Go with the flow?

Relations between settlements and the Nederrijn between 0 CE – 1250 CE in the region of Wageningen

Msc Thesis — Wageningen University and Research

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Abstract

The land that is shaped by the rivers in the Rhine-Meuse delta has attracted people since ancient times. The Nederrijn at Wageningen is one of the places in the Netherlands where a high push moraine meets the dynamic river system. The high elevation, fertile soils and roads crossing the region have drawn settlers to this area. From the period between 0 CE and 1250 CE there is little written information on how the inhabitants of the area interacted with the dynamics of the Nederrijn. During the study period the region has periods of high floods frequencies and periods with fewer floods plus the occasional major flood. This makes it plausible that people living close the Nederrijn adapted their place of habitation accordingly. In this research the regions around Wageningen, Rhenen and Randwijk were examined. The locations of settlements during this period were gathered from archaeological and written evidence. The characteristics of each settlement such as, settlement type, elevation, geomorphological unit and soil type were gathered. This was visualised in maps which show the location and physical characteristics of each settlement. The maps, elevation data and geomorphological data provided information on the vulnerability of each settlement to changes in the behaviour of the Nederrijn. The timeline of the settlements was then compared to the behaviour of the Nederrijn. The resulting timeline of the flooding regime and the settlements was used to draw conclusions on whether the Nederrijn impacted the location of settlements. The results showed that settlements in Wageningen experienced little direct influence from the Nederrijn. The settlements were mostly located on the push moraine facing away from the river. A notable exception is Rijnwijk which was founded close to the river in the end of the research period. This was possible during a quit period of the Nederrijn which allowed for habitation closer to the river. The region around Randwijk was more vulnerable to floods which is reflected in the changing habitation pattern. A period of intense flooding combined with social unrest at the end of the Roman period resulted in the abandonment of the lowest settlements. The habitation in the region of the push moraine on which Rhenen is situated did not show a direct impact by the flooding regime of the Nederrijn. In contrast to Wageningen, Rhenen did not show the start of settlements on lower grounds at the end of the research period. The city of Wageningen was eventually founded not on the high sands as other settlements in the region, but on the natural levee at the foot of the push moraine. This transition was made possible by the first dikes and the relatively low activity of the Nederrijn.

1 Introduction

1.1 Background

The late Roman Period and the early Middle Ages was a dynamic period in the Dutch river area. The fertile river area and the trade routes along the rivers made this area attractive to live **(Pierik & Van Lanen, 2017, Cohen et al., 2016, Van Lanen et al., 2016)**. However, social unrest and changes in the environment caused people to move their settlements to different locations throughout the early middle ages **(Pierik & Van Lanen, 2017)**. After the departure of the Romans until approximately 1000 CE, there is a gap in written sources about this region. The lower Rhine river system was very active during the Holocene and continued to change human settlement distribution during the Roman Period and the Early Middle Ages **(Gouw & Erkens, 2007; Berendsen & Stouthamer, 2000; Pierik et al., 2017)**. Archaeological evidence suggests that settlements in the lower Rhine-Meuse delta did not remain in the same place during this period **(Pierik & Van Lanen, 2017; Van Dinter & Van Zijverden, 2010).** This relocation is linked to changes in river dynamics, e.g. an increase in flooding frequency or flow channel abandonment which changes the local geomorphology **(Pierik & van Lanen, 2017; Dinter & Zijverden, 2010; Dinter et al., 2017, Cohen et al., 2016; Maas, 1998; Toonen et al., 2012)**. Inhabitants along the branches of the Rhine were vulnerable to these changes before the construction of elaborate dike systems and other flood protection infrastructure managed the river flow **(Hesselink et al., 2003).**

The city of Wageningen is located on the southwestern part of the Veluwe push moraine close to the Nederrijn, the central branch of the Rhine in the Netherlands, **(Ten Brinke, 2005)**. This area has traces of human presence dating back to 2900 BCE **(oudwageningen.nl)**. These traces consist of burial mounds that were constructed on top of the Wageningse Berg **(oudwageningen.nl)**. More recent findings include human settlements such as farmsteads and bronze and iron tools. Later artefacts point to contact with the Roman Empire, such as roof tiles found on top of the Wageningse Berg **(oudwageningen.nl)**. The migration period following the collapse of the Western Roman Empire, between the 4th and 6th century CE, was a dynamic period which saw the displacement of peoples in the Dutch river area **(Fouracre, 1995)**. During and after this period the land around Wageningen would be part of several states, which resulted in different socio-economic circumstances for the region.

Figure 1 Location of the research area (modified after www.pdok.nl).

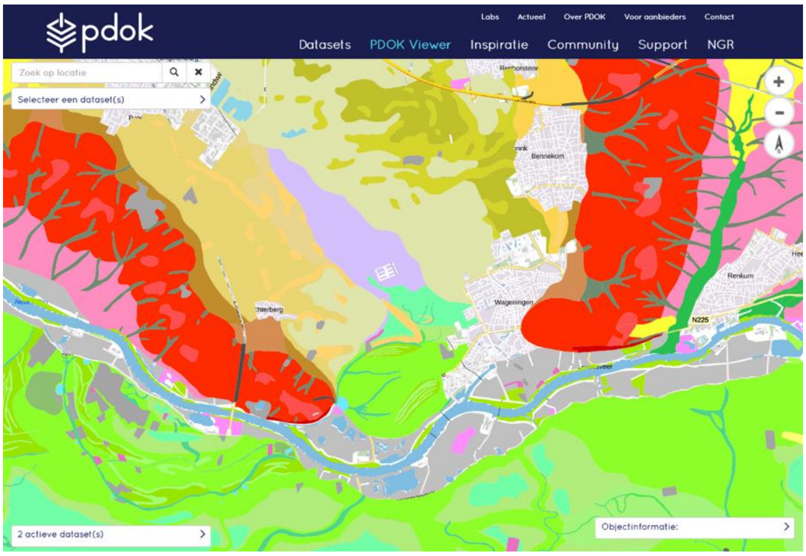

Figure 2 Geomorphology of the region of Wageningen (www.pdok.nl).

Settlements emerged in the region as it was the crossroads between the Betuwe, Utrecht and the Veluwe. Routes between north and south were established here by making use of the ford at Lexkesveer along with routes connecting population centres in Utrecht and Gelderland **(Van Lanen, 2017)**. The roads would eventually draw people that could profit from this intersection of routes, leading to the origin of predecessors of Wageningen such as Rijnwijk **(Gast et al., 2013; Vervloet pers. comm.)**. The current location of the city was established in the 12th century at the foot of the Wageningse Berg (**figure 1 and figure 2)**. The city had an important role by controlling the Nederrijn as a fortification and the proximity of a ford, namely the Lexkesveer **(Willems, 1981; wageningen.nl)**. The occurrence of productive agricultural grounds on the levee, the ford in the river and high grounds on the flanks of push moraine made the area around Wageningen a favourable place to settle even before the founding of the current city **(Van Dinter & Van Zijverden, 2010)**.

There is archaeological evidence of predecessors of Wageningen dating back to around 600 CE **(oudwageningen.nl)**. Settlements have been found that existed during the period 600-1000 CE. The location of these settlements has not been constant over time. The lack of written sources from this period makes it hard to explain why some centres of habitation moved. Proposed causes for the moving of settlements in the Dutch river area are linked to social unrest and changing river dynamics **(Van Dinter et al., 2017; Pierik & Van Lanen, 2017).** It is known that the Nederrijn shifted its course during the Early Middle Ages and that there were changes in its flooding regime **(Toonen et al., 2012)**. The morphodynamical processes of the river had free rein in shaping the land through which it flowed which has led to several floods in the Gelderse Vallei, even after the creation of dikes **(Knol, 2005; Berendsen & Stouthamer, 2000)**. If the relocation of settlements in the area of Wageningen was directly caused by changes in the river is still uncertain.

The region is distinct from the western Rhine-Meuse delta, due to the position of the river close to the push moraine (figure 2). This results in a different type of landscape with distinct geomorphological units close to each other, providing more options for people to live. The broader region comprises of the southern point of the Utrechtse Heuvelrug, the southwestern point of the Veluwe push moraines, the southern point of the Gelderse Vallei, and the northern part of the Betuwe floodplain. The evolution of habitation during the Early Middle Ages can be investigated by looking at the differences and similarities between the landscape. In this research the settlement location shifts and Nederrijn dynamics are investigated to answer whether there is a relation between the two processes in this region in the period 0 CE – 1250 CE.

1.2 Research question

The question that will be answered at the end of this research is:

- Are changes in settlement location between 0 CE and 1250 CE in the regions of Wageningen, Rhenen and Randwijk caused by river dynamics?

The sub questions that answer the research question are:

- Where were settlements located during this period?
- How did the elevation and geomorphology of the location of settlements change over time?
- How did the Nederrijn behave during this period?
  - What shifts in the location of the Nederrijn channel occurred during this period?
  - When did major historical floods occur and when were periods with increased flooding?
- How do the changes in settlement location of each region compare to each other?

1.3 Hypothesis

Connections in changes in flooding regime have been made to changes in the elevation of settlements in the Rhine-Meuse delta **(Pierik & Van Lanen, 2017)**. The same relation is expected to be seen in parts of the study area with low elevation and proximity to the river. The expected cause for these changes is extreme floods and increases and decreases in flooding regime. Settlements with high elevation are expected to show less influence by flooding, but relations can occur with movements of the channel if the settlements rely on the river for economical or infrastructural purposes. The expectation is that within the study area there will be less change that can be directly linked to river dynamics in settlements located on morphological units that are not directly linked to the river. This encompasses the push moraines and the high coversands north of the river. The connection that is found by **Pierik & Van Lanen** is expected to be found in the floodplains and on the border between high sand areas and the clayey river areas.

2 Methodology

2.1 Research area

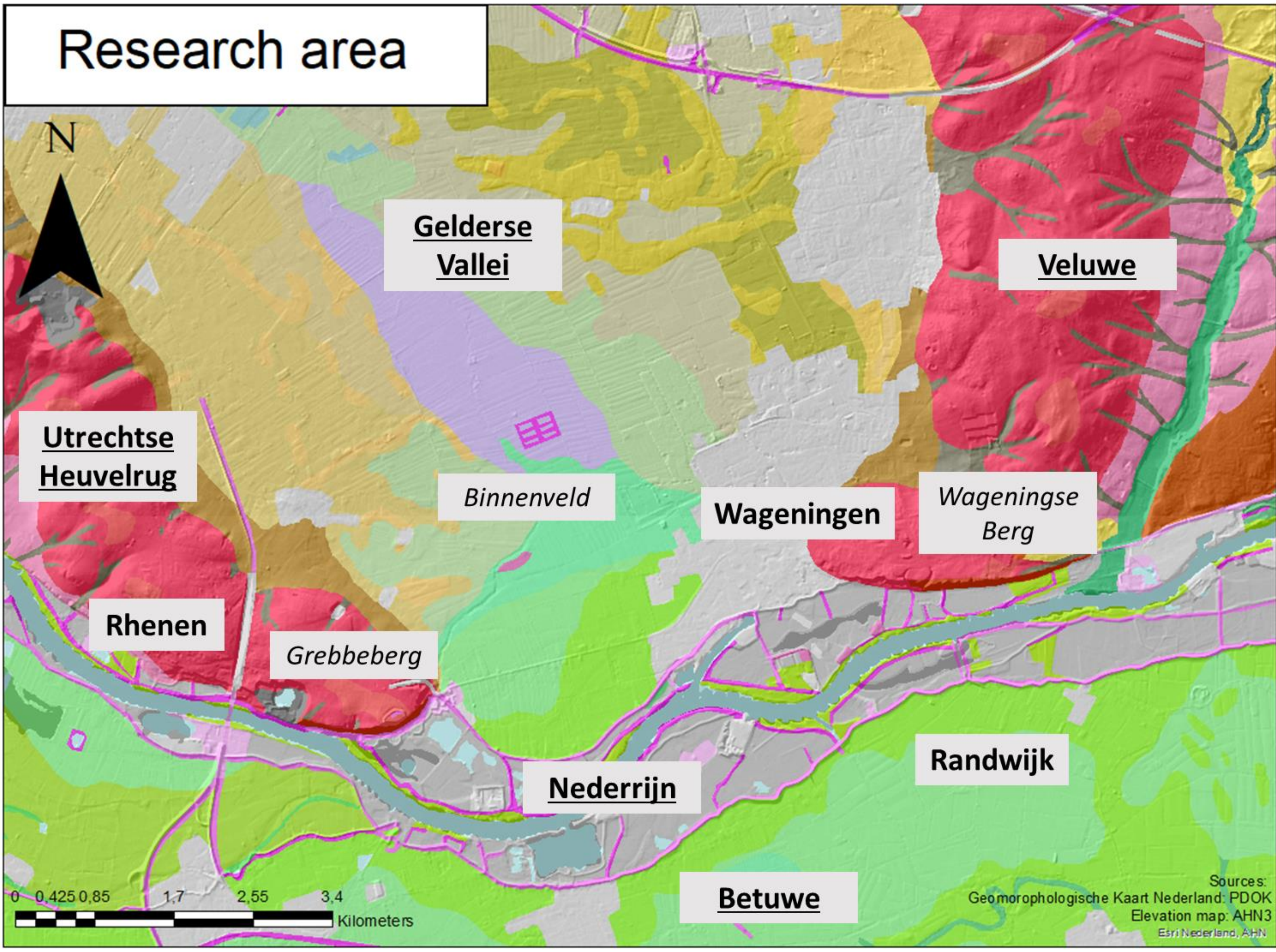

Figure 3 Map of the research area with the important topological features labeled

The research area comprises of the municipality of Wageningen, the municipality of Rhenen and the north side of the Betuwe directly south of Wageningen with the village of Randwijk (**Figure 3**). There are several different landscape types present. Wageningen is mainly defined by the southern tip of the Veluwe, the Wageningse Berg, and the flanks of the push moraine. This section is bordered by Binnenveld, the southern part of the Gelderse Vallei, with peat and alluvial soils in the west, and the floodplain of the Nederrijn in the south. Rhenen is located on the southern tip of the Utrechtse Heuvelrug with the Grebbeberg as the closest high point to the city. The region is bordered by peat and alluvial soils in the west and the floodplain of the Nederrijn in the south. Rhenen is similar in geomorphology compared to Wageningen because both regions are dominated by a high ground on top of push moraines and the flanks that extents into the Gelderse Vallei. The northern part of the Betuwe, which shall be referred to as Randwijk for the purposes of this research, is located on the floodplains south of the Nederrijn. Randwijk is mainly dominated by the clayey, low-lying soils in floodplain with the slightly higher natural levee close to the river. The elevation with respect to the river is relatively low compared to the other two regions, since there is no push moraine or other elevated geomorphological unit.

The focus of this research is on the changing settlement locations around Wageningen during the early Middle Ages and the contemporary river dynamics. The Nederrijn had different phases of activity with different channels that it followed. In this research the different flooding regimes and flow paths are investigated in order to relate them to the settlement locations in the research area. Rhenen and Randwijk are chosen as nearby regions to compare the habitation pattern of Wageningen. Rhenen has a similar geomorphology to Wageningen. Both are located on a push moraine consisting of the same type of sediments and both border the Nederrijn. Randwijk is chosen because it is close to Wageningen and it also borders the Nederrijn. However, it lacks the high ground provided by the Wageningse Berg and can therefore be used to investigate the influence of mentioned high ground on the location of settlements.

2.2 Data

2.2.1 Habitation data

Both literature sources and an online database were used for locating historical settlements. The online database **Archis III** was used for obtaining archaeological data. Archis is part of the Rijksdienst voor het Cultureel Erfgoed (RCE) which manages archaeological registration and monuments in the Netherlands. The processing of the habitation data will be discussed in section 2.3.1

2.2.2 Environmental data

The geomorphological data comprises of multiple map files

- Elevation data **(AHN3)**
- Paleo elevation map **(Cohen et al., 2017)**
- Geomorphological map **(PDOK)**
- Soil map **(PDOK)**
- Paleogeography of the Rhine-Meuse delta **(Cohen et al., 2012)**
- Paleogeographical map 70 CE – 270 CE **(Groenhuijzen, 2018)**

2.3 Method

2.3.1 Habitation data

Literature on the general history of the region is used for a first indication of where settlements might have been situated. The main source for this is the book **Geschiedenis van Wageningen (Gast et al., 2013)** which provides general information on historical habitation in the municipality of Wageningen. Additional information is obtained during conversations with the local archaeological and historical association **Oud Wageningen**. Accounts of archaeological findings and historical research by Oud Wageningen provides additional background information on the history of the area. Information on historical habitation in the region of Rhenen and Randwijk is obtained through literature research of local sources e.g. findings by historical associations and books covering the history of the region. The sources for each location will be provided in the results.

Archis.nl is used to obtain locations of archaeological sites in the research area from which the settlement locations will be determined. All the datapoints in the research area are downloaded. The data is imported into **Microsoft Excel** in order to categorize the data and to start evaluating the points. Filtering of the data is done by selecting the desired time frame and by omitting polygon data. The polygon data represent large research areas and points of interest are given as point data, therefore the polygons themselves can be omitted from the selection. Next, the data points that indicated habitation are selected from the remaining points. The criteria that were followed for this selection are given below. The resulting datapoints are entered in Archis to be examined in detail. The examination in Archis gives access to detailed information that is provided for each data point. Furthermore, it provides access to reports and literature related to the archaeological findings, thereby giving insight on how the conclusions about the findings were draw. This allows for research reports that were not yet included in the preselection in Excel, to be consulted in the evaluation in Archis. This method ensures that all the information on the archaeological value of certain parts of the research area, as well as summary information on findings are taken into account. Through the three-stage evaluation of selecting time period, filtering habitation data and verifying with Archis, a final dataset of historical settlement sites was made.

The criteria that are used to select likely habitation locations are:

- Direct archaeological evidence of habitation, e.g. traces of residential complexes
- Indirect archaeological evidence with a strong case made for habitation in literature, e.g. post holes, abundant archaeological find material
- Written evidence of a settlement with an estimated location in literature, e.g. mentions in charters, documents
- Direct archaeological evidence of structures that would have served populations in proximity e.g. burial grounds, churches, fortifications

Archaeological sites that indicated settlements or signs of nearby habitation were selected. The locations of habitation found in the literature research were verified with archaeological findings. The table with the data for each point is depicted in **appendix A**. Every location and its verifications will be depicted in the results section.

Each habitation point was categorized in a time period in order to detect changes in settlement locations over time. The time periods chosen for this research are;

- Period 1, 0 CE – 500 CE corresponding to the Roman period
- Period 2, 500 CE – 900 CE corresponding to the early Middle Ages
- Period 3, 900 CE – 1250 CE corresponding to the high Middle Ages

This classification of the periods is based on the established classification of archaeological periods and the time periods in the paleo geographical map **(Archis, Cohen et al., 2012).** It allows for straightforward comparisons between changes in habitation and river dynamics because they both use the same time periods

2.3.2 Geomorphological and soil data

The elevation of the region is directly influenced by the river and has seen changes in elevation over time due to fluvial and tectonic processes **(Berendsen & Stouthamer, 2000)**. The *Algemeen Hoogtebestand Nederland* **(**Dutch General Elevation model**, AHN)** is the main source for elevation in the research area. The paleo elevation map produced by Deltares **(Cohen et al., 2017)** is an additional source to account for changes in elevation that may have occurred in certain areas due to river processes. However, the maps from this report do not cover the entire research area and have a coarse resolution compared to the AHN. Therefore, AHN is used as the default reference for elevation. For places with a substantial difference between historical elevation and current elevation, e.g. drained peat lands, the paleo elevation map serves as an extra reference for historical elevation at a certain location.

The geomorphological map and soil map that are used in this research are the maps published by **Publieke Dienstverlening op de Kaart (PDOK).** The geomorphological map is a 1:50000 that covers the entire country of the Netherlands and gives a detailed representation of the geomorphological units present in the research area. The soil map has the same scale as the geomorphological map and gives a detailed representation of the soil types according to the Dutch soil classification system.

The flow paths that the Rhine took during its lifetime can be found in the subsoil in the shape of buried alluvial ridges **(Gouw & Erkens, 2007)**. Based on this a map has been made that provides a reconstruction of where the alluvial ridges were situated during a certain period **(Berendsen & Stouthamer, 2000; Cohen et al., 2012).** This map represents the paleogeography by indicating the positions of former channel belts of the Rhine delta. This is the main source for determining the location of the Nederrijn during the period of interest of this research. Sources such as historical maps and archaeological findings are used in addition because this map only provides the approximate location of the alluvial ridge and the not exact location for the channel **(Gast et al., 2013; Renes, 1997)**. Despite this uncertainty of the exact location of the Nederrijn, the channel belts provide a good indication of where the river was active during each period

The flood time series of the Rhine that is used is the historical flood data from the research of **Toonen (2013) and Cohen et al. (2016). Toonen (2013), Cohen et al. (2016)**, **Van Dinter et al. (2017)** and **Peng et al. (2020)** are the main sources on information considering changes in flow regime, avulsions, channel shifting and other behavioural changes of the Rhine that affected the Nederrijn near Wageningen. Changes in flooding regime will be used to formulate different time periods within the whole considered time series. Due to the incomplete registration of relatively small floods in time, the focus will be on large floods i.e. floods with a recurrence time around 1 per 1000 years **(Toonen, 2013)**

3 Results

3.1 Habitation data

The points with historical habitation in the regions of Wageningen, Randwijk and Rhenen are depicted in **figure 4.** The points are found through literature research and examining archeological data. The coordinates of the points are based on the locations of the relevant archeological locations given in **Archis**. The background map consists of a paleogeographic map **(Groenhuijzen, 2018)** and an elevation map **(AHN3)**. The paleogeographic map is a reconstruction of the geographic situation for the period 70 CE – 270 CE. Buildings are not present in the map as well as artificial structures such as dikes. It is therefore more useful to represent the historical situation because the soil map (**bodemkaart 1:50000)** and the geomorphological map **(geomorfologische kaart 1:50000)** contain buildings and therefore do not present soil and geomporphological data for build-up areas. The settlement locations are presented in **Appdix A** along with the type of settlement, the habition period and the sources.

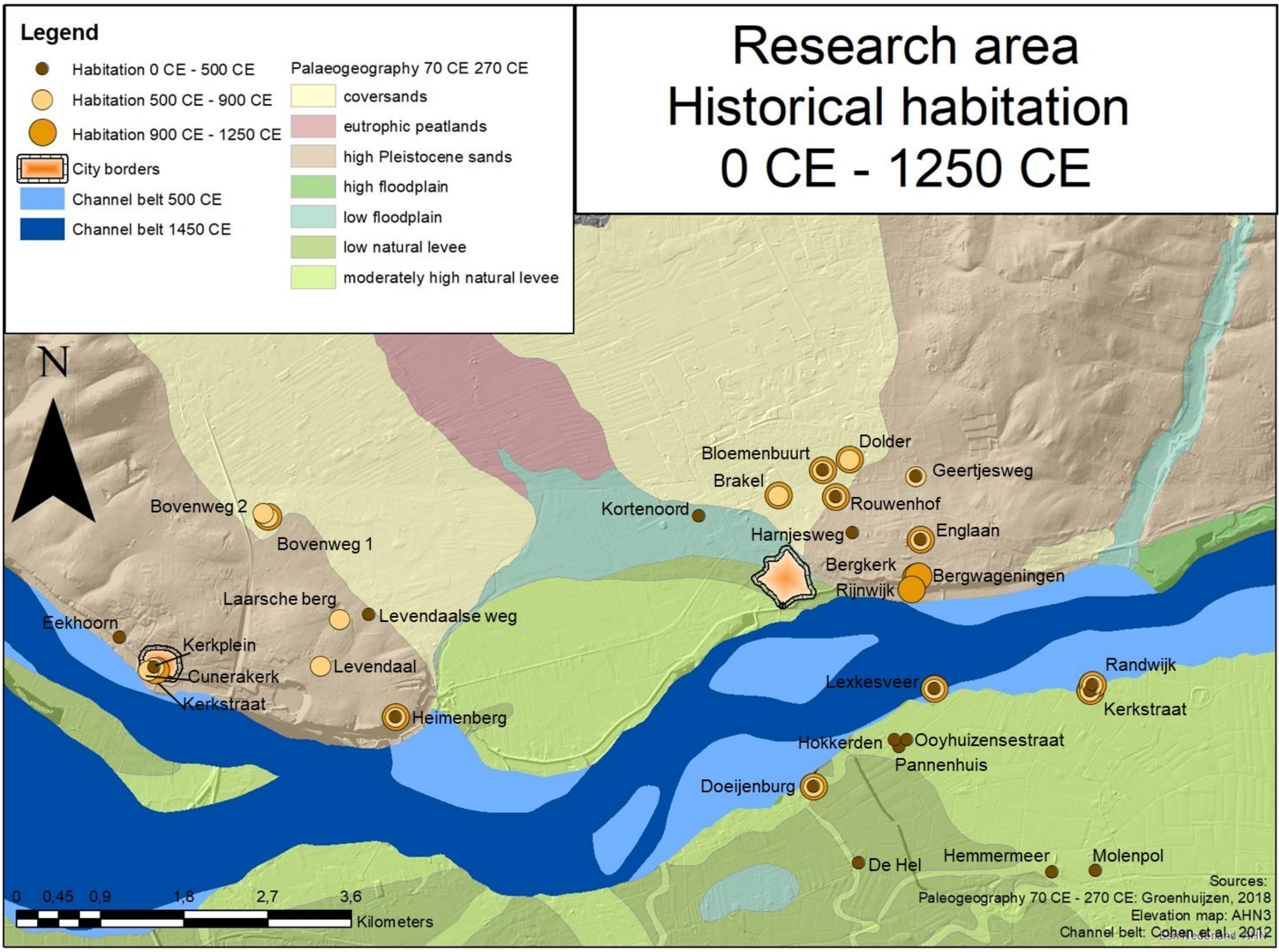

Figure 4 Habitation map for the entire research area for the period 0 CE - 1250 CE. The habitation and ages are based on archaeological data from Archis and corresponding literature. The background map is a DEM (AHN3) and a paleogeographic map (Groenhuijzen 2018).

3.2 Elevation

The elevation for each location is presented in **figures 5-13**. The figures are presented for each time period per region. The elevation is the height above Amsterdam Ordnance Datum (NAP) according to the AHN **(AHN3)** with the paleo elevation **(Cohen et al., 2017)** provided for locations were data was available. The graphs of the elevation for Wageningen are displayed in **figure 5,6** and **7.** The general elevation distribution of settlements has a similar distribution during the three periods. Kortenoord in period 1 is a low point that does not return in the later periods. Rijnwijk in Period 3 is a relatively low settlement in the last period. The average elevation is given in **table 1**.

Table 1 Average elevation and number of settlements per period for the region of Wageningen

Period Wageningen	Elevation (AHN)	Number of settlements
1	16.69	6
2	15.39	6
3	19.78	8

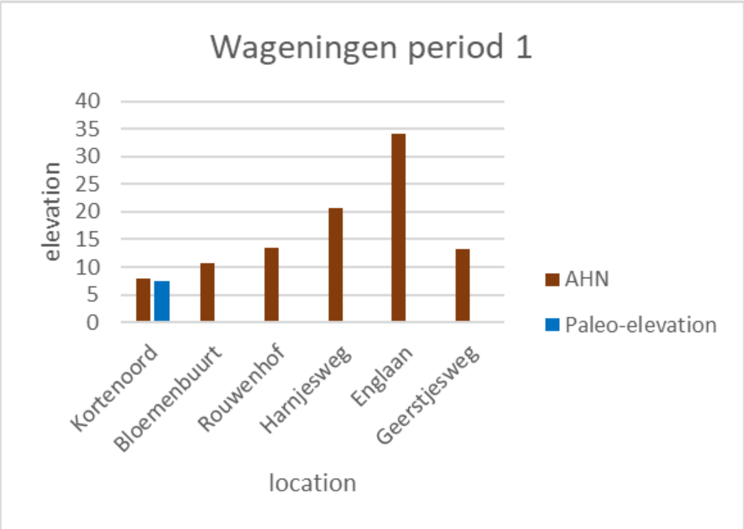

Figure 6 Elevation for the settlements in the region of Wageningen during period 1 (0 CE - 500 CE).

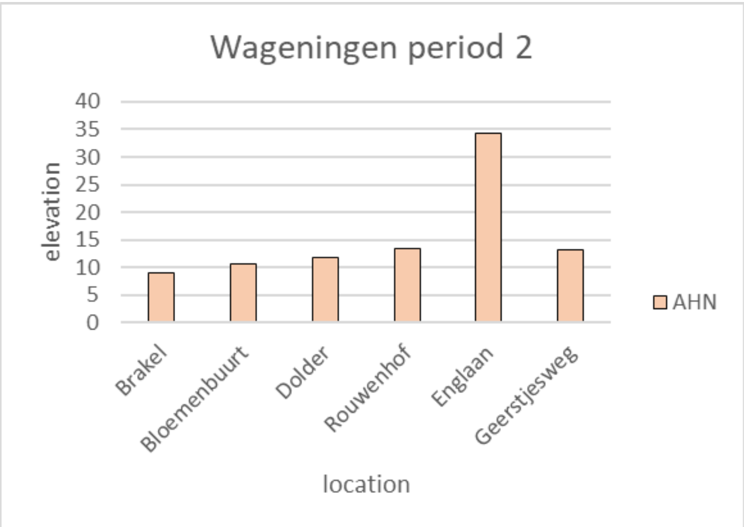

Figure 5 Elevation for the settlements in the region of Wageningen during period 2 (500 CE - 900 CE).

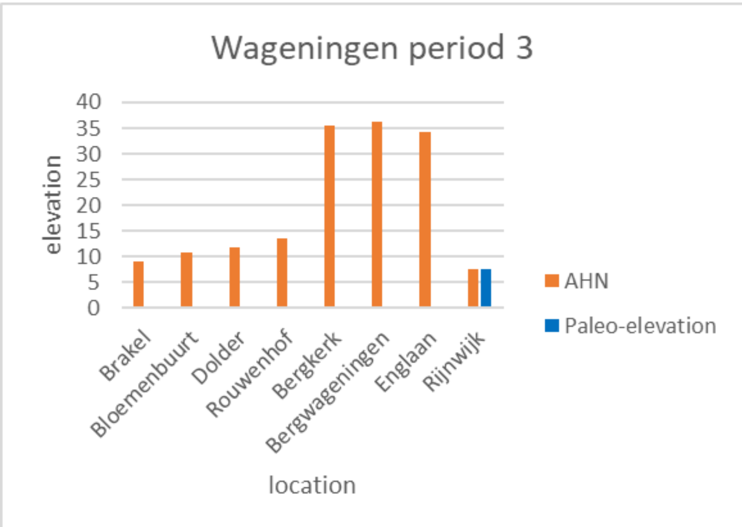

Figure 7 Elevation for the settlements in the region of Wageningen during period 3 (900 CE - 1250CE).

The difference in elevation between the Randwijk settlements is relatively low compared to Wageningen **(figure 8, 9** and **10)**. The paleo-elevation data is present for all the points in the region and indicates some difference between current and historical elevation. This can be due to settling of the soil or erosion processing taking place. The largest differences can be found in settlements located in the floodplain, such as Hemmermeer, Molenpol and De Hel, which are located farthest away from the river. The average elevation **(AHN)** for period 2 and 3 is higher than the average elevation of period 1, 7.89 m+NAP and 7.63 m+NAP respectively **(table 2)**.

Table 2 Average elevation and number of settlements per period for the region of Randwijk

Period Randwijk	Elevation (AHN)	Elevation (Cohen 2017)	Number of settlements
1	7.63	7.68	10
2	7.89	7.98	4
3	7.89	7.98	4

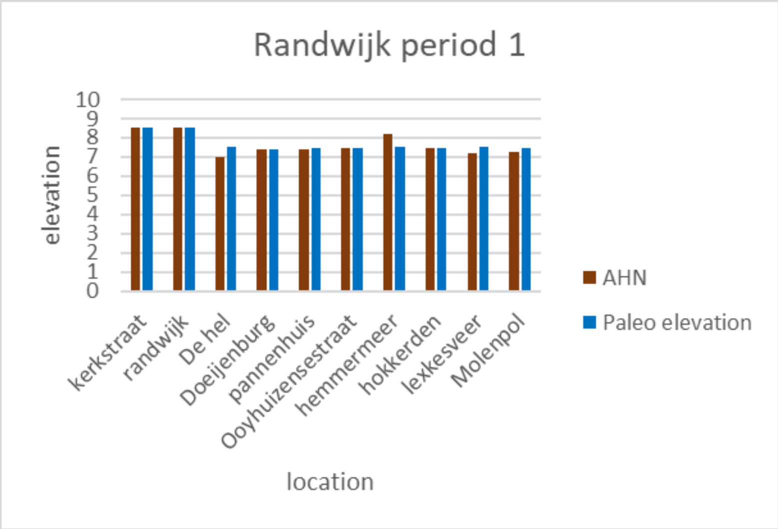

Figure 8 Elevation for the settlements in the region of Randwijk during period 1 (0 CE - 500 CE).

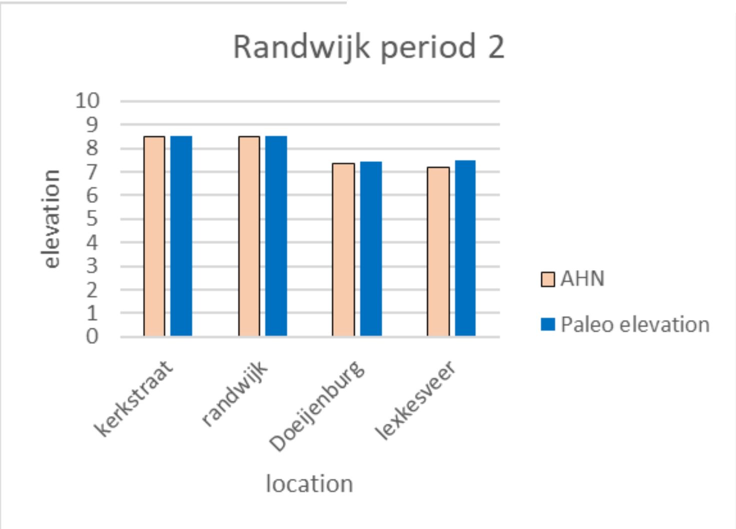

Figure 9 Elevation for the settlements in the region of Randwijk during period 2 (500 CE - 900 CE).

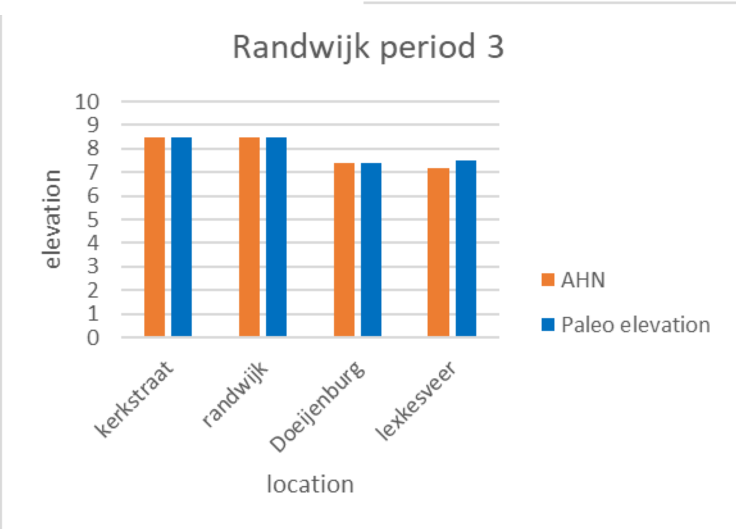

Figure 10 Elevation for the settlements in the region of Randwijk during period 3 (900 CE - 1250 CE).

The elevation in the region of Rhenen has de largest difference in average elevation between period 1 and 2 **(table 3)**.The main trend in the three periods is that some relatively high settlements above 40 m+NAP, such as Heimenberg and Levendaal, and a larger number of relatively low settlements between 20 and 9 m+NAP, such as Kerkplein, Bovenweg 1, Bovenweg 2 are constant over time. Laarsche weg is the only intermediary with 25.72 m+NAP in period 2, see **figure 11, 12** and **13**. The reason for the difference in average elevation between period 1 and 2 is the relatively high ratio of relatively low settlements and relatively high in compared to period 2 and 3.

Table 3 Average elevation and number of settlements per period for the region of Rhenen

Period Rhenen	Elevation (AHN)	Number of settlements
1	23.05	4
2	23.28	7
3	23.31	3

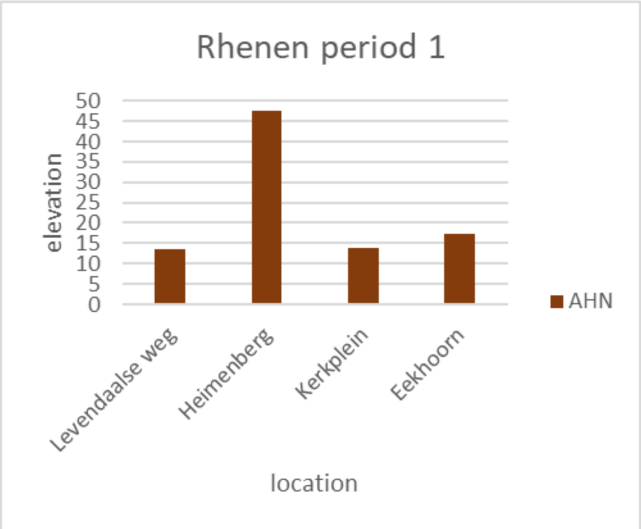

Figure 11 Elevation for the settlements in the region of Rhenen during period 1 (0 CE - 500 CE).

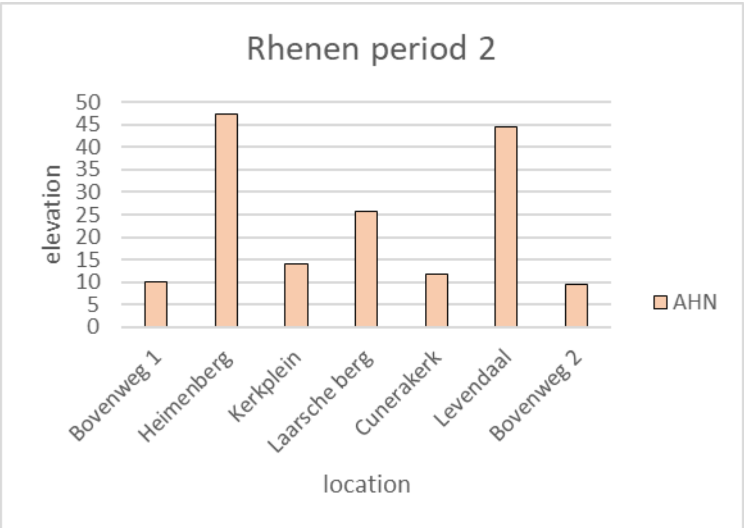

Figure 12 Elevation for the settlements in the region of Rhenen during period 2 (500 CE - 900 CE).

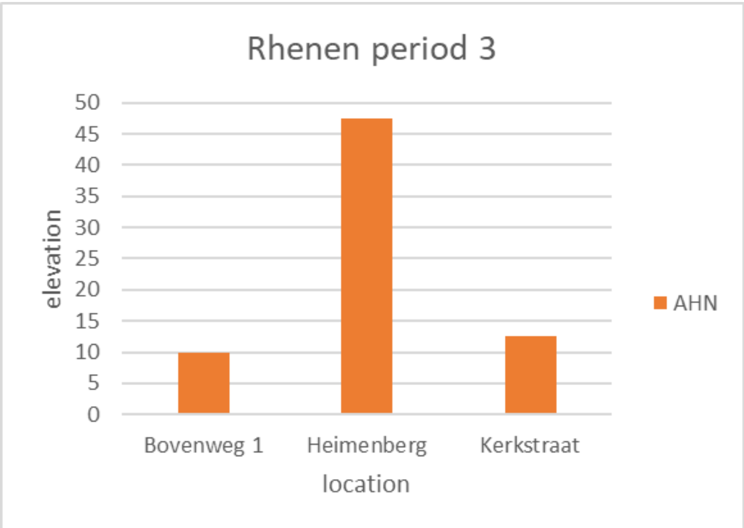

Figure 13 Elevation for the settlements in the region of Rhenen during period 3 (900 CE -1250 CE).

3.3 Geomorphology

Appendix B provides for each location the geomorphological unit according to the Dutch geomorphological map **(geomorfologische kaart 1:50000)** and the paleogeomorphological unit according to research by **Groenhuijzen (2018)**. The soil type according to the Dutch soil map **(bodemkaart 1:50000)** is depicted in the last column. Data from the geomorphological map does not always give useful results due to the occurrence of archaeological sites in build-up areas where the geomorphology is not depicted on the map, mainly in the region of Wageningen,. Even though the geomorphological map has a more detailed legend, the occurrence of buildings makes it less useful than the paleogeomorphological map for describing relations between settlement locations and geomorphology.

The settlements in the region of Wageningen are located on the high Pleistocene sands associated with the push moraine, and the coversands. The exceptions are Kortenoord and Rijnwijk. Kortenoord is located on the lower floodplain which is linked to clayey soils. According to the paleogeomorphological map, Rijnwijk is located on the high Pleistocene sands, but the soil type is defined as sandy loam. This can be explained by the modern geomorphological map, which indicates this area as being excavated, which would have allowed for the deposition of fluvial sediments after the period of the paleo geomorphological map.

The dominant paleogeomorphological unit for settlements in the region of Randwijk is the moderately high natural levee. The exception is De Hel which is located on the low natural levee. This is consistent with the modern geomorphology which classifies this place a floodplain/ levee-like plain. The soil type is the same for every location, heavy sandy loam and light clay, with the exception of Kerkstraat which has a coarser soil with light sandy loam.

The settlements in the region of Rhenen are distributed over the high Pleistocene sands and the coversands. The two settlements which are located on the coversands are Bovenweg 1 and Bovenweg 2, which are relatively close to each other. The modern geomorphology map divides the high Pleistocene sands into smaller units: outwash plains, alluvial material and high push moraine. The soil map indicates that the outwash plains are currently build-up areas while the coversands, alluvial materials and push moraines are dominated by humus rich soils with coarse sand.

3.4 Maps

The maps in this chapter are a detailed representation of the habitation in each region during the designated periods. The area of habitation illustrates the general area of habitation. The differences of these areas between maps provide an indication of the shifting settlement locations over time. The channel belts are retrieved from **Cohen et al (2012)**. The background map consists of a DEM **(AHN)** and a paleogeographical map of the period 70 CE – 270 CE **(Groenhuijzen, 2018)**. The paleogeographical map is used for the three periods because of the lack of maps specific for the other periods and the relatively small differences between this map and the current geomorphological map. Changes that did happen during the study period were mainly in the channel belt and those changes are incorporated in the channel belt layer (**Cohen et al., 2012)**.

The distribution of settlements in the region of Wageningen between period 1 and 2 is similar with little change in the general area of habitation, see **figure 14 & 15**. In both cases the main concentration is located on the boundary between the high Pleistocene sands, the push moraine, and the neighbouring coversands. The main exception is Kortenoord which is present in period 1 and absent in period 2 and is located in the lower floodplain. The report discussing the findings at Kortenoord point to habitation at the transition between the floodplain and the coversands in period 1 so the coordinates on the maps in this research can differ from the exact location **(Hessing & Schrijvers, 2005)**. Period 3 has a clearer distinction between two areas of habitation see **figure 16**. The first area is located at the transition between the high Pleistocene sands and the coversands, and the second area is concentrated on the Wageningse berg. (**Gast et al., 2013)**. Rijnwijk is situated at the foot of the Wageningse berg and is the first settlement located near the Nederrijn channel belt. The city of Wageningen itself is founded on the low natural levee at the border of the push moraine. The change in the shape of channel belt near Wageningen happens between the end of period 2 and the end of period 3 when the channel belt starts to move south.

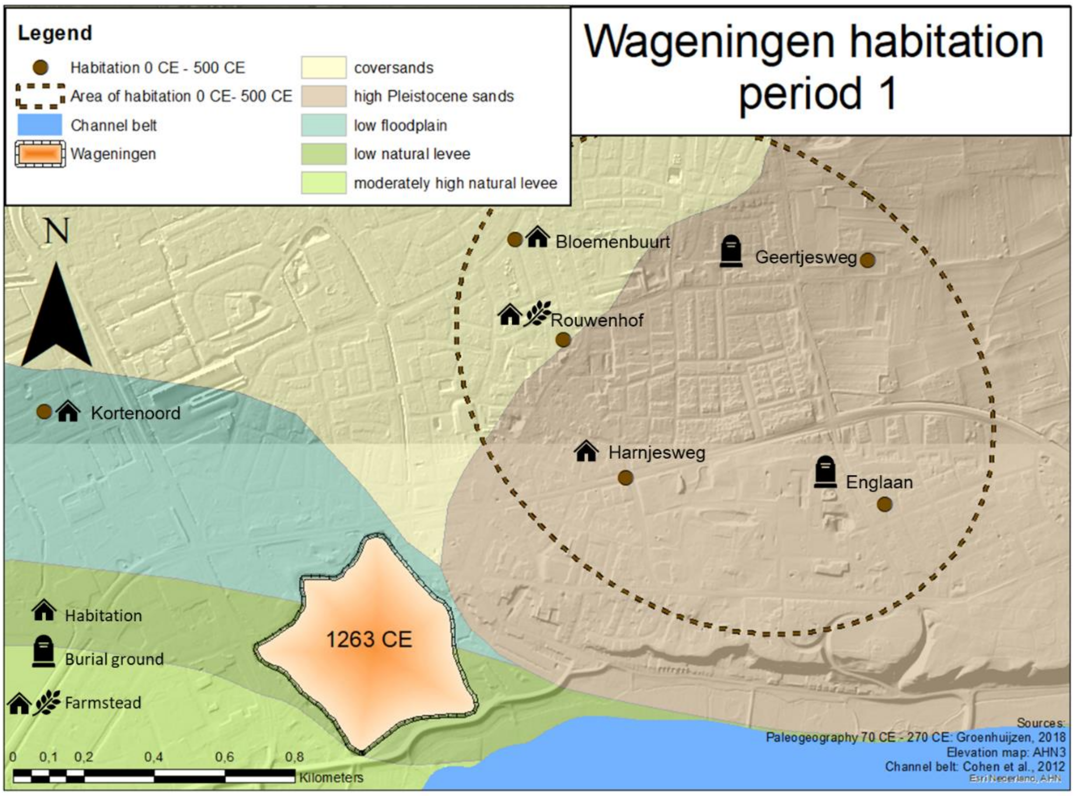

Figure 14 Habitation point in the region of Wageningen during period 1 (0 CE - 500 CE). The area of habitation is the general area that encompasses points in the same geomorphological region as defined in the paleogeographical map.

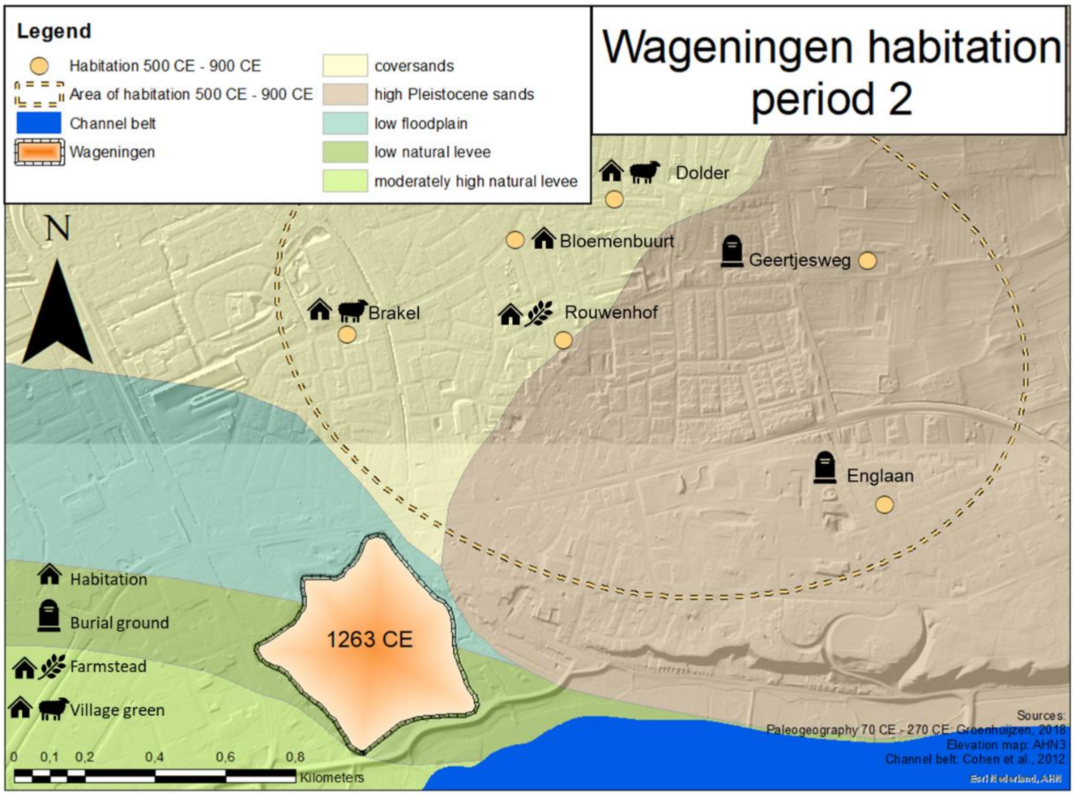

Figure 16 Habitation point in the region of Wageningen during period 2 (500 CE - 900 CE). The area of habitation is the general area that encompasses point in the same geomorphological region according as defined in the paleogeographical map.

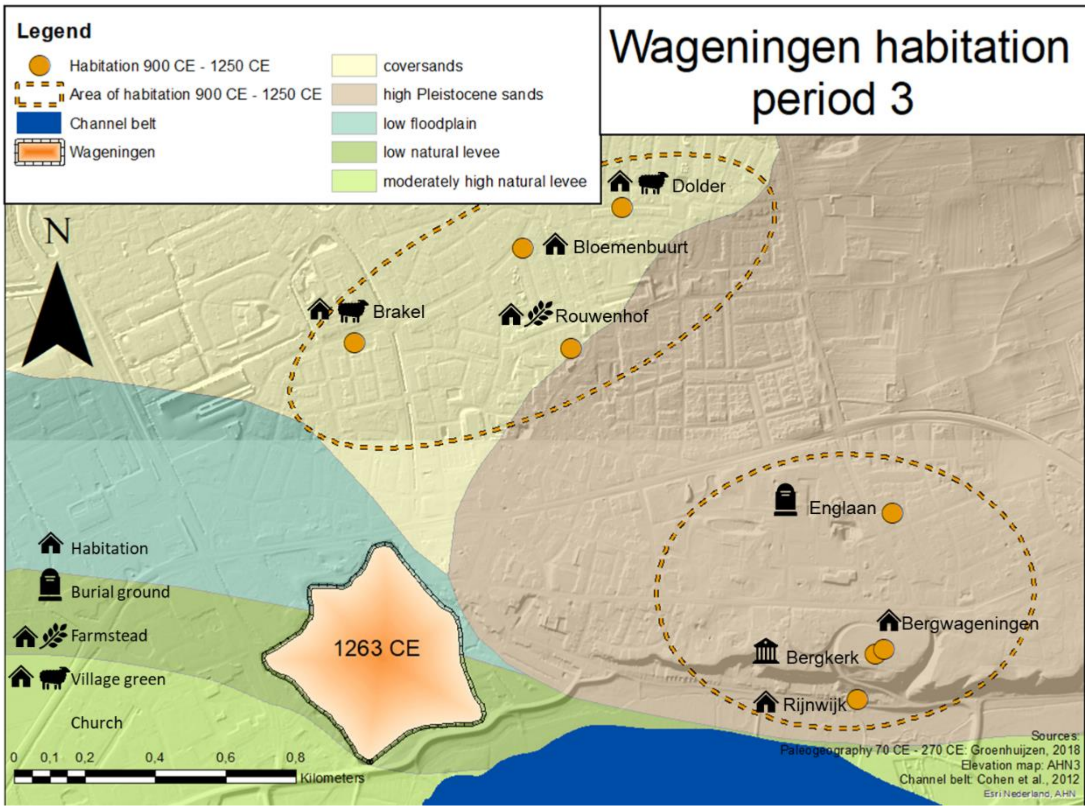

Figure 15 Habitation point in the region of Wageningen during period 3 (900 CE - 1250 CE). The area of habitation is the general area that encompasses points in the same geomorphological region as defined in the paleogeographical map.

The habitation in the Randwijk region in period 1 is distributed over an area ranging from the natural levee to the high floodplains further away from the channel belt **(figure 17)**. Habitation further away from the channel belt such as De Hel, Hemmermeer and Molenpol are situated near old streams linked to a crevasse **(pdok.nl)**. This old crevasse created the relatively small natural levees in the floodplain and thus created relatively suitable settlement locations. The area of habitation in period 2 is smaller than in period 1 and concentrated on the high natural levee, close to the channel belt **(figure 18)**. Period 3 has the same settlements and therefore the same area of habitation as period 2 **(figure 19)**. The habitation is continuing during the entire timeline for the archaeological sites at: Doeijenburg, Kerkstraat and Randwijk. Lexkesveer was present as a ford in the river throughout the three periods but is not directly linked to a settlement. The channel belt near Randwijk is broader during period 1 and 2 and starts to become narrower during period 3 and starts to move further away from the habitation at Randwijk and Doeijenburg

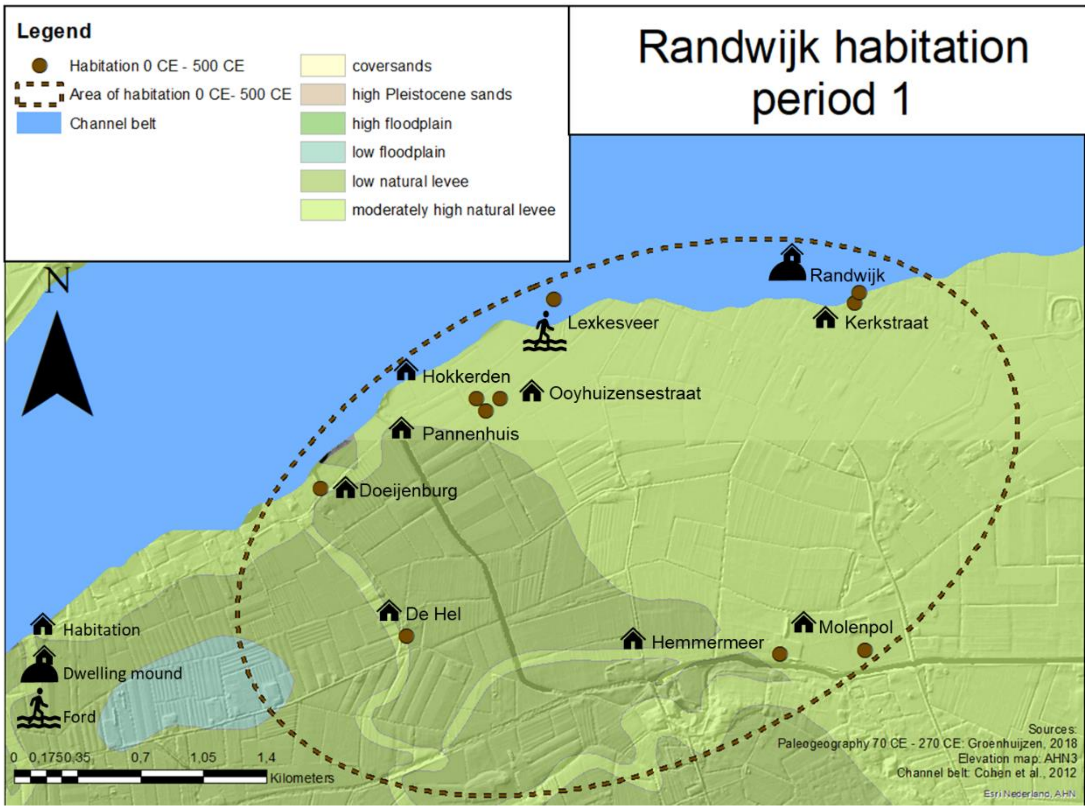

Figure 17 Habitation point in the region of Randwijk during period 1 (0 CE - 500 CE). The area of habitation is the general area that encompasses points in the same geomorphological region as defined in the paleogeographical map.

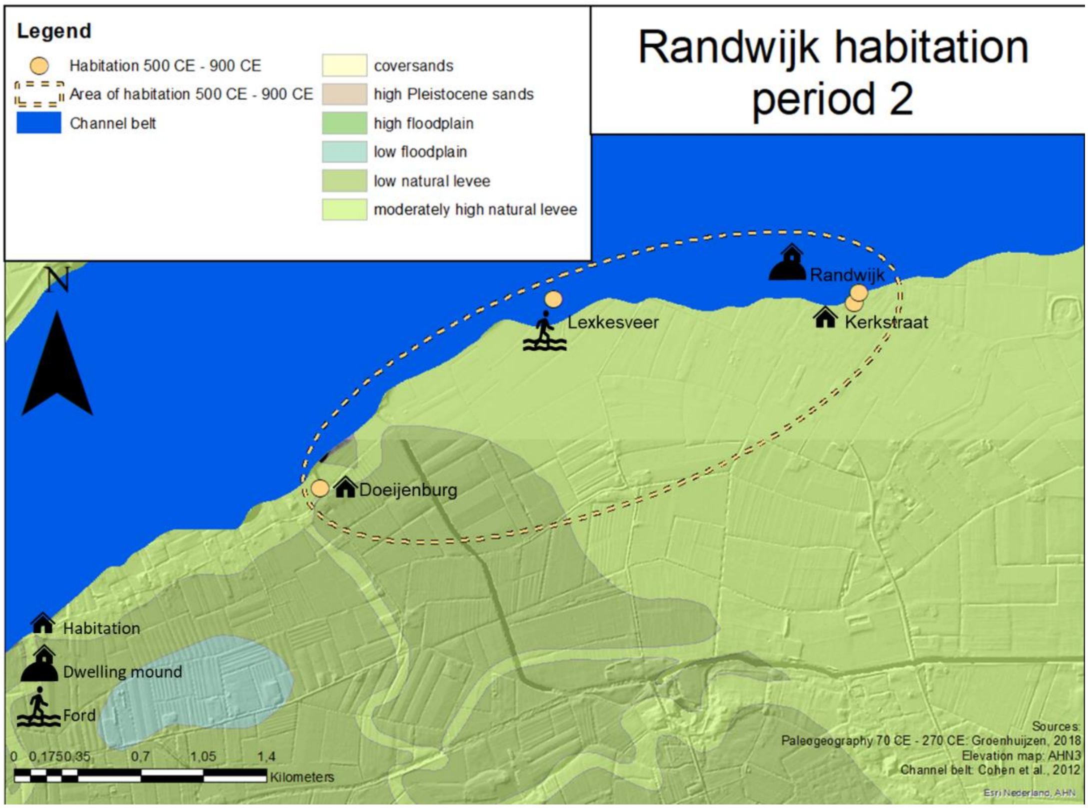

Figure 19 Habitation point in the region of Randwijk during period 2 (500 CE - 900 CE). The area of habitation is the general area that encompasses points in the same geomorphological region as defined in the paleogeographical map.

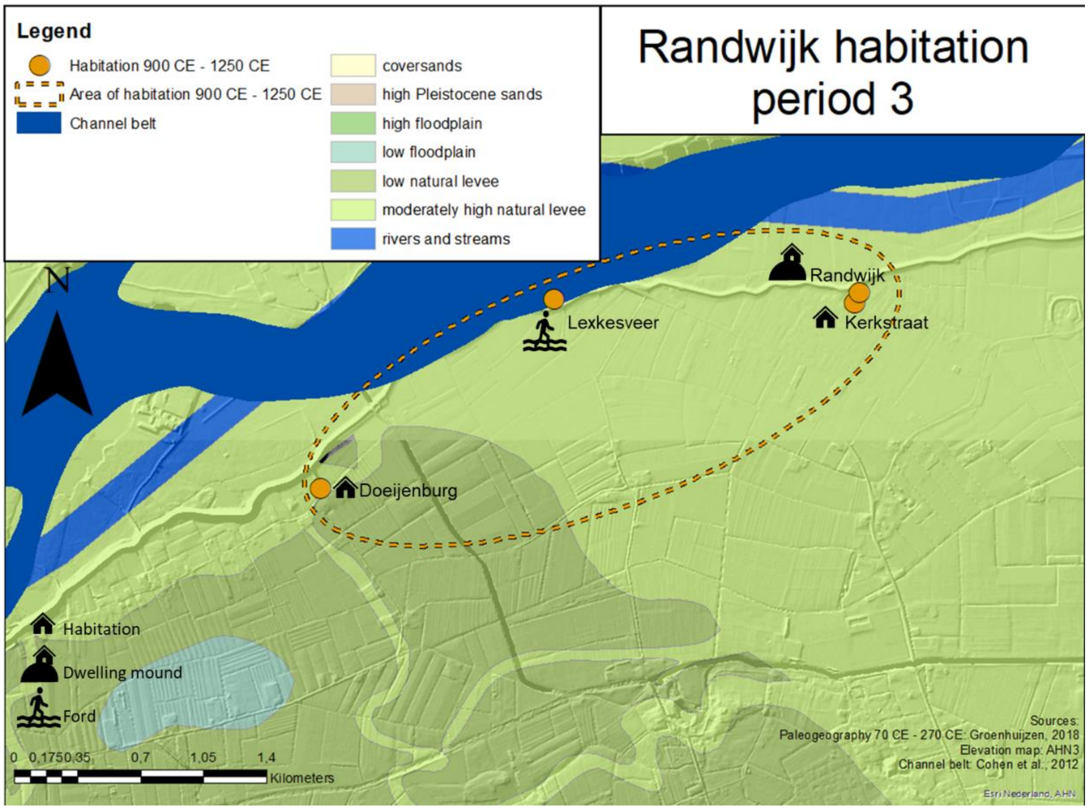

Figure 18 Habitation point in the region of Randwijk during period 1 (900 CE - 1250 CE). The area of habitation is the general area that encompasses points in the same geomorphological as defined in the paleogeographical map. The rivers and streams in the legend refers to the Nederrijn channel identified in the paleogeographic map and does not apply for the period depicted in this map

The region of Rhenen has two distinct areas of habitation. In period 1, the first area is located at the Nederrijn around the current city of Rhenen on the border of the Pleistocene sands and the natural levee **(figure 20)**. The second area is located on the Pleistocene sands of the Grebbeberg extending towards the coversands of the Gelderse Vallei. The area around the city of Rhenen has signs of habitation during the entire timeline and although it is close to the channel belt, this area of habitation is situated on the relatively high flank of the push moraine. A change that occurs in period 1 is that the evidence for habitation is only through burial grounds whereas confirmed habitation appears in period 2. The extend of the second area varies over time and is larger in period 2 and 3 when it extends further north along the border of the push moraine and the coversands **(figure 21 and 22)**. This pattern that habitation was mostly concentrated on the flanks of the push moraine and the higher parts of the coversands is similar to the habitation pattern seen in the region of Wageningen. The fortification at Heimenberg stands out as it is present is every period. The channel belt near Rhenen is located further north during period 1 and 2 and start to become narrow and move south during period 3, moving further away from the Grebbeberg and the habitation near the city of Rhenen.

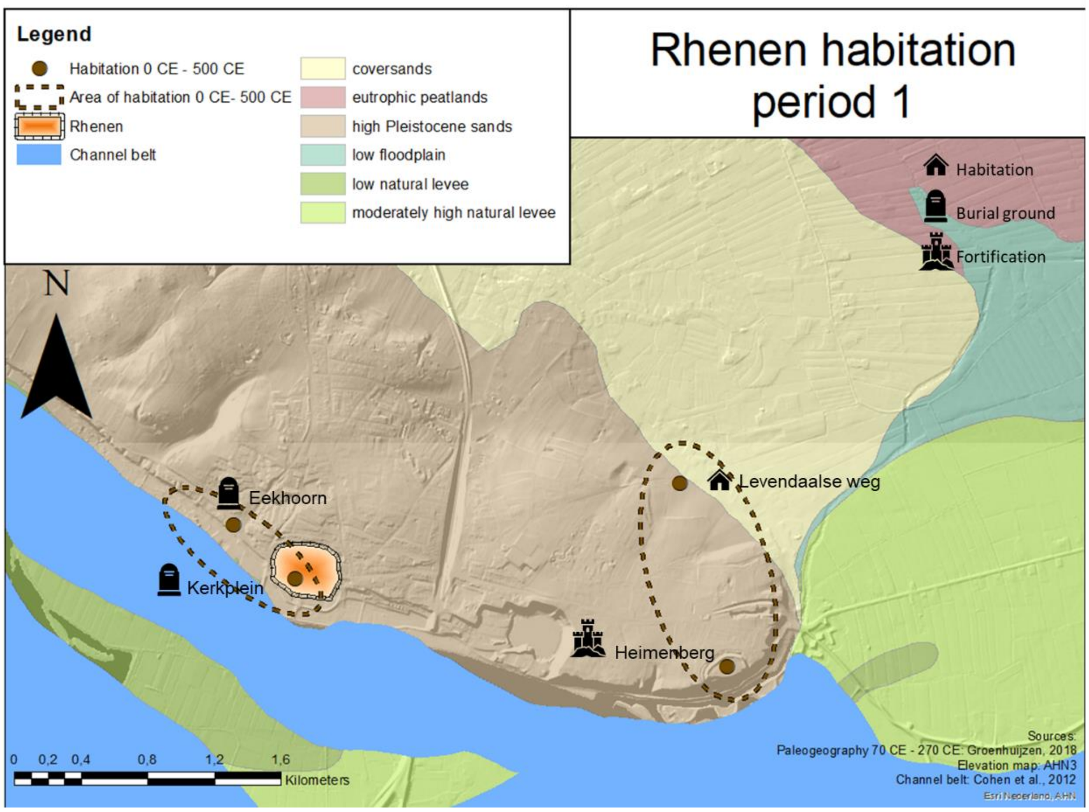

Figure 20 Habitation point in the region of Rhenen during period 1 (0 CE - 500 CE). The area of habitation is the general area that encompasses points in the same geomorphological region as defined in the paleogeographical map.

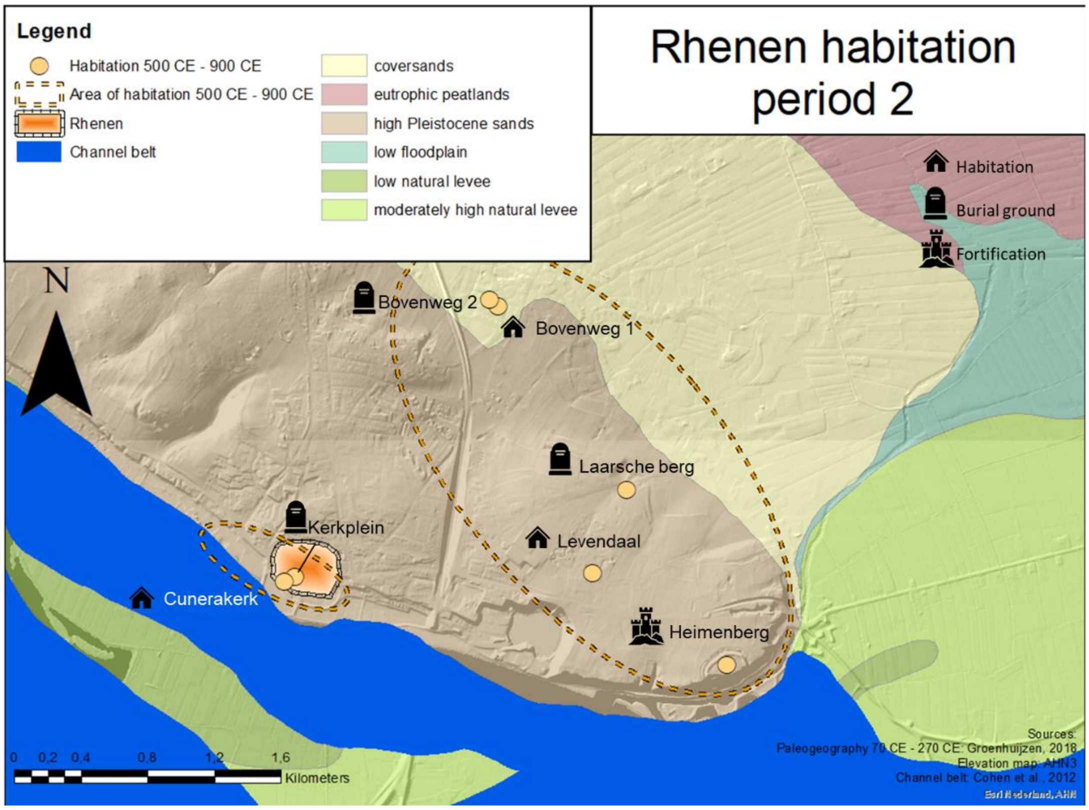

Figure 22 Habitation point in the region of Rhenen during period 2 (500 CE - 900 CE). The area of habitation is the general area that encompasses points in the same geomorphological region as defined in the paleogeographical map.

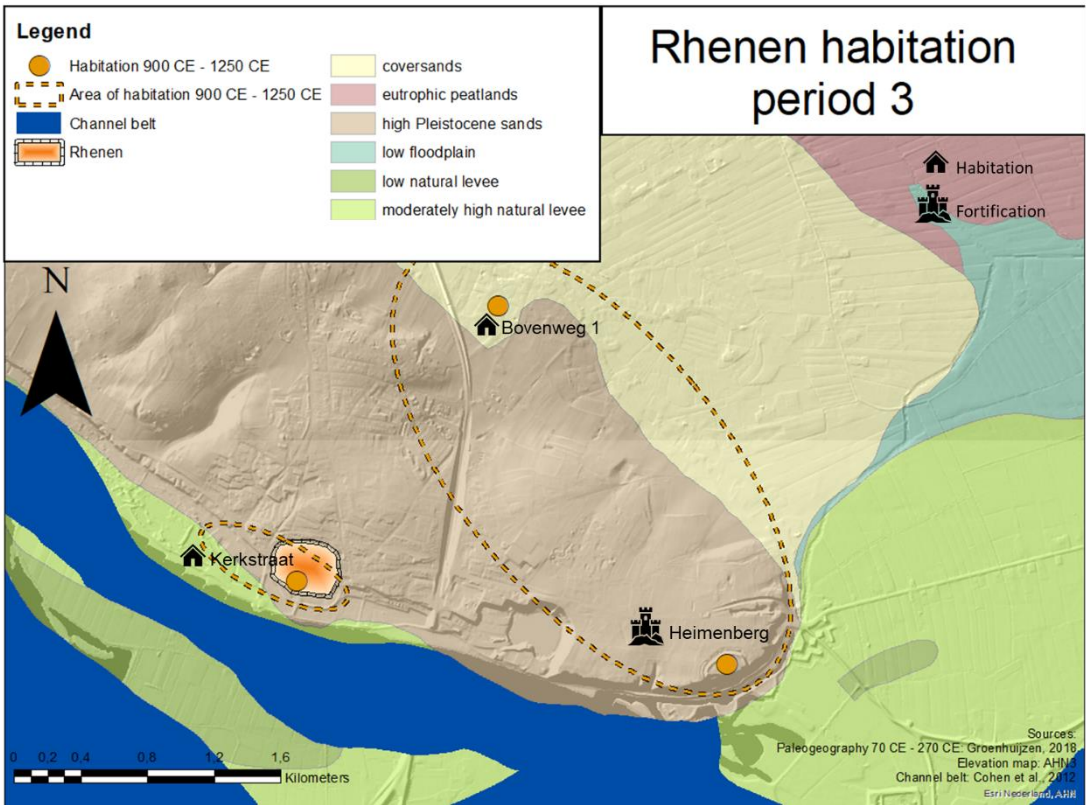

Figure 21 Habitation point in the region of Rhenen during period 9 (900 CE -1250 CE). The area of habitation is the general area that encompasses points in the same geomorphological region as defined in the paleogeographical map.

3.5 Flood data

Establishing historical floods is done through the examination of researches that used geomorphological research and historical sources to establish the flood record of the Rhine. The first research that focussed on floods of the Lower Rhine was conducted by **Toonen (2013)**. The ages and intensities of the floods are based on floodplain and oxbow lake deposits. Floods with a reoccurrence time of a millennium and longer, millennial floods, were identified and one of these floods occurred in the time period of this research. This flood occurred in 784 CE and it is suggested that these types of millennial floods had a large impact on the geomorphology of the river system. These large events do not correspond directly to periods with a relatively high number of floods. The period of intense flooding identified by **Toonen,** within the time period of interest, is 300 CE – 700 CE. Periods with fewer major floods are 800 CE - 1000 CE and 1200 BCE - 300 CE **(figure 23).**

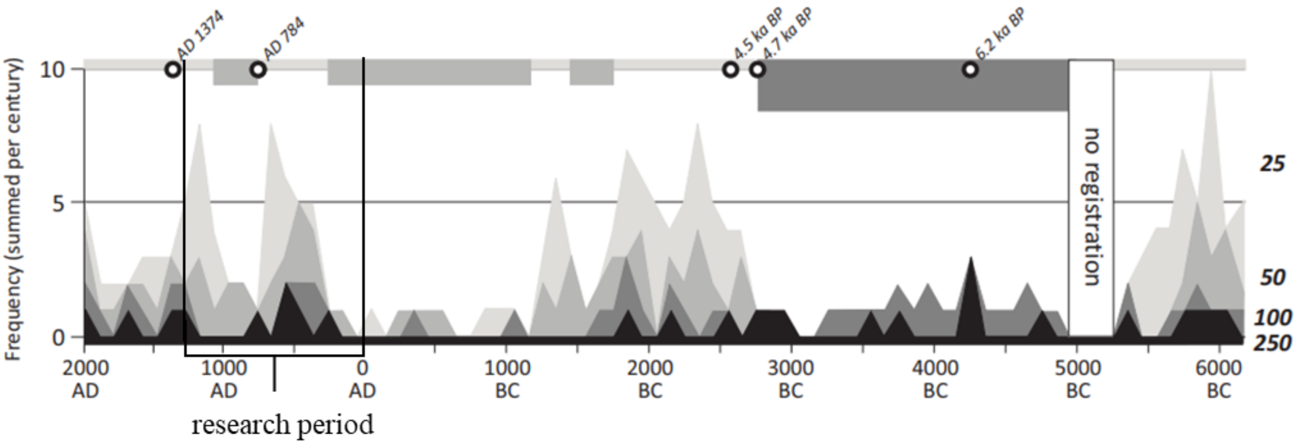

Figure 23 Reconstruction of historical floods of the Rhine from 6000 BCE to the present. Frequency is given as floods per century with recurrence times of 250, 100, 50, 25 years corresponding to black, dark grey, grey and light grey. Millennial floods are given at the top of the figure (modified after Toonen 2013).

The second research is the Deltares report by **Cohen et al. (2016)**. This report mainly builds on the research of **Toonen (2013)** and expands on the results. The main aim of this report is to explore new insights into historical river flooding and how these insights can be applied to archaeological research in the river area. The focus is on peak discharges that have a recurrence time of larger than 500 years. The largest events are summarized in **table 4.**

Table 4 largest historical floods with time of repetition (Modified after Cohen et al. 2016)

Name event	**Age** ***(low/high estimate 2σ)***	**Period**	**Recurrence time** ***(reach of estimates in brackets)***
784-5 flood	784-5 CE *(738-992)*	2	1150 *(500 - 2600)* ***millennium flood***
Amerongen-1.3 event	686 CE *(617-755)*	2	575 *(50- 2050)*
Visveld-1.7 event	282 CE *(100-464*	1	525 *(150 - 800)*

In addition, there is summarization of the avulsions and river diversions that have taken place between 500 BCE and 1000 CE, see **table 5**. This shows how the Nederrijn was impacted by changes in other branches of the Rhine and how this might have impacted the nature of the flow near Wageningen. Two new branches that influenced the development of the Nederrijn within the research period are the Waal, between 219 and 465 CE, and the Gelderse IJssel, between 314 and 481 CE. Both branches developed in period 1 and they both led to an overall loss of discharge of the Nederrijn. Their formation coincides with the Merovingian High from 300 to 700 CE, a period of intense flooding, which probably contributed to the formation of the new branches **(Toonen, 2013; Cohen et al., 2016)**. This implies that the overall change in river dynamics was relatively high during this period which led to the formation of crevasses and the cutting of meanders. The loss of relative discharge for the Nederrijn compared to the other Rhine branches did not seem to have influenced the flooding regime of the Nederrijn in following centuries **(figure 23)**.

Table 5 river diversions in the Rhine between 500 BCE and 1000 CE (Modified after Cohen et al. 2016)

New branch	Losing branch	Start dating New branch 1st possibility	#	Start dating New branch 2nd possibility	#
Nederrijn	reorganization of branches in Overbetuwe	ca. 500 BCE	1	20 ± 60 BCE	2
Waal-Bruchem	**Nederrijn** and downstream branches	ca. 500 BCE	1	200 BCE	2
Lek-Hollandse IJssel	**Kromme Rijn, Oude Rijn, Utrechtse Vecht**	293 ± 62 BCE	1	96 ± 75 BCE	2
Linge	**Nederrijn** and downstream branches	229 ± 103 BCE	1	18 ± 46 BCE	1
Hollandse IJssel	reorganization of branches in southwestern Utrecht	96 ± 75 BCE	2	217 ± 73 BCE	1
Lek	**Kromme Rijn, Oude Rijn, Utrechtse Vecht**			44 ± 30 CE	1
Waal	**Nederrijn** and downstream branches	219 ± 58 CE	1	465 ± 56 CE	1
Gelderse IJssel	**Nederrijn** and downstream branches	314 ± 48 CE	1	481 ± 44 BCE	2

Sources: (# columns) 1: **Berendsen & Stouthamer, 2001**; 2: **Cohen et al., 2012**

The third research is conducted by **Peng et al (2020).** It differs from the research by **Toonen (2013)** because it uses natural levee deposits instead of floodplain deposits to determine the age an intensity of paleo floods. The research is conducted on the Meuse river and not the Lower Rhine river system. The results display a different overall trend as the research by **Toonen (2013)**, with less flooding during the Early Middle Ages **figure 23**. Despite the differing results between the floodplain-based reconstruction and the levee-based reconstruction during the research period, they both show the same flood trends, albeit in different magnitudes.

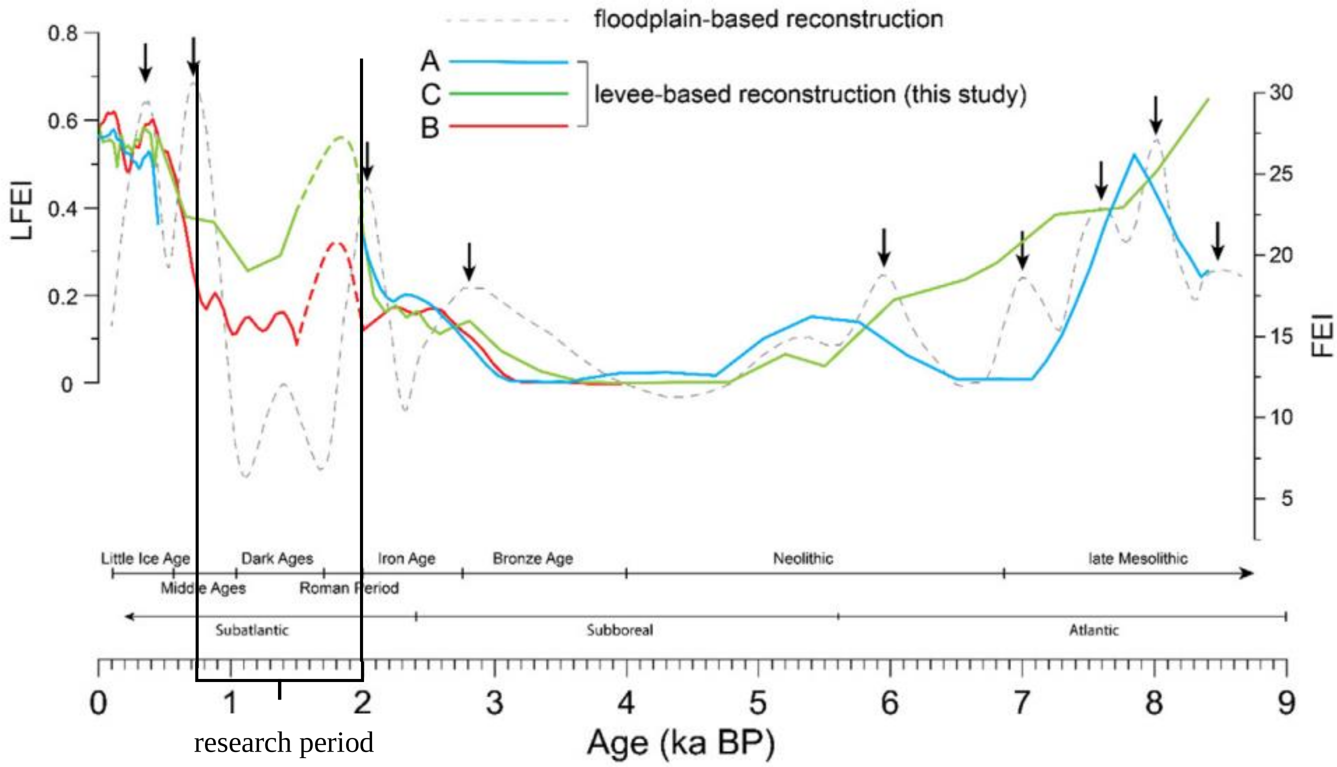

Figure 24 levee-based reconstruction of historical floods in the Meuse river. The grey dashed line is based on floodplain sediments (Peng et al., 2020) and the coloured lines are based on the levee sediment approach by Peng et al. (2019).

With the results of the flood data and the timeline of the habitation **figure 25** was made. The periods of relatively intense flooding and the periods of less frequent intense floods are displayed in green and blue respectively. Major floods are displayed as vertical lines with the error bar at the top of each line. The dates of the major floods are derived from **table 11 (Cohen et al., 2016)**. The periods of relatively more and less frequent floods are derived from **Toonen et al. (2013)**. With this figure it is possible see overlap between the time periods of the habitation points and the occurrence of major floods. When combining the timeline in this figure with the elevation data **(figures 5 to 13)** and geomorphological data **(figures 14 to 22)** to account for vulnerability for each habitation point, an assessment can be made to which extend the changing habitation patterns can be linked to the flooding regime. The exact length of the bars used to define the period in which a habitation point was occupied was determined with the ages given in the sources corresponding to the archaeological sites **(appendix A)**. The begin dates and end dates are not precise for every point due to varying certainty of age determination of archaeological findings. However, the age determinations do provide an estimate of the period in which a habitation point was occupied.

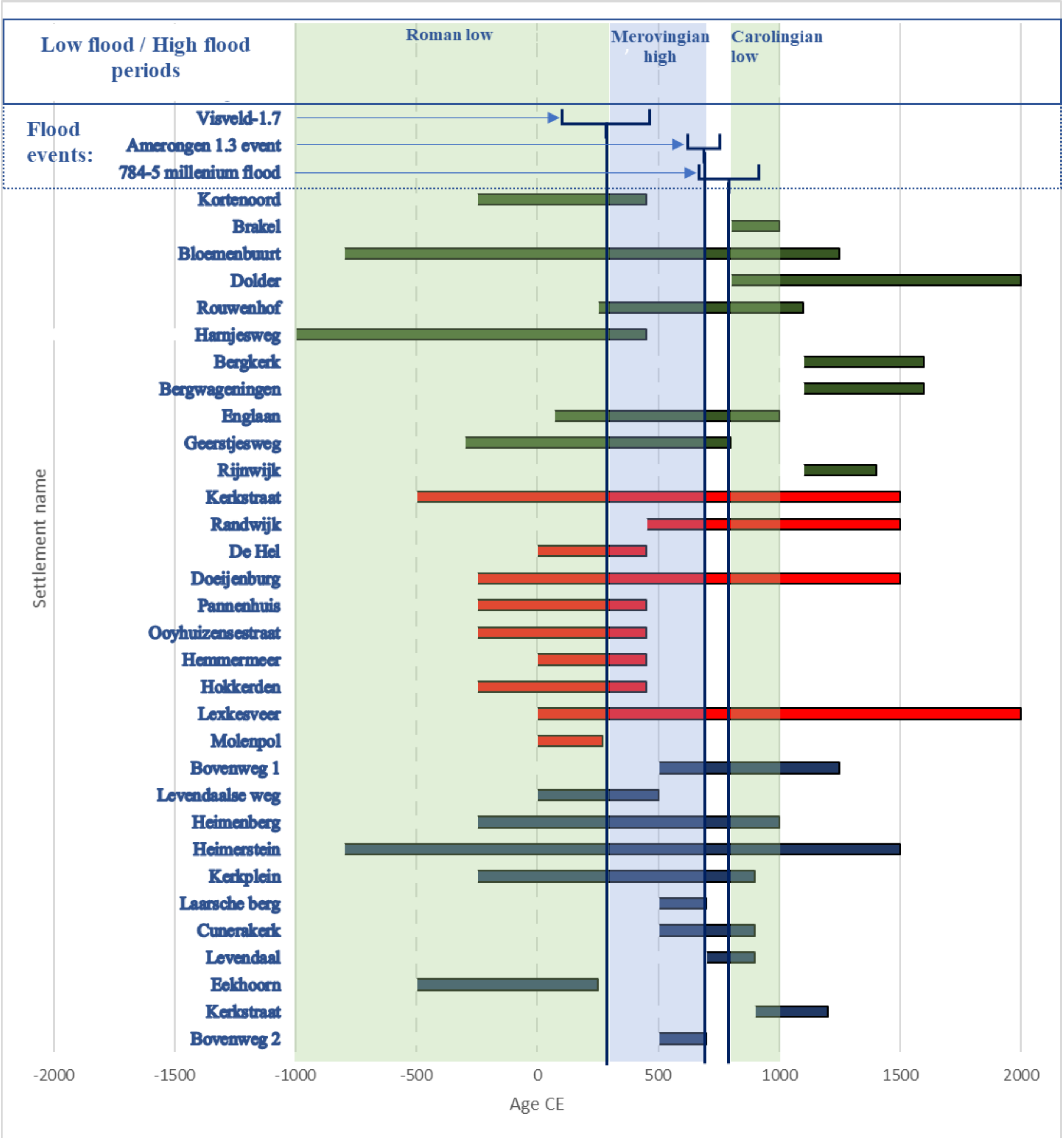

Figure 25 Timeline of settlements in the study area (green Wageningen, red Randwijk, blue Rhenen). The green vertical bars are periods with less floods. Vertical blue bars are periods with more floods. Vertical blue lines are major flood events with the uncertainty given at the top of the line.

For the region of Wageningen (green bars) the two points that are relatively vulnerable are Kortenoord and Rijnwijk. The disappearance of Kortenoord as a settlement corresponds to the Merovingian high and is within the error bar of the Visveld-1.7 flood. Rijnwijk was founded during a period with a relative low frequency of flooding after the Carolingian low **(figure 25)**.

The elevation in the region of Randwijk is relatively low meaning that the vulnerability for floods is relatively high. De Hel, Pannenhuis, Ooyhuizensestraat, Hemmermeer, Hokkerden and Molenpol all disappear during the Merovingian high and within the error bar of the Visveld-1.7 flood. The dwelling mound at Randwijk originates during the Merovingian high and close to the Amerongen 1.3 and the 784-5 millennium flood. This suggests that the flooding regime required elevated places for habitation during this period.

The habitation in the region of Rhenen was located on a relatively high elevation with consequently a low risk of flooding. The settlements of Kerkplein, Cunerakerk, Eekhoorn and Kerkstraat are located relatively close to the channel belt especially in period 1 and 2 **(Figure 20 & 21)**, but there is no clear link between changes in these settlements and the floods during this period **(figure 25)**.

4 Discussion

The trends in the average elevation of settlements in time differ per region. The changes in elevation in Wageningen are most extreme with the average elevation decreasing between period 1 and 2 by 1.30 m and increasing between period 2 and 3 by 4.39 m **(table 1, figure 4,5 and 6)**. The relatively large changes in average elevation are mainly driven by the amount of habitation points located on the Wageningse berg. The lowest group of points that is persistent over time is the group located on the edge of the high Pleistocene sands and the coversands. With an elevation between 8 and 15 m+NAP and with no evidence of river water reaching this area, they do not seem to be influenced by major changes in river dynamics since there is little substantial change in settlement location over time. The relatively high elevation and the location on the slope facing away from the river resulted in no direct impact of the Nederrijn on the habitation locations. Environmental factors that had a larger role in hampering habitation deeper into the Gelderse Vallei were water originating from the peatlands and seepage of groundwater **(Renes, 1997; Renes, 2009)**. Therefore, the patterns found by **Pierik & Van Lanen (2017)** do not return in the changes in habitation patterns seen in the region of Wageningen. The two locations that do occur within the areas subjected to river influence are Kortenoord and Rijnwijk **(figure 14** and **16)**. Kortenoord was located on the low floodplain with an elevation of 7.81 meters **(AHN3)** and 7.5 meters paleo elevation. The discontinuation of the habitation after 450 CE coincides with an increase in flooding during the Merovingian high and the large Visveld-1.7 flood in ca. 282 CE (**figure 25**). The abandonment of this relatively low site during the late Roman period is in line with the transition to higher elevations during this period found in **Pierik & Van Lanen (2017)**. Rijnwijk appeared during period 3 around 1100 CE. This period had fewer major floods in the river area and the broad and shallow channel of the Nederrijn allowed for the ford at Lexkesveer to be exploited **(Toonen, 2013; Mulder & Franzen, 2006; Gast et al., 2013)**. The occurrence of Rijnwijk at the edge of the Nederrijn channel belt could only have been possible if floods were not too frequent and not too severe. However, the vulnerability of Rijnwijk is not very conclusive due to the steep hill face at the location of Rijnwijk and therefore large range of elevation at the potential location.

Some settlements have evidence for their existence due to mentions in literature but lack the archaeological evidence. A settlement of special interest in this research is Rijnwijk. The exact location of this settlement has been and is still not certain. Some sources mention it as a precursor of Randwijk south of the Nederrijn, while other sources place it north of the river. Etymological evidence that suggests that the name Rijnwijk is not directly related to Randwijk, is in line with stronger evidence that it was located north of the Nederrijn **(Muller, 1905; Gast et al., 2013, Mulder & Franzen, 2006; Vervloet pers. comm.).** The proposed location of Rijnwijk is at the foot of the Wageningse berg bordering a now abandoned bend of the river. The purpose of the settlement was the transhipment of goods over the ford in the river at Lexkesveer where goods could be moved with a crane from one ship onto another. The Lexkesveer served as a crossing place between the Betuwe and the Veluwe and was connected to the Diedenweg, an important road between Amersfoort and Nijmegen **(Gast et al., 2013)**. The commercial success of Rijnwijk was directly dependent on the behaviour of the Rhine in this period and can therefore serve as a direct indicator for the effect of fluctuations in the Nederrijn. The period in which Rijnwijk is existed is relatively quit in terms floods and saw a decrease in overall discharge of the Nederrijn **(table 5)**. Rijnwijk originated during a relatively low-flood period after the Merovingian high and after the 784-5 millennium flood **(figure 25)** and could therefore have made use from the broad and shallow channel of the Nederrijn at Lexkesveer **(figure 4)**. The decrease in Nederrijn dynamics during period 3 is visible in **figure 4** where the channel belt is less broad in 1450 CE than in 500 CE therefore suggesting less active change in channel diversions. This is due to the lack of major floods that would have enhanced the activity of channel diversions, such as. meander cutting.

The changes in settlement elevation in Randwijk are relatively small compared to Wageningen. The change in average elevation is an increase of 30 cm between periods 1 and 2 and no change between period 2 and 3 **(table 2)**. The number of settlements decreases between period 1 and 2 and remains stable between period 2 and 3 **(figure 17, 18 and 19)**. The elevation difference is mainly due to the abandonment of settlements with lower elevations. The increase in elevation and the decrease of settlements can be explained by the increase of flooding during the Merovingian high and the abandonment of the Roman Limes. The change in habitation pattern between period 1 and 2 is also observed by **Pierik & van Lanen (2017).** They found that the early and middle Roman period was characterized by a relatively high number of settlements. The number of settlements dropped after the abandonment of the Limes and the average elevation became higher during the Merovingian high **(figure 25)**. The decrease in settlements can be linked to the disappearance of the local castellum and therefore abandonment of surrounding habitation centres **(Groenhuijzen, 2019; Willems, 1981)**. The lack of settlement shift in Randwijk in period 2 and 3 does not completely align with the results of **Pierik & Van Lanen (2019)**. The further increase in settlement elevation that was reconstructed in other parts of the delta after the Merovingian high is not observable in Randwijk. A reason for this could be that the settlements were already located on the highest point in the landscape and had therefore no other place to relocate to. The overlap between the Merovingian high, the Visveld-1.7 flood, the disappearance of the lowest settlements and the creation of the dwelling mound of Randwijk suggest that the Nederrijn had a strong impact on the habitation in the region of Randwijk **(figure 25)**. After this initial transition to higher grounds the major Amerongen 1.3 event flood and the 784-5 millennium flood do not show a direct impact on the overall habitation pattern in this area.

The changes in elevation in Rhenen are relatively small compared to Wageningen. Between period 1 and 2 the increase is 0.23 m and between period 2 and 3 the increase is 0.03 m **(table 3)**. The settlements in Rhenen do not have large changes in average elevation despite changes in the number of points because of a constant habitation pattern. There is constant habitation on top of the high push moraine, 25 m to 47 m+NAP, on the border between Pleistocene sands and the coversands, between 9 m and 14 m+NAP and the river facing flank around the city of Rhenen, between 11 m and 17 m+NAP **(figures 11, 12, 13, 20, 21 and 22)**. When only considering the river facing region, the average elevation decreases between all the periods. However, the lowest elevation is still 2.5 m higher than the lowest river facing point in Wageningen. The direct impact of the river on the elevation of settlements is uncertain due to the relatively high points compared to the river. Although the changes in elevation do no match the patterns found in **Pierik & van Lanen (2017)**, the preference for settlements on high locations over lower locations closer to the river shows that floods and changing river morphology may have limited the expansion of settlements to the more productive natural levee. The channel belt was located right at the edge of the Pleistocene sands during most of the research period which implies that river processes were happening close to the points of habitation around the current city of Rhenen **(figure 20, 21 and 22)**. Despite this drawback, the relatively small distance to the river meant that the fertile river soils could still be used for agriculture and other purposes without inconvenient travel time.

The most common geomorphological units for settlements in Wageningen and Rhenen are coversands and high Pleistocene sands **(figure 4)**. These Pleistocene sands contained sandy soils rich in organic matter and the less rich coversands show signs of human induced fertilization. In both Wageningen and Rhenen there is no major shift in dominant geomorphologic unit and soil type. This translates to the maps where there is no major shift in general area of habitation, with the exception of Rijnwijk. A difference that is noticeable is the founding of the cities of Wageningen and Rhenen. Rhenen was founded on the relatively high edge of the Pleistocene sands where habitation can be found since period 1, whereas Wageningen was founded on the relatively low natural levee. The fact that Wageningen was founded on a vulnerable position shows that there were changes in how the river behaved and how the population dealt with threats from the river. In **Gast et al. (2013)** a migration from the location of Rijnwijk along the edge of the Wageningse berg to the current position of the city is proposed. The benefit of having direct access to the river, being able to construct a water filled moat and the start of river embankment made this new position for a large settlement, not seen earlier on the natural levee, possible **(Renes, 1997)**. That the city of Rhenen did not make this transition to the levee could be due to the already available space on the relatively flat and high outwash plain and the lack of early embankment construction, while being close to the benefits of the river.

Changes in geomorphological unit and soil type are less pronounced in Randwijk. The geomorphological unit is the same for all points, despite the shift in elevation observed after period 1. The soils are all dominated by calcareous sandy clay. Other soils in the region are heavy clay soils which would have been less suitable for habitation due to the low elevation and wetter soil conditions. Despite the small change in soil type there is a transition visible in the disappearance of habitation from small natural levees along old crevasses. These crevasses, while providing the same soil benefits and relative elevation as the larger natural levee directly bordering de Nederrijn, were not safe enough to provide a stable place for settlements during times with increased flooding at the end of the Roman period.

The locations of archaeological sites can be determined by several factors. One of these factors is the location of areas of interest. These areas of interest are determined based on expectations, that depend on; previous findings, mentions in literature, exploring excavations, findings in comparable environments etc. **(Flokstra, 2005; Leuvering, 2007)**. The resulting maps with archaeological values can determine where future excavations will take place **(Van der Berghe, 2008)**. If a place within the area of interest can be explored, due to e.g. construction projects, it can lead to findings in places where it was previously impossible to conduct archaeological research due to already present buildings and infrastructure **(Boshoven, 2017; Van der Weerden & Wemerman, 2009)**. Places that are accessible for research are more likely to be extensively explored and larger excavations are possible **(Heidinga, 1990; Van Es, 1964)**. Therefore, the possibility exists that settlements in non-build-up areas have a higher representation due to the possible unexplored settlements in less accessible locations.

Habitation can be derived from different types of evidence. Straightforward types of habitations are settlements described in literature **(Gast et al., 2013)** and conclusive findings of dwellings **(Hermsen, 2014)**. This research also includes indicators of nearby habitation. This includes churches, burial grounds and fortifications. Examples of these indicators are the burial grounds near Wageningen and Rhenen, the church on the Wageningse berg and the fort on the Heimenberg. These structures do not directly serve as a residence or settlement, but they are facilities for people living in the proximity. Therefore, they can serve as a type of 'habitation' within the context of this research, with the assumption that people lived close enough to these structures to make them indications of settlements **(Heidinga, 1990, Gast et al., 2013)**.

The period that this research focusses on is a period from which little written sources are known. The exact location and time frame of data points is therefore based on archaeological findings and sources from later periods. The number of sources vary strongly per location. Some settlements have strong archaeological evidence while others are only mentioned in contemporary sources. Another factor is the inaccuracy of coordinates provided in **Archis**. It is mentioned in a number of reports that the exact point where evidence of habitation was found is not the exact point given on the map in Archis, but as part of the larger area where the excavations where conducted **(Delfin-van Mourik Broekman, 1984; Hessing & Schrijvers, 2005)**. This influences the accuracy of pinpointing exact locations for settlements. The effect of inaccurate coordinates may influence the later determination of corresponding elevation, geomorphology and soil type. The effect of this is expected to not be significant because of the nature of the inaccuracies. The coordinates correspond to the general area of the excavations, i.e. a central point of the research area or place of interest and are therefore representative of the general area. There were no major differences in geomorphology between the location description in the reports and the locations presented on the map .

5 Conclusion

The changes in settlement locations during the period 0 CE to 1250 CE in the regions of Wageningen, Rhenen and Randwijk are partly influenced by the Nederrijn. Three major floods occurred during in 282 CE, 686 CE and 784 CE and between 300 CE – 700 CE there was period of increased flood frequency. After and before this period the flood frequency was relatively low and the Nederrijn would progressively have less discharge due to the formation of new river branches.

Most of the settlements in the region of Wageningen were situated on the relatively high push moraine and coversands during the research period. The high elevation of the Wageningse berg provided protection from direct influence of changing river dynamic and provided stability for permanent settlements near the present city of Wageningen. Large floods did not cause major changes in habitation patterns in this area but the lack of floods. However, the decrease in Nederrijn discharge and decrease of activity in the channel belt during period 3 did allow Rijnwijk to be established at the edge of the Nederrijn.

The settlements in the region of Randwijk were located on the natural levees. Therefore, they experienced more consequences from the changing Nederrijn dynamics. This caused settlements that were located on lower elevations further away from the river to disappear when the flooding increased during the late Roman period. Therefore, the changing habitation pattern in this region is largely impacted by the changes in flooding regime.

The region of Rhenen, like Wageningen, shows little flood related changes in settlement location. The channel belt directly bordered the high Pleistocene sands on which several settlements where located and where the city of Rhenen was eventually founded. The research shows that in the area of Rhenen there was no shift to nearby low clayey areas, such as the natural levees, from high and sandy grounds such as push moraines.

It can be concluded that the impact of changing Nederrijn dynamics was; if the possibility was there, the risk of potential floods would be avoided. When the possibility was not available, the settlement location and elevation was influenced by the flooding regime and discharge of the Nederrijn. At the very end of the research period the city of Wageningen could only be founded on the low clayey soils during a period of relatively low river activity and with the aid of the first dikes in the region. This confirms that without those circumstances it would not have been a preferred location for Roman and early Medieval settlements to be located.

6 Recommendations

Further research is needed to include undiscovered settlement locations and to more accurately date, locate and assess already mentioned settlement locations. More precise maps of the Nederrijn with a larger temporal resolution will provide more an accurate picture of the possible impact the river had on nearby settlements. Follow-up research can investigate individual settlements, such as Rijnwijk, and answer what the effect of the Nederrijn was on that specific location during the early Middle Ages.

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Appendix A

Name	Type	Region	Period	Source	Archis case identification number
Kortenoord	habitation	Wageningen	250 BCE - 450 CE	**Gast et al., 2013, Hessing & Schrijvers 2005**	3130499100
Brakel	village green	Wageningen	800 CE - 1000 CE	**Gast et al., 2013 Wijsenbeek et al., 2009**	2124779100
Bloemenbuurt	habitation	Wageningen	800 BCE - 1250 CE	**Gast et al., 2013**	-
Dolder	village green	Wageningen	800 CE - 2000 CE	**Gast et al., 2013, Van der Weerden & Wemerman 2009**	2147150100
Rouwenhof	farmstead	Wageningen	250 CE - 1100 CE	**Gast et al., 2013, Hermsen 2014**	2249576100
Harnjesweg	habitation	Wageningen	2000 BCE - 450 CE	**Gast et al., 2013**	-
Bergkerk	church	Wageningen	1100 CE - 1600 CE	**Gast et al., 2013**	3141944100
Bergwageningen	habitation	Wageningen	1100 CE - 1600 CE	**Gast et al., 2013**	3057534100
Englaan	burialground	Wageningen	70 CE - 1000 CE	**Gast et al., 2013, Willems 1981**	2937428100
Geerstjesweg	burialground	Wageningen	300 BCE - 800 CE	**Gast et al., 2013, Van Es 1964**	2872685100
Rijnwijk	habitation	Wageningen	1100 CE - 1400 CE	**Gast et al., 2013, Muller 1905, J.A.J. Vervloet personal communication 17-02-2020**	-

Name	Type	Region	Period	Source	Archis case identification number
Kerkstraat	habitation	Randwijk	500 BCE - 1500 CE	**Flokstra 2005**	3065083100
Randwijk	dwelling mound	Randwijk	450 CE - 1500 CE	**Willems 1981**	3112176100
De hel	habitation	Randwijk	0 CE - 450 CE	**Havinga 1969**	3142462100
Doeijenburg	habitation	Randwijk	250 BCE - 1500 CE	**Havinga 1969**	3142413100
Pannenhuis	habitation	Randwijk	250 BCE - 450 CE	**Willems 1981**	2938392100
Ooyhuizensestraat	habitation	Randwijk	250 BCE - 450 CE	**Willems 1981**	3140631100
Hemmermeer	habitation	Randwijk	0 CE - 450 CE	**Willems 1981, Modderman 1949**	2784468100
Hokkerden	habitation	Randwijk	250 BCE - 450 CE	**Willems 1981**	2709064100
Lexkesveer	ford	Randwijk	0 CE - 2000 CE	**Gast et al., 2013**	-
Molenpol	habitation	Randwijk	0 CE - 270 CE	**Bijvanck 1947**	2939080100

Name	Type	Region	Period	Source	Archis case identification number
Bovenweg 1	habitation	Rhenen	500 CE - 1250 CE	**Visscher 1995**	2025975100
Levendaalse weg	habitation	Rhenen	0 CE - 500 CE	**Visscher et al. 1996**	2034999100
Heimenberg	fortification	Rhenen	250 CE - 1000 CE	**Heidinga et al. 1990, Janssen 1840**	2849657100
Kerkplein	burial ground	Rhenen	250 BCE - 900 CE	**Delfin-van Mourik Broekman 1984**	2952494100
Laarsche berg	burial ground	Rhenen	500 CE - 700 CE	**Heidinga 1990**	3112021100
Cunerakerk	habitation	Rhenen	500 CE - 900 CE	**Van Tent & Vogelzang 1996**	3146983100
Levendaal	habitation	Rhenen	700 CE - 900 CE	**Heidinga 1990**	3111999100
Eekhoorn	burial ground	Rhenen	500 BCE - 250 CE	**Heeringen 1999, Leuvering 2007**	2159803100
Kerkstraat	habitation	Rhenen	900 CE - 1200 CE	**Delfin-van Mourik 1984**	2952478100
Bovenweg 2	burial ground	Rhenen	500 CE - 700 CE	**Ypey 1959**	3246142100

Appendix B

Name	Region	Period	Geomorphology (geomorfologische kaart 1:50,000)	Paleogeography 70 CE – 270 CE	Soil type (Bodemkaart 1:50,000)
Kortenoord	Wageningen	250 BCE - 450 CE	building	low floodplain	building
Brakel	Wageningen	800 CE - 1000 CE	building	cover sands	building
Bloemenbuurt	Wageningen	800 BCE - 1250 CE	building	cover sands	building
Dolder	Wageningen	800 CE - 2000 CE	building	cover sands	building
Rouwenhof	Wageningen	250 CE - 1100 CE	building	cover sands/high Pleistocene sands	building
Harnjesweg	Wageningen	2000 BCE - 450 CE	high push moraine	high Pleistocene sands	building
Bergkerk	Wageningen	1100 CE - 1600 CE	high push moraine	high Pleistocene sands	building
Bergwageningen	Wageningen	1100 CE - 1600 CE	high push moraine	high Pleistocene sands	building
Englaan	Wageningen	70 CE - 1000 CE	high push moraine	high Pleistocene sands	building
Geerstjesweg	Wageningen	300 BCE - 800 CE	alluvial fan	high Pleistocene sands	humus rich sandy soil; coarse sand
Rijnwijk	Wageningen	1100 CE - 1400 CE	plain caused by excavation	high Pleistocene sands	calcareous alluvial soils; sandy loam

Name	Region	Period	Geomorphology (geomorfologische kaart 1:50,000)	Paleogeography 70 CE – 270 CE	Soil type (Bodemkaart 1:50,000)
Kerkstraat	Randwijk	500 BCE - 1500 CE	natural levee	moderately high natural levee	calcareous alluvial soils; light sandy loam
Randwijk	Randwijk	450 CE - 1500 CE	natural levee	moderately high natural levee	calcareous alluvial soils; heavy sandy loam and light clay
De Hel	Randwijk	0 CE - 450 CE	floodplain and levee-like plain	low natural levee	calcareous alluvial soils; heavy sandy loam and light clay
Doeijenburg	Randwijk	250 BCE - 1500 CE	natural levee	moderately high natural levee	calcareous alluvial soils; heavy sandy loam and light clay
Pannenhuis	Randwijk	250 BCE - 450 CE	natural levee	moderately high natural levee	calcareous alluvial soils; heavy sandy loam and light clay
Ooyhuizensestraat	Randwijk	250 BCE - 450 CE	natural levee	moderately high natural levee	calcareous alluvial soils; heavy sandy loam and light clay
Hemmermeer	Randwijk	0 CE - 450 CE	natural levee	moderately high natural levee	calcareous alluvial soils; heavy sandy loam and light clay
Hokkerden	Randwijk	250 BCE - 450 CE	natural levee	moderately high natural levee	calcareous alluvial soils; heavy sandy loam and light clay
Lexkesveer	Randwijk	0 CE - 2000 CE	plain originated by excavation	moderately high natural levee	calcareous alluvial soils; heavy sandy loam and light clay
Molenpol	Randwijk	0 CE - 270 CE	natural levee	moderately high natural levee	calcareous alluvial soils; heavy sandy loam and light clay

Name	Region	Period	Geomorphology (geomorfologische kaart 1:50,000)	Paleogeography 70 CE – 270 CE	Soil type (Bodemkaart 1:50,000)
Bovenweg 1	Rhenen	500 CE - 1250 CE	belt coversands & old arable cover	cover sands	high humus rich dark soils; coarse sand
Levendaalse weg	Rhenen	0 CE - 500 CE	slope of alluvial material (+/- coversands)	high Pleistocene sands	high humus rich dark soils; coarse sand
Heimenberg	Rhenen	250 CE - 1000 CE	push moraine plateau	high Pleistocene sands	humus rich sandy soil; coarse sand
Kerkplein	Rhenen	250 BCE - 900 CE	outwash plain (sandr)	high Pleistocene sands	building
Laarsche berg	Rhenen	500 CE - 700 CE	high push moraine	high Pleistocene sands	humus rich sandy soil; coarse sand
Cunerakerk	Rhenen	500 CE - 900 CE	outwash plain (sandr)	high Pleistocene sands	building
Levendaal	Rhenen	700 CE - 900 CE	high push moraine	high Pleistocene sands	humus rich sandy soil; coarse sand
Eekhoorn	Rhenen	500 BCE - 250 CE	outwash plain (sandr)	high Pleistocene sands	building
Kerkstraat	Rhenen	900 CE - 1200 CE	outwash plain (sandr)	high Pleistocene sands	building
Bovenweg 2	Rhenen	500 CE - 700 CE	belt coversands & old arable cover	cover sands	high humus rich dark soils; coarse sand