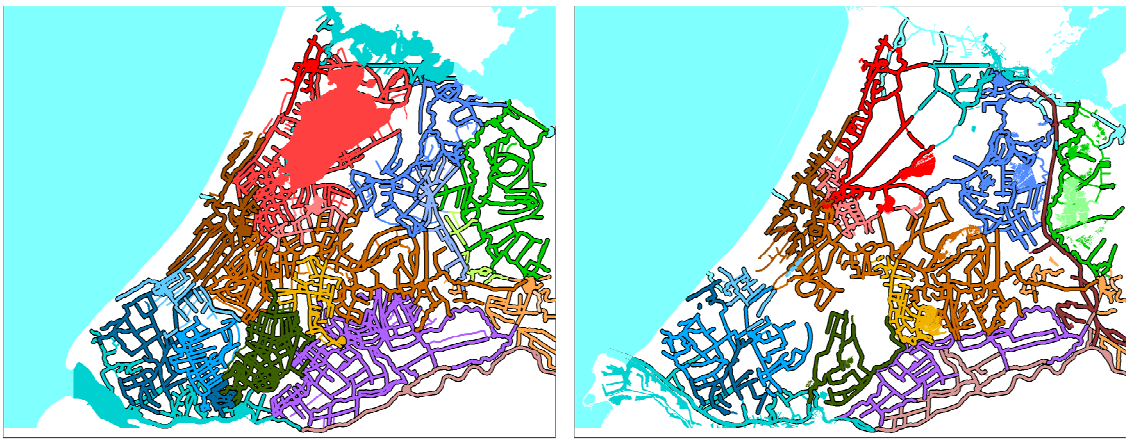

Fig. 4. Comparison of the six main water systems in the Dutch Golden Age (left) and the present day (right). The Oude Rijn system (1) in brown, draining to red (IJ and North Sea) in the north and yellow (Gouwe and Hollandse IJssel) in the south, the Vecht system (2) in light green, the Amstel system (3) in blue top-centre, the Rotte system (4) in dark green, the Westland system (5) in blue, draining to dark blue left bottom corner and the Krimpener- and Lopikerwaard system (6) in purple. The Southern border of these systems is formed by the river Lek (light brown).

PROJECT OUTLOOK

The next phase of the project will focus on the completion of the line geometry with the late medieval water board maps. After completing the basic line geometry the next step is making the point geometry table containing the relevant water engineering works. This will demand quite some cartographical analysis since most of these structures are only noted in the map as text, or even as toponyms. With this information the exact boundaries of the historical water boards and the effective drainage and drainage direction could be established and added to the data of the line geometry table.

When the GIS provides enough insight into the water management systems, special attention could be given to the water management within the cities. Cities not only needed a degree of water safety, but also demanded a certain standard of water quality. For this purpose special sluices and pumps to get rid of the city's waste-water were installed (vuilwatermolens). To integrate these water quality systems into the GIS the city plans from the Dutch Golden Age will be digitized in the same manner as those from the medieval period (the Jacob van Deventer city plans). [Kosian et al. 2016]

When the water information is completed in the GIS the areas where peat was extracted can be researched. Several water boards have had maps made and updated on the change of the landscape due to peat extraction. [Bolstra 1745] Using the described system of georeferencing the water maps these 17th and 18th century peat polders can be accurately mapped, providing immediate insight into their influence onto the water system and the water safety. It also provides an insight into the energy landscape of the Dutch Golden Age.

Also dedicated areas for horticulture and agriculture in the new polders around the seventeenth century cities can be mapped and integrated into the GIS. This would form a comparable historic dataset on water safety, water quality, energy and food landscapes around the cities of Holland from the late medieval period to the present day. This dataset can be used for heritage management in times of extreme changes and adaptation policies as well as providing historical data and inspiration for planners in the field of water safety and climate adaptation.

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