Bachelor thesis

Suitable locations for LOP weirs in Rivierenland

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Waterschap Rivierenland

Preface

Dear reader,

in front of you lays my bachelor thesis report ‘Suitable locations for LOP weirs in Rivierenland’. This thesis has been written to conclude the bachelor Civil Engineering at the University of Twente. Over a period of ten weeks, I worked on the assignment created by Water board Rivierenland. Unfortunately, there was no possibility to go to the offices in Tiel and meet any of the employees in real life. Despite this, I think I obtained some valuable experiences through all the online meetings I had. For that, I would like to thank everyone who helped me in any way.

Special thanks go out to Harald Smeets for guiding me through the organisation and endless feedback on my report and to Marc Wilborts for his enthusiasm and dedication to the pilot which he will execute. Next, I also want to thank Wessel van der Sande, my supervisor from the university. He was a big help in structuring my thesis, both in the preparation as execution phase, and gave the needed feedback to make my thesis a better product. And last but not least, a big thanks goes out to my housemates from Huize Edelweiss who helped me to relax after the long days at my home office.

Mark Swinkels

Enschede, 19-02-2021

Summary

The global climate is changing rapidly and the effects of this are increasingly visible in the Netherlands. Rainfall gets heavier and summers get drier. The latter also affects the Rivierenland water board after several dry consecutive summers. With the management area between the major rivers of the Netherlands, a sufficient supply of water is possible almost everywhere, except in three areas around Nijmegen. These areas are completely dependent on rain and seepage water. This study examines the possibilities of using LOP (bulkhead) weirs in the areas of Citters, Groesbeek and Ooijpolder to retain water and create a higher groundwater level at the start of the growing season.

To begin with, an analysis was drawn up based on a number of criteria in which it is determined at parcel level which locations are suitable for a LOP weir. It emerged from this that the Citters and Ooijpolder areas appear unsuitable because of the strong influence of the Meuse and Waal rivers on the groundwater level. Retaining water makes sense in these areas until the water levels in the rivers drop, then the ditches will also drain. In Groesbeek there does seem to be a reason to assume that LOP weirs have an effect here. 13 locations in b and c waterways have been selected as suitable locations.

Next to this, a first step was taken for this research to come into contact with landowners. A meeting took place with the local department of the ZLTO, from which it was concluded that they are going to draw up a survey that will be distributed among farmers in the three sub-areas. This survey is used to map out what water problems are at play, what ideas landowners themselves have to solve this, whether measures have already been taken and whether landowners are open to participating in a pilot project from the water board.

This study also looked at the issue of handing off water level management by installing small weirs and which laws and regulations are involved. The first thing that struck was that not everyone within the organization believes in the usefulness and necessity of taking measures in the short term. From a legal point of view, it is new and at first sight impossible to outsource water level management. A lot can be learned here from other water boards where drought has been at play for much longer and more intensely and where there is a different view of the law.

Finally, some measures other than the LOP weir that could be used to conserve water have been explained. This showed that, despite the somewhat higher costs, the LOP weir is the most controllable way to retain water. Other solutions close waterways, reduce the capacity of the watercourse or cannot be adjusted after installation.

Samenvatting

Het klimaat op de wereld verandert in een rap tempo en de effecten hiervan zijn steeds vaker ook in Nederland zichtbaar. Neerslag wordt heviger en zomers worden droger. Dit laatste raakt waterschap Rivierenland na een aantal droge zomers achter elkaar ook. Met het beheersgebied tussen de grote rivieren van Nederland is er bijna overal altijd voldoende toevoer van water mogelijk, behalve in drie gebieden rondom Nijmegen. Deze gebieden zijn volledig afhankelijk van regen en kwelwater. In dit onderzoek wordt er gekeken naar de mogelijkheden om LOP (schotbalk) stuwen in de gebieden Citters, Groesbeek en Ooijpolder in te zetten om water vast te houden en een hogere grondwaterstand te creëren aan het begin van het groeiseizoen.

Om te beginnen is er aan de hand van een aantal criteria een analyse opgesteld waarin op perceel niveau wordt bepaald welke locaties geschikt zijn voor een LOP stuw. Hieruit is gekomen dat de gebieden Citters en Ooijpolder ongeschikt lijken vanwege de sterke invloed van de Maas en de Waal op het grondwaterniveau. Water vasthouden heeft in deze gebieden zin, tot de waterstanden in de rivieren zakken, dan zullen ook de sloten door de bodem leeglopen. In Groesbeek lijkt er wel reden te zijn om er van uit te gaan dat LOP stuwen hier effect hebben. 13 locaties in b en c watergangen zijn geschikte locatie aangemerkt.

Daarnaast is er voor dit onderzoek een eerste slag geslagen om in contact te komen met landeigenaren. Er heeft een gesprek plaatsgevonden met de lokale afdeling van de ZLTO waaruit is gekomen dat zij een enquête gaan opstellen die verspreid zal worden onder boeren in de drie deelgebieden. Middels deze enquête wordt er in kaart gebracht wat voor water problemen er spelen, welke ideeën landeigenaren zelf hebben om dit op te lossen, of er al maatregelen genomen zijn en of landeigenaren open staan om deel te nemen aan een pilot project vanuit het waterschap.

In dit onderzoek is er ook gekeken naar het afgeven van het peilbeheer door het plaatsen van kleine stuwen en welke wet- en regelgeving hierbij komt kijken. Wat allereerst opviel is dat binnen de organisatie nog niet iedereen gelooft in het nut en de noodzaak om op korte termijn maatregelen te treffen. Ook juridisch gezien is het nieuw en op het eerste gezicht onmogelijk om peilbeheer uit handen te geven. Hierin kan een hoop geleerd worden van andere waterschappen waar droogte al veel langer en heviger speelt en er een andere kijk op de wet is.

Tot slot is er nog een uiteenzetting gemaakt van enkele andere maatregelen dan de LOP stuw die gebruikt zouden kunnen worden om water te conserveren. Hieruit bleek dat de LOP stuw, ondanks de wat hogere kosten, de best regelbare manier is om water vast te houden. Andere oplossingen sluiten watergangen af, verminderen de capaciteit van de watergang of zijn niet meer aan te passen na plaatsing.

Table of contents

Table of tables

Table of figures

1 Introduction

1.1 Problem statement

The Netherlands has worldwide fame for its history in water management. For centuries, land reclamation has taken place and great efforts have been put up to keep the water out of the areas where people live. Naturally, major disasters, like the floods in 1953, led to huge projects to make sure water does not go places we do not want it to. Next to keeping people safe, farmers like groundwater to be low to make sure that their land does not get too wet. This makes it easier to cultivate the land with heavy machinery and when water is required for crops, they irrigate. As a result, the culture in the Netherlands concerning water was that all water that enters the country should drain to the sea as soon as possible. In this way, the chances of floods are low and thus the costs of damage are low. Since the near floods in the '90s of the last century, the programme 'Room for the river' has been set up to make more space for water in our landscapes. It also came apparent that it is wise to have a buffer for periods of drought and more and more policy is responding to this. For example, the possible increase in the water level of lake IJssel to enlarge the sweet water basin.

Because of more and longer periods of drought, problems start to occur in agriculture. In general, the lack of sufficient amounts of surface water is not a direct problem since groundwater can be pumped up. This, however, becomes tricky when several dry years follow each other up since water usage in dry years is higher than in wet years (CBS, 2020). Drinking water has priority over water for irrigation and irrigation bans are increasingly being imposed in the summer.

For water board Rivierenland, drought for agricultural lands has never been a real issue. The management area of the water board is situated between the biggest rivers in the Netherlands and far enough away from the sea to not have the negative impact of brackish or saltwater. However, in the far east part of the management area, around Groesbeek, in Citters and the Ooijpolder, ditches are running dry (Schel, 2020). This in combination with the longer periods of drought forms a problem for the water board.

A solution to this could be the usage of LOP (Agriculture Development Plan) weirs. LOP weir has become the name for weirs that are easily adjustable by farmers and an example of one can be found in Figure 1. These weirs are placed by landowners in secondary (b) and tertiary (c) waterways to try to retain water and letting it infiltrate in the soil around it. This is especially useful in areas where there is little to no water supply. Infiltration in the soil can be used to decrease the risk of drought. LOP weirs are being used in different areas around the Netherlands, in great appreciation of water authorities as well as landowners (Hylkema, 2019). When placing a LOP weir in an ideal location it can raise the groundwater level in the soil in an area of more than 5,0 hectare (see Figure 2) and conserve up to 2000 m3 of water (Zaaijer, 2013).

Figure 1: LOP weir (Dommel)

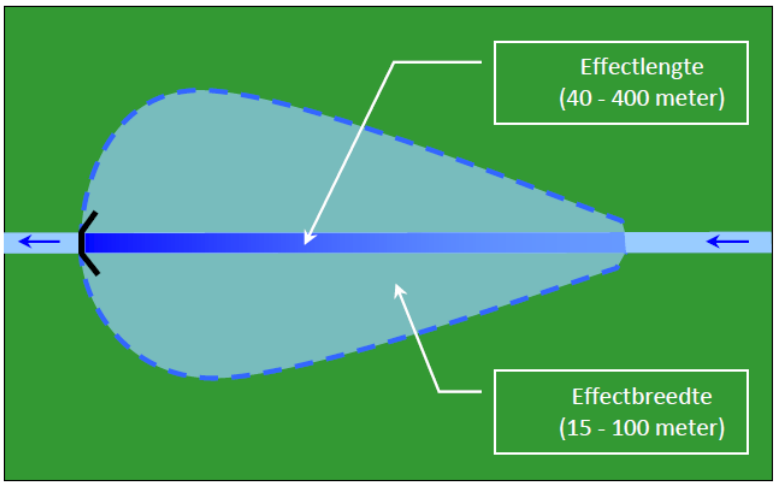

Figure 2: Area of influence of a LOP weir (Zaaijer, 2013)

What water board Rivierenland wants to know is whether LOP weirs are applicable in their management area. By carrying out a pilot in cooperation with farmers, experiences can be gained such as where the weirs are the most effective and under what circumstances. If, after evaluation, it appears that the application of LOP weirs is desirable within the management area of the water board, this can be translated into policy and action.

1.2 Study area

The management area of the water board (appendix A), which stretches from the German border at Nijmegen to national park the Biesbosch, has been divided into a great number of drainage areas (afwateringsgebieden). The focus areas for this thesis project are Citters, Groesbeek and Ooijpolder. In these areas, there is no possibility to let in water from the rivers. In appendix B, a map of all drainage areas can be found and in Figure 3 the location of the focus areas can be seen.

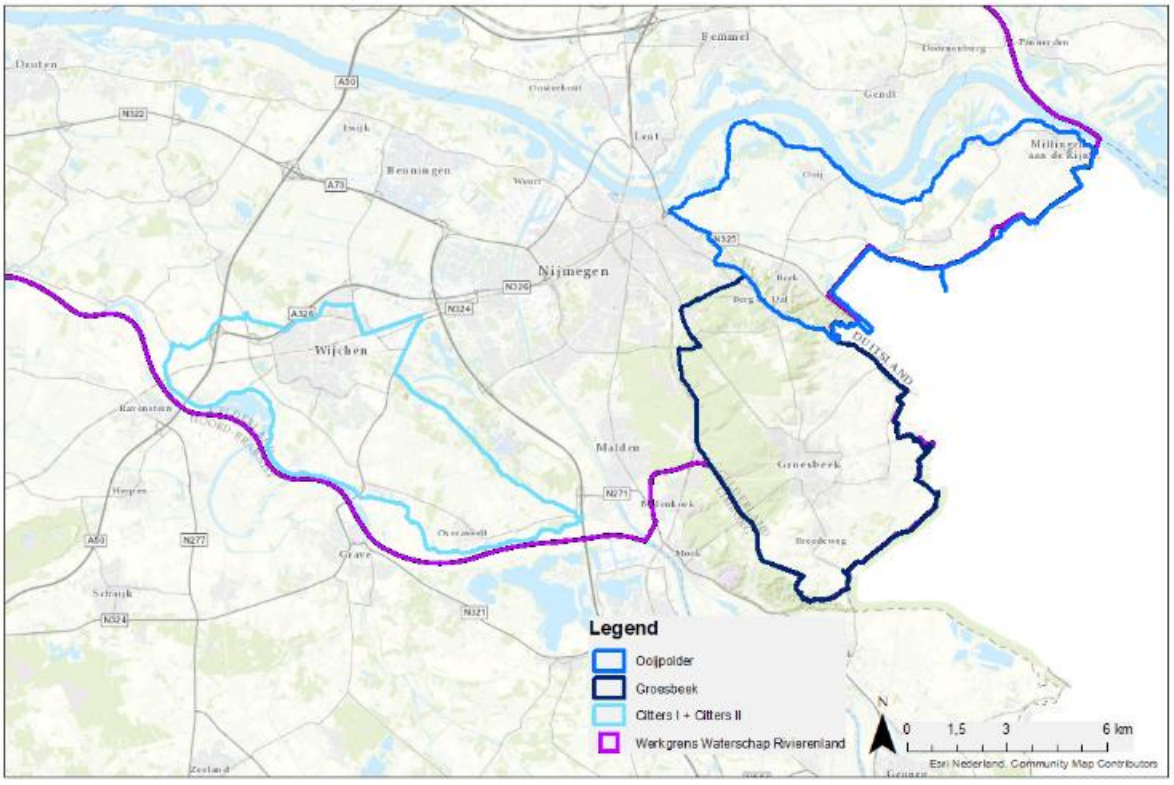

Figure 3: Focus areas

1.3 Research objective

The objective of this research project is to provide water board Rivierenland with integral advice on their pilot on LOP weirs. Most focus in this advice will lay on suitable locations. To qualify a location as suitable, there will be looked at (1) the physical aspects of the location as well as (2) the willingness of landowners to cooperate. The rest of the advice will consist of (3a) the view of the water board on the placement of the weirs and (3b) the legal consequences of this. Lastly, this will be combined with (4) a first global investigation into the type of weirs that could be placed and their costs.

1.4 Research questions

All aspects mentioned in the research objective have been caught in the following research (sub-) questions:

1. Which parcels are suitable to place LOP weirs?
2. How to connect to landowners to find out who is open to participating in a pilot with LOP weirs?
3. In what way does the water board remain involved after placing the weirs?
    a. How much authority can be given out of hands and how does the water board feel about this?
    b. Who is responsible for collateral damage if mismanagement of LOP weirs takes place?
4. What types of weirs are available and possible to place, how does this relate to the suitableness of a parcel and what costs are associated with the different type of weirs?

By answering the first question, the theoretical basis for the pilot has been made. The second question sets the first step in finding out which landowners want to participate. The third and fourth question provide valuable information to set up the pilot and make it to success.

1.5 Theoretical framework

1.5.1 Retaining water

In periods of water surplus water can be retained in the capillaries of the water system (Jeuken et al., 2015). This results in the lowering of peak discharges and some water is being saved for dryer periods. Two ways to do so are heightening the bed level of a ditch and putting up a weir. When the bed level of a ditch is heightened, the drainage from the surrounding lands stops at a higher level. More water is being retained in the soil rather than discharged by the ditch.

Weirs have the same effect, less drainage can take place, and on top of that surface water is available. A benefit of a weir over a higher bed level is that there is relatively good control on the water level in the ditch. The landowner can lower the weir, and thus the water level in his land, at any time. When the land is relatively flat, the usage of a weir can result in great amounts of water that can be stored, which is interesting for irrigation and lowering of peak discharges in creeks and rivers downstream.

To be successful in retaining water, the management of the weir should be on point. At the end of spring, ditches fall dry because the water level in the ground gets below the level of the ditch. Therefore, water should be stored in the ditches when there is a surplus, in the winter. In this way, the moment at which the ditch does fall dry can be postponed as much as possible. A visualisation can be seen in Figure 4.

Figure 4: Desired control according to 'handboek agrarisch stuwpeilbeheer' (Zaaijer, 2013)

1.5.2 Criteria for LOP weirs

All in all, there are about seven circumstances that are important for the ability of a LOP weir to retain water (Zaaijer, 2013). Not all circumstances, of course, have to be perfect to make the placement of a weir feasible but if all aspects are considered, the most suitable locations can be found. Three of the points listed by Zaaijer are mentioned in other sources as well (de Louw & Vermeulen, 2001; Hoogvliet et al., 2014; Jeuken et al., 2015; Kuindersma & Breman, 2014). Therefore, they are considered to be most important.

The most important circumstances are:

1. The area should have acceptable to well permeable soil. In clay or peat areas the LOP weir is way less effective than in a sandy area.
2. Placing a weir in areas with little slope has a greater effect due to a greater length of influence.
3. Placing a weir in waterways where there is a possibility of water supply. This offers possibilities for retaining maximum water with the weir even during dry periods.

Less important circumstances which still have an impact on the water retaining capability are:

4. Placing a weir in an area with drained lots works positive (with a sufficiently high reservoir level in the waterway, the surface water can flow via the drains to far below the lots and infiltrate there.
5. Placing a weir in such a way that water behind the weir can also raise in side-ditches. It can be stated that weirs in an area with a high ditch density have a greater effect.
6. Placing a weir in seepage areas (kwelgebieden). Seepage is a form of water supply (see point 3). The control of a LOP weir can be less precise in areas with water supply because the ‘lost’ water can be replenished quite easily.
7. The water conservation capacity of a LOP weir is greater in areas with high groundwater levels. Water can be retained there all year round, while ditches in infiltration areas are dry for (large) part of the year.

1.5.3 Past experiences

In the period between 1998 and 2005, several thousand LOP weirs have been placed in the province of Noord-Brabant because of the ‘Waterconservering 2e fase’ project (de Louw & Vermeulen, 2000; Zaaijer, 2013). Despite various attempts to evaluate the effect of these weirs, often in small areas, no solid conclusion could be proven, often due to a lack of sufficient amounts of data. The general opinion concerning weirs in ditches is, however, that they are promising for the better use of available water on a local level (Delsman et al., 2018). This might be one of the reasons that other water boards in the Netherlands have already done pilots or implemented a system with LOP weirs and older weirs have not been removed. A quick look into literature shows positive results in the region Zuidwestelijke Delta en Rijnmond-Drechtsteden (Schipper et al., 2014).

Based on research done for water board Brabantse Delta (Zaaijer, 2013) it can be said that:

1. The efficiency of a LOP weir depends strongly on location-specific circumstances
2. Maybe even more important is the active use of a LOP weir. If a LOP-weir is being used actively, it can result in a decrease in irrigation costs of €400,- per year per weir
3. Based on experience at water board Brabantse Delta and research results in the context of the 'Sticking to the source' project, additional gains can be made by optimizing the LOP weirs into a pinch weir (a V-shaped hole in one of the stiffeners)

The FWOO (Fresh Water Options Optimization) project (Hoogvliet et al., 2014) has made a nationwide suitability map for weirs. This map can show a first glans of where weirs could be applicable in the Netherlands. More information can be found in chapter 2.1.

1.5.4 Self-management

In the project 'Landbouw op peil' the water board is hesitant to give control of water levels to farmers (Kuindersma & Breman, 2014). The report states that due to the merging of water boards the distance between farmers and water boards has grown and as a result, the knowledge of water management has been lost by the farmers and the knowledge of farming has been lost at the water boards. By putting responsibilities for water management at farmers this process can be turned around. Managers of the water board were interested and a goal of the project was to see if farmers can help to carry out some tasks from the water board. In the pilot from water board Rivierenland managers also want to give the responsibility of the weirs to the farmers. However, they are not sure yet how much is desirable and, legally speaking, feasible.

Next to that, the problem or challenge of monitoring the use comes up. Previous projects show that farmers are unlikely to systematically and frequently measure groundwater levels (Personal communication; M. Berg; 24-11-2020). The water board is in most cases unable to do it since there are just too many places to monitor. To successfully evaluate the pilot at hand, serious thought has to be given to the way the measuring of water levels will be done.

1.5.5 Assessing interview data quality

Since a great part of this research relies heavily on interviews it is good to assess the data gathered from them. This will be done based on eight points mentioned by (Barnes & Atfield, 2014). These points are

- Examine the representativeness of data
- Establish the credibility of interviewees (expertise, motive, power,…)
- Weigh data in terms of credibility
- Checking for/handling outliers
- Look for contradictions
- Look for corroboration (agreement between participants)
- Triangulate different types of evidence if possible (combine published info with interviews)
- Gain feedback from participants

1.6 Reading guide

Chapter two of this report will start with the theoretical approach to where LOP weirs could be placed. This is followed by the description of an interview with a board member of the local farmer's organisation in chapter three. Chapter four contains the views from different employees of the water board. Chapter five lists some alternative ways of retaining water before heading to the discussion, conclusion and recommendations in respective chapters six, seven and eight.

2 Physical aspects

By analysing the physical aspects of the area, possible suitable locations for weirs can come forward. This chapter, therefore, focuses on the land characteristics, how they influence the suitability of the location for a LOP weir and will conclude with an analysis to arrive at the most suitable locations.

2.1 FWOO map

The FWOO (fresh water options optimization) project (Hoogvliet et al., 2014) has made a nationwide map of places where weirs in ditches could be applicable. This has been done based on cartable characteristics, following the method described by Massop (Massop et al., 2012). Six factors have been taken into account.

- Potential soil retention
- Potential retention in surface water
- Ground-level slope
- Ditch distance
- Spread length
- Pipe drainage

This data has been categorised into three categories, not promising, promising and very promising. A zoomed map to the focus areas of this thesis project can be found in Figure 5. The figure shows (very) promising and not promising areas for the implementation of weirs in the capillaries of the water system. The focus areas of this thesis, Citters, Groesbeek and Ooijpolder, have been rimmed. Citters and Ooijpolder are green for about half of their area. Groesbeek has only one green grid cell. It is important to mention that this research has been done with relatively large grid cells (250x250 m). Therefore, certain factors, like ground-level slope, might actually be much more negative in the hilly area around Groesbeek, where individual parcels may be flat.

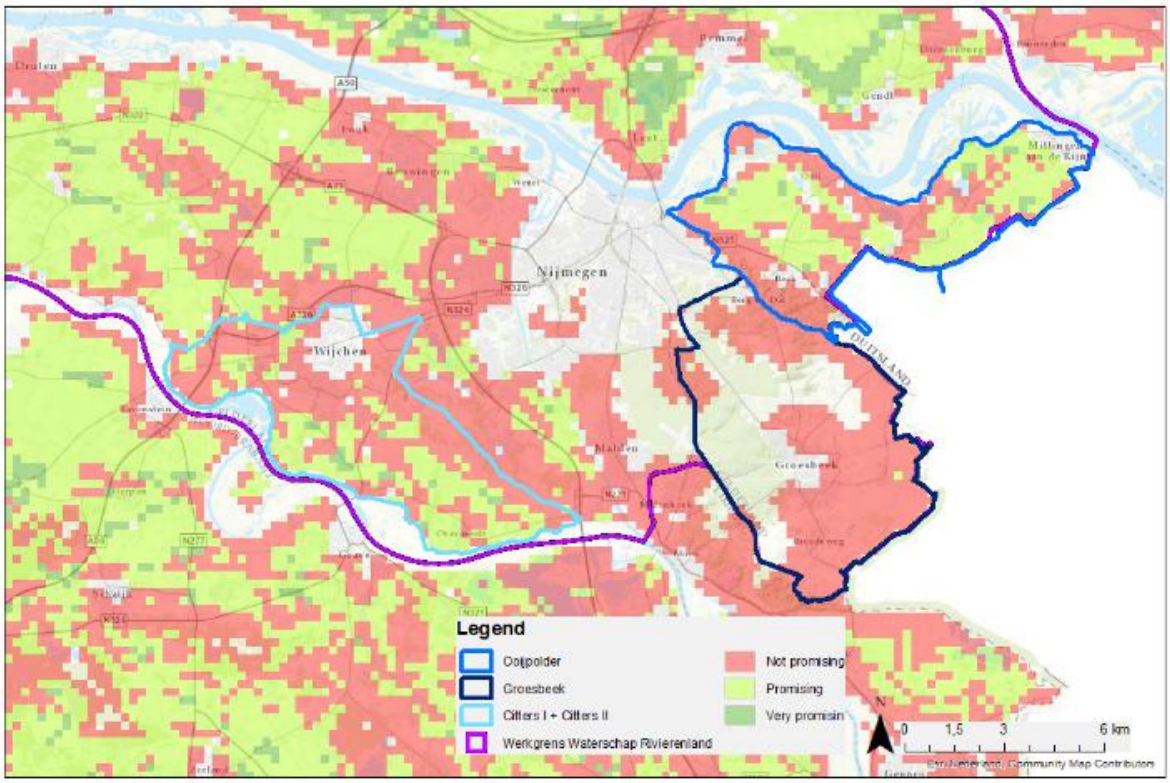

Figure 5: FWOO opportunity map weirs

2.2 Circumstances Zaaijer

To determine where LOP weirs theoretically might have success, the seven circumstances from (Zaaijer, 2013), stated in chapter 1.5.2, are investigated for the focus areas. Combining these circumstances in an analysis leads to locations in B and C waterways where LOP weirs should have the most effect. The analysis will take place based on maps and thus all circumstances are captured in maps.

2.2.1 Soil permeability

One of the most important circumstances for a LOP weir to have an effect is the composition of the soil it is placed in. Water that is stored in a ditch should be able to infiltrate sideways into the parcels (Keulen & Vermulst, 1997). The "Bodemkaart van Nederland" (soil map of the Netherlands) provides information on the important characteristics of the soil composition in the Netherlands up to a depth of 1,2 meters with a scale factor of 1:50000 (de Vries). The soil maps for the focus areas can be found in appendix C and a detailed legend has been made by (de Vries, 2003).

In Citters and the Ooijpolder, the majority of the upper layer of soil consists of riverclay. Clay has a low storage capacity and the permeability for water is not great (Keulen & Vermulst, 1997). When looking at some of the drilling profiles in the areas (*Dinoloket*), which can be found in appendix D, it becomes clear that under this layer of clay the soil consists of sand. This means that the water that could be stored in these areas in ditches, which are likely to be at least one meter below ground level, will sink into the soil fairly quickly as soon as the adjacent rivers drop in height.

In Groesbeek, however, the situation is different. The soil map of the Netherlands shows loamy soils humus podzol soils and sandy soils. Each of which is a different kind of sandy soil. For the Groesbeek area, some drilling profiles have been gathered as well (*Dinoloket*). These show indeed that the top layers consist of sand and clay layers that can be found deeper in the ground, which are the conditions that are needed for the best effects of a weir (Keulen & Vermulst, 1997).

2.2.2 Slope

If the slope of the area is small, the effect of a single weir is large. The area of influence of a single weir is larger since the water level will be higher over a large area (van Bakel, 2013). This principle is illustrated in Figure 6.

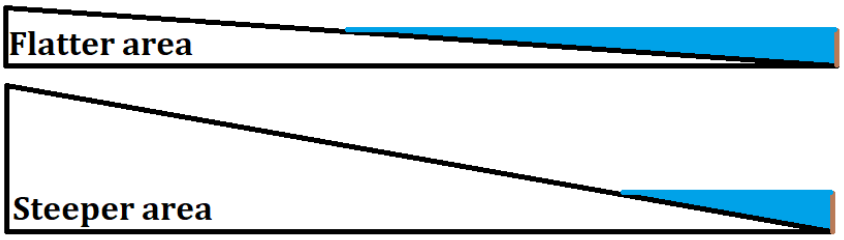

Figure 6: Area of influence weir

To include the slope in the analysis, the slope per parcel in all three focus areas has been calculated. This has been done based on the "AHN 2 0,5 meter maaiveld raster, opgevuld". This is a raster map with the heights of the ground in the Netherlands (appendix E). All not ground-level objects, like trees, buildings, and bridges, have been removed and those cells have not been filled again (*AHN 2*, 2011). The difference in height between a cell and its surrounding cells has been calculated for all cells. After this, based on the "Basisregistratie Kadaster" (*Basisregistratie Kadaster*, 2021), the average slope over a parcel has been calculated.

2.2.3 Water supply

Possibilities of water supply decrease the need for very precise management of the weir. Therefore, the main waterways in the focus areas have been mapped based on data of the water board. These maps can be found in appendix F.

2.2.4 Drained parcels

When having drainage available in a parcel, water can more easily infiltrate from the ditch into the land and the area of influence increases. Therefore, the drained parcels have been indicated on the maps in appendix G. This data has been derived from the "Buisdrainagekaart 2017" (Massop & Schuiling, 2016, 2017).

2.2.5 Side ditches

A, B, and C waterways have been mapped by the water board. This information will be used to determine the exact suitable location of a LOP weir in B and C waterways. No separate map has been made of this because the number of waterways is too big for an overview.

2.2.6 Seepage

The degree of seepage has been caught in maps as well (appendix H). This data was available at the water board in two forms, a highwater dataset from the 10th of January 2003 and a dry summer dataset from the 8th of August 2003. Because this project concerns retaining water in dry periods, the dataset from the dry summer has been chosen.

2.2.7 High groundwater level

This data has also been provided by water board Rivierenland in the forms of a GLG (average low water level) map (appendix I). This map is based on the three lowest groundwater levels in a period between the first of April and the thirty first of March (hydraulic year). The average of these yearly values over at least eight years is being used as GLG.

2.3 Suitable locations

This paragraph of the chapter explains how the most suitable locations for LOP weirs in the three focus areas have been determined. This is done based on the information gathered on the circumstances listed in paragraph 2.2.

In Citters and the Ooijpolder, the upper layer of soil consists of clay followed underneath by sand. If ditches in those areas are not deeper than the clay layer, surface water retention can take place. The effect on the drainage of a parcel will be minimal but retaining surface water might be feasible (Keulen & Vermulst, 1997). The area of Groesbeek, when looking at the soil composition, seems more suitable for infiltration.

Next, a selection on the size of the parcels has been made. All parcels smaller than 3000 m^2 have been filtered out. This because when placing weirs at bigger parcels, neighbours will experience fewer effects. On top of that, in this way, all parcels used as built area are filtered out. After this, parcels with the lowest possible slope are selected. To obtain a workable number of parcels for the rest of the analysis the maximum allowed slope percentage has been set for 1,2% in Groesbeek, 1,5% in the Ooijpolder and 1,8% in Citters.

To conclude the analysis a weighted overlay of the drainage map, the seepage map and the GLG map has been made on the parcels left. Weights have been assigned to the layers as shown in Table 1. By applying those weights, the values of the three layers are closer to each other which makes them more comparable. The GLG weight is negative since the data was in meters relative to the ground level. This means that the smaller the value, the better the result. These maps can be found in appendix J.

Map	Values	Weight
Drainage in parcels	0 or 1	0,75
Seepage	< 0 up to 3	0,20
Average low water level	0 up to 2	-0,25

Table 1: Weights used to overlay maps

The last and final step is to indicate the spots in B and C waterways where weirs could be placed. The parcels with the highest score in the weighted overlay have been selected and zoomed in to. They have been categorised by the owner and the waterways have been added to the maps. The indication of locations for LOP weirs in Citters and the Ooijpolder can be found in appendix K, Figure 7 on page 10 shows this map for the area of Groesbeek.

2.4 Conclusion

The conclusion of this analysis with cartable data is that there is little chance of any influence on the groundwater level when placing LOP weirs in Citters or the Ooijpolder. Nevertheless, there have been places selected that might have a high potential of retaining surface water. In Groesbeek 13 locations in B and C waterways have been selected in which a LOP weir could have a positive effect on the groundwater level. The groundwater level in this area is not under great influence of any river and the soil seems suitable for infiltration. The slope of parcels is only small in a selected part of the area, so suitable locations are close to each other.

2.5 Comparison with FWOO

After analysing on parcel-level it is interesting to see what the difference is with the results from the FWOO project as described in 2.1. The map in Figure 5 shows that the Citters and Ooijpolder areas are relatively suitable for water conservation with weirs. Groesbeek, however, colours red with only one light green pixel. This is quite different when comparing this with the results of the analysis described in the rest of the chapter.

One of the differences in the analysis methods is that there has been looked at the soil in terms of the amount of water that potentially could be stored in the FWOO project. This has been translated into the criteria ‘potential soil retention’ and ‘potential surface water retention’. Potential soil retention is the amount of water that could be stored between the GVG (average spring groundwater level) and the surface. Potential surface water retention has been calculated based on a possible water level heightening in all ditches depending on 5 different soil types. This tends to a quantitative approach where this thesis only looks at the permeability characteristics of the soil.

Furthermore, the grid cells in the FWOO project were 250x250m which is relatively large. This mostly affects the factor slope. In the FWOO project, the slope was calculated by taking the largest difference in the ground level of the surrounding grid cells. This thesis calculated the slope in the same way but with grid cells of 0,5x0,5m. An average of all those values over a parcel has been taken to determine the suitability.

Finally, there were some differences in input like seepage and spread length which led to differences in the outcome of the two approaches.

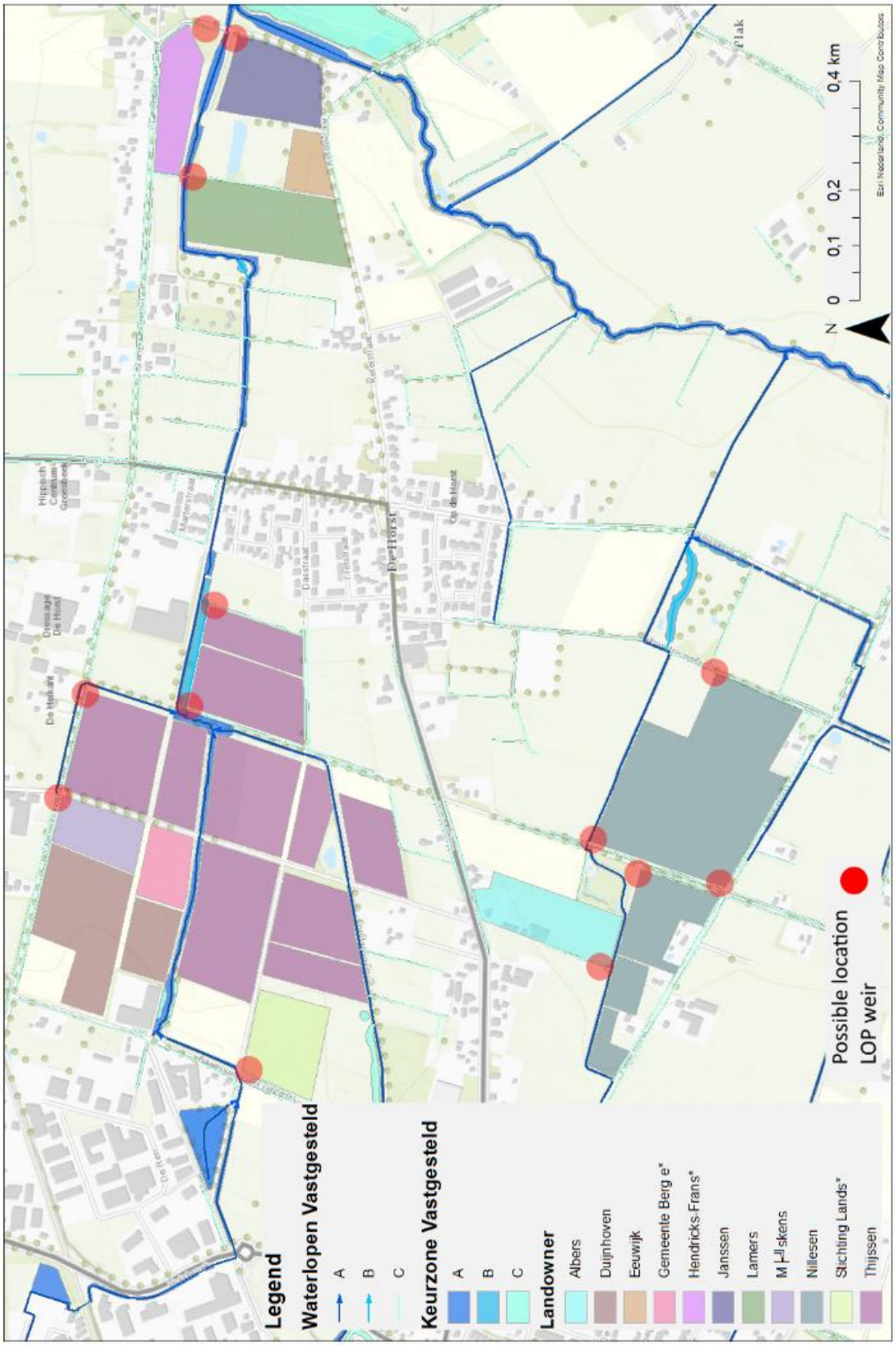

Figure 7: Suitable locations for LOP weirs in Groesbeek

3 Landowners

This chapter describes the first step which has been taken to lay contact with landowners. Besides, landowners should be on board to make the pilot feasible. They need to be informed in an early stage and can provide valuable input to make a pilot a success.

3.1 Interview ZLTO

For this research project the ZLTO (Southern Agri- and Horticulture Organisation) department Rijk van Nijmegen has been approached. This organisation serves the interest of farmers in this region in which the focus areas lay and acts as a bridge between government and farmer and is thus the first one to turn to when contact with farmers is needed. A first consultation has taken place with the board member of ZLTO Rijk van Nijmegen in charge of the water portfolio, Mr Poelen. After a brief introduction of all attendees, Mr Poelen explains the situation in Groesbeek. “About 25 farmers use reels and pumps to irrigate the land during periods of drought. 3 of them extract water from the Leigraaf (a stream with water from the local treatment plant), the rest pump up water from the groundwater. In the south of the area, there is a Natura2000 area, the Bruuk. This area is susceptible to drought and a plan is in place to use 'graften' (slope kink) to channel seepage water from the St. Jans mountain to this area. This also prevents flooding from occurring in the lower parts of the municipality.”

The ZLTO would like to undertake the implementation of this project to demonstrate to the environment that they are actively working on tackling drought and protecting nature. In recent years, a picture has emerged that during periods of drought, farmers simply roll out their reels and extract water at the expense of nature. The ZLTO would like to prove the opposite. Most farmers realize that drought is a problem that must be addressed. Continuing on the current path does not seem feasible in the long term, also because the water board may be forced to set a water stop.

Within other departments of the LTO, outside the management area of water board Rivierenland, the drought problem has been visible for some time. Steps have been taken to implement water-saving or water-retaining measures ("Ondersteuning voor boeren in aanpak van droogte," 2020). Mr Poelen continues: “It would be ideal if every farmer is encouraged to draw up a farm water plan. In this way, with the delta plan agricultural water management (Jonkers, 2013) in mind, meaningful solutions can be sought for each farmer at a parcel level.” This delta plan has been set up to advise and support farmers with for example the prevention of water- or drought damage and the reduction of pollution in ground and surface water

Making a water plan for all farmers would take too long for now. The water board has the wish to set up a pilot before the coming drought period. This is why the idea arises to draw up a survey in collaboration with ZLTO and the water board in the short term, preferably mid-February. Unfortunately, visiting farmers is not possible at the moment due to the measures to limit contacts. The survey is meant to collect from the farmers/land users whether and to what extent drought affects their land, whether they have ideas about measures to retain water, whether they have already taken measures themselves and whether they are willing to participate in a pilot project. Such a pilot project could 100% financed by the water board to make sure things happen quickly. After this, the existing arrangement with partly self-financing innovative water retaining measures could help to expand the project (appendix L) (Rivierenland, 2018). The survey will be made by the ZLTO. Water board Rivierenland will check and confirm the content and the ZLTO will send it to farmers and collect the answers.

3.2 Interpretation

What came forward in the interview is that the ZLTO and the farmers it represents are concerned about drought. The motivation, however, at this point, tended to be more due to an imminent watering ban rather than to be sustainable. Despite this, the motivation is there to move, and they know the ball is with them. The theoretical approach described in chapter 2 of this report can be seen as a basis for measures that can be combined with the practical know-how of landowners. An important aspect of the story is that if the water board wants to create opportunities before the start of the next drought period, they will have to throw in some money. It is expected that landowners are much more reticent when they have to co-finance a pilot when they do not know if they can benefit from it.

4 Water board

This chapter describes interviews with employees from the water board. Gathering views from people who have an affinity with the focus areas and have sometimes been working there for decades is very valuable.

4.1 Area coordinator

The first interview that has been held was with the area coordinator of the “Rijk van Maas en Waal”, Mr Riemersma. This function concerns coordinating all assignments and projects in the area, like projects of the water board, but also projects of, for example, municipalities, provinces, nature organisations and the state. By coordinating these, the work of different parties can be carried out more efficiently and with less inconvenience.

Mr Riemersma explains that the areas Ooijpolder, Groesbeek and Citters have been put forward to find solutions for drought problems because these are areas where there is no inlet of water from the rivers. In periods without rainfall, it is therefore only possible to obtain water here by pumping it up.

The Ooijpolder area has the word polder in its name. This would make you think that sufficient water is available all year round through seepage and that water could be let in from the river. “Due to the many sand tracks in the soil, there is indeed a lot of seepage, but at a low water level in the Waal, a river that mainly drains rainwater, this seepage is in the direction of the river. In periods of little rain, the water level in the Waal is low and the groundwater swirls through the soil towards the river.” reacts Mr Riemersma. “A possible inlet is not expected to have much effect on the groundwater level, because this incoming water will also flow away to the river. The situation is similar in Citters. Groundwater flows back to the Meuse during dry periods. An inlet could easily be made at Heumen, but here too, its effect is questioned.”

One of the directors of the Rivierenland water board asked the ZLTO in the summer to encourage farmers to think about solutions to retain rainwater. Now it is up to the water board to collect these ideas and see what can be done. To this end, a project manager has been appointed who will hold "kitchen table dialogues" with farmers and landowners.

Mr Riemersma explains that important waterways are indicated by the water board as category A waterways. These are managed by the water board anyway. A weir in a B or C category waterway will reduce the immediate discharge in A waterways and give opportunities to infiltrate. With this, water board and farmers can use the sponge effect of the soil to hopefully have more water available in toe soil in fry periods. If a farmer is given control over the height of a weir, proper agreements must be made if other farmers will also have consequences. The best situation would be to place the weirs in such a way that a farmer with several parcels benefits from them and does not affect other parcels negatively.

4.2 Team leader management and maintenance

The second interview was with a management and maintenance team leader at the Rivierenland water board. His work area is the Rijk van Nijmegen and the land of Maas and Waal.

From his point of view, drought is a problem in this area, but not for farmers. “Almost all farmers have pulses with which they extract water from the soil. The quantities with which they do this have no significant influence on the groundwater level. Besides, the farmers have always used pulses and why would pumping water suddenly be a problem now.” he explains.

“Retaining water to maintain a higher groundwater level or letting in water makes no sense. In the dry areas, the water will sink immediately and in areas where water could be retained, it is often already wet. The effect of a weir in a dry area would probably be that a ditch does not dry up in 4 days, but only after 6 days. This makes the investment questionable to the result.”

The team leader mentions that there is a negative view on farmers because they pump up water at the expense of nature. A solution to change this image could be to water the land at night instead of during the day so it is less visible to the public. This has barely any effect on the amount of water that is used, it is only less visible (Coussement T., 2020).

4.3 Advisor water level management, senior water level manager and former area manager

The third interview has been conducted with an advisor in water level management and the senior water level manager of the focus areas as well as with the former area manager. This last person has worked in the area for about thirty years and has been relocated last year. He has a load of practical knowledge about the area and therefore has been invited to tag along.

According to the former area manager, retaining water in Groesbeek is a utopia. This has two reasons, first of all, the slopes in the area. Placing weirs around Groesbeek is of no use because the landscape is too hilly. The length over which water conservation can take place is simply too short. Secondly, all the capacity of the water system is needed in the area to be able to discharge water during downpours. An example of an extreme downpour in 2016 is cited in which about 85mm of rain fell in 45 minutes. Such short, heavy rainfall occurs especially in the dry periods when the weirs are best raised as high as possible. This can result in a lot of flooding because the water system is blocked by weirs.

In Citters and the Ooijpolder, it is indeed the case that the groundwater is, in fact, a communicating vessel with the Maas and the Waal, respectively. Last spring, water was retained as much as possible in Citters and that was all washed away (weggezijgd) in June.

The water level manager adds that the work carried out in this research must be validated by a hydrologist and it must also be examined per location whether the theory corresponds with practice. If you get farmers ready to participate in a pilot, it is wise to offer them proven solutions, otherwise, you run the risk of losing support.

The advisor on water level management concludes that the areas there is being talked about are target level areas. The water board, therefore, admits that it has insufficient resources to maintain water levels here. In Citters and the Ooijpolder, the influence of the river is simply too great and around Groesbeek the number of measures that can be taken is limited and the amount of effect the measures that can be taken is not expected to be much.

4.4 Legal

4.4.1 Internal legal department

To understand the legal impacts of placing a weir in the water system, questions have been asked to the legal department of the water board which has been followed up with a phone conversation (Personal communication; D. Steenland, 29-01-2021).

What rules are there for the installation of dams, or other measures that retain water, by a landowner?
The rules of the 'keur' Water Board Rivierenland 2014 (the 'keur' is a regulation containing the rules that a water board applies to the protection of flood defences, waterways and associated structures) apply to this ("Keur Waterschap Rivierenland," 2014). In general, someone should not just make any changes to the water system. This is prohibited on the grounds of the 'keur'. The water board can grant a permit for certain work and activities. The frameworks for this are included in the policy rules of the 'keur'. In addition to the policy rules, there are also general rules that belong to the 'keur'. The general rules laid down in the 'keur' exempt many common activities from a license. But then the conditions and regulations of the general rules must be met.

Who is responsible for collateral damage if the weirs are managed poorly? Is there a difference if the weirs are 100% funded by the water board or if the landowner chooses to build a weir?
In general, weirs are managed by the water board. The water board is responsible for this. If there are complaints in our area about the operation or management of weirs, those complaints should be reported to the water board. It is then a question of whether the water board responds adequately (= appropriately) to those complaints. If people feel that they suffer damage through the actions or omissions of the water board, they can hold the water board liable for this. If it leads to a lawsuit, the judge will investigate whether the damage is the result of the act or omission of the water board. The judge will also check whether the water board has responded adequately to complaints. And whether the water board is ultimately responsible for the damage.

What are the consequences if the target level or the desired discharge in a watercourse can no longer be achieved due to the backwashing of water over which the water board has no control?
The water board has the best-efforts obligation to comply with the levels in the water level decision or the levels in a target water level plan. The water board is responsible for water management and therefore water level management in our area.

How far can (and will) the water board go in handing over the water level management?
Due to the task assigned to the water board by law, the water board is and will remain responsible for water management in our area. It is therefore not advisable to outsource water level management from that point of view.

In the phone conversation following these answers, Ms Steenland explained that the law is always behind on innovations. For this case, this means that it is hard to give full control over the weir to the landowner, at least for now. It is, according to her, important to make contingency plans. If someone is ill at the water board, it is known who should carry out their tasks to keep the area safe. When a landowner who should change the height of a weir is ill or on holiday for example, who makes sure that the weir is managed well. She suggests that frequent or even continuous monitoring would help the water board to take action if needed.

4.4.2 Method water board Limburg

According to the lawyer at water board Rivierenland, there are quite some legal obstacles to placing LOP weirs. Therefore, it is interesting to know how other water boards, which are experienced with the weirs, are handling this. For this, an interview with Mr van Dijck from water board Limburg has been set up.

Mr van Dijck explains: “Two weeks ago we had a high-water wave in the Meuse river and in Eijsden, the point where the Meuse enters the Netherlands, the discharge was about 1700 m3 per second. Despite this, we still are in a drought period. The groundwater levels are still low. Last summer, for example, the discharge in the Meuse was around 25-30 m3 per second. If the discharge gets less than 15 m3 per second, the drinking water supply and water supply to Chemelot (chemical industry in Limburg) gets in danger. This would mean that no water could be used for nature and agriculture. Luckily, this has never happened yet.”

According to Mr van Dijck farmers that water the land use between 55 and 60 m3 pumped up water per hour per reel. This is not much concerning industry and companies that provide drinking water. Nevertheless, it is a very visible usage of water in periods of drought. In addition to pumping up a lot of water and the Meuse, which is often very low in summer, it also rains less and less in Limburg. In 2019, more than 900mm of water should have fallen, but this got stuck around 450mm. All this added up means that there has been a state of drought within water board Limburg for almost two years.

Because water board Limburg already had a lot of LOP weirs before the most recent merger of water boards in the province, something about this has been included in the ‘keur’. “The ‘keur’ offers space for works of art in waterways that are not included in the ‘legger’. We install the weirs and remain the owners of them. Management of the weir is in the hands of the landowner. If this is the municipality, it can be decided to transfer this management to the landowner of the adjacent parcel. There is one restriction in all of this, and that is that the water board can order landowners in times of drought to set the weir to the highest position.” Explains Mr van Dijck.

According to Mr van Dijck, it is true that they go against the water law, but so far there have not been any negative experiences. Moreover, a weir is only installed when the landowner asks for it and most of the ditches in which they are installed run dry 80% of the year. Hopefully, placing a weir will be seen as a solution to a problem rather than undermining the law.

4.5 Interpretation and assessing data quality

4.5.1 Representativeness of data and corroboration

When reading this chapter, it might have come to light that not all interviewees from water board Rivierenland are really positive about implementing the LOP weir as a measure against drought in the areas around Nijmegen. For the areas of Citters and the Ooijpolder, the dependency of the groundwater level on the adjacent rivers is too big. In Groesbeek there might be some possibilities, but issues are raised here as well.
Both the team leader management and maintenance (4.3) and Mr van Dijck from water board Limburg (4.4.2) mention that farmers do not extract a huge amount of water which is of great influence on the groundwater table.

4.5.2 Credibility of interviewees

The interviewees come from different layers of the organization, from the area coordinator to the person who has been manually adjusting weirs in one of the areas for years. None of the interviewees has an interest in sketching a more beautiful picture of the situation than it is and frankly none of them does. It is the landowners who are immediately saddled with consequences such as a watering ban. Since the three focus areas are target water level areas and that no water level is required to be maintained, the water board has nothing to lose.

4.5.3 Weigh data in terms of credibility

So, when weighing the data in terms of credibility it seems as if the interviewees told a reliable story. There is no reason to assume anyone holding back or giving false information.

4.5.4 Triangulate different types of evidence

It is indeed the case that the soil types in Citters and the Ooijpolder make it hard for LOP weirs to succeed, see chapter 2.2.1. The example of the extreme downpour in 2016 checks out as well (Wezel, 2016). There are also sources confirming that heavy rain leads to flooding in the Groesbeek area (Haverkamp, 2019; T. Maas, 2020).

4.6 Conclusion

To conclude this chapter, it can be said that the water board is not immediately thinking positively about a pilot with LOP weirs in the focus areas around Nijmegen. There are practical objections but also some from the point of view of regulations. People are, however, open to new ideas and there is, for example, a lot to learn from other water boards. Finally, there does not seem to be any reason to assume otherwise than that the interviewees have passed on reliable information.

5 Technical aspects

Up to this point, the research has mainly been focussed on the LOP weir. This is because the water board came up with the idea to set up a pilot with these types of weirs. In this chapter, a brief look will be taken at the LOP weir as well as other water retention measures that more or less have the same effect.

5.1 LOP weir

The LOP weir has been described and explained in chapter 1 of this report. The placement of a LOP weir will cost approximately €2250 (Schel, 2019). This corresponds with the rule of thumb that the water board uses for a sheet pile, which is €1200 per meter (Personal communication; J. Kroon, 27-01-2021). Water board Limburg places LOP weirs only on existing culverts. Because they buy them in big numbers they can place them for about €2000 (Personal communication; T. van Dijck, 11-02-2021).

5.2 Pinch weir (knijpstuw)

Another solution that lays very close to the LOP weir is a pinch weir. This type of weir is, however, not adjustable in height. The consequence of this is that the weir will be less high than the LOP weir because the groundwater will be too high during periods of land cultivation. A pinch weir also has advantages. For example, the landowner no longer has to look after it after installation and the weir causes a delay in the discharge of peaks in rainfall, leading to less nuisance from water (Zaaijer, 2013). The costs of a pinch weir are estimated at €3000 (Schel, 2019).

Figure 8: Pinch weir (VLM)

5.3 Road plate

A cheaper version of the pinch weir is a road plate. With a price of €755 for a plate of 14*1800*6000 mm excluding installation, this is a considerable alternative (Personal communication; R. Martens, 01-02-2021, Merwestaal). Road plates are ideal as a solution until a better fitting weir can be placed (Maashorst, 2020), or as a pilot to see if conservation of water is possible in practice. They have proven their effect (W. A. a. Maas, 2020).

Figure 9: Road plate weir (Maas)

5.4 Inflatable ball

Placing an inflatable ball in a diver is one of the easiest and probably cheapest ways of retaining water (Mulder, 2018). Choosing this option, however, has some major drawbacks. Firstly, this can only be done in places where divers are available. These places may not be the most suitable for the best result or be not suitable at all. Secondly, no difference in water level can be made, in fact, there is no overflow possibility. When the ditch is full and more water gets to it, it will overflow onto land or roads next to it. An inflatable ball could, just like the drive plate, be, however, used as an intermediate solution (Schriek, 2018).

Figure 10: Inflatable ball (Schriek, 2018)

5.5 Ditch elevation

Using ditch elevation is a passive form of water retention (Hoogvliet et al., 2014). The situation in winter gets wetter structurally resulting in a higher water level in spring. An advantage of this method is that there is no possibility of heightening weirs too late or placing measures like an inflatable ball too late. Disadvantages are that the capacity of the water system is smaller, whilst this might be needed in periods of large rainfall and the storage capacity for surface water decreases.

5.6 Conclusion

With all their unique characteristics, all measures described in this chapter help to retain water. Whether it is by closing off a ditch, making it smaller, or by (temporarily) placing a weir. Measures like the inflatable ball are very useful as a quick intervention. The placement of a more sustainable measure like a proper weir could take longer due to possible calculations and delivery times, as well as subsidy requests to finance these often more expensive means.

6 Discussion

The analysis explained in paragraphs 2.2-2.4 of this report is limited. Not only the number of circumstances that have been taken into account but also the weighing of them against each other is limited to the best knowledge of the author. On top of that, the analysis has not been done quantitative nor has it been validated.

The analysis in chapter two concludes that in Citters and Ooijpolder weirs could be used to retain surface water if the soil characteristics locally allow this. It is however questionable to what extent this has any impact and whether it is not just a drop in the ocean. On the other hand, it could be argued from a sustainability point of view that every little bit helps.

In the second phase of this report, interviews have taken place. These were mainly with people that have practical knowledge of the areas. Even though this is a valuable contribution, the research would have been more complete if an ecologist and more important a hydrologist would have been involved. They could have given valuable input for the research, especially in chapter two.

7 Conclusion

This chapter looks back at the research questions as formulated in paragraph 1.4 of this report. The questions will be answered based on the results of the research.

Which parcels are suitable to place LOP weirs?

The first sub-question of this research is dealt with in the second chapter. By analysing the area based on seven criteria, an attempt was made to arrive at the best possible locations for weirs in the three areas. Only part of the Groesbeek area turned out to be really suitable for this. This is contrary to the expectations of the FWOO project, which also made an analysis based on national data and saw more opportunities in the two other areas. The difference is likely due to the more locally focused analysis in this report.

How can landowners be approached to find out who is open to participating in a pilot with LOP weirs?

To find out which farmers are open to participating in a pilot with LOP weirs, contact was made with the local ZLTO department. With the help of the water board, they will send a broad questionnaire to their members about any problems with water they have and how they plan to solve them.

In what way does the water board remain involved after placing the weirs?

How much authority can be given out of hands and how does the water board feel about this?

This question is quite hard to answer because, within the water board, there is a certain degree of scepticism from all sides about the success of a pilot with LOP weirs. In addition, there are still a few hurdles in the way of regulations. In terms of regulations, a lot can be learned from other water boards. Despite the doubt, everyone seems open to new ideas and solutions for the increasing water shortage during dry periods, however, solid proof of a working solution is appreciated. Looking at the question purely from a legal point of view shows that at the moment it is not possible to outsource water level management. Because this is ultimately a pilot, it might be that something is possible on a small scale.

Who is responsible for collateral damage if mismanagement of LOP weirs takes place?

At the bottom of the line, the water board always remains responsible for water level management and the water board also bears the consequences for not performing this task properly. Water board Limburg gave away the management of their LOP weirs to the landowners under only one condition which is that they can order them to put it in the highest position. They take it for granted that they do not obey the water law and think this is necessary to tackle the enormous drought problem they face.

What types of weirs are available and possible to place, how does this relate to the suitableness of a parcel and what costs are associated with the different type of weirs?

Next to the LOP weir, there are several other ways to retain water in ditches. The costs of most of these other measures are lower, but this often reflects on the degree of flexibility and applicability. A LOP weir is by far the most controllable option due to the adjustability of the water level in small steps. Other methods to retain water could be used as an intermediate solution for quick results pending further research or funding.

With the answers to the research questions, a light can be shed on the research objective. The research objective is *to provide water board Rivierenland with integral advice on their pilot on LOP weirs*. This advice reads: Validate the selected locations in Groesbeek and finance and carry out the pilot with LOP weirs. This will result in valuable information on the effectiveness of weirs, will show the organisation that changes in the water system can help retaining water, even at a small scale and can pave the way to change regulations to make further measures possible. The LOP weir is most effective for this since it is highly adjustable.

8 Recommendations

First of all, it is important to validate this theoretical research in the field. For the Citters and Ooijpolder areas to see whether surface water can be retained based on soil layers in ditches and for Groesbeek already whether the designated locations are actually suitable.

Besides this, the success of water conservation measures depends on the extent to which they contribute to sustainable water management (Keulen & Vermulst, 1997). In the past, water conservation measures have sometimes backfired in this regard. Examples of this are the acidification of nature areas as a result of the conservation of rainwater and the obstruction of the migration of organisms through the construction of weirs. An ecologist should look into the threads not moving water brings to the flora and fauna in the areas and how severe they are if ditches otherwise run dry quickly.

Next, when executing a pilot, monitoring is one of the most important aspects. Monitoring of the performances of the weirs should tell what the effect is and whether the pilot provided what was expected. Think about measuring the water height in the ditch, groundwater levels at a certain distance from the ditch and rain. It would be best to measure everything automatically so the influence of every rain shower can be measured.

Furthermore, in the process of writing this thesis, there has been contact with J. van Sommeren who provided two locations that he thought to be suitable for LOP weirs (appendix M). At these spots there used to be weirs for seepage water retention to provide backpressure to the dike in cases of high water. Due to the dike reinforcements that took place over the years they were not needed anymore and have been removed. Since these locations where outside the areas in this research they have not been investigated. These locations may require another type of weir than a relatively small LOP weir. This has to be looked into further.

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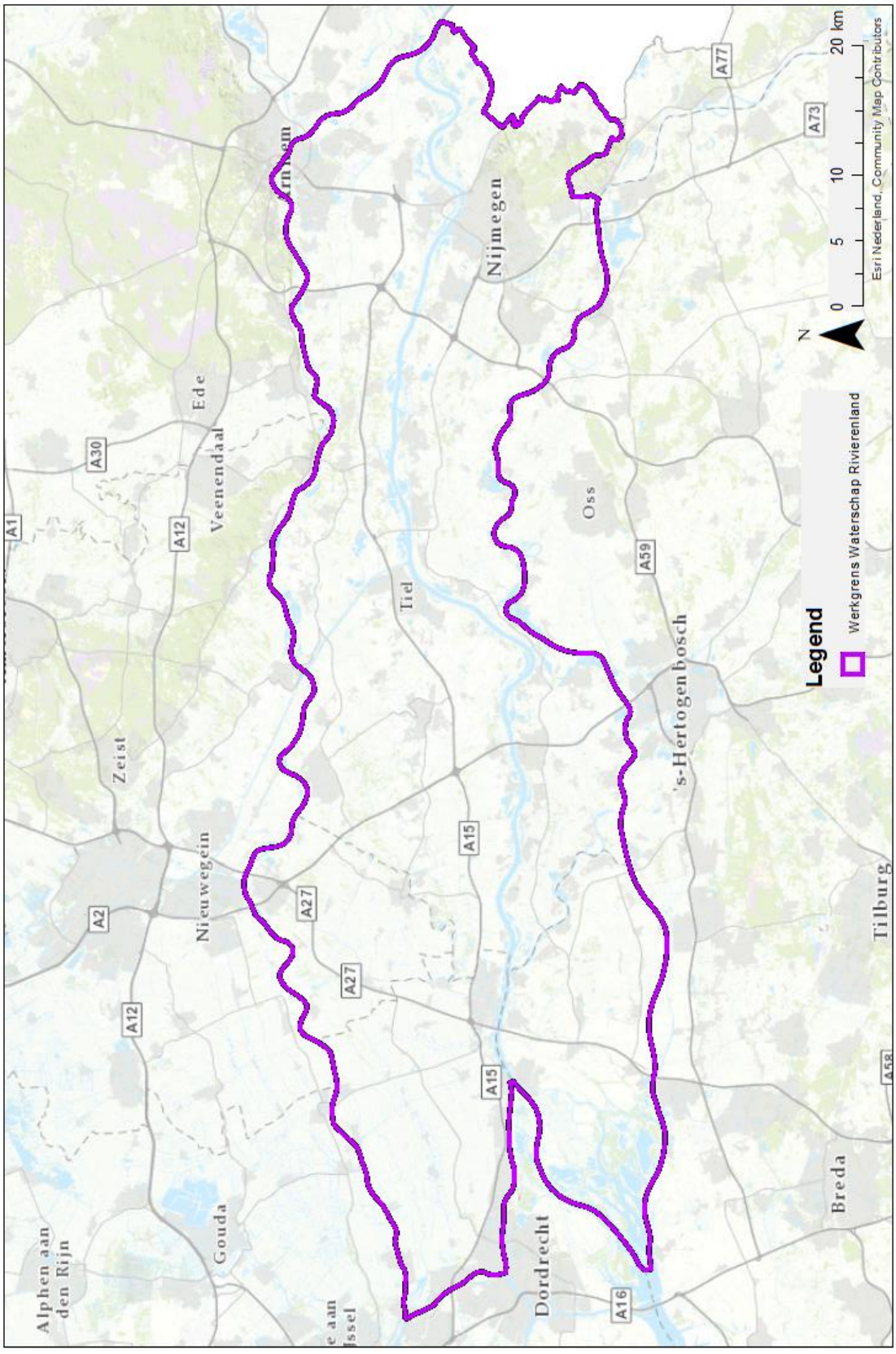
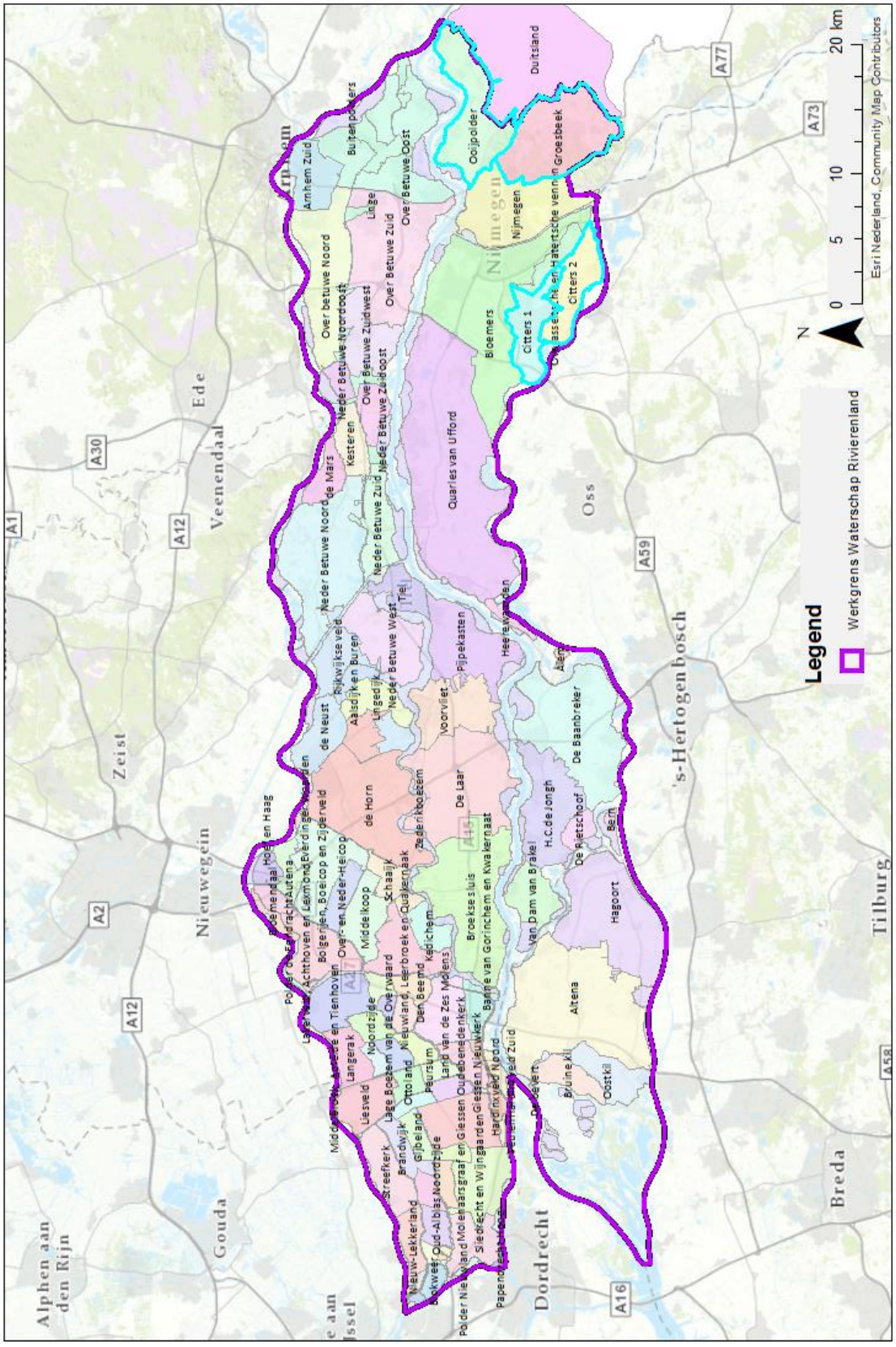
Appendices

Appendix A – management area water board Rivierenland

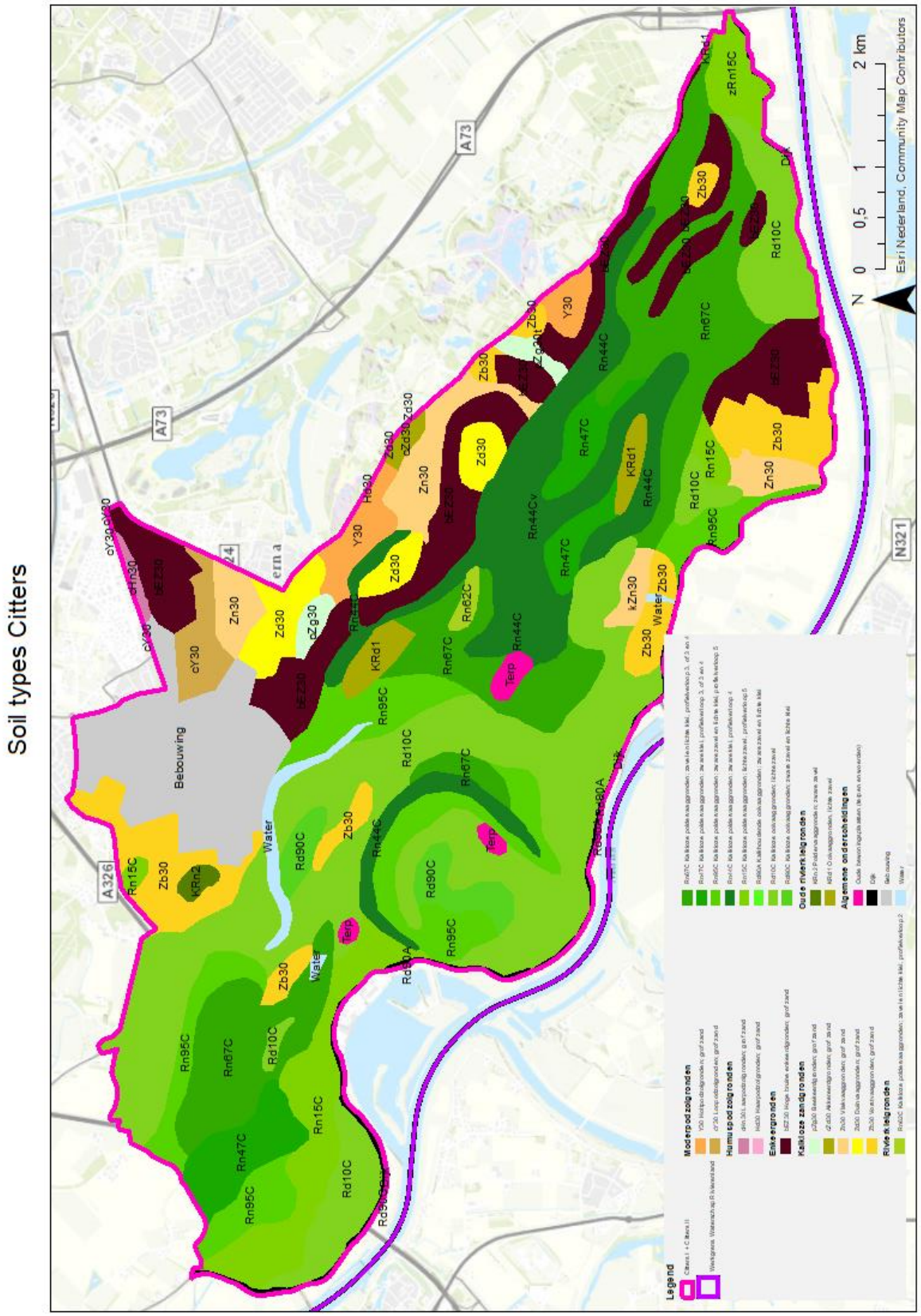
Management area waterboard Rivierenland



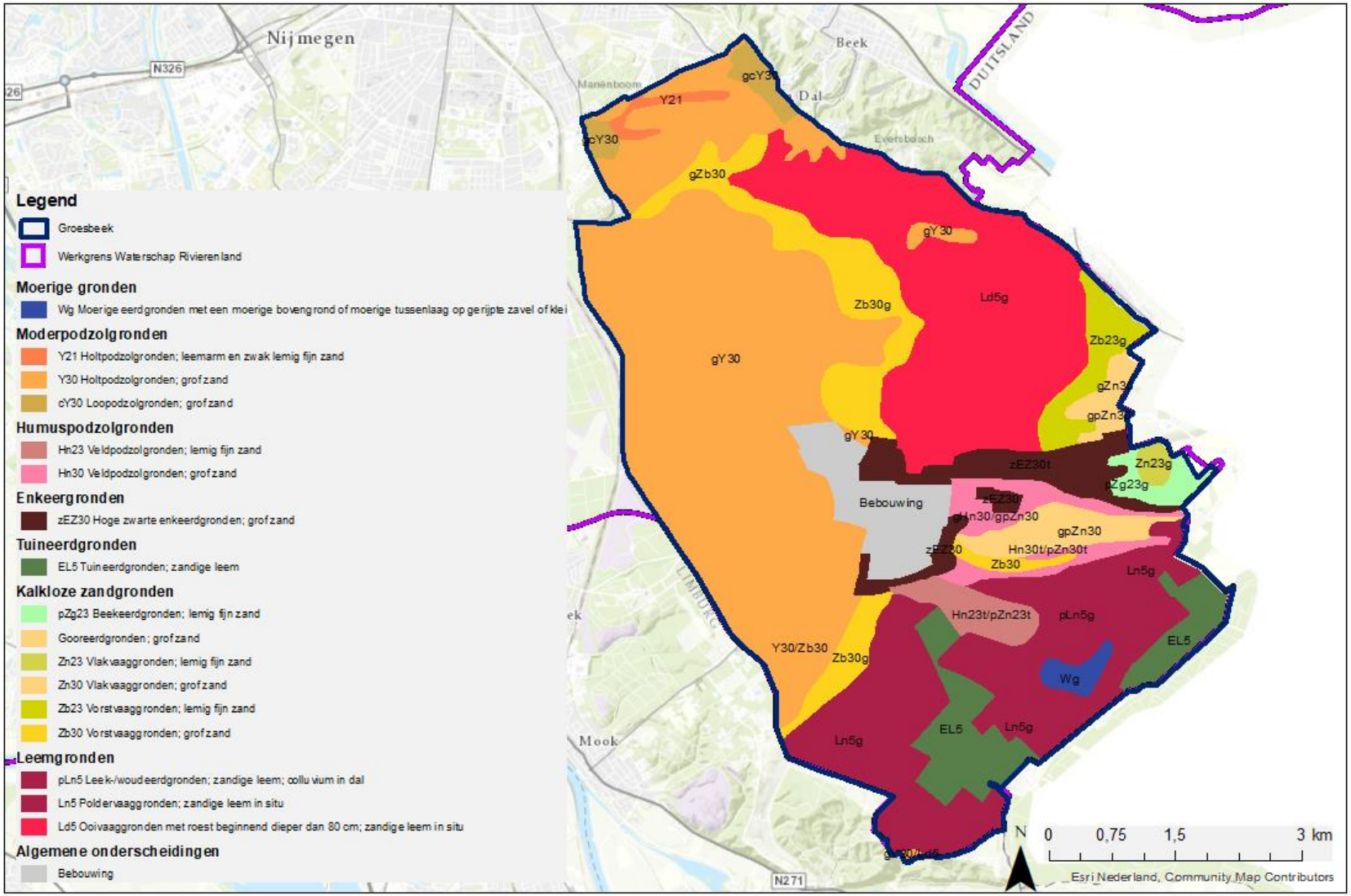
Appendix B – Drainage areas



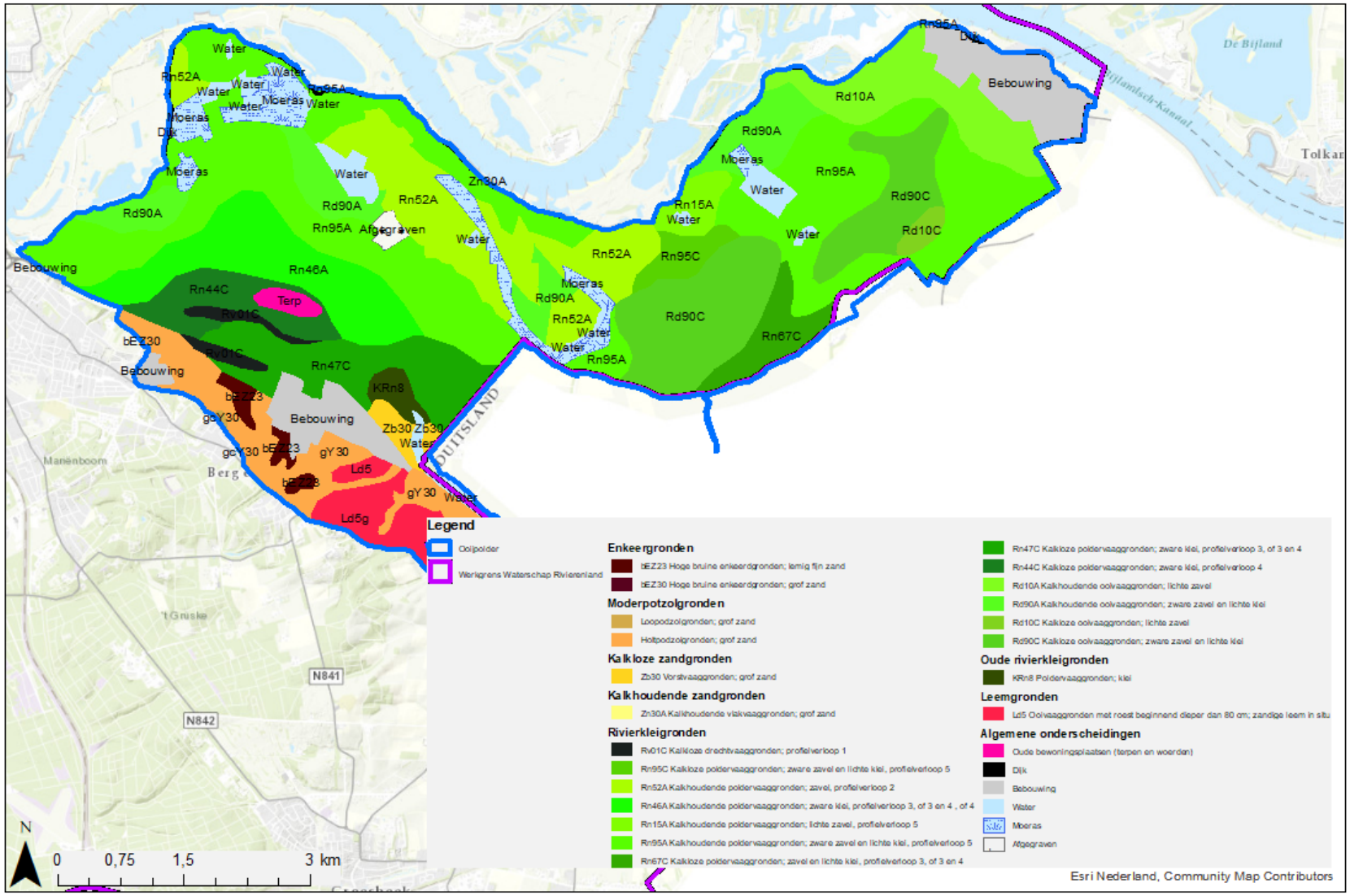
Appendix C – Soil type maps



Soil types Groesbeek



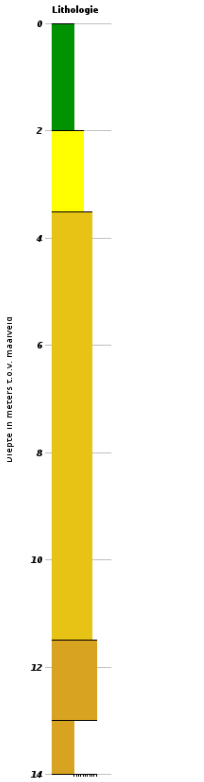
Soil types Ooijpolder



Appendix D – Ground profiles DINOloket

Citters

Boormonsterprofiel

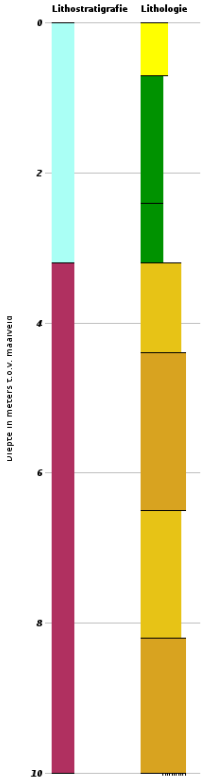


Identificatie :	B45F0080
Coördinaten :	177910 , 421820 (RD)
Maaiveld:	8.31 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Overig

Lithologie

- Klei
- Zand fijne categorie
- Zand grove categorie
- Grind
- Stenen

Boormonsterprofiel



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Maaiveld:	7.67 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

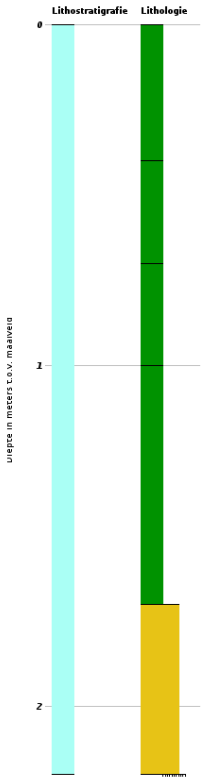
Lithostratigrafie

- EC
- KR

Lithologie

- Klei
- Zand fijne categorie
- Zand grove categorie
- Grind

Boormonsterprofiel



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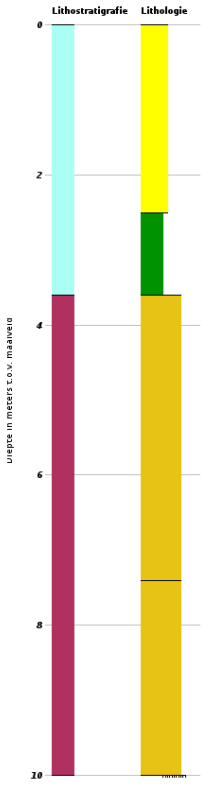
Coördinaten :	174520 , 424040 (RD)
Maaiveld:	6.25 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Standaard Boor Beschrijvingsmethode
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC

Lithologie
- Klei
- Zand grove categorie

Boormonsterprofiel



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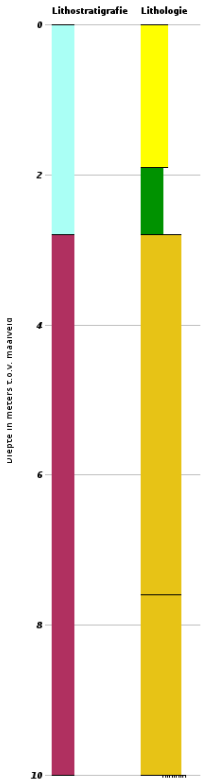
Coördinaten :	180310 , 420950 (RD)
Maaiveld:	7.87 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC
- KR

Lithologie
- Klei
- Zand fijne categorie
- Zand grove categorie

Groesbeek

Boormonsterprofiel



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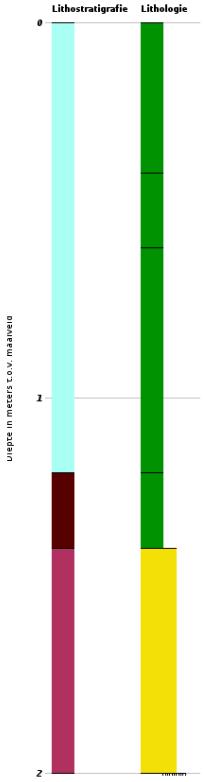
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC
- KR

Lithologie
- Klei
- Zand fijne categorie
- Zand grove categorie

Boormonsterprofiel



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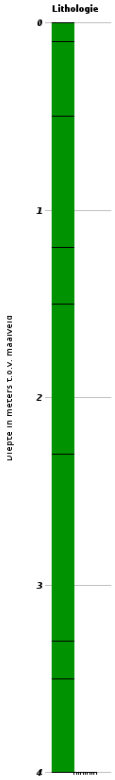
Maaiveld:	7.10 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC
- KRWY
- KR

Lithologie
- Klei
- Zand midden categorie

Boormonsterprofiel



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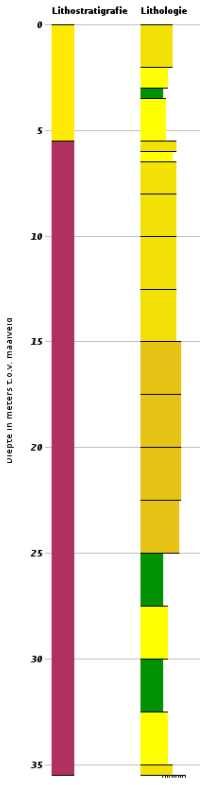
Maaiveld:	9.13 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend

Lithologie

- Klei

Boormonsterprofiel



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Coördinaten :	195280 , 422480 (RD)
Maaiveld:	15.12 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Gevalideerd in ondergrondmodel

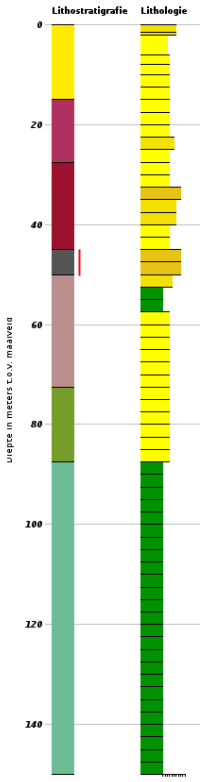
Lithostratigrafie

- BX
- KR

Lithologie

- Klei
- Zand fijne categorie
- Zand midden categorie
- Zand grove categorie

Boormonsterprofiel



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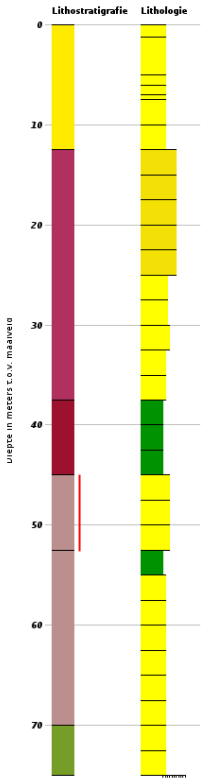
Maaiveld:	22.33 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Gevalideerd in ondergrondmodel

Lithostratigrafie
- BX
- KR
- KRTW
- NN
- KI
- OO
- BR
- Gestuwd

Lithologie
- Klei
- Zand fijne categorie
- Zand midden categorie
- Zand grove categorie

Boormonsterprofiel



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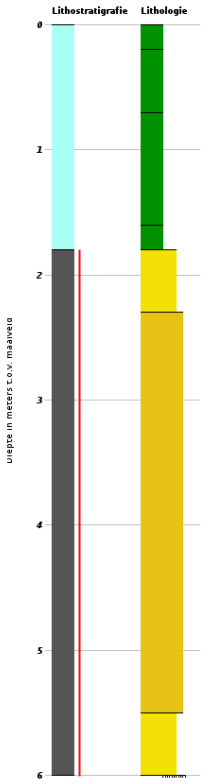
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Gevalideerd in ondergrondmodel

Lithostratigrafie
- BX
- KR
- KRTW
- KI
- OO
- Gestuwd

Lithologie
- Klei
- Zand fijne categorie
- Zand midden categorie

Ooijpolder

Boormonsterprofiel



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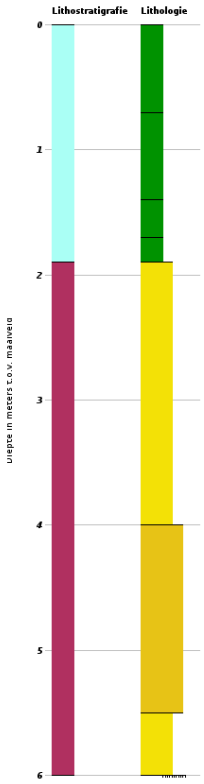
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC
- NN
- Gestuwd

Lithologie
- Klei
- Zand midden categorie
- Zand grove categorie

Boormonsterprofiel



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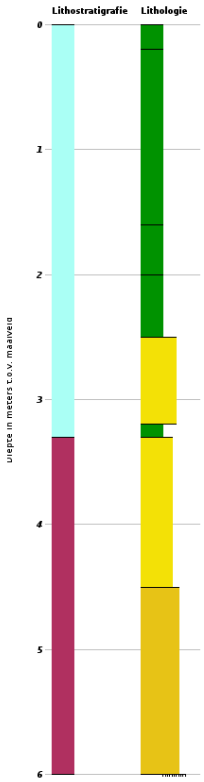
Coördinaten :	196122 , 427549 (RD)
Maaiveld:	11.20 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC
- KR

Lithologie
- Klei
- Zand midden categorie
- Zand grove categorie

Boormonsterprofiel



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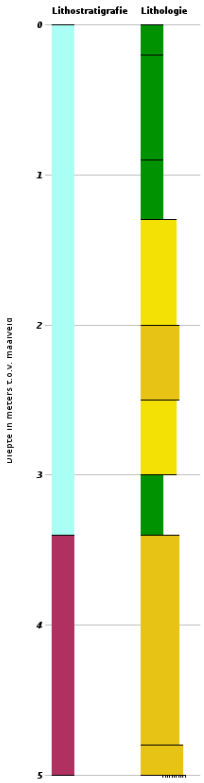
Coördinaten :	190156 , 428933 (RD)
Maaiveld:	10.00 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC
- KR

Lithologie
- Klei
- Zand midden categorie
- Zand grove categorie

Boormonsterprofiel



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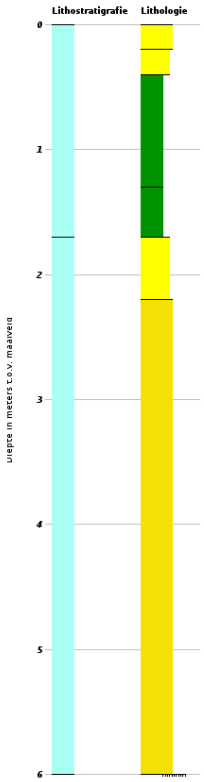
Maaiveld:	10.10 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC
- KR

Lithologie
- Klei
- Zand midden categorie
- Zand grove categorie

Boormonsterprofiel



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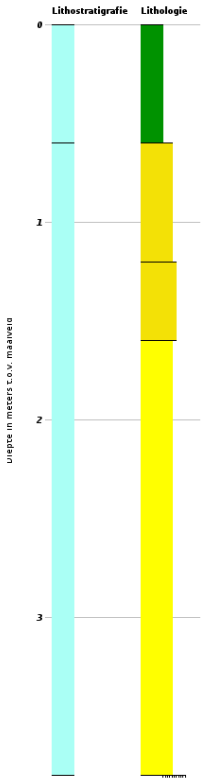
Coördinaten :	196131 , 429448 (RD)
Maaiveld:	10.30 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC

Lithologie
- Klei
- Zand fijne categorie
- Zand midden categorie

Boormonsterprofiel

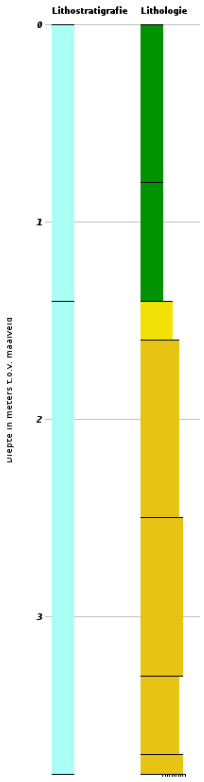


Identificatie :	B40D1005
Coördinaten :	199878 , 429287 (RD)
Maaiveld:	11.10 m t.o.v. NAP
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

Lithostratigrafie
- EC

Lithologie
- Klei
- Zand fijne categorie
- Zand midden categorie

Boormonsterprofiel



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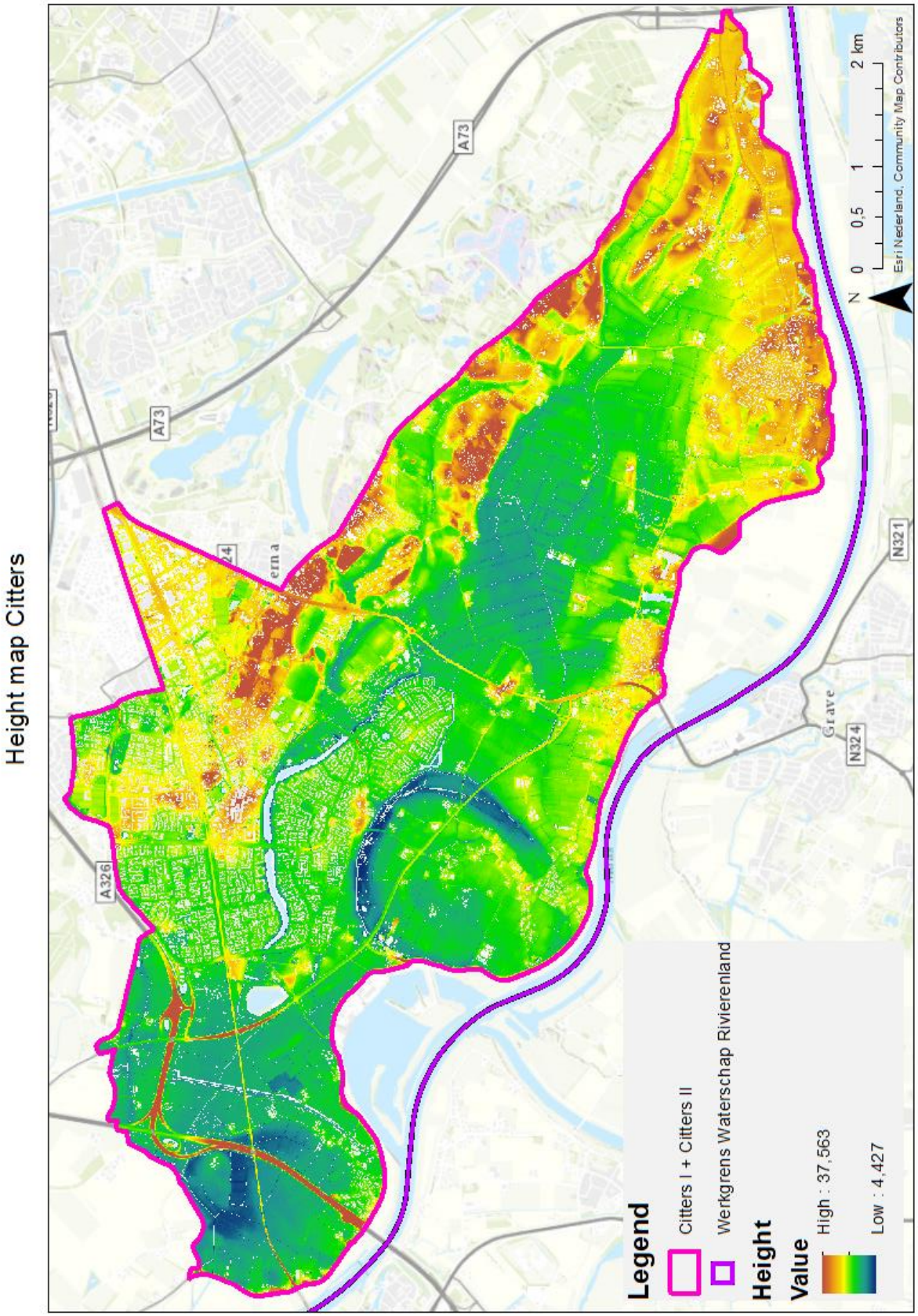
Beschikbare informatie:	Digitale opnamegegevens
Beschrijfmethode:	Onbekend
Kwaliteit interpretatie:	Geautomatiseerd toegekend

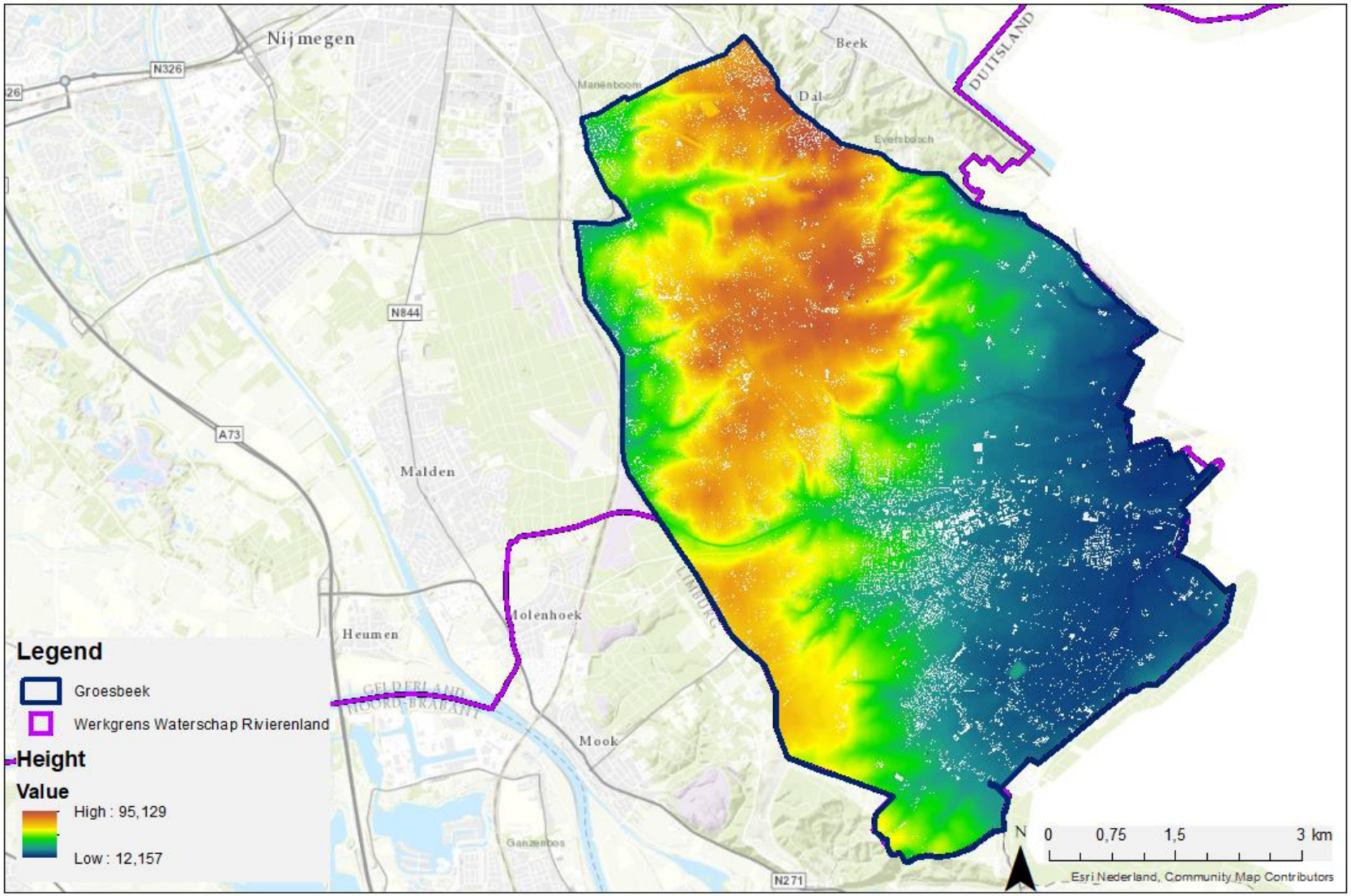
Lithostratigrafie
- EC

Lithologie
- Klei
- Zand midden categorie
- Zand grove categorie

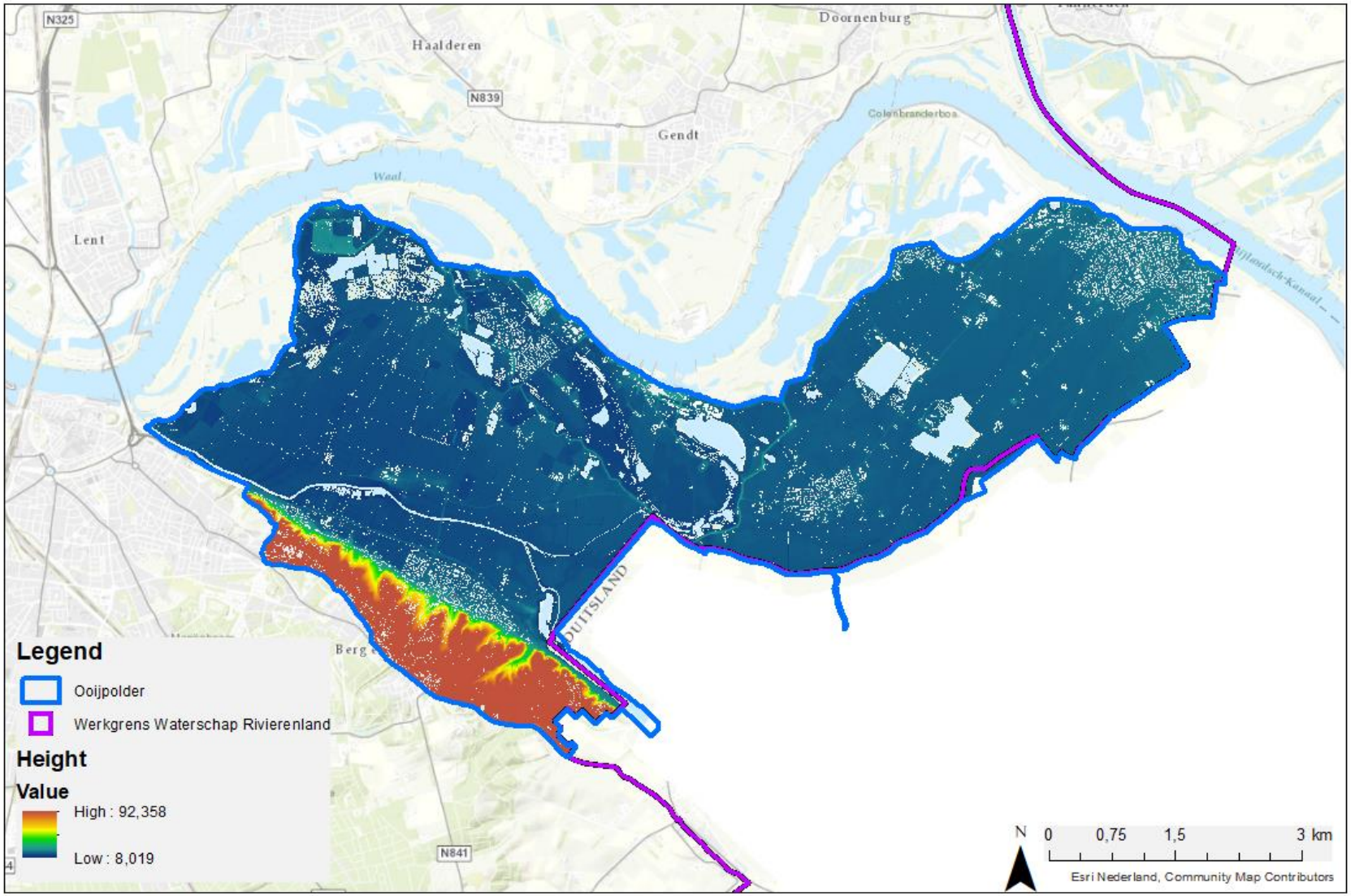
Appendix E – Height maps



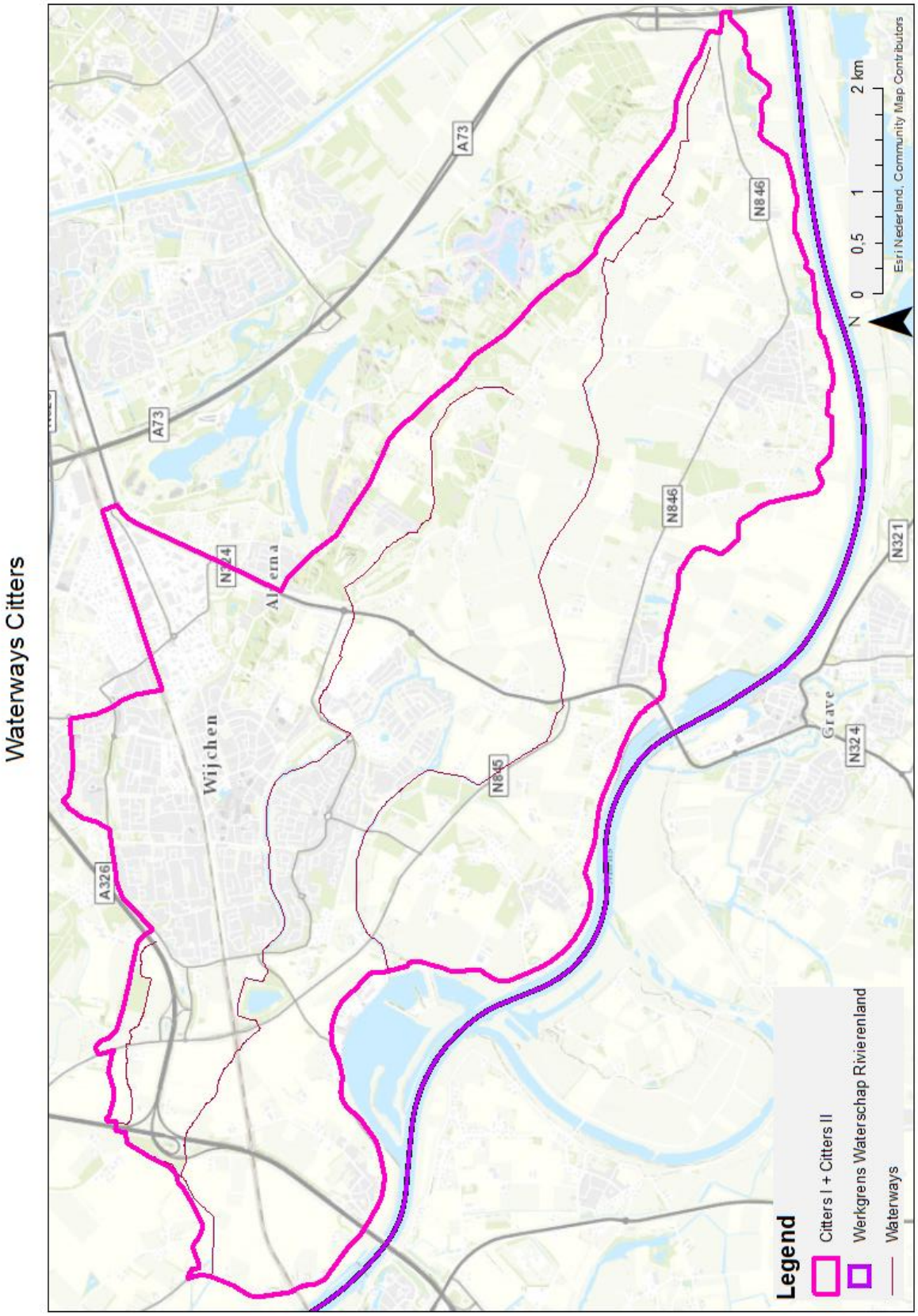
Height map Groesbeek



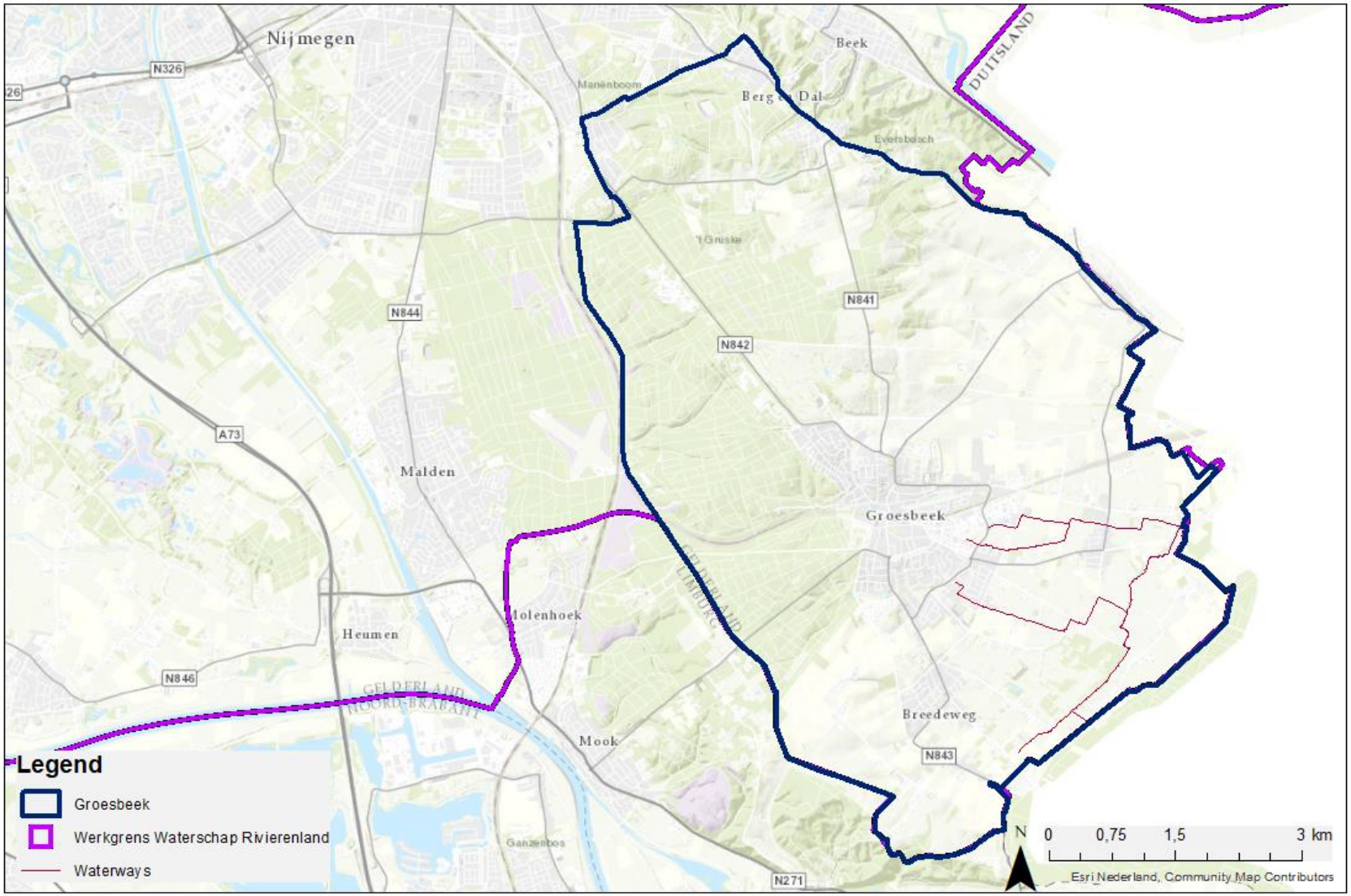
Height map Ooijpolder



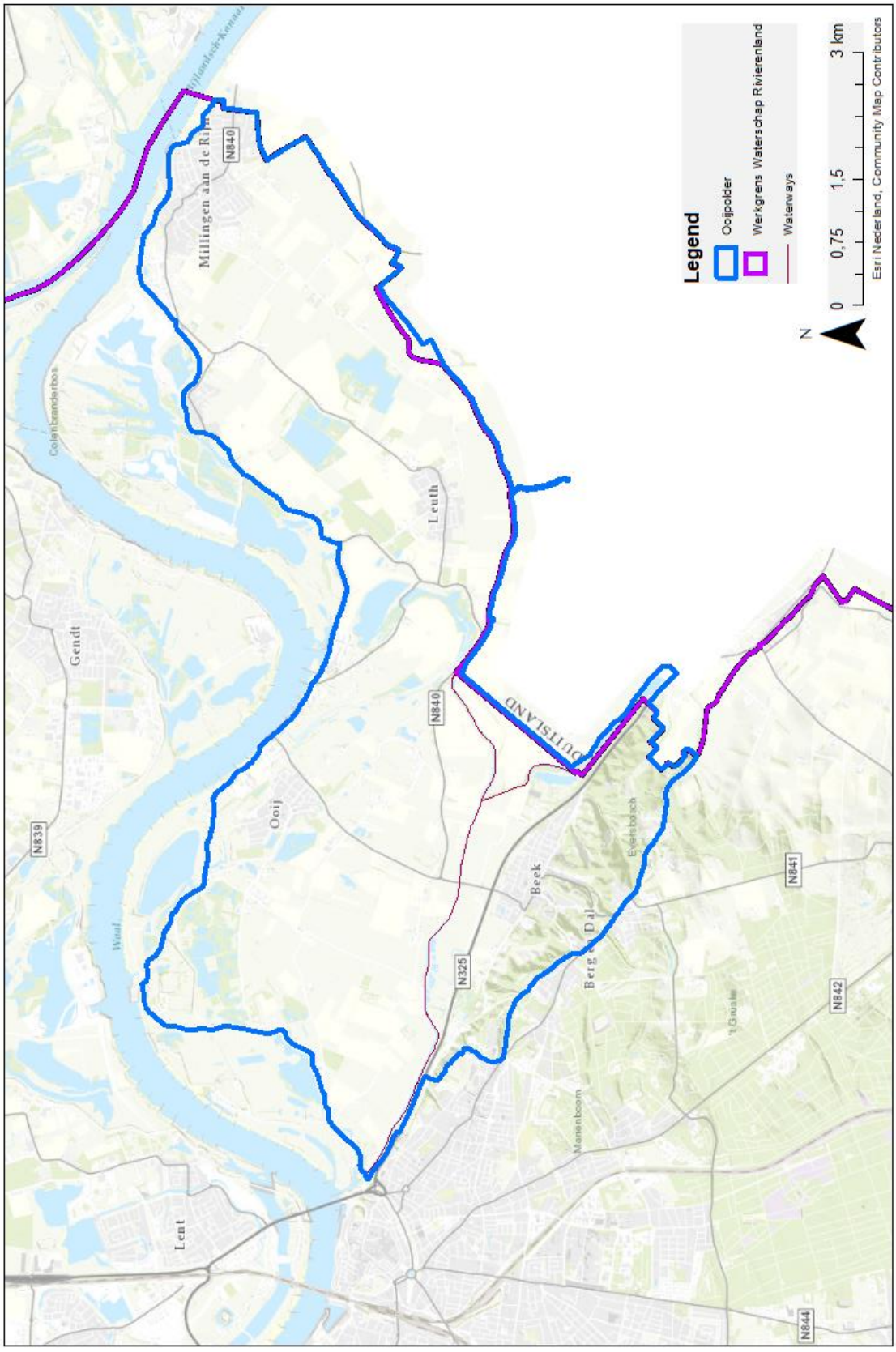
Appendix F – Waterway maps



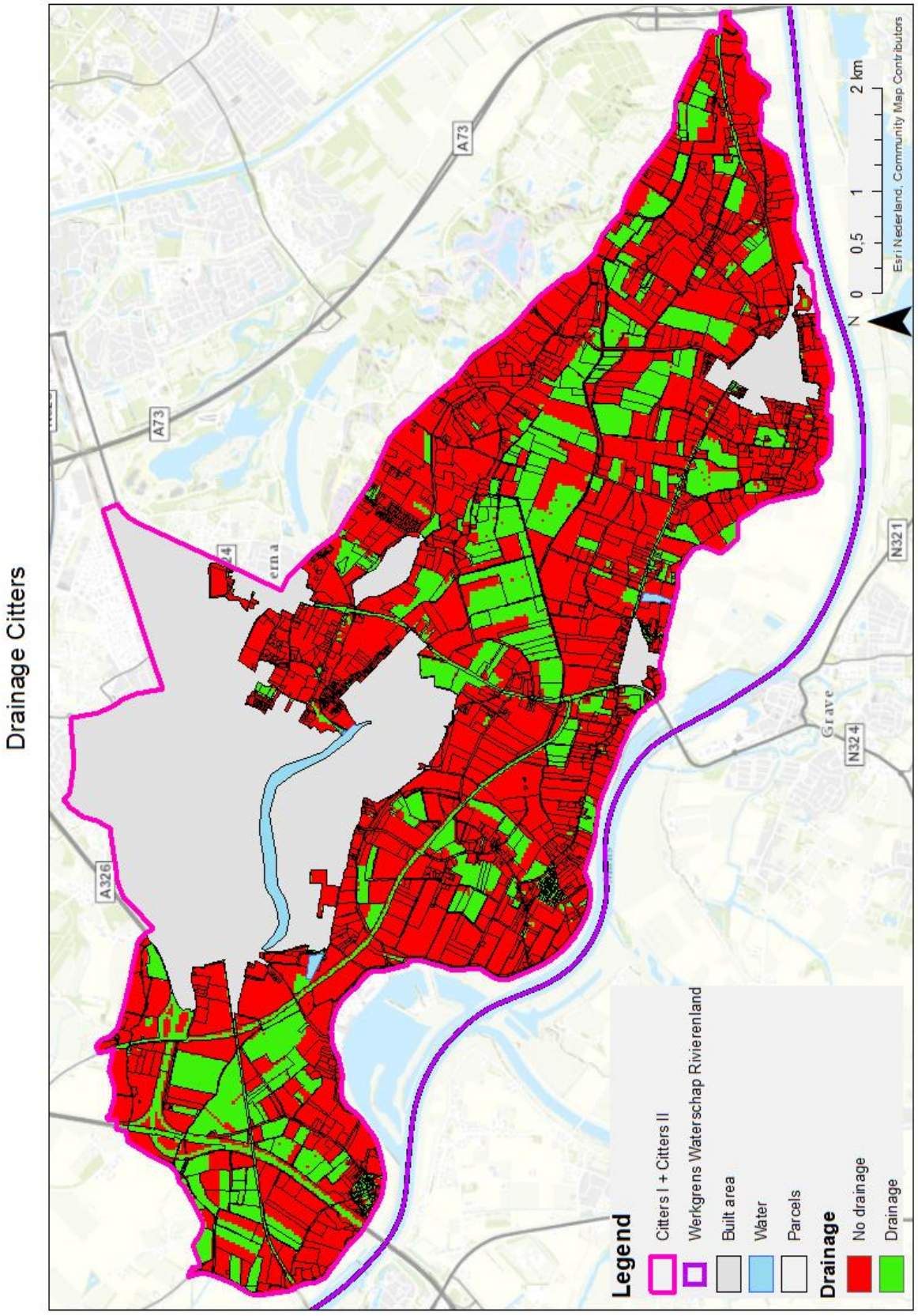
Waterways Groesbeek



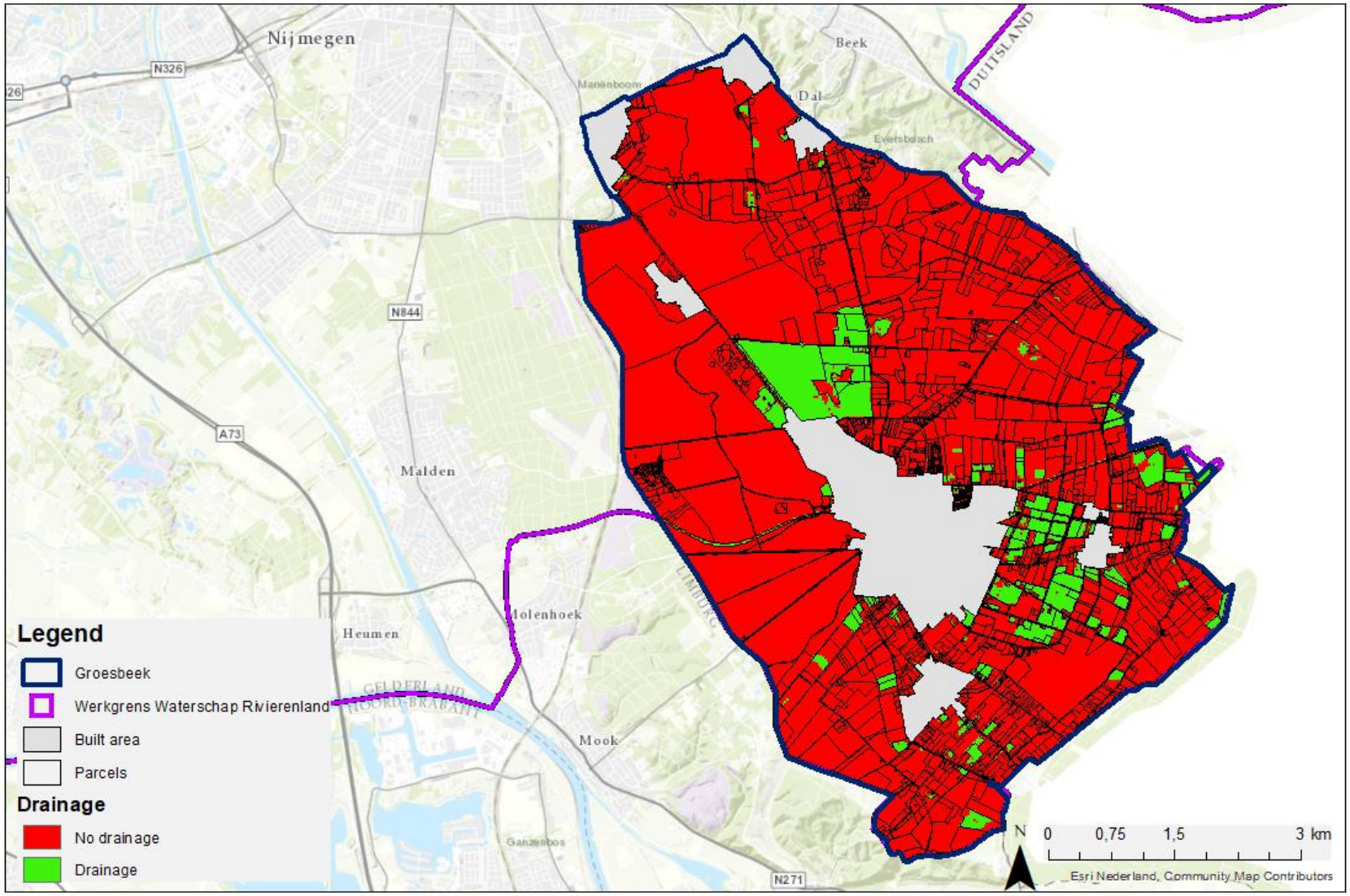
Waterways Ooijpolder



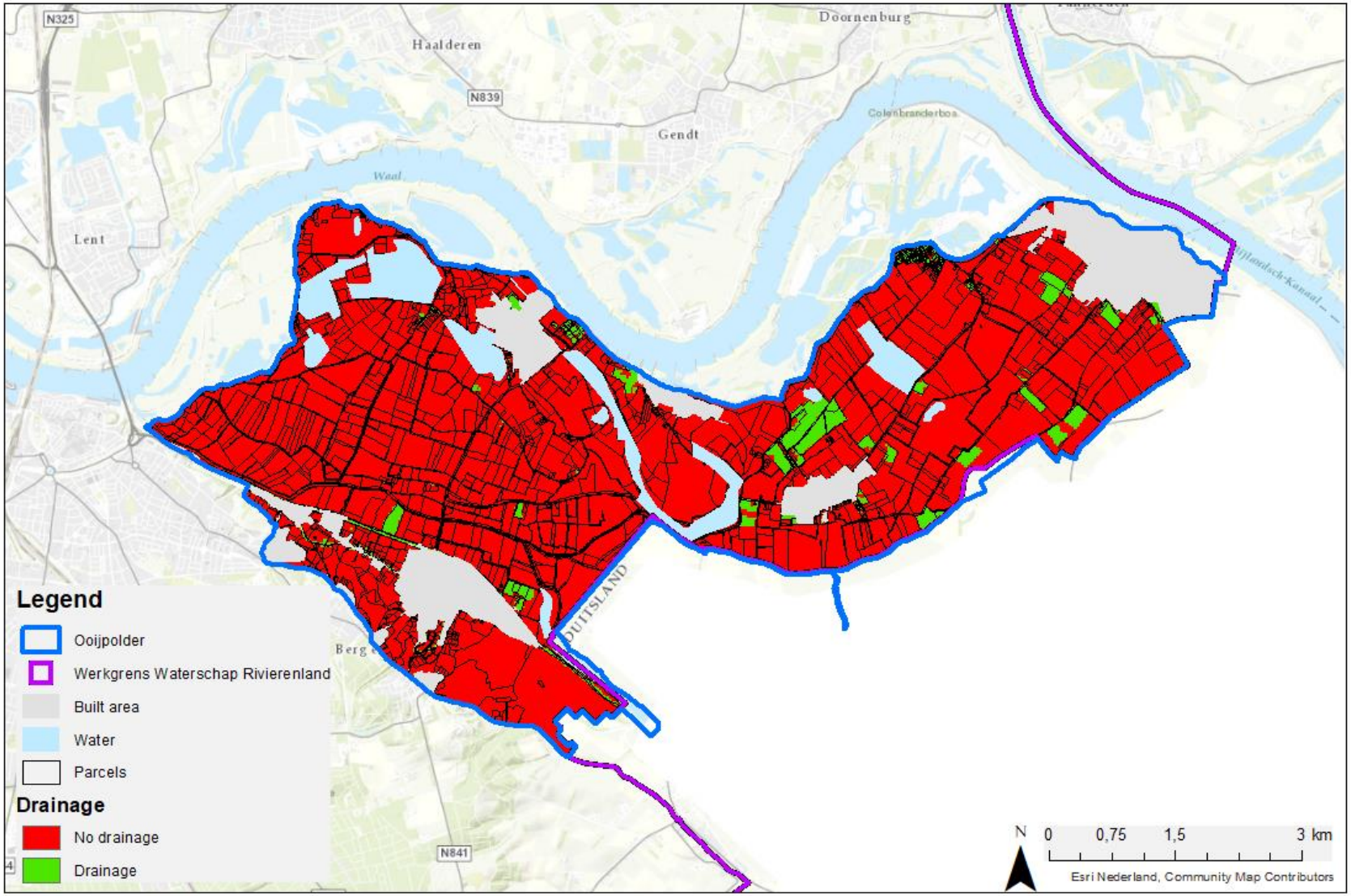
Appendix G – Drainage maps



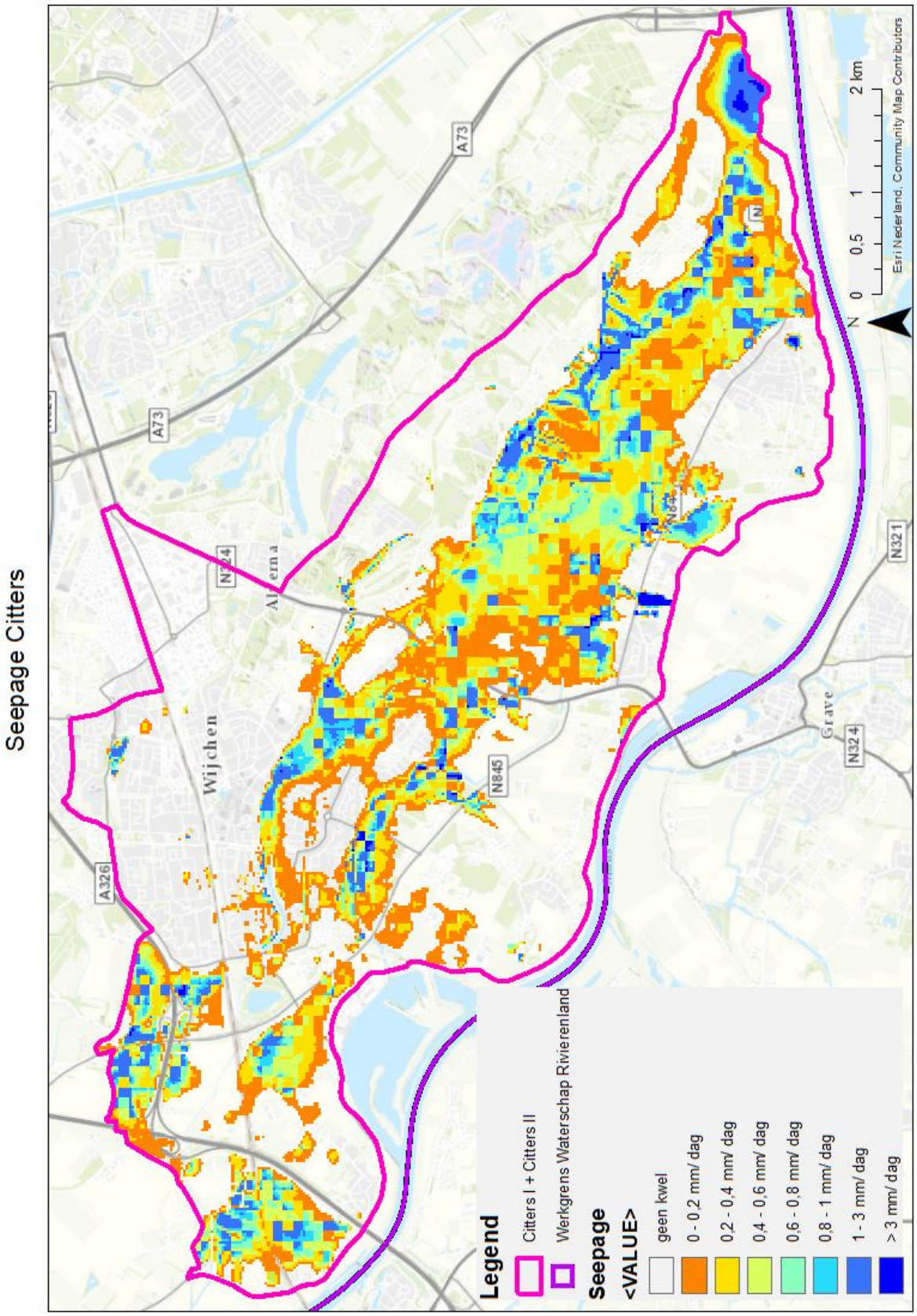
Drainage Groesbeek



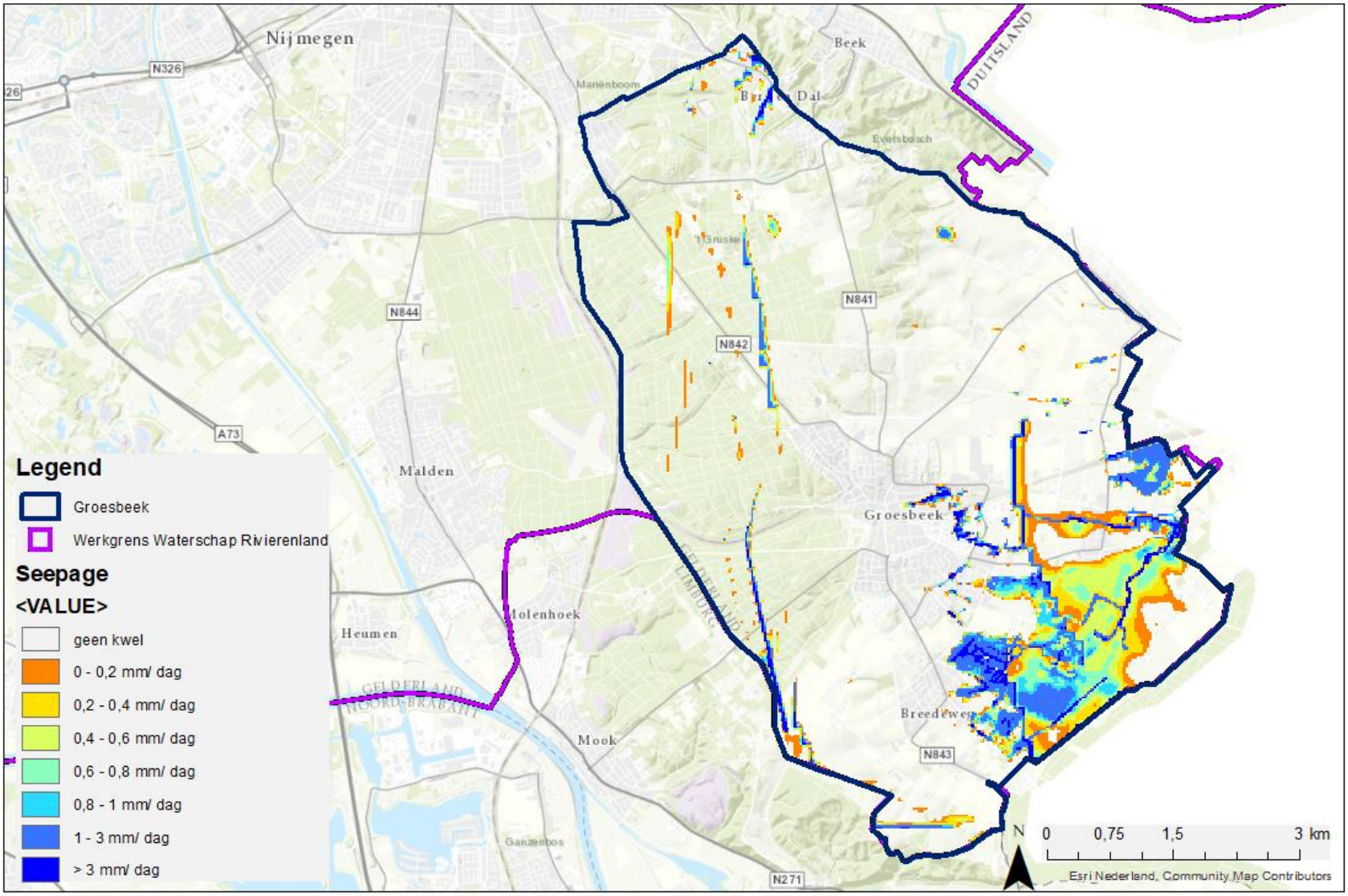
Drainage Ooijpolder



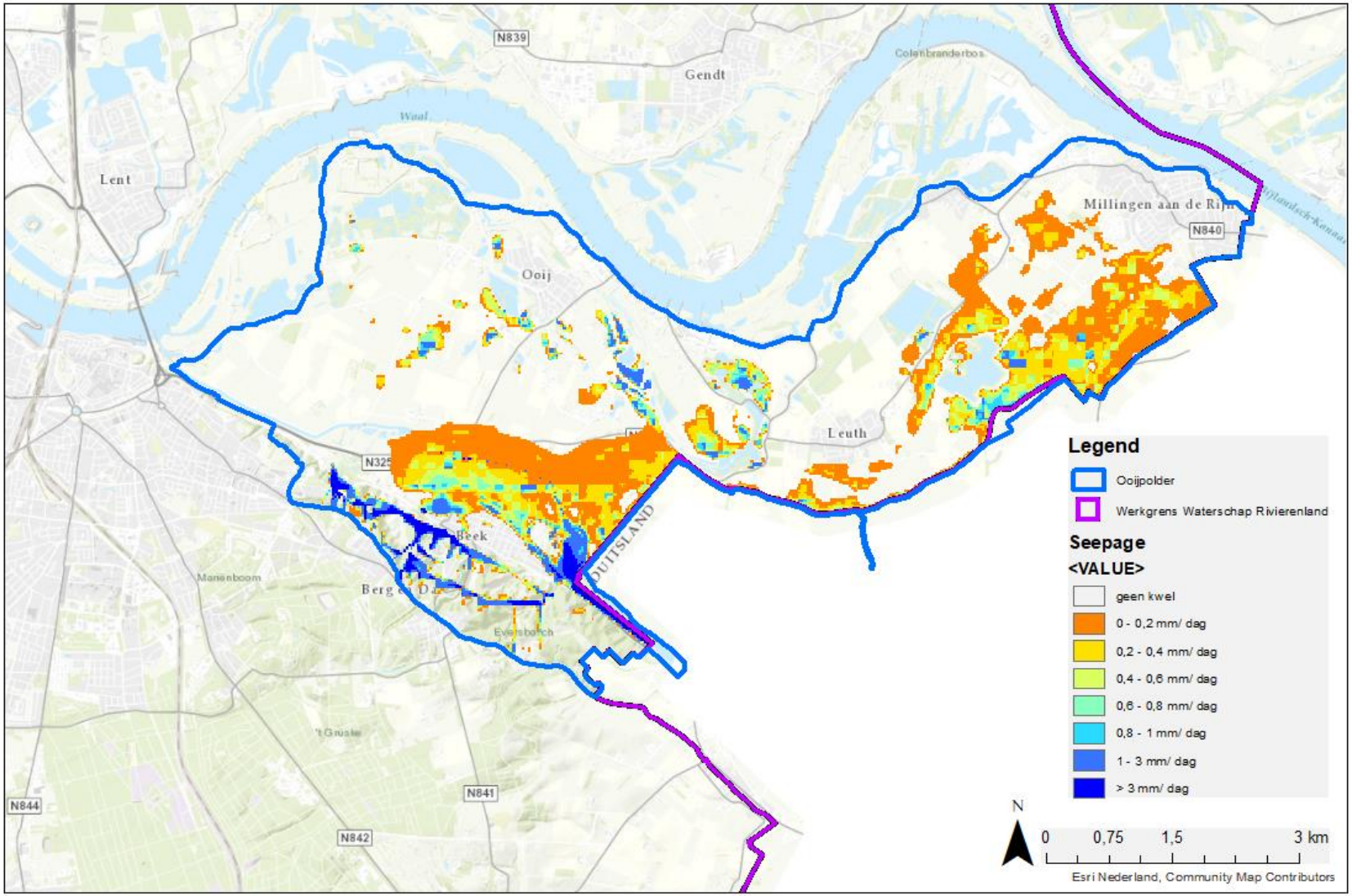
Appendix H – Seepage maps



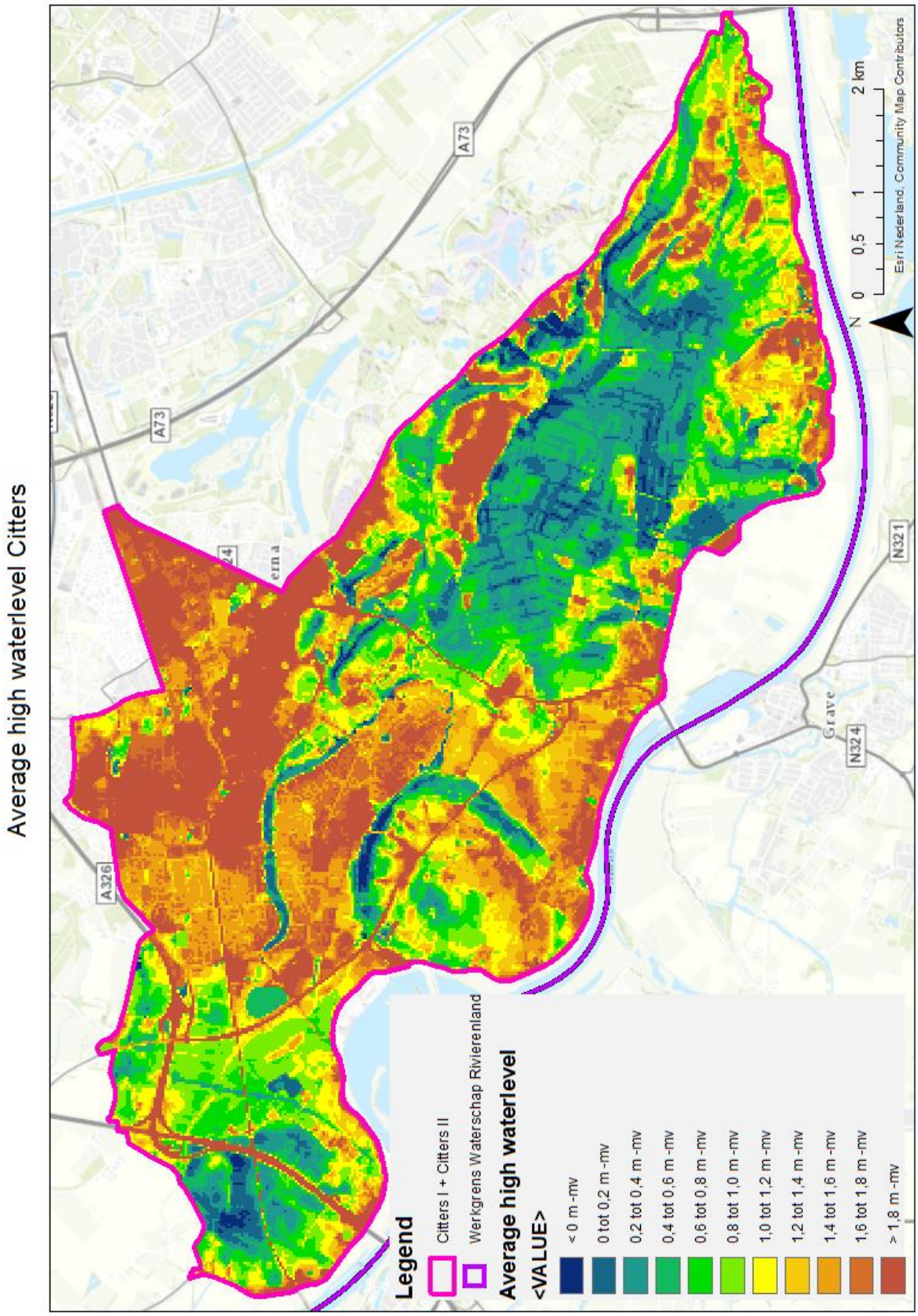
Seepage Groesbeek



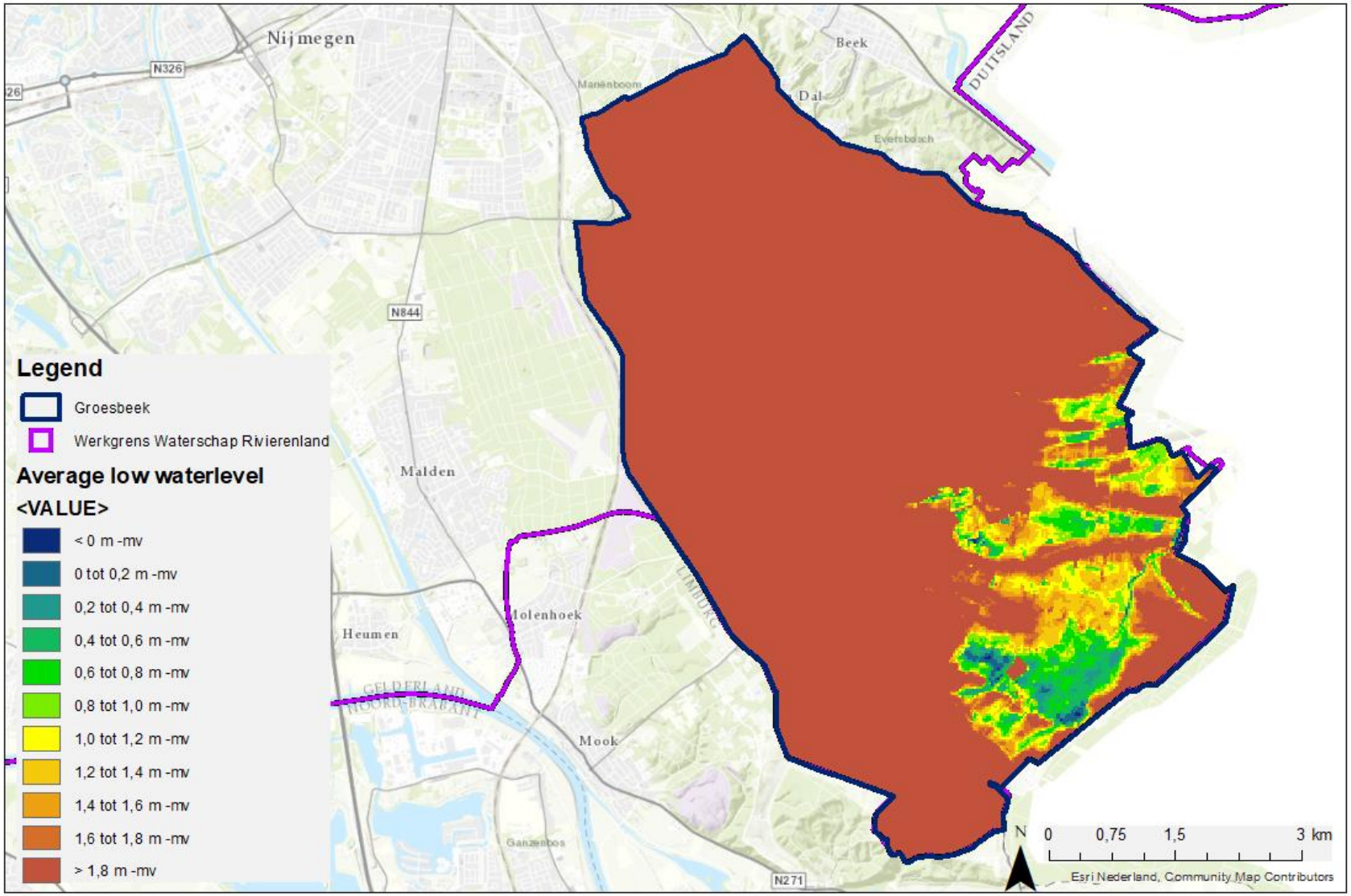
Seepage Ooijpolder



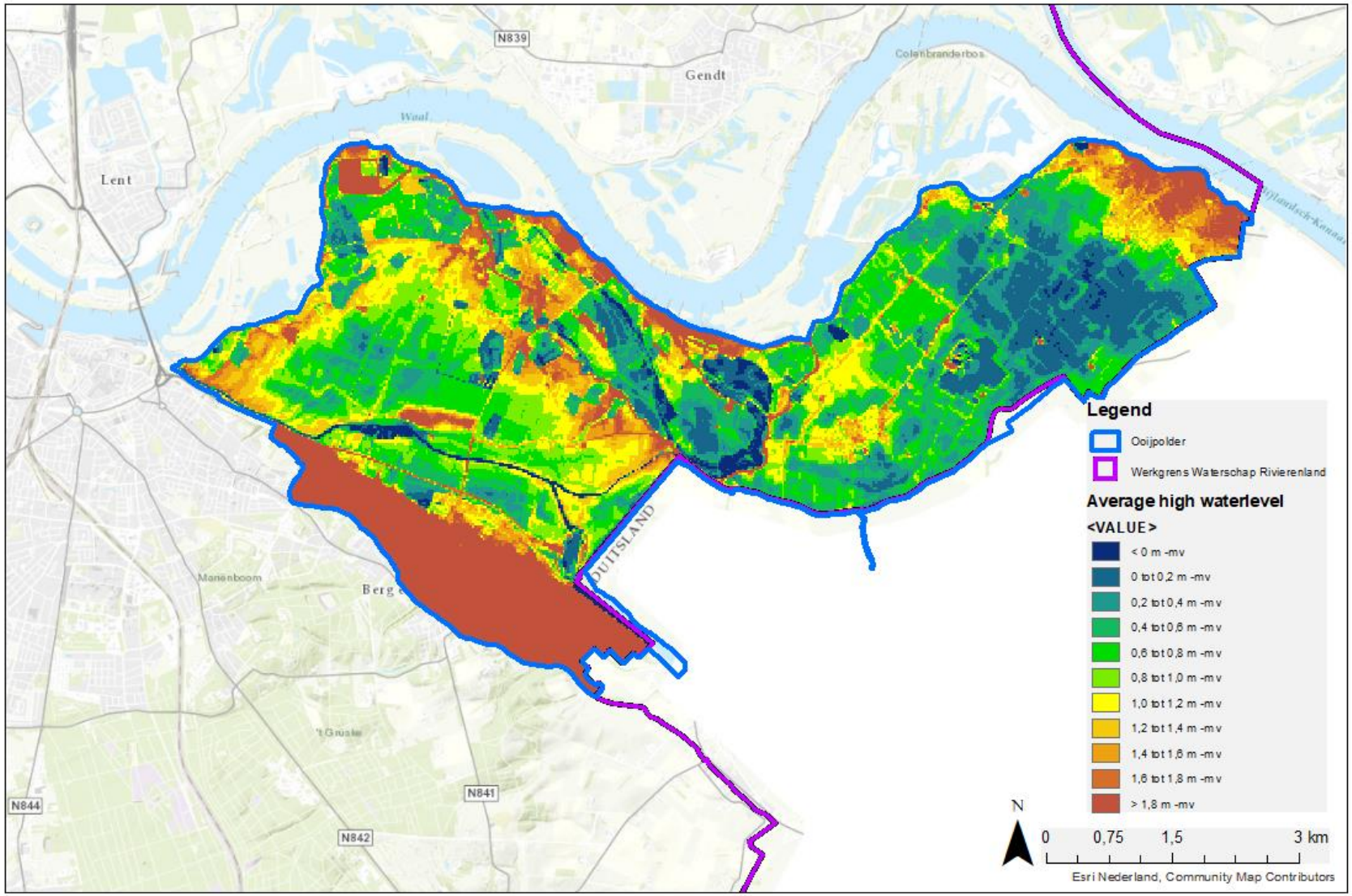
Appendix I – GLG maps



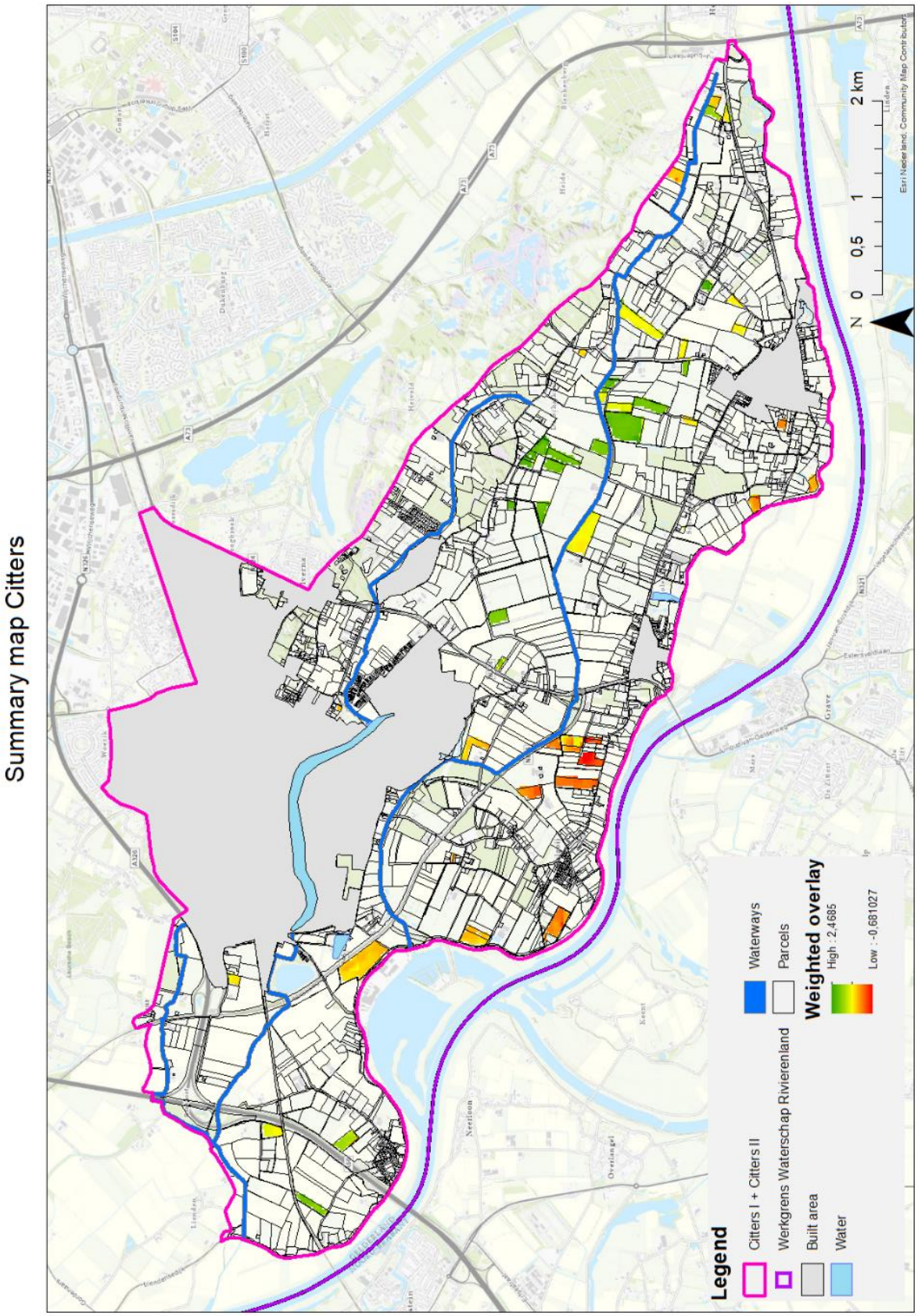
Average low waterlevel Groesbeek



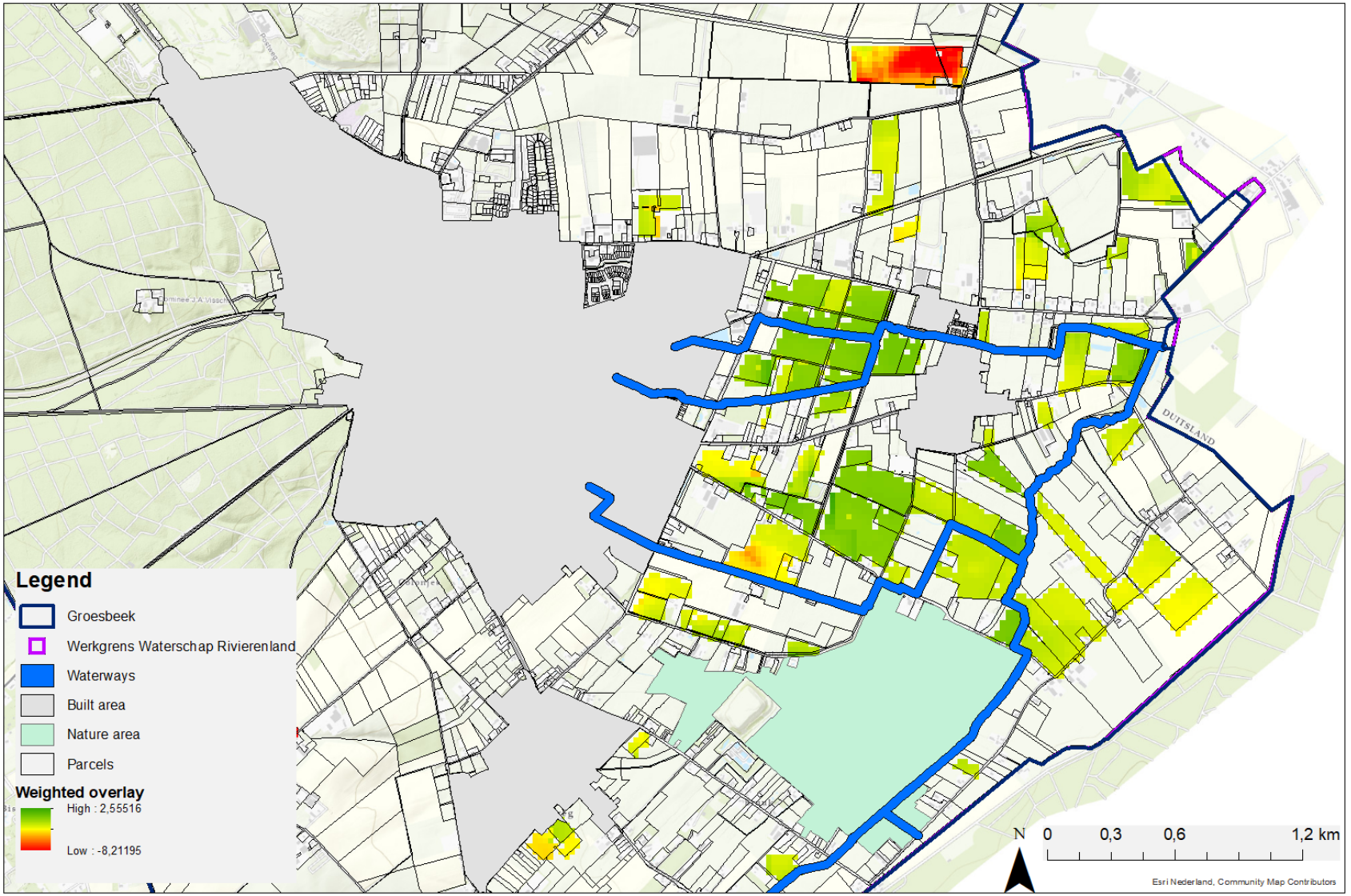
Average high waterlevel Ooijpolder



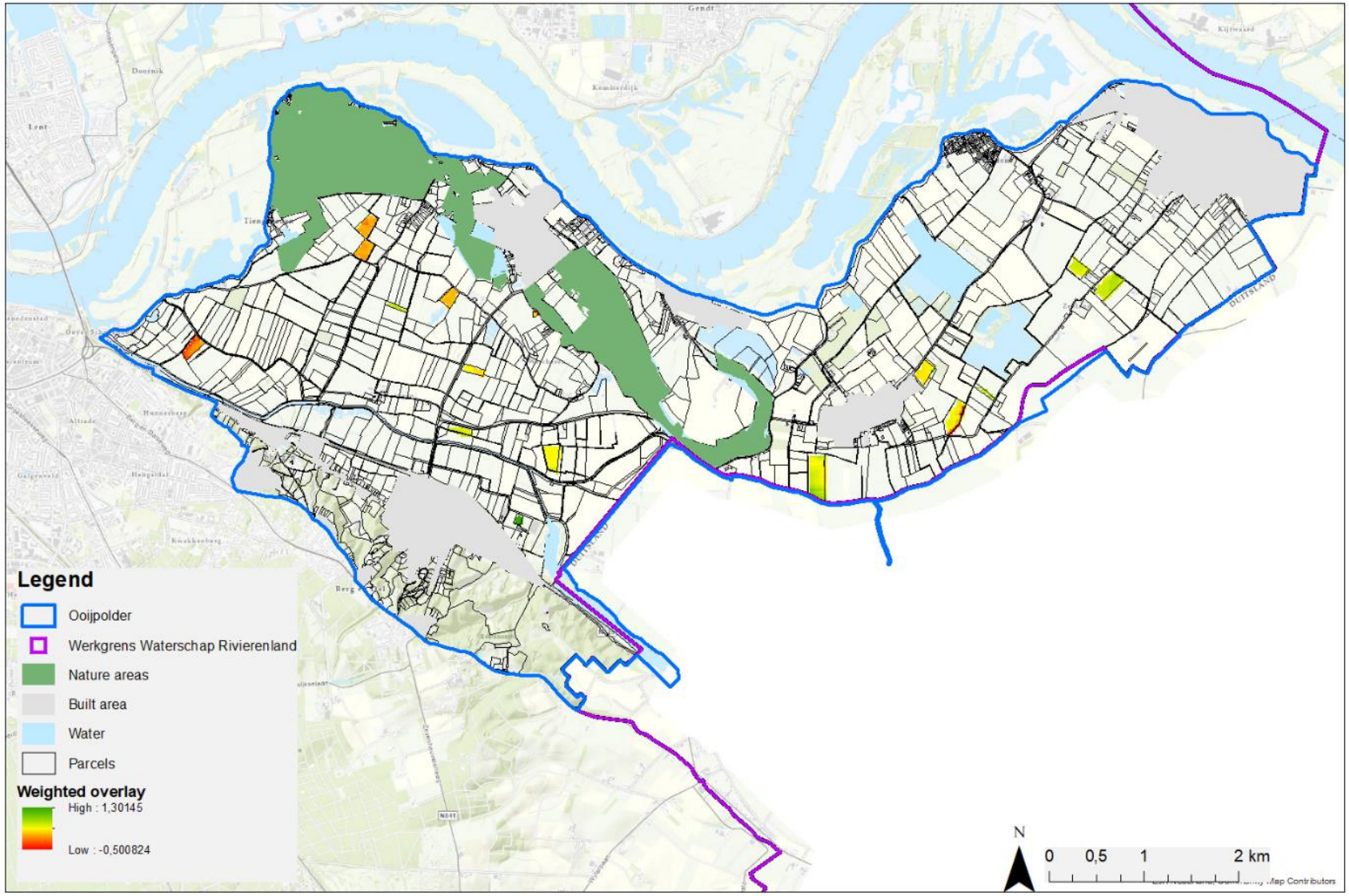
Appendix J – Weighted overlay



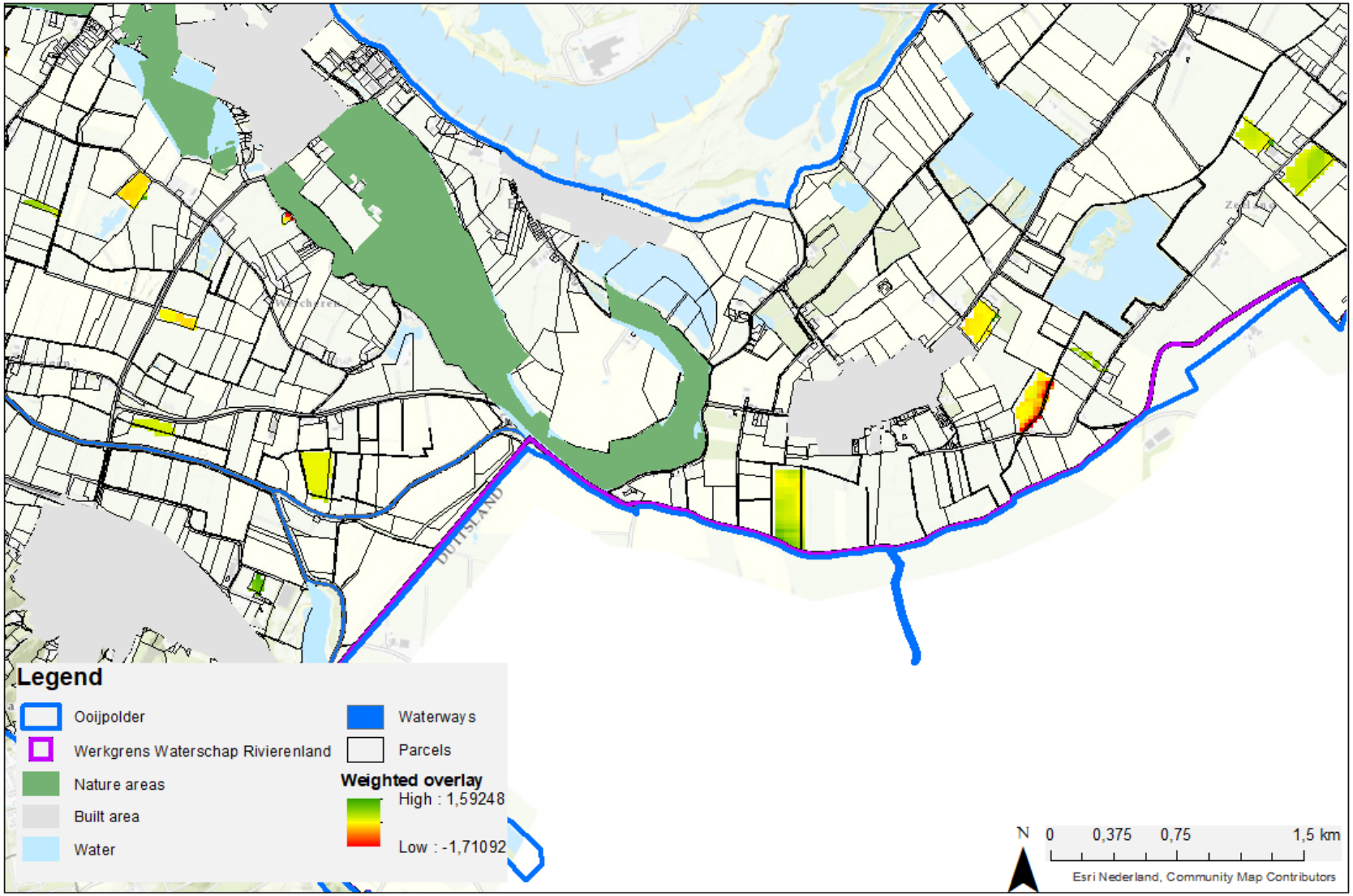
Summary map Groesbeek



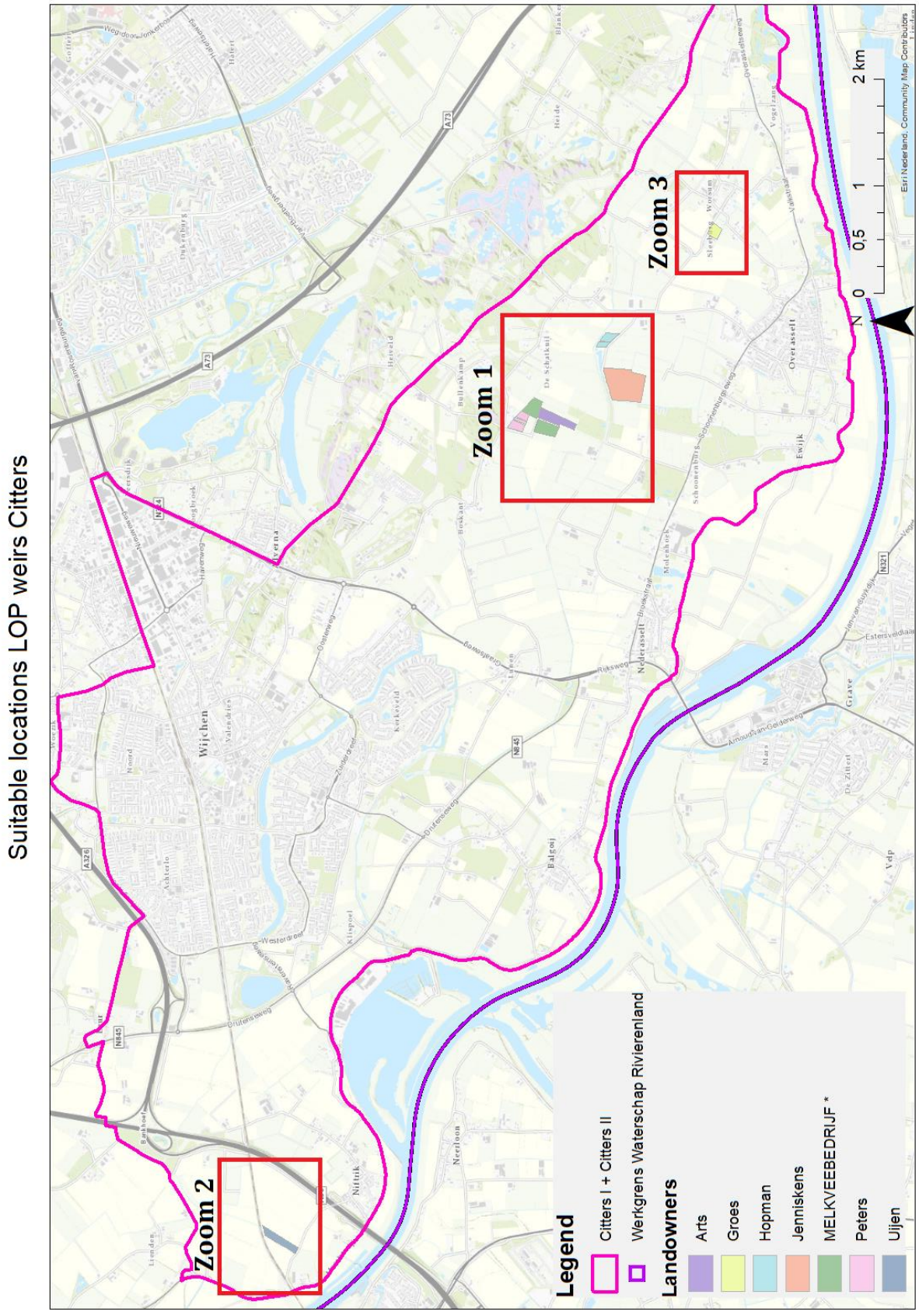
Summary map Ooijpolder



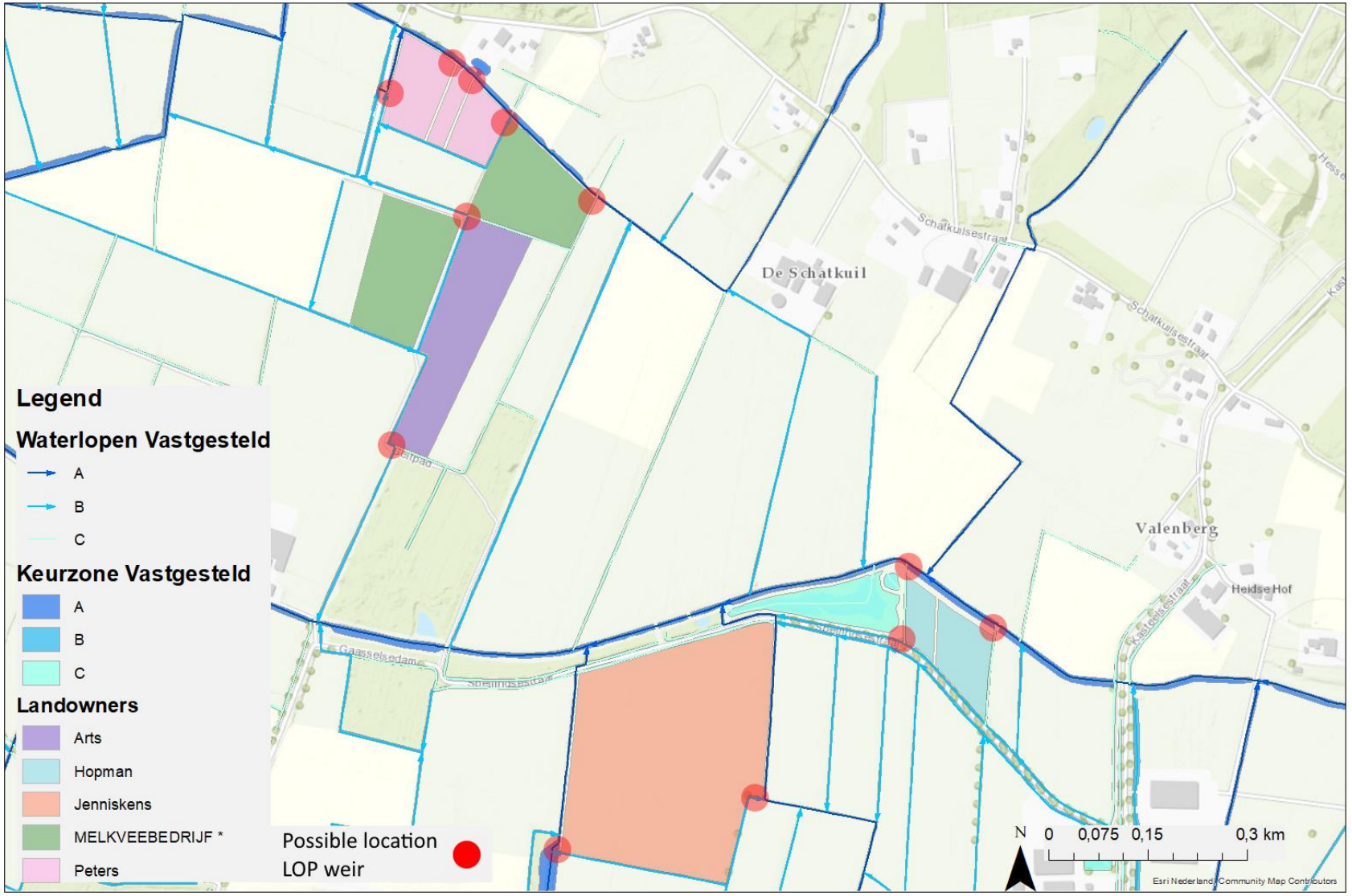
Summary map Ooijpolder



Appendix K – Suitable locations for LOP weirs

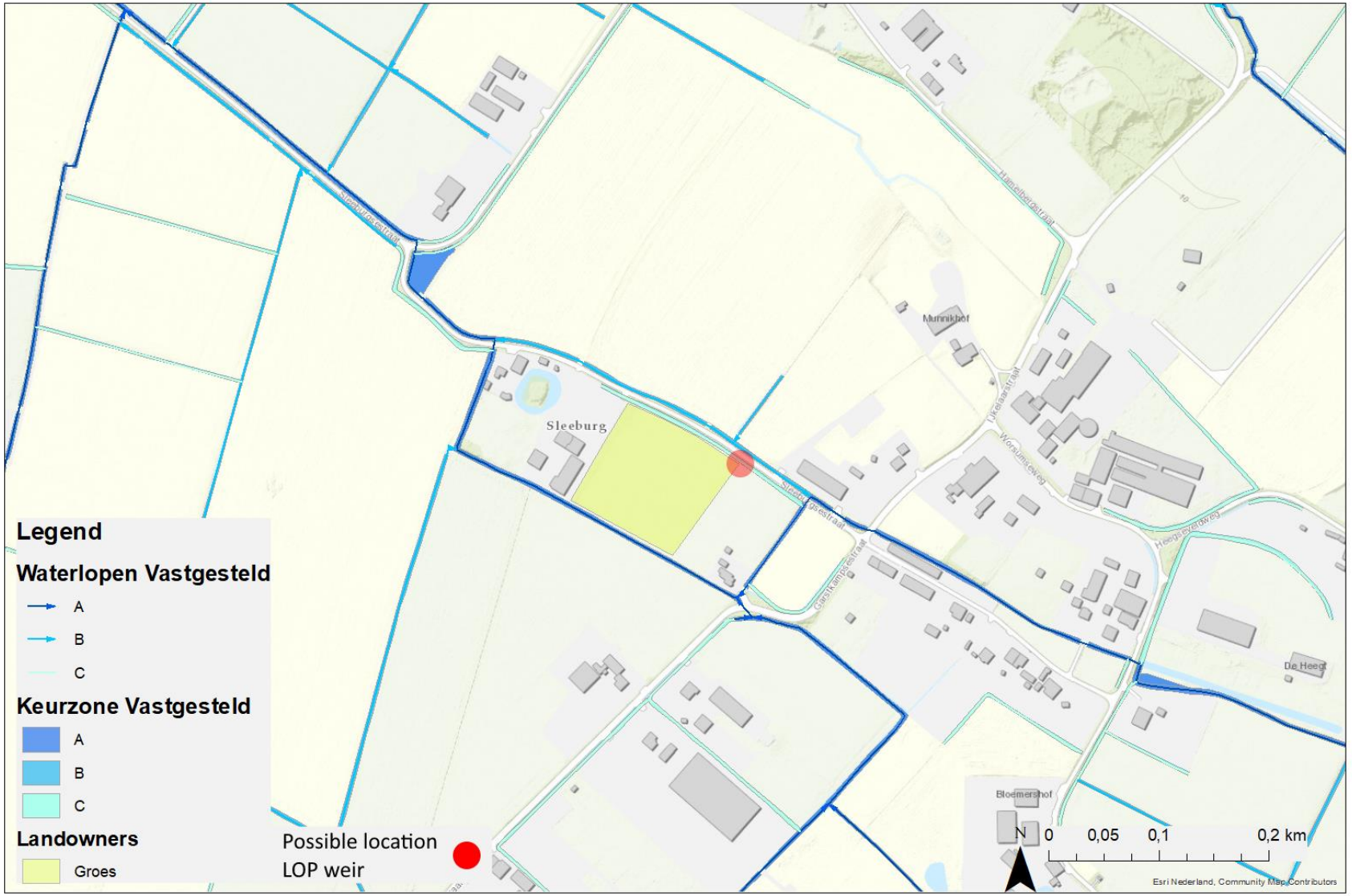


Suitable locations LOP weirs Citters zoom 1

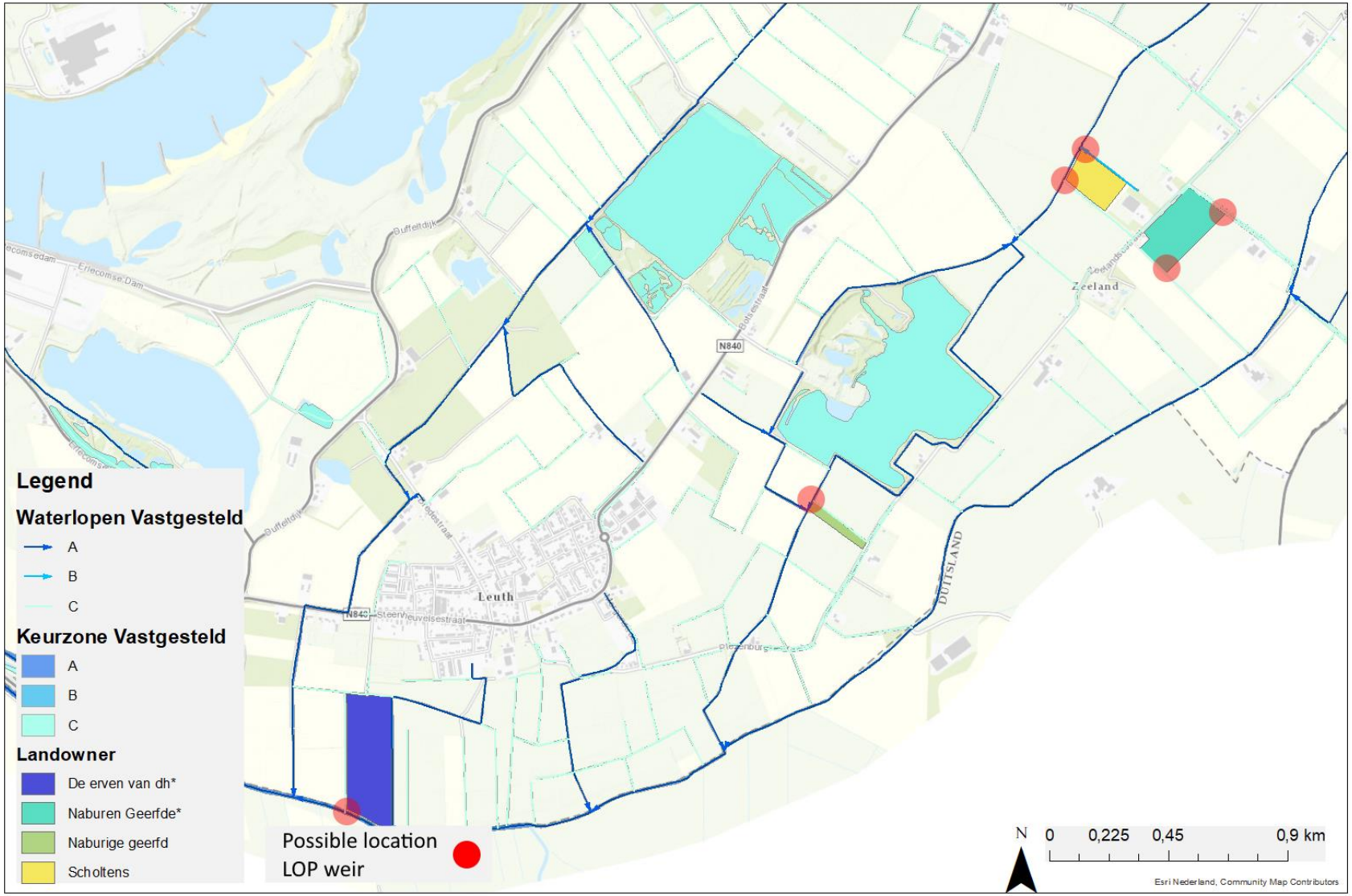


Suitable locations LOP weirs Citters zoom 2

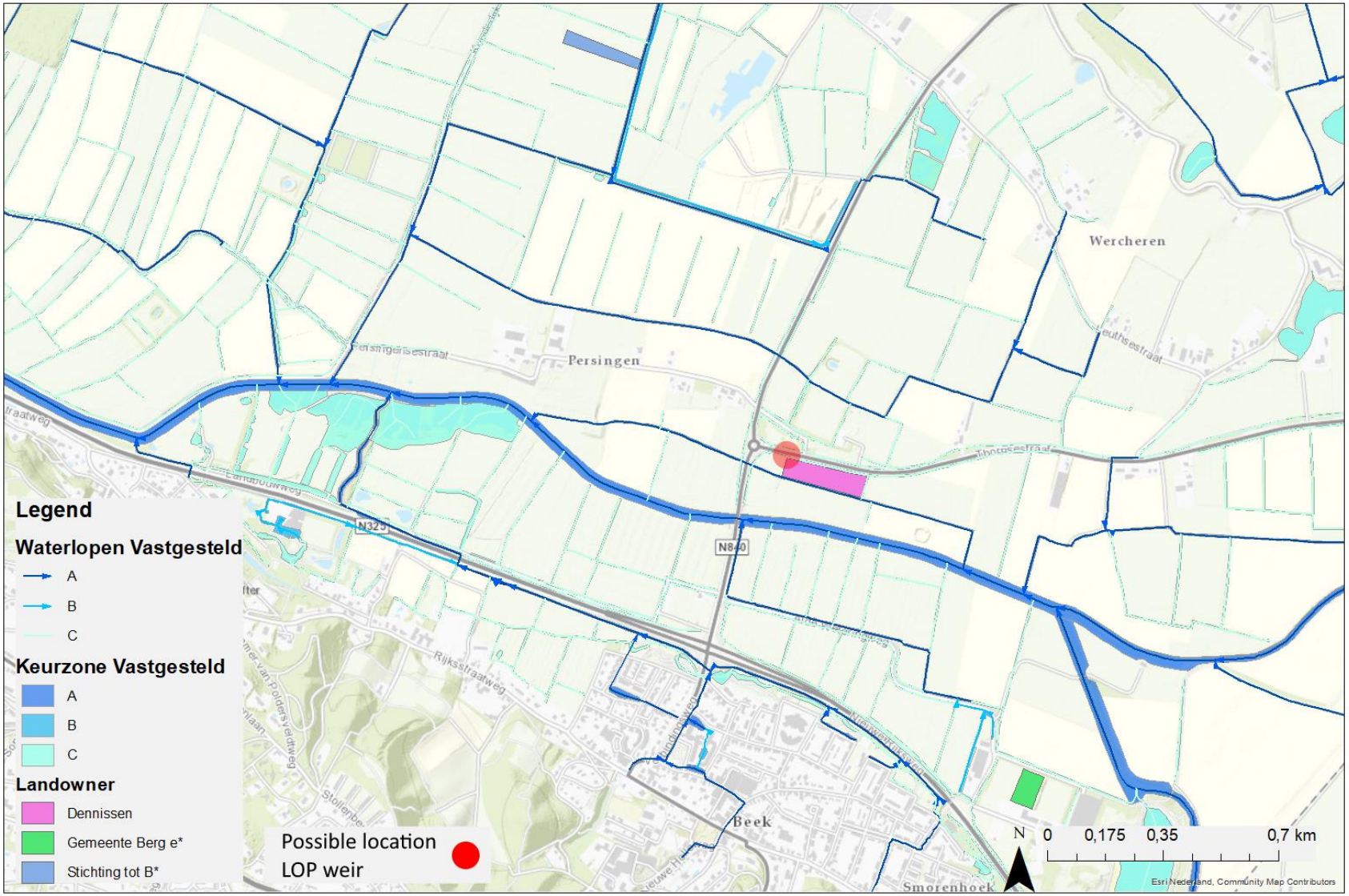
Suitable locations LOP weirs Citters zoom 3



Suitable locations LOP weirs Ooijpolder East



Suitable locations LOP weirs Ooijpolder West



Appendix L – Factsheet other innovations

Factsheet 12: Overige innovaties						
	Toelichting					
Omschrijving maatregel	Innovaties die niet onder één van de hiervoor genoemde maatregelen vallen, kunnen ook in aanmerking komen voor subsidie.					
Subsidiabele sectoren	**Akkerbouw**	**Boomkweek**	**Fruit**	**Grasland**	**Tuinbouw**	**Glastuinbouw**
	Ja	Ja	Ja	Ja	Ja	Ja
Bijzonderheden sectoren:						
Relevant voor:	Alle deelgebieden					
Advies gebruik/ opmerkingen						
Potentiële waterbesparing (%)	Verwachte besparing van meer dan 10% ten opzichte van haspelberegening.					
Randvoorwaarden subsidie:	De maatregel moet een verwacht waterbesparend effect hebben van minimaal 10%. De maatregel moet toepasbaar zijn binnen minimaal 2 agrarische sectoren en de maatregel mag niet onder één van de andere maatregelen vallen.					
Subsidievergoeding	Percentage op investering: tussen de 25-40%.					
Controle	Bedrijfsbezoek 1: Tijdens het eerste bedrijfsbezoek wordt de subsidieaanvraag met de desbetreffende ondernemer doorgenomen en worden de afspraken en voorwaarden voor subsidieverlening besproken. Bedrijfsbezoek 2: Het tweede bedrijfsbezoek zal plaatsvinden wanneer het systeem is geïnstalleerd en in werking is. Dan zal worden bepaald of de afgesproken maatregel volgens afspraken en voorwaarden is gerealiseerd.					
Bewustwording en kennisdeling	Vastleggen informatie: Een voorwaarde voor subsidieverlening is het vastleggen en delen van informatie over zaken over watergebruik (aantal en omvang giften), wateropslag en wateraanvoer en het inschatten van de waterbesparing t.o.v. de toepassing zonder de maatregel. De ervaringen en de (tussen)resultaten zullen tijdens de 2e controle en kennisuitwisselingen met andere ondernemers worden besproken. Kennisuitwisseling: Gevraagd wordt om gedurende de openstelling van de subsidieregeling (t/m 2021) minimaal 2 keer ervaringen uit te wisselen met het waterschap, (Z)LTO en andere ondernemers. Hierbij komen onderwerpen aan de orde zoals ervaringen met de maatregel, waterbesparing, gebruikersgemak, energiekosten en tijdsinvestering.					

Appendix M – Locations Sommeren

Rooijsestraat

Heemstraweg