Verkennend onderzoek naar ecosysteemdiensten in de Amsterdamse Waterleidingduinen

Luc Geelen

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Bij de voorpagina

Ecosysteemdiensten…… er is niets nieuws onder de zon.

Al sinds we op aarde rondlopen halen we voedsel, water en kleren uit onze omgeving. En met het gebruik beïnvloeden we onze omgeving.

De Amsterdamse Waterleidingduinen hebben hun huidige omvang te danken aan het feit dat het gebied sinds 1853 een belangrijke rol speelt bij het leveren van een basisbehoefte in Amsterdam: drinkwater. In 1853 werd er in Amsterdam 1 cent per emmer voor het duinwater betaald. Een ecosysteemdienst avant la lettre.

De drinkwaterfunctie heeft er voor zorggedragen dat de duinen in het drukste deel van Nederland toch niet zijn volgebouwd met huizen en hotels, zoals bijvoorbeeld in België is gebeurd.

De Amsterdamse waterleidingduinen behoren nu tot de top natuur in Europa, het Natura2000 netwerk, en leveren ook nog eens ontspanningsmogelijkheid voor vele duizenden bezoekers. Hoe dit in de AWD ruimtelijk gecombineerd wordt is nu in beeld gebracht door Daniël Wille (Annex 2).

Het benoemen van ecosysteemdiensten heeft als belangrijkste doel een goede afstemming te vinden tussen het functioneren van ecosystemen en de behoeftes van onze maatschappij, het socio-economische systeem. Deze eerste verkenning voor de AWD geeft een globale indruk van de bestaande situatie. Het operationaliseren van het concept ecosysteemdienst op locaal niveau is een hele puzzel maar biedt mogelijkheden voor verder onderzoek en beleidsverkenning.

Luc Geelen

Leiduin

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Colofon:

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Annex 1 Overzicht van ecosysteemdiensten

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1 Inleiding

In het Kader van het LIFE+ project “Amsterdam Dunes, Source for Nature” (LIFE11 NAT/NL/776) kreeg Waternet in 2011 van de Europese Commissie de vraag om een quick scan uit te voeren naar “ecosystem services” in de AWD. Deze opdracht heeft geresulteerd in samenwerking met Universiteit Leiden en een afstudeerproject voor Daniël Wille. Het studenten rapport is klaar en vormt de basis voor deze “quick scan” het rapport van Wille (2016) is bijgevoegd aan het eind als Annex 2 !

In deze notitie wordt kort ingegaan op de volgende vragen:

- Waar komt de vraag van de EU vandaan?
- Wat zijn “ecosystem services” oftewel ecosysteemdiensten?
- Wat zijn de belangrijkste ecosysteemdiensten van de AWD

2 Waar komt de vraag van de EU vandaan ?

Ecosysteemdiensten werden als concept op de agenda geplaatst door enkele toonaangevende publicaties in de jaren ’90 (o.a. Costanza et al., 1997; Daily, 1997). Vooral het artikel van Costanza in het wetenschappelijk tijdschrift Nature, kreeg ruime weerklank in de wetenschappelijke wereld. Het ecosysteemdienstenconcept was tot eind de jaren ‘90 vooral het speelveld was van de academische wereld, de publicatie van het Millennium Ecosystem Assessment van de Verenigde Naties zorgde echter voor de doorbraak van het concept in de beleidswereld (MA, 2005). Het rapport concludeert dat op wereldschaal twee derde van de ecosysteemdiensten ernstig bedreigd zijn door niet-duurzaam gebruik en beheer van ecosystemen en legt een verband tussen het verlies van biodiversiteit en armoede in de wereld. Het rapport benadrukt daarbij de noodzaak om ecosysteemdiensten te integreren in beleidsplanning en het beheer van ecosystemen. In de EU werd in 2011 een nieuwe Europese biodiversiteitsstrategie (COM/2011/244, 2011) goedgekeurd. (Het startjaar van ons LIFE+ project!!). Hierbij werd een lange termijn visie tot 2050 uitgewerkt en werden hoofdstreefdoelen voor 2020 vastgelegd. **Met deze strategie wil de EU het biodiversiteitsverlies en de aantasting van ecosysteemdiensten in de EU uiterlijk tegen 2020 stoppen en waar mogelijk ongedaan maken**. De strategie bestaat uit zes streefdoelen waaraan telkens een aantal concrete acties gekoppeld zijn. Volgens streefdoel twee moeten ecosystemen en ecosysteemdiensten tegen 2020 gehandhaafd en verbeterd worden door groene infrastructuur op te zetten en ten minste 15% van de aangetaste ecosystemen te herstellen. Als concrete actie onder streefdoel 2 zou elke lidstaat hiervoor tegen 2014 de toestand van de ecosystemen en ecosysteemdiensten op hun grondgebied in kaart moeten brengen en evalueren en tegen 2020 de economische waarde van die diensten beoordelen en integreren in nationale en Europese beleidsindicatoren. De waterdoelstellingen benadrukken het halen van de KRW-doelstellingen voor waterkwantiteit en waterkwaliteit. In het kader hiervan heeft de Europese commissie een blauwdruk voor het behoud van de Europese wateren opgesteld (COM/2012/673, 2012). Ook in deze blauwdruk worden ecosysteemdiensten vermeld als doel (bescherming van biodiversiteit en ecosysteemdiensten) en als instrument (methodologie voor het bepalen van kosten en baten van watermaatregelen). Het netwerk van Natura 2000-gebieden vormt de kern van Europa ’s Groene infrastructuur. Deze gebieden zijn niet alleen hotspots van biodiversiteit, maar leveren ook een heleboel ecosysteemdiensten. De EU is in het bijzonder geïnteresseerd in hoe Waternet in de AWD N2000 doelstellingen m.b.t. het behoud en herstel van biodiversiteit combineert met ecosysteemdiensten. Het complementair gebruik van een dubbele strategie, waarbij zowel wordt ingezet op de bescherming van specifieke habitats en soorten als op de bescherming van ecosysteemdiensten, kan dan een win-winsituatie creëren die én ecologische voordelen oplevert, én tegemoet komt aan een maatschappelijke vraag naar het gebruik van ecosystemen.

3 Wat zijn ecosystem services oftewel ecosysteemdiensten?

Conform het Millennium Ecosystems Assessment (MEA) kunnen we ecosysteemdiensten beschrijven als: **De voordelen die mensen van ecosystemen ontvangen** (Duraiappah et al., 2005).

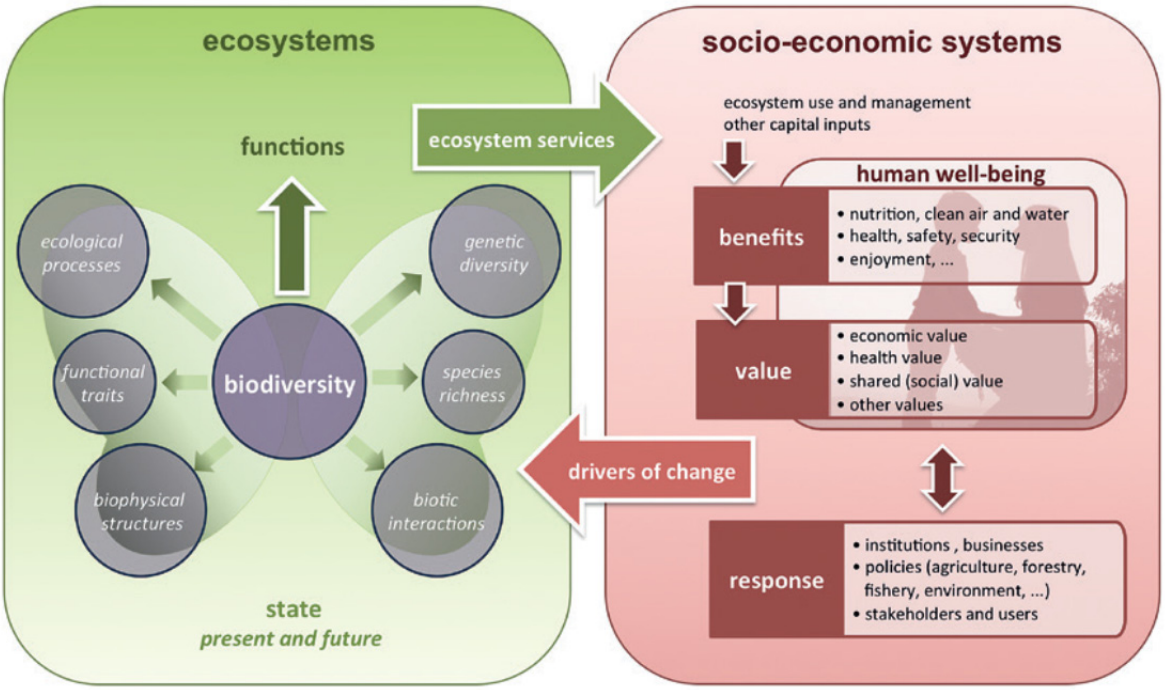

Figure 1. The conceptual framework drawn up by the MAES initiative (Maes *et al.*, 2013a). It links socio-economic systems with ecosystems via the flow of ecosystem services and through the drivers of change that affect ecosystems either as consequence of using the services or as indirect impacts due to human activities in general.

In een ecosysteembenadering worden zowel ecologische als economische en sociale aspecten in eenzelfde methodologisch kader verenigd. Dit methodologisch kader kan de basis vormen voor een duurzaam beleid en beheer, waarbij de waarde van ecosystemen in de besluitvorming meegenomen wordt. Een ecosysteembenadering is dus een integrale benadering van de relatie tussen mens en natuur, waarbij zowel de menselijke afhankelijkheid van ecosystemen als de impact van de mens op die ecosystemen een plaats krijgen. Er zijn verschillende methoden ontwikkeld om ecosysteemdiensten te beschrijven.

Voor de indeling van ecosysteemdiensten in het kader van LIFE projecten wordt gebruik gemaakt van de CICES-classificatie (Common International Classification of Ecosystem Services). CICES is een hiërarchische indeling van ecosysteemdiensten die voldoende flexibel is om zowel op Europese als op lokale schaal ecosysteemdiensten in kaart te brengen.

Section	Division	Group
Provisioning	Nutrition	Biomass
		Water
	Materials	Biomass, fibre
		Water
	Energy	Biomass-based energy sources
		Mechanical energy
Regulation &	Mediation of waste, toxics and other nuisances	Mediation by biota
		Mediation by ecosystems
	Mediation of flows	Mass flows
		Liquid flows
		Gaseous / air flows
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection
		Pest and disease control
		Soil formation and composition
		Water conditions
		Atmospheric composition and climate regulation
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions
		Intellectual and representative interactions
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic
		Other cultural outputs

Figure 2: The CICES classification V4.3. Note: The green section should be labelled correctly as "regulation & Maintenance". Source: http://cices.eu/cices-structure

In Nederland wordt deze indeling ook aangehouden , zie Annex 1, waar Productiediensten, Regulerende diensten en Culturele diensten staan aangeduid.

4 De belangrijkste ecosysteemdiensten van de AWD

Met het rapport “Ecosystem services evaluation and mapping; a case study in the Amsterdam Water Supply Dunes” (Annex 2) is een basis gelegd voor de beschrijving en kartering van ecosysteemdiensten in de AWD. Wille heeft dit onderzoek uitgevoerd in het kader van zijn Bsc afstudeerproject bij CML Universiteit Leiden. Gezien de beperkte tijd, de projectperiode liep van 16/2/2016 - 3/6/2016, is een keuze gemaakt om een beperkt aantal diensten in beelden en getallen weer te geven. Zie ook Annex 1

Het belang van de AWD voor natuur, drinkwaterwinning, recreatie, kustverdediging en ruwe materialen is in beeld gebracht en hiervan zijn verschillende kaarten opgeleverd. Ook wordt een beeld geschetst van de economische waarde van de diensten voor waterwinning, recreatie, kustverdediging en ruwe materialen, dit lukte in het korte tijdsbestek echter niet voor de biodiversiteit.

Een aantal kerngetallen die Wille (2016) voor de AWD noemt:

- Totaal oppervlak van de AWD: 3400 ha;
- N2000 habitat: 71,6% van het oppervlak classificeert en een 1168,8 ha is zelfs prioritair habitat H2130
- Aantal rode lijst soorten waargenomen via NDDF in afgelopen 3 jaar : 214
- Van de Nederlandse rode lijsten van planten en dieren komt resp. 25,2% en 9,8 % in de AWD voor.
- In 2014 werd 52,4 Mm3 water geïnfiltreerd en 63,3 Mm3 water gewonnen uit de AWD ten behoeve van drinkwaterproductie
- Het aantal bezoeken dat aan de AWD gebracht wordt is geschat op 1 miljoen.

Het overzicht van de economische waarde is nieuwe informatie. Hierbij moet de kanttekening geplaats worden dat verschillende methoden zijn gebruikt voor de verschillende diensten en dat hierbij arbitraire keuzes gemaakt moesten worden. De recreatieve waarde zou bijvoorbeeld ook uitgedrukt kunnen worden in benefits in verband met verminderde gezondheidsrisico’s en vóórkomen medische kosten. Bij de Kustverdediging kan ook gekeken worden naar de investeringen die Rijkswaterstaat en het Hoogheemraadschap van Rijnland doen in het onderhoud van het kustsysteem. De waarde voor de drinkwatervoorziening is momenteel evident. Maar hoe druk je dat uit in euro’s? De huidige functies gaan al samen sinds 1853 toen er totaal anders tegen de waarde van natuur werd aangekeken als tegenwoordig. Toen werd het voornamelijk als winst gezien voor het gebied en de bevolking. Nu de huidige infrastructuur voor de infiltratie en winning er eenmaal is kan ook de grondwaterstand hersteld worden zonder dat de inmiddels bebouwde omgeving daar last van heeft. Iets wat anders niet meer mogelijk zou zijn. Wille heeft in zijn rapport ‘een’ berekeningsmethode gekozen, maar dat is zeker niet dé methode zo die er al zou zijn. Duidelijk is wel dat de AWD een cruciale functie heeft voor de drinkwatervoorziening van de metropool Amsterdam.

Hoewel er dus nog veel haken en ogen lijken te zitten aan het lokaal implementeren van het ecosysteem concept is het wel van belang om deze ervaring uit te bouwen. Bijvoorbeeld door het uitbouwen van de natuurwaardering met fauna aspecten, een gevoeligheidsanalyse bij gebruik van andere valuatiemethoden, en voor de rol van het duin bij koolstof en stikstof kringlopen. Ook het reinigend vermogen voor bodem, water en lucht zijn interessante elementen voor verder onderzoek.

Het in kaart brengen van verschillende ecosysteemdiensten levert een beeld van de verschillende functies en interactie in kaartbeelden (figuur 3) . In hoofdlijnen lijkt het resultaat te stroken met de zoneringsgedachte uit de beheervisie voor de AWD.

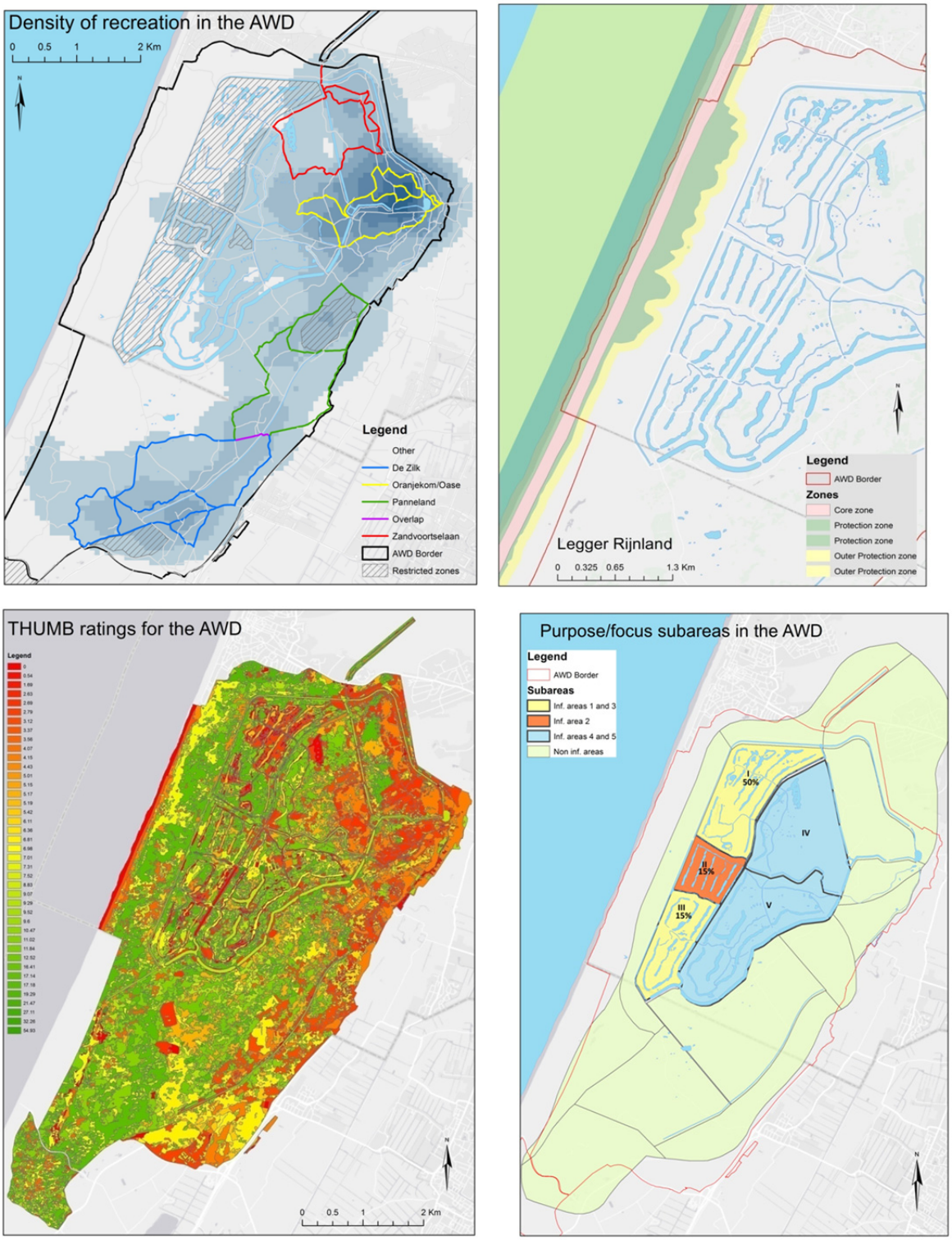

Figure 3: Spatial distribution of recreational use (top left), sea defence function (top right) , the rating for nature values of the vegetation types (bottom left) and water catchment areas in the AWD (bottom right) . (after Wille, 2016 see Annex 2 for explanation).

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Annex 1 Overzicht van ecosysteemdiensten

In rood omkaderd de in de case studie van Wille (2016) verkende diensten van de AWD. Zie Annex 2

Annex 2 Bsc Research Project by D.A. Wille

Ecosystem services evaluation and mapping;

a case study in the Amsterdam Water Supply Dunes

Ecosystem services evaluation and mapping

a case study in the Amsterdam Water Supply Dunes

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30-06-2016

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ABSTRACT

Ecosystem services are the services that ecosystems can provide for humans. Identifying and studying these services can give insight into the working of these services (or functions) and with that identify overlap in spatial distribution and possible conflicts between services as a result of these overlaps. Furthermore ecosystem services can be given an economical value as a tool to determine their worth, in money, to humans. Five major ecosystem services of the AWD, located in a Natura2000 area, have been identified, described, mapped and given an economical value. These services are: Water extraction, Conservation, Recreation, Coastal protection and Raw materials. The results of this report have mostly been gathered from literature and pre-existing data, no lab- or fieldwork was done to gain any of the presented results. With the information of the spatial distribution of the separate services several spatial overlaps were identified that could indicate potential conflicts between services. One certain conflict was found between the Water extraction and Recreation services. The economical valuation showed that four services (excluding Conservation) have a considerable economical value, with the Water extraction being the uncontested number one.

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1. Introduction

1.1 General background

1.1.1 Humans and nature

Before the Neolithic Revolution that occurred roughly around 10.000 BC, humans lived solely as hunter-gatherers. During this time everything humans used came directly from nature (Feniks, 2007). However with the Neolithic Revolution and all the changes made after that until this day we have removed ourselves further and further away from nature, almost completely living outside of it, thus losing our touch with nature (Emerald, 2004). According to the German philosopher Helmuth Plessner, shaping our surroundings to our pleasing (creating culture) is what defines us as humans. Humans are "Artificial by nature", Plessner states (La coultre, 2007). Nature has become, in the eyes of many, an extra addition to life or even something to be avoided, a nuisance that just makes their life in the city less pleasant. It is easily forgotten that still today most of the things we use daily come from nature, be it directly or indirectly. For example plastic, a material that is the pinnacle of what is considered to be unnatural, is derived from crude oil that is a naturally occurring substance. Granted, it is artificially pumped up and then processed, all by humans. The origin, however, still lies in nature. Through this reasoning all the "unnatural" products that humans fabricate come directly or indirectly from nature. A broad used term for such a tangible or intangible product or service derived from nature is an "ecosystem service".

1.1.2 What are ecosystem services?

In short, ecosystem services are the "benefits that people obtain from ecosystems" as defined by the Millennium Ecosystems Assessment(MEA) in 2005 (Duraiappah et al., 2005). This is a very broad description of the term and does not give much insight. However, "The Economics of Ecosystems and Biodiversity (TEEB)" (Barker, Mortimer, & Perrings, 2010) as well as the MEA have divided these ecosystem services into separate classes in order to give structure to the wide range of ecosystem services that exist. For more in depth information on MEA and TEEB, see Appendix 1. A third ecosystem service classification system is CICES (Common International Classification of Ecosystem Services). This classification is slightly different from TEEB and nowadays in use by the EU-LIFE unit (EC, 2016). CICES and its structure is explained in the Method.

1.1.3 Financial values

Through the different classes of ecosystem services it becomes clear what kind of benefits humans gain from ecosystems. However, this does not show the economical value of ecosystems, only the kind of services. Giving an estimate of how much ecosystems are valued in money is a tough task considering the complexity and wide range of different kinds of services. Not to forget the current value on the market for a specific product that can fluctuate.

Costanza published an article in Nature in 1997 that gave an estimated value of all the ecosystems in the world combined. This peer-reviewed article gave an estimate of a total worth of US$16-54 trillion($10^{12}$) per year, with an average of US$33 trillion per year. In that same year the global Gross National Product was around US$18 trillion (Costanza et al., 1997). These numbers are so immensely high one can hardly begin to comprehend the sheer size, especially considering these numbers are minimum estimates. However, it does show very clearly that humans are not only dependent on ecosystems to stay alive but also

that the economy of the world is heavily dependent on its ecosystems and through that the proper functioning of the ecosystems.
Now that it has been determined that ecosystems have an immense value it becomes clear that we have a high interest in the proper functioning of complete, unharmed ecosystems. This argument arises from a purely economical point of view, the intrinsic value of nature does not even come into play here, even though that arguably could be reason enough on its own.

1.1.4 Benefits of identifying and valuating ecosystem services

The identifying and valuating of ecosystem services can serve not only as a tool to identify potential profits but also to understand the functioning of an ecosystem and perhaps with this understanding improve its functions if necessary, whether these are intrinsic or not. An ecosystem where several large ecosystem services, all with considerable financial stakes, are present in one ecosystem is the AWD (Amsterdamse Waterleiding Duinen).

1.2 The AWD as an ecosystem

The Amsterdamse Waterleiding Duinen (AWD) is located between Zandvoort and Noordwijk on the border of the provinces of Noord-Holland and Zuid-Holland in the Netherlands, Figure 1. With 3400ha it makes up a large part of the Natura 2000 area "Kennemerland-Zuid" that has a total surface area of 8164ha (van Buuren, 2000; synbiosys.alterra.nl(1)). For more information on N2000, see Appendix 2.

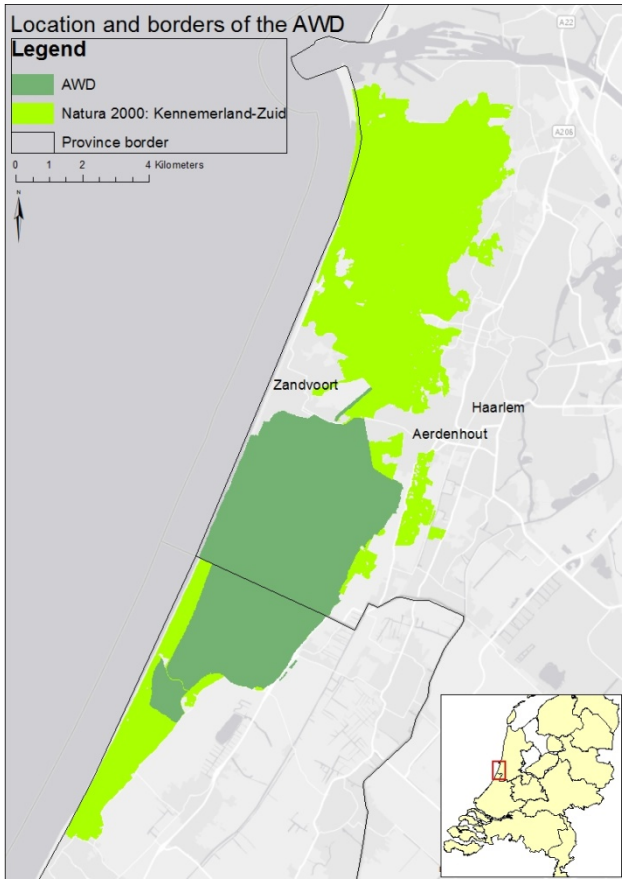

Figure 1: The Natura 2000 area with in dark green the AWD. (Source: Waternet)

While the AWD is part of a Natura 2000 area and serves a large recreational purpose it also provides the drinking water for 2/3 of the city of Amsterdam (awd.waternet.nl(1)). Furthermore, being located on the coast and largely consisting of dunes the AWD also plays an important role in the protection against the sea.

So far four different major functions of the AWD have become apparent; the providing of drinking water, nature, recreation and the protection from the sea. These four are easy to identify but many more remain and even these four might consist of smaller functions. This is not yet properly understood and researched for this particular ecosystem.
It also is easy to imagine that these functions might hinder each other in some ways. For instance the process of obtaining drinking water needs the extended network of canals, this comes at the cost of surface area of the Natura 2000 area that otherwise might have more space for species or tourists. These possible conflicts have also not been indentified for this particular area.

By recognizing the functions of the AWD as ecosystem services and creating a framework with the help of the classification system of CICES an understanding of the working and interactions of the different functions of the AWD can be obtained.

1.3 Proposition

In the context of the LIFE+ dune habitat restoration project 'Amsterdam Dunes - source for nature' the manager of the Amsterdam Dunes, Waternet, was asked to deliver an inventory on the ecosystem services provided by the Natura2000 area.
This concrete demand from the EU was the reason for this study topic.

The question that this report shall strive to answer in order to comply with the request is the following: *What are the main ecosystem services that the AWD provides and how are they currently located/distributed throughout the area?*

To answer this staged research question the following list of goals will be met in order to provide a step by step process that leads to the main question:
1. Define the term "Ecosystem services" to be used in this report.
2. Evaluate the ecosystem services of importance within the AWD.
3. Develop a procedure to valuate the identified ecosystem services.
4. Description of the selected ecosystem services of the AWD including their values.
5. Maps of the distribution of ecosystem services of the AWD including identification of possible overlap and conflicts among the ecosystem services.

2. Materials and Methods

2.1 General notes on methodology

As this is a literature study no lab work was done to reach any of the presented information of findings in this report. Therefore no lab journal was kept as this was redundant. Instead a log was kept of time spent in the field with employees of Waternet who showed me different areas and aspects of the AWD to obtain knowledge and generally to get to know the area, see Appendix 13. Note that these are not structured field observations, some come closer to tours, others appointments to discuss a certain topic or gather information. Furthermore a list of all persons I came into contact with and that contributed to this report in any way shape or form can be found in the acknowledgements.

ArcGIS version 10.2.2 was used to make all maps, which will from now on be referred to as ArcGIS. All ArcGIS maps were made with material made available by Waternet or Hoogheemraadschap van Rijnland. The origin of ArcGIS material and what steps in ArcGIS were taken to come to the end result will be elaborated upon below separately for each service.

Important to note is that this report will only focus on the current state of the AWD and will not go into detail on how the current state came to be or any future predictions or models. Furthermore, while ecosystem services can and will stretch across the AWD borders, this paper will focus on the services within the borders of the AWD and not further.

2.2 Ecosystem services classifications selection

CICES is for large parts comparable to the TEEB classification with a few alterations. As can be seen in Figure 2, as opposed to TEEB (Appendix 1), the Habitat Services section is nonexistent. Instead this portion has been merged with the Regulation section. Another large change that does not become apparent from Figure 2 is that CICES does not include the abiotic services/outputs in this classification. Instead, a separate classification table for this has been compiled see Figure 3 (cices.eu). CICES is used by the EU-LIFE unit as a tool to evaluate the LIFE+ projects and from which this report find its origin (EC, 2016). As CICES is the tool of choice for the EU-LIFE unit and this report was made for this unit CICES was chosen over the other classifications (MEA and TEEB).

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	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic
		Other cultural outputs

Figure 2: The CICES classification V4.3. Note: The green section is labelled correctly as "regulation & Maintenance". Source: http://cices.eu/cices-structure

Section	Division	Group	Examples
Abiotic Provisioning	Nutritional abiotic substances	Mineral	e.g. salt
		Non-mineral	e.g. sunlight
	Abiotic materials	Metallic	e.g. metal ores
		Non-metallic	e.g. minerals, aggregates, pigments, building materials (mud/clay)
	Energy	Renewable abiotic energy sources	e.g. wind, waves, hydropower
		Non-renewable energy sources	e.g. coal, oil, gas
Regulation & Maintenance by natural physical structures and processes	Mediation of waste, toxics and other nuisances	By natural chemical and physical processes	e.g. atmospheric dispersion and dilution; adsorption and sequestration of waters in sediments; screening by natural physical structures
	Mediation of flows by natural abiotic structures	By solid (mass), liquid and gaseous (air)flows	e.g. protection by sand and mud flats; topographic control of wind erosion
	Maintenance of physical, chemical, abiotic conditions	By natural chemical and physical processes	e.g. land and sea breezes; snow
Cultural settings dependent on abiotic structures	Physical and intellectual interactions with land-/seascapes [physical settings]	By physical and experiential interactions or intellectual and representational interactions	e.g. caves
	Spiritual, symbolic and other interactions with land-/seascapes [physical settings]	By type	e.g. sacred rocks or other physical structures or spaces

Figure 3: The abiotic CICES classificationV4.3. Source: http://cices.eu/cices-structure

2.3 Methodology per service

This report will focus on a select amount of ecosystem services which are listed below. Among these five ecosystem services are the four main services, see Introduction, of the AWD and were therefore chosen over others as not all ecosystem services could be properly evaluated.
As the described services required separate approaches, sources and functions in ArcGIS the method for each service will be described separately. Finally the approach for validating the ecosystem services is given.

2.3.1 Conservation

In order to define and map this service three approaches were taken that all give an unique perspective on the matter. When combined these give a versatile view of this service. These three are the N2000 habitat types, NDFF and the THUMB vegetation type rating. These three will be separately described below.

N2000

In 2007 the spatial distribution of the Natura 2000 habitat types in the AWD was mapped (Oosterbaan et al., 2010), seen in Figure 4. This distribution is the most recent one available at this time and will serve as the base for the description of this service.
The ArcGIS material for Figure 4 comes directly from Watenet and has not been altered in any way with the exception of the layout.

NDFF

The NDFF (Nationale Databank Flora Fauna) is the most complete databank of the Netherlands concerning observations of wildlife bundling over 100 databanks and validating all information before it is added (ndff.nl).

To obtain the results the following settings and/or search functions were used:

- The borders of the AWD were drawn and used as the search area from which data was gathered.
- Seperate searches were done for all the possible groups that were available. The groups are as following: Mammals, Birds, Reptiles, Amphibians, Fish, Butterflies, Moths, Dragonflies, Insects, Arthropods, Vascular plants, Mosses, Lichen, Algae, Fungi and Molluscs. See Appendix 5.
- The time period for the data was set to three years. This time span was used as a compromise between comprehensiveness in terms of data cover and being allowed to assume that data represent the current situation.
- Another filter that was applied concerns the status of the species present in the area and databank. Instead of using all the species that are observed in the area and present in the databank the choice was made to use the search option present to only incorporate Red list species. When comparing all species with only Red list species it became clear that the selection made helped a great deal in filtering out clutter. For instance for the vascular plants group the records went up over tenfold, this included pest species and created one big cloud of dots if one were to map them as done in Appendix 8.

Raw data of the separate groups listed above was compiled into the tables found in Appendix 5. Furthermore ArcGIS shapefiles containing the locations of the sightings were available on www.ndff.nl and were used to create the maps found in Figure 5 and Appendix 7 combined with additional ArcGIS material originating from Waternet. These raw shapeflies downloaded from www.ndff.nl came in Polygon shapes that proved to be useless without further editing. In order to transform these polygons to actual points the ArcGIS tool "Feature to Point (Data Management)" was used, this resulted in maps like Appendix 7. With points it was possible to obtain the depiction of the sightings density with the use of the ArcGIS tool "Point Density (spatial analyst)" on the combined observations of the vascular plants, mosses, lichen and fungi. Sadly the same could not be done for the other remaining group, being mostly animals. Due to the mobility of most animals, as opposed to the groups that are used, mapping these sightings would say little to nothing about the actual spread of the individuals. For instance a Fallow deer (*Dama dama*) can be seen in the South of the area and be in the North the next day. This could also result in one individual being spotted in multiple places leading to even more inaccuracy of the locations. These problems combined resulted to the decision to exclude these groups for this model.
The above described problem with double counting also made it impossible to say anything conclusive about population numbers, this concerns all groups albeit perhaps more so for moving organisms as opposed to sedentary.
When comparing the amount of Red List species in the AWD with the total of the Netherlands it was unclear how Lichen are categorized by the IUCN Red List. Probably under plants, however without certainty these 20 Lichen species could not be taken into consideration for the calculating of the percentage. The result is that the percentage shown in Table 4 can be a bit lower than the real percentage for 82 (not 62) plant species which would be 33,3% instead of 25,2%.
In order to check for bias in the NDFF distribution a second map was made with the localities of sighting of the same group in Figure 5 but with all species instead of just Red List species (Appendix 8).

THUMB
As another tool to gain insight into the spatial distribution of this service the vegetation ratings method THUMB was used (KWR, 2010). Here a grading (THUMB) is given for a certain type of vegetation (DVN types). For DVN (De Vegetatie van Nederland) types several kinds of valuation methods are possible (Witte, 2010). However THUMB was chosen over others as this method applied the most to the AWD area. These THUMB grades were integrated with the data of Figure 4 and through ArcGIS Figure 6 was created.

Financial aspect
It was not possible to give a monetary value to this service.

2.3.2 Drinking water
The service of drinking water is limited to the process of naturally filtering water in the AWD before it is pumped out of the N2000 area and further processed before it is ready for consumption. Other closely related services concerning water were intentionally left out or only mentioned shortly. To come to the results information gathered from Waternet documents was used, cited in relevant text.

Water prices/values calculations
Here the prices of one m3 water are considered equal to the cost as well as the values. The reasoning behind this is that all the numbers calculated are done with prices of water paid to a third party (WRK water) or the expenditures that were made in order to keep a process going (within the AWD). Hence without the addition of a profit margin the price or value of one m3 of water is the same as the cost for the same m3 of water. All numbers used for the calculations come directly from Waternet.

The calculation of the price of WRK water is as follows:

Total expense on WRK / m3 of WRK water = price of one m3 WRK water

€5,980,588 / 42,972,414 = €0.139

The two posts that make up the price of Oranjekom water and used in the calculation are BWW (Beheer Waterwingebieden, department of Bron en Natuurbeheer) and PROD-I&W (Productie proces Infiltratie en Winning, department of Production) who are worth 5 and 10 eurocents per m3 of (Oranjekom) water respectively. Adding these two posts that amount to 15 eurocents to the 14 eurocents of the value of WRK water the total value of one m3 Oranjekom water comes on at 29 eurocents.

2.3.3 Recreation
The service of recreation here is described and illustrated through three subsequent factors; the visitor numbers in the AWD, the distribution of these visitors and finally the density of the recreation in the AWD based on the distribution and numbers of visitors.

The choice was made to use visitor counts as an indicator for the impact on the area.
The visitor numbers and the distribution over the entrances of 2002 (Webster, Jaarsma, 2003) were extrapolated to the estimated current visitor numbers of 1 million per year, Table 7 . As described in the service the study of 2002 shows that 99% of the total visitors use the four main entrances. Furthermore it was assumed that most visitors use the suggested routes seen in Figure 11. As there is no definitive number available for the actual percentage of visitors that use the suggested routes as opposed to other paths the choice was made to take 90% of the total current visitors per year that stick to the suggested routes. This resulted in the numbers in Table 8. Here, per entrance 90% is taken and added up to the total amount of 889,200 as the total visitors that only walk the suggested routes per year. The remainder, a total of 110,800, is spread over the rest of the AWD (the paths labelled as "other" in Figures 11 and 12. Langevelderslag is not used and counts towards the "other". The population for the different paths, corresponding with the legend in Figure 11, can be seen in Table 1 below. As a final assumption; all populations are spread evenly over their appointed path types.

Table 1: Different populations for the types of paths used for de density analysis in Figure 12. Important to note is that routes originating from one entrance overlap at certain points, just like "overlap" but for one path type. Here the populations are doubled to correct to the proper frequency by which the path is used.

Path type	Population
Other	112,000
De Zilk	192,600
Oranjekom/Oase	368,100

Panneland	188,100
Overlap	380,700
Zandvoortselaan	140,400

ArcGIS
The routes in Figure 11 were made by using a complete road network shapefile of the AWD. Once this figure was finished it could serve as a base for Figure 12. The arcGIS tool that was used to depict the path density and recreation intensity in the AWD was the "Line density (Spatial Analyst)" tool. With the population function in this tool the figures from Table 8 were added to the model.

2.3.4 Coastal defence
A lot of information was obtained in cooperation with Hoogheemraadschap van Rijnland. For instance the ArcGIS shapefile of the legger that was combined with other ArcGIS material provided by Waternet to come to the combined image depicted in Figure 15.
Figure 16 is also a product of ArcGIS but consists of just one layer, provided by Waternet. Due to ArcGIS complications that could not be resolved other layers such as the borders of the AWD could not be added and as a result the image might not be as clear as others. When comparing Figure 16 with Figure 15 the waterways in the AWD can be easily identified and through this serve as a point of reference.
In the process of describing the financial aspect astronomical numbers were found in the used literature concerning the protected value by the primary barrier and the costs accompanying a flood scenario. In order to get some more conclusive/precise numbers additional contact with Rijnland was required. Here a document (DPV, 2014), still in production, was obtained with more precise numbers of flood damages that was a follow up on the report that provided the initial numbers (Vergouwe, 2014).

2.3.5 Raw materials and food
For this service the usage of ArcGIS was not needed as there was no relevant information that required mapping. Although it could certainly be possible and interesting where the control of Fallow deer and the cutting/removing of plants took place; no information of this was available and therefore was not explored any further for this report.
The base of this service comes from literature, cited in the relevant text, and contact with Waternet employees.

2.4 Procedure for validating ecosystem services
As every service required a separate approach concerning the financial aspect is was not achieved to create a model that would allow the valuation for all ecosystem services. Instead several "rules of thumb" were used in order to keep consistency in the process of finding the values of the ecosystem services that are shown in this report:

- All values were divided per year when possible. Allowing for a single scale of measure.
- The year 2014 was used for all numbers, costs and income, when possible. This was the most recent year of which all data was complete concerning data originating from Waternet. When other years and/or dates are presented the origin of the data is other than Waternet and will be specified in the relevant text.
- When possible income after costs was the norm. If information for this lacked, income before costs was used.

3. Results

3.1 Nature and conservation

3.1.1 Natura 2000 habitat types distribution

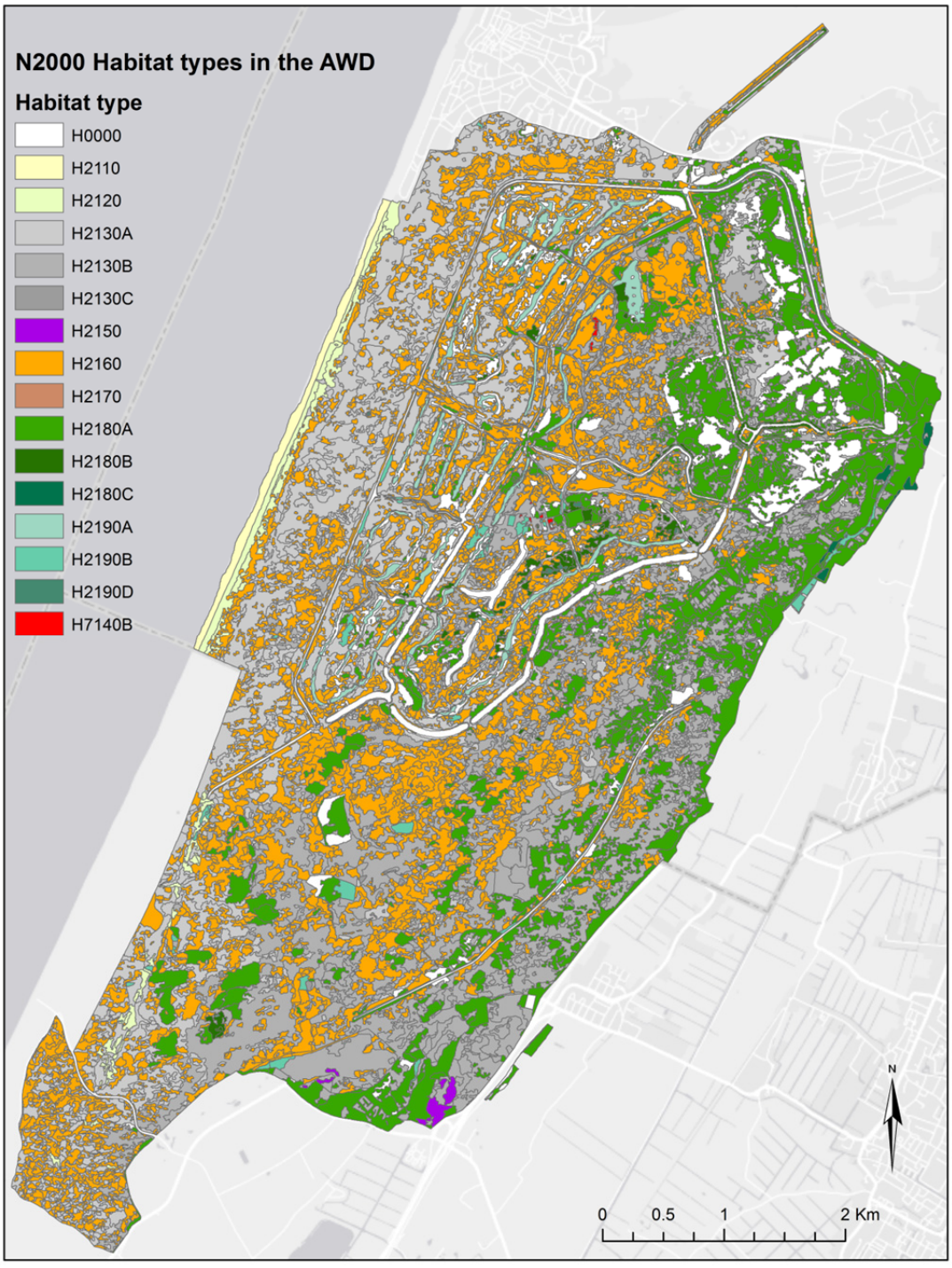

Figure 4: N2000 habitat types present in the AWD in 2007.

Figure 4 shows the N2000 habitat types that are present and their localities in the AWD in 2007. A detailed description of each habitat type seen in the legend of Figure 4 can be found in Appendix 4.

Table 2: Types of N2000 habitats with their surface in ha. Source: Oosterbaan et al., 2010.

Habitat type	Surface, ha
H0000	778,4
H2110	1,2
H2120	45,6
H2130A	599,8
H2130B	567,3
H2130C	1,7
H2150	4,8
H2160	722,2
H2170	0,3
H2180A	539,5
H2180B	27,9
H2180C	4,3
H2190A	61,7
H2190B	33,0
H2190D	2,0
H7140B	1,4
Total	**3391,1**

In Table 2 the surface areas of the N2000 habitats found in the AWD are shown. It becomes clear that four habitat types dominate the dunes of the AWD (H2130A, H2130B, H2160 and H2180A) together taking up 71,6% of the total surface area of the AWD.
Remarkable is that 22,0% of the surface of the AWD consists of H0000 and therefore lacking a N2000 habitat type. Naturally a large portion of this is open water but it also consists of Pine forest. This can be seen in the North-East part of the map as white patches mostly surrounded by light green patches of H2180A (dry boreal forest). However the largest part of H0000 is spread out over other habitat types and cannot be seen in Figure 4 (Oosterbaan et al., 2010).

3.1.2 Red list species

With data of the NDFF (Nationale Databank Flora en Fauna) an inventory was made of the amount of IUCN Red List species that are present in the AWD. In Table 3 below a summary can be seen of how many species were found per category in the AWD in the last three years. A complete list of all the Red List species can be found in Appendix 5 including names, the total amount of species and the total sightings. Sightings here is the total amount of counts registered. This is not the same as the total amount of individuals and therefore says very little to nothing about population numbers, this will be touched upon in the discussion.

Table 3: Red List species in the AWD per category for the last 3 years.

Category	Species
Mammals	6
Birds	50
Reptiles	1
Amphibians	2
Fish	0
Butterflies	8
Moths	0
Dragonflies	5
Other insects	5
Arthropods	0
Molluscs	2
Vascular plants	44
Mosses	18
Lichen	20
Algae	0
Fungi	53
Total	**214**

Summary statistics of the IUCN Red List only give information for plants and animals, lacking information on Fungi and Lichen. However, for these two groups it can be shown how many of the total Red List species in the Netherlands can be found in the AWD. Table 4 shows that for the animals almost 10% of all Red List animals in the Netherlands can be found in the AWD. For the plants this percentage goes up to 25% of all Red List species in the Netherlands. Considering that the Netherlands has a land surface of 3.389.300ha and the AWD only 3400ha, giving the AWD a 0,01% of the Dutch landmass, the percentages for the plant and animals in Table 4 are far out of proportion. This clearly indicates that the AWD serves as a safe haven for biodiversity.

Table 4: Amount and percentage of Red List species in the AWD compared to the total of the Netherlands. (source: iucnredlist.org(3))

	AWD	Netherlands	% in AWD
Animals	79	806	9,8%
Plants	62	248	25,2%

With the data of NDFF a map, Figure 5, was constructed with the localities of all vascular plants, fungi, mosses and lichen sighted in the AWD in the last 3 years. In order to make the map as plain as possible all the four groups have not been separated in this image and are shown in the same colour. To see the localities of the individual groups see Appendix 7. In Figure 5 some clusters can be observed. The most dense clusters can be found in the North-East region of the AWD.

When comparing the locations of the observations in Figure 5 with the locations of the N2000 habitat types in Figure 4 it becomes clear that H2130 (Fixed coastal dunes) and H2160 (Dunes with Hippophae rhamnoides) harbour the most red list species that are depicted in Figure 5. H2180A (Wooded dunes, dry) come in third. This correlates with the size of the surface of the above mentioned habitat types. This correlation can lead to two conclusions. First, these habitat types are highly important for the red list species they harbour and with that form a better habitat than other habitats found in the area. The second possibility is that

the mere size of these habitats cause the higher number of species present instead of the quality of the habitat. For this the assumption that the species are spread out evenly over the areas has to be made and with that that all species present do not distinguish in different types of habitat. An assumption I personally think to be highly unlikely.
When comparing Figure 5 with Appendix 8 it becomes clear that there is a bias towards certain areas. The points clearly form paths, suggesting the observations are not done at random but only on specific routes. This takes away a bit of the gravity of this figure

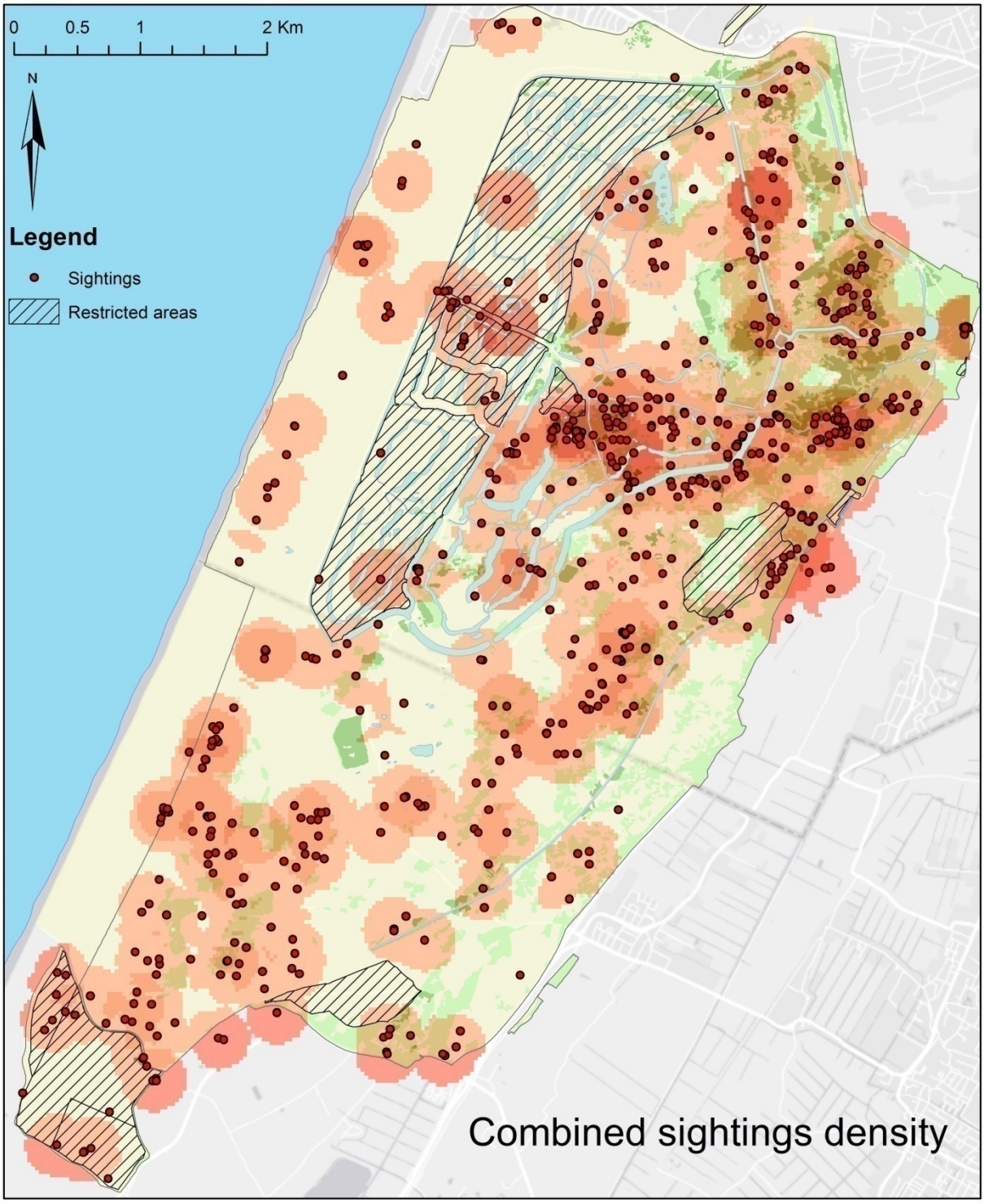

Figure 5: Combined sightings density of vascular plants, fungi, mosses and lichen in the AWD. The red buffer around the dots indicates an overlap with other dots, more overlap gives a darker buffer.

yet it does not prove that certain groups/species do not occur in some places, merely that they are not observed there. Therefore this figure still serves a purpose albeit with the knowledge that the data requires improvement.

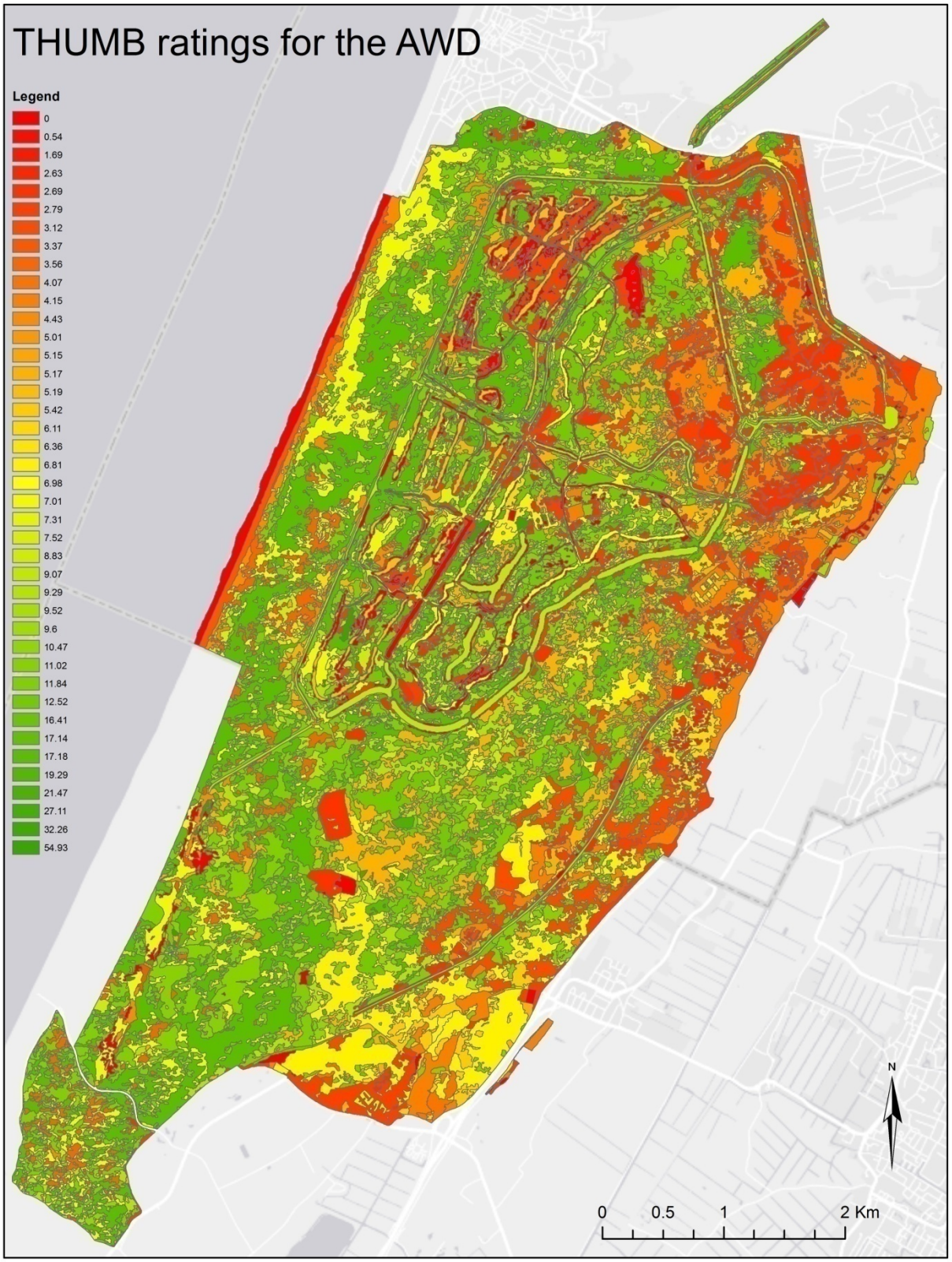

Figure 6: Spatial distribution of the THUMB rating for the vegetation types in the AWD.

3.1.3 THUMB

Figure 6 shows the spatial distribution of the THUMB ratings for the vegetation types in the AWD. In the legend the actual scores can be seen. However these score should be interpreted in a simpler classified grading system with maximal five classes reaching from very bad to very good (Witte et al. 2011). Here it can be seen that the Eastern part of the AWD is, in general, low scoring and the more Southern and Western score, mostly, high. Another low rating part is the beach along with first dune ridge, which is to be expected as there is little or even no vegetation found here. Also large low rating parts are found in infiltration area one and four (for reference, see Figure 9). Note that here, as opposed to Figure 4 also the waterways have been graded for the vegetation that they contain (for instance Reed, *Phragmites australis*, growing along the banks). The N2000 does not integrate water as a habitat and is labelled as H0000.

3.2 Water in the AWD - Provisioning

The water that is pumped out of the Oranjekom is considered to be an ecosystem service, not the actual final product, but the source for drinking water. Once the water leaves the Oranjekom it enters the final purification stage that is done in an industrialized and completely artificial way before it is pumped to the consumers.

3.2.1 Sources of water

The water that is present in the AWD and is used for the production of drinking water comes from two major different sources. The first is the naturally occurring water that originates from precipitation which is not directly used (by plants or animals, not humans) or evaporates but is taken up into the ground and forms a natural aquifer in the soil of the dunes (Waternet1, 2016). The naturally occurring water was for a long time the only source of water used for the production of drinking water in the AWD, as a result the dunes started to dry out (Appendix 11).

In 1957 the first river water, pre-filtered and pumped from Nieuwegein, began flowing into the dunes of the AWD and was artificially infiltrated to maintain a workable water level (Groen, 1978). With this the second source of water present in the AWD, called WRK (Watertransportmaatschappij Rijn-Kennemerland) water (surface water from the river Rhine), and used for the production of drinking water was introduced. With this WRK water the fresh water aquifer was able to grow again and maintain a stable volume, see Figure 7.

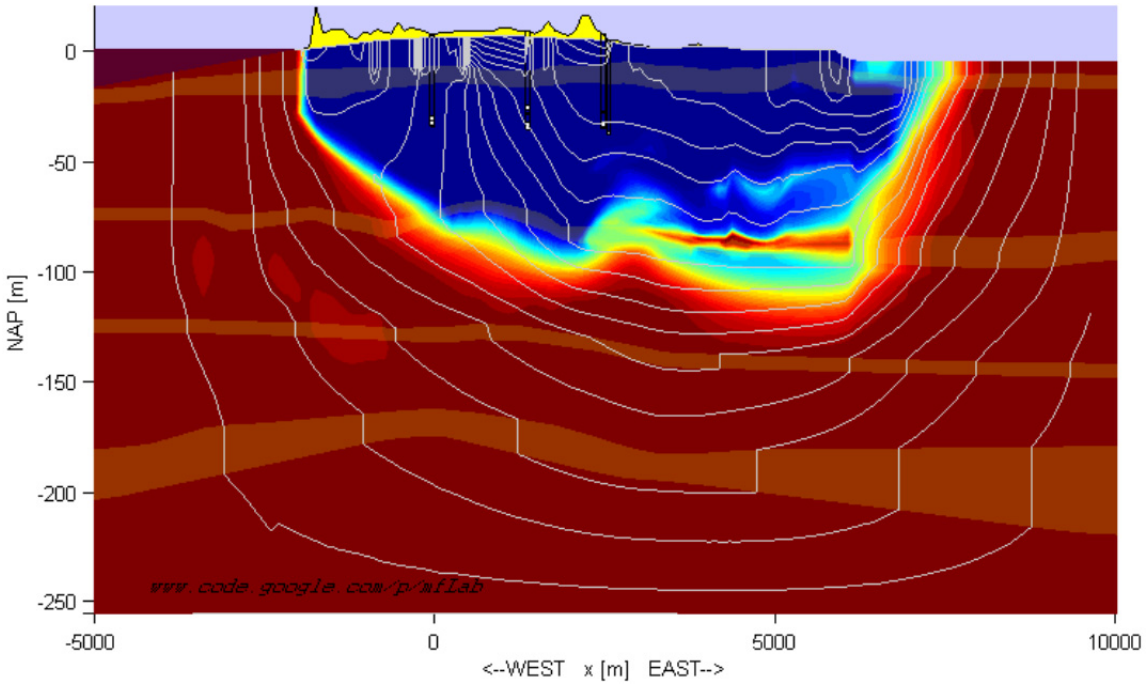

Figure 7: The simulated situation of the groundwater under the AWD in 2010. (Source: Waternet.)

3.2.2 Water extraction

As seen in Figure 8 there are five separate infiltration areas in the AWD that are actively used for the infiltration and extraction of water that is transported via canals to the Oranjekom. From here the water will leave the area and begin the final purification process. 80% of the infiltration and extraction of water takes place in infiltration areas one, two and three (50%, 15% and 15% respectively). The remaining 20% comes mostly from infiltration areas four and five and adjacent dune area.

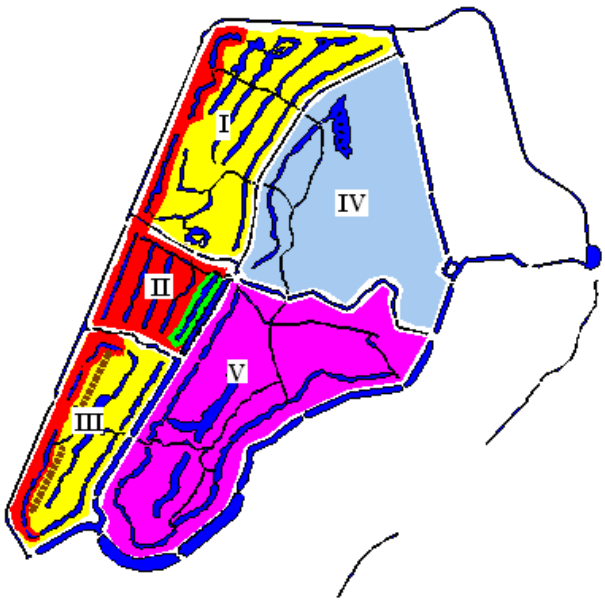

Figure 8: The five different infiltration areas in the AWD. Source: Waternet.

Figure 8 shows that areas one, two and three feature the colour red that indicates a flexible water level regime. The colour yellow indicates the same regime with the exception of the breeding season (15 feb. - 15 july) where the water will be held above a certain level to allow (water)birds a good breeding ground (Waternet1, 2016). As a result the areas covered by red and yellow can have an unnaturally high fluctuation of the water level and can even fall completely dry. These three areas (mostly area two) provide a buffer for the rest of the AWD to fill up fluctuations in precipitation, out-take of water from the AWD or other calamities that have the potential to cause water levels to change. Due to the presence of such a buffer the rest of the AWD can have a more stable (ground)water level.

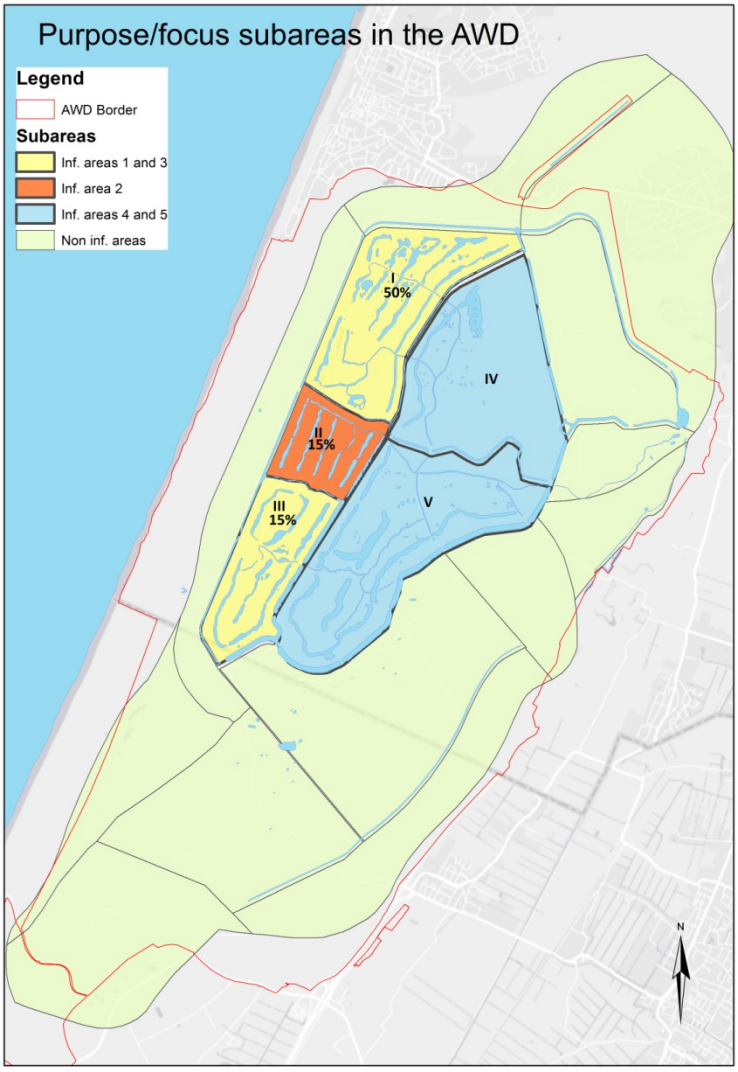

Figure 9: The five different infiltration areas of the AWD with the amount of water produced in %.

This is the case in infiltration areas four and five, shown in purple and blue in Figure 8.
The effects of the water level fluctuation on the functioning of the ecosystem will be elaborated upon in the conservation section.
Aside from the five infiltration areas there are two more sources of naturally filtered water. These are the Oosterkanaal and the Boogkanaal, shown in Figure 10.
In these canals both phreatic as well as pumped up dune water is won. The water from these two separate canals is pumped to the canal system of the infiltration areas and finds its way to the Oranjekom.
The canal system is constructed in such a way that all the water will naturally flow to the Oranjekom through the use of difference in elevation. The water levels of all canals can fluctuate but have working levels at which they are ideally kept. With the Oranjekom at +0,5meters above NAP(sea level) and the highest canal at a working level of +6,1 meters above NAP it is ensured that all water in the canals flows in the correct direction and the Oranjekom receives a steady flow of water(Waternet2, 2016). The same principle applies for the WRK water that flows to the infiltration areas. See Figure 10for the direction of the water flows in the canals.

Figure 10: The waterways and their direction that flow through the AWD.

As a last point of the capabilities that the natural filtering by the dunes has in store; the area holds strategic water stocks in case pollutions occur in the river Rhine and the influx of WRK water stops. This stock ensures production for over three months without any surface water intake (Waternet1 (2016). This stock also regulates the water temperature in such a way that water is relatively cool in summer and warm in winter.

3.2.3 Financial aspect

In 2014 the total amount of water pumped out of the Oranjekom was 63.370 million m3. 52.431 million m3 of this originated from WRK water that was pumped into the AWD. Therefore the so called "Netto-onttrekking" of the dunes, water that was not artificially put into the ecosystem of the AWD, was 10.939 million m3 (Waternet2, 2016). The separate waters present in the AWD and their values/costs can be seen in Table 5. The value and the cost are the same as the values of the different kinds of water have been calculated by using the posts of expenditure for these corresponding waters as this was the only way to find any form of value.

Table 5: The value/cost for three kinds of waters in the AWD with amounts of water in m3 for 2014.

Source	Amount in M m3	Value/cost per m3 in €	Total value in €
WRK	52.431	0.140	7,340,340
Netto	10.939	0.290	3,172,310
Total/Oranjekom water	63.370	0.290	18,377,300

With the help of the numbers found in Table 5 the difference between the total cost of the WRK water and the value, in costs, of the Oranjekom water can be calculated. This difference is the added value that the ecosystem gives to the water as it finds its way through the AWD. For the year 2014 this added value is €11,036,930.-.

Besides the yearly income of the water that leaves the AWD there is another large, if not the largest, value found in the ecosystem service of filtering and storage of water. As described above the increase in value of the water due to the natural filtering is a price tag that can be put on a certain amount of water, for instance €0.29 per one m3 of water that leaves the Oranjekom. An extra value, or perhaps better described as a saving in costs, is the total cost of replacing the natural filtering service in the AWD with an industrial method. This would entail expanding the described final filtering plant at the location Leiduin to be able to house the extra filtering processes that would be necessary to replace what is now done naturally in the AWD. Costs for the designing and building of the facilities, hiring of extra staff and extra maintenance are just some examples. And after that the whole water system in the AWD would have to be removed or changed, bringing about even more costs. Finally the potential accidents, disturbance, and pollution during the work in the AWD are a factor that might be of large, indirect, consequences and costs. Even though it was not possible to find any conclusive numbers for these scenarios the expectation is that these are very high.

3.3 Recreation

The AWD is a popular nature area that is accessible to visitors from dusk to dawn. Most visitors come to the AWD to walk through and experience nature, engage in nature photography, jog or ride on horseback. Cycling in the AWD is not allowed, nor is fishing or any other form of hunting/poaching.

3.3.1 Visitor numbers

The AWD receives a total of 1 million estimated visits per year currently. This is a number that several employees of Waternet have confirmed, it must be stressed that this is a best estimate and not actually counted. The last precise visitor count for a complete year was done for a study in 2002 made by Webster and Jaarsma of the University of

Wageningen(Webster, Jaarsma, 2003). This gave a total of 646.500 visits, as seen in Table 6 the visitor counts were done in five major entrances to the AWD: Zandvoortselaan, Oase, Panneland, De Zilk and Langevelderslag. The location of these entrances can be seen in Figure 11. Four of these entrances have parking facilities for cars and ticket machines and are considered by Waternet to be the main entrances (Wandelkaart, 2016). Langevelderslag being the exception, lacking a ticket machine and a lower visitor count. There are other smaller entrances, for instance along the coast, see Figure 11. These are only accessible on foot or by bike and are considered to not have an significant impact on the total visitor numbers and are therefore as a result not counted and/or used for this study. To elaborate on this; Table 7 shows that on average 76,3% of all visitors came to the AWD by car so entrances that facilitate parking for cars are expected to receive the most visits by far. Langevelderslag lacked counts for the visitors that travelled to the AWD by car or bike. As this entrance is more isolated from urban areas and at that time was not directly accessible from a parking lot the amount of visits plummet. Table 7 shows that Langevelderslag only sees 1.1% of the total visits in the year 2002. The smaller entrances are expected to receive even less visits and where therefore not used in the study done by Webster and Jaarsma.

Table 6: AWD visitor counts for 2002 per type of transportation and access point. Source: Webster, Jaarsma, 2003.

Access	**Transportation**			
	Car	**Bike**	**On foot**	**Total**
Zandvoortselaan	70,700	18,500	11,900	101,100
De Oase	212,200	33,000	19,100	264,300
Panneland	104,200	21,900	9,200	135,300
De Zilk	105,900	9,600	22,900	138,400
Langevelderslag	-	-	7,400	7,400
Total (2002)	**493,000**	**83,000**	**70,500**	**646,500**

Table 7: AWD visitor counts for 2002 in % per type of transportation and access point. Source: Webster, Jaarsma, 2003.

Access	**Total%**	**Transportation%**		
		Car	**Bike**	**On foot**
Zandvoortselaan	15.6	69.9	18.3	11.8
De Oase	40.9	80.3	12.5	7.2
Panneland	20.9	77.0	16.2	6.8
De Zilk	21.4	76.5	6.9	16.6
Langevelderslag	1.1	-	-	100.0
Total (2002)	**100.0**	**76.3**	**12.8**	**10.9**

Table 8 shows the extrapolated visitor numbers per entrance when the percentages of the official count done by Webster and Jaarsma in 2002 are divided over 1 million visitors. Assumed is here that all visitor use these five entrances and not the other five smaller entrances. Note that the total percentage now actually is 100% as opposed to Table 7, this has been corrected from the numbers of Webster and Jaarsma.

Table 8: Extrapolated visitor counts per entrance for the AWD to the current situation.

Access	Total%	Total visitors	90% of visitors
Zandvoortselaan	15.6	156,000	140,400
De Oase	40.9	409,000	368,100
Panneland	20.9	209,000	188,100
De Zilk	21.4	214,000	192,600
Langevelderslag	1.2	12,000	x
Total (current)	**100.0**	**1,000,000**	**889,200**

3.3.2 Distribution

As seen in Figure 11 not all the parts of the AWD are accessible to visitors. Infiltration areas I, II and III form the largest part of forbidden terrain. Addressed in the Water-provisioning service, these three areas are responsible for the larger part of the infiltration process of the WRK water. To make this process as safe and efficient as possible only Waternet staff is allowed in these areas.

Based on visual confirmations is has been concluded that by far most of the visitors leave the AWD through the same entrance through which they entered (Webster, Jaarsma, 2003). This does seem a logical conclusion as when one comes to the AWD by car or bike one will return to the means of transportation used.
According to forester Alfons Daniëls most of the visitors of the AWD make use of the four main entrances (Zandvoortselaan, De Oase, Panneland and De Zilk). This is in agreement with the numbers in the study of Webster and Jaarsma, Table 7. These four entrances are also the only ones that are the beginning and ending of suggested looped routes through the area that are marked on the map (Wandelkaart, 2016) sold to visitors showing the paths through the AWD. These routes, seen on Figure 11, are by far the most frequently walked paths according to forester Alfons Daniëls. In Figure 11 each entrance has a separate colour for its own routes that begin and end at that specific entrance. While each entrance has two routes the choice has been made to not make a distinction between the two and consider the spread of visitors over the routes to be even for each individual entrance. A small portion of two routes is shown in purple where these two overlap, this should be a very busy part of the trail. The rest of the paths and roads in the AWD are shown in grey, labelled as "other".

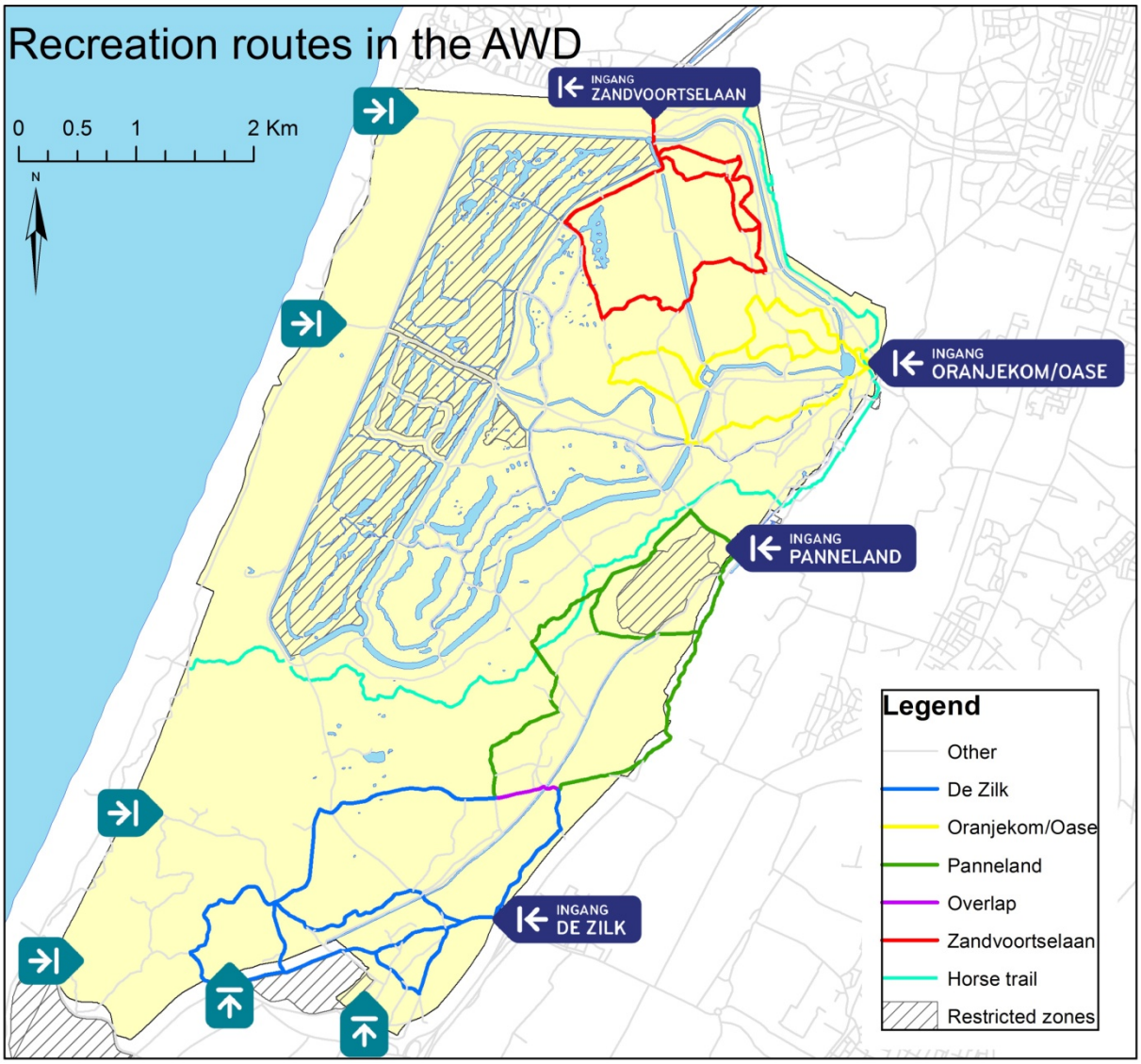

Figure 11: The recreational routes in the AWD per main entrance.

The length of the suggested routes can be found in Appendix 12. Furthermore, one LAW (Long Distance Walking route) is crossing the AWD but is not shown on the walking map sold to recreationists. The actual use of this route is unknown.
Figure 11 also shows a horse trail crossing a large part of the AWD, however no information is available about the frequency by which this path is used. Therefore, aside from showing it on the map, this aspect will not be discussed and this report will focus on the four main entrances with their corresponding routes.

Now that it has become clear how the road network in the AWD is laid out, where visitors can enter and how the visitors are distributed over these entrances, these factors can be combined to show the density in which visitors spread out over the AWD. Figure 12 shows the density of the paths and the intensity by which they are used. When looking at Figure 12 it becomes clear that the recreational intensity is at its peak in the middle of the yellow routes, originating from the Oranjekom/Oase entrance. This was to be expected when one takes the visitor numbers and the layout of the path into account.

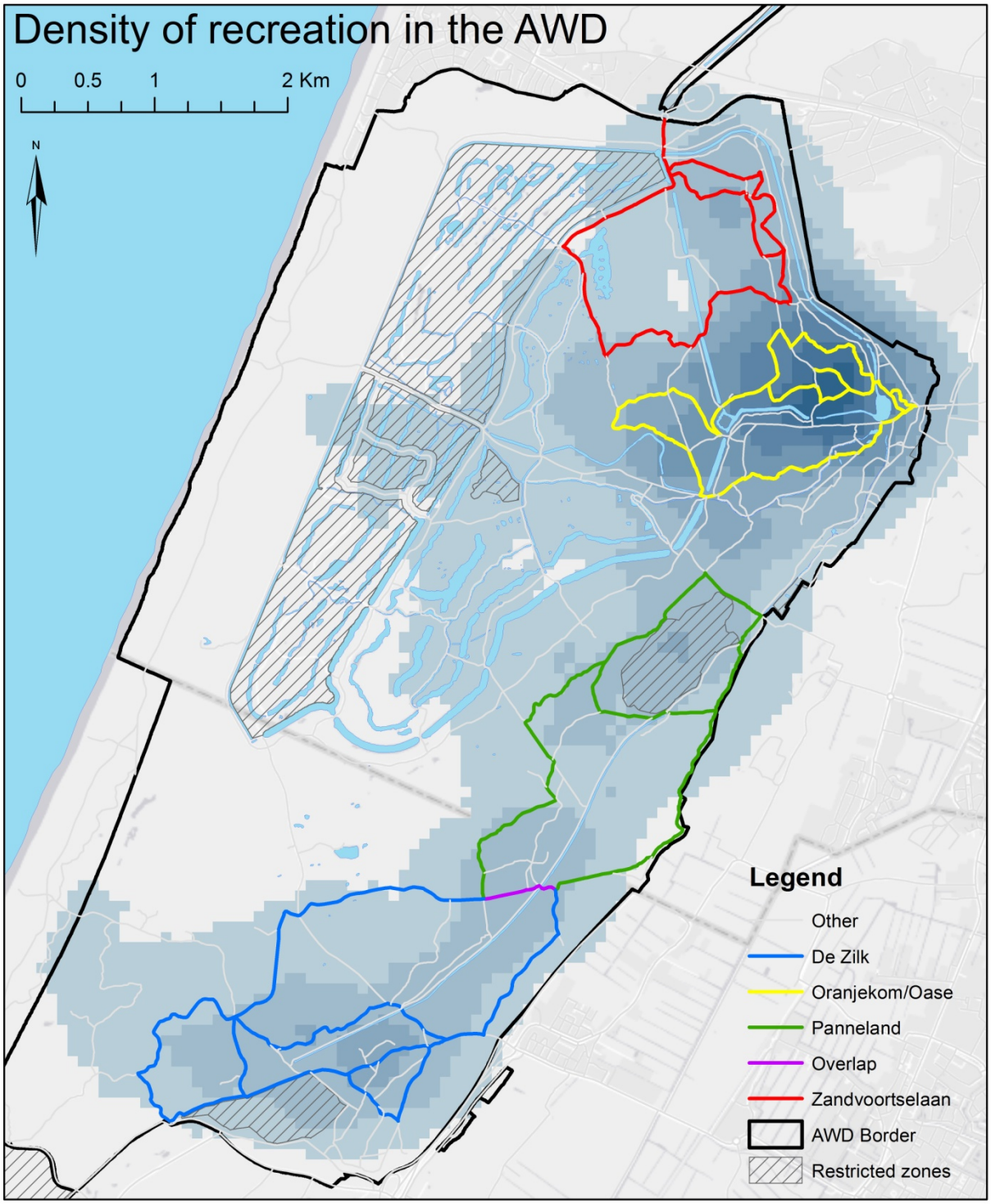

Figure 12: The density of recreation in the AWD in eight categories.

Overall, the whole East part of the AWD seems to be the most affected by the visitors of the AWD with the North-East as an absolute high point. The whole West, South-West and North-West part show to be a much more quiet area. This was also to be expected as this side has no main entrances and no suggested walking routes. Important to note is that this tool does not take the borders of the AWD or the restricted zones into account.

3.3.3 Financial aspect

All visitors need to pay a fee to gain entrance to the AWD. Several entrances have facilities for car parking, for a fee. At the entrance of De Oase is a visitor centre with a small shop. The income of these three posts for 2014 can be seen in Table 9,

Table 9: Total income before costs of 2014 of sold access cards, parking cards and various sales in the shop. Source: Waternet.

Access	€ 196,728
Parking	€ 320,722
Shop sales	€ 13,499
Total	**€ 530,949**

Naturally, not all the land Waternet owns is dedicated to nature or the filtering of water. Besides the necessary office buildings, roads, the space needed for the final, industrial, filtering of water and so on some parts are leased of to third parties. This includes several recreation and catering facilities (at the entrances Zandvoortselaan, De Oase and Panneland) a camping, a gliding club and a national weather station. The total of this sum amounts to € 65,592.14

Table 5 shows the total sum of the income that is made directly or indirectly from the ecosystem service of Recreation.

Table 10: The summation of the different incomes regarding recreation based on previous tables.

Access and parking fees	€ 517,450
Shop sales	€ 13,499
Leases	€ 65,592.14
Total	**€ 596,541.14**

3.4 Coastal defence

The protection against the sea is of paramount importance in the Netherlands as two thirds of the Dutch landmass would be under water if it was not for the so called dyke rings (Dijkringen).These dyke rings are areas of the Netherlands that are surrounded by dykes or other forms of flood protection. There are 53 major dyke rings in the Netherlands, not counting the small dyke rings, see Figure 13 (Stive et al., 2011). Each of these dyke rings are, up to a certain degree independent and can protect and prohibit, depending on the severity of the flood, other dyke rings to also become flooded (Vergouwe, 2014). The AWD is located in dyke ring number 14, seen in Figures 13 and 14 where an overview of all the dyke rings of the Netherlands can be seen.

The responsibility of the dyke rings, regional water management and treatment of waste water are divided among "waterschappen" who are all part of the Unie van Waterschappen. In total there are 23 waterschappen (uvw.nl). Important to note is that the borders of the dyke rings and the waterschappen do not necessarily follow each other. For instance; one dyke ring can consist of multiple waterschappen and one waterschap can cover multiple dykerings. The care of dyke ring 14 is divided over four of these waterschappen.

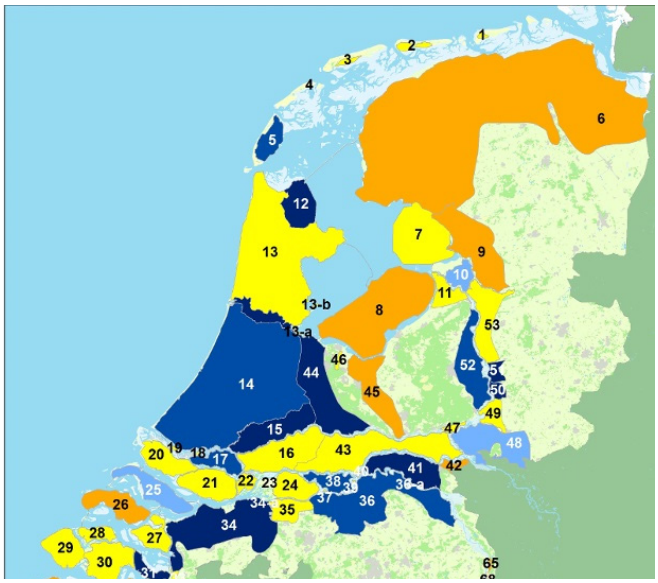

Figure 13: The Dutch dyke rings. (Source: helpdeskwater.nl)

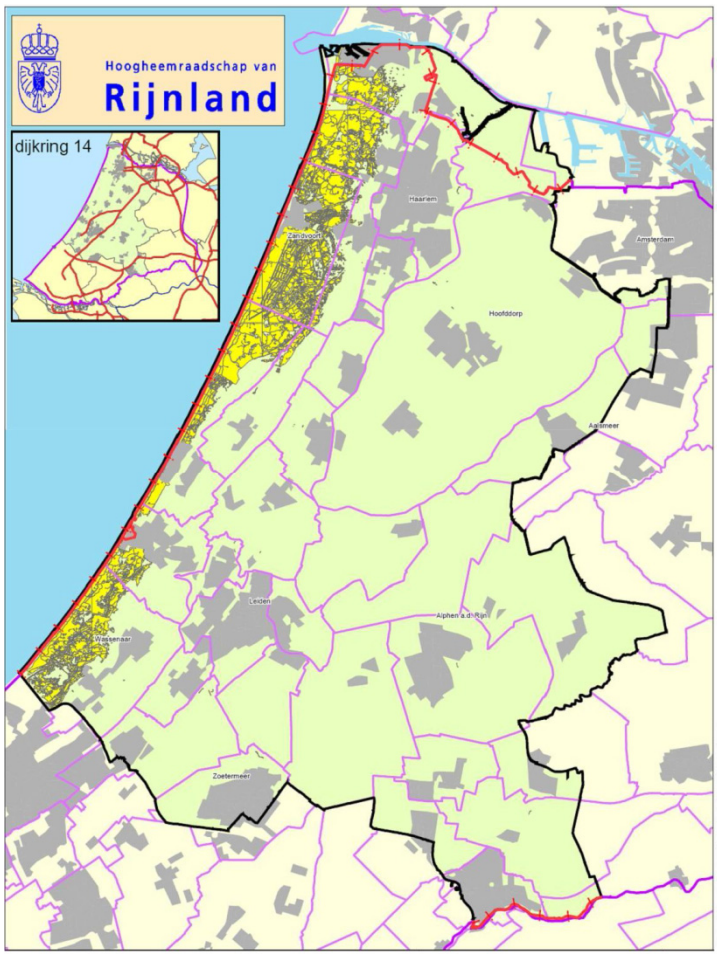

Figure 14: The surface of Hoogheemraadschap van Rijnland, the inset shows the Dijkring 14. Dune areas, including the AWD, in yellow along the coast. (Source: Hoogheemraadschap van Rijnland)

The larger part of dyke ring 14, including the part where the AWD is located, is under the care of the waterschap "Hoogheemraadschap van Rijnland", see Figure 14.
Dyke ring 14 is the second largest dyke ring of The Netherlands with a surface of 224.200ha, a total of 3.591.00 inhabitants and housing some of the largest cities of the Netherlands such as Amsterdam, Rotterdam and Den Haag (Vergouwe, 2014).

3.4.1 National government, Rijkswaterstaat

As the executive organisation of the Dutch ministry of Infrastructure and Environment Rijkswaterstaat manages the Dutch waters, including the sea. This entails the task of setting norms for the primary barriers. Together with the waterschappen Rijkswaterstaat also tests the barriers if these function properly and live up to the norms. Another major role that needs to be highlighted is the task of maintaining the sandy coasts on the Netherlands with sand supplementations that are essential to maintain the current coastline (Ministerie van Infrastructuur en Milieu, 2015). An example of such sand supplementations is the Zandmotor, an artificial peninsula of 128ha that erodes naturally, spreading sand along the Dutch coast in the process. On a yearly basis Rijkswaterstaat nourishes about 12Mm3 to the Dutch coast (rws.nl).

3.4.2 Hoogheemraadschap van Rijnland

While the Hoogheemraadschap van Rijnland (Rijnland for short) is responsible for more than just the coast along the North Sea in their appointed part of dyke ring 14 this report will only focus on the coast in the vicinity of the AWD. It has become apparent in Figure 1 that the borders of the AWD do not quite reach the actual coast at any point. The border of the ownership of Amsterdam does, however, reach as far as the beach for quite a portion, as can be seen in Figure 15. For this service, the borders of the AWD will be put aside and the entire area, related to coastal protection, in the vicinity of the AWD will be looked at as a whole. Where one to only focus on the coastal protection specifically within the borders of the AWD the result would be an incomplete view of the functioning of this dune service.

The coast adjacent to the AWD is what Rijnland calls a primary water barrier (primaire kering). For dyke ring 14 this primary water barrier is 41km long (Vergouwe, 2014). This primary water barrier is divided into five different zones. These zones have separate functions, rules and restrictions. These five zones will be explained briefly below and can be seen in Figure 15.

The following descriptions made by Rijnland are specific for sandy coast, or natural dunes, and thus apply here (Rijnland, 2012).

- Core zone: In the case of this areas this is the first dune ridge. This zone is the actual barrier against water. (red)
- Protection zone landside: This zone is space reserved for possible rise of sea level for the next 200 years. (green)
- Protection zone seaside: The area where sand will spread over the beach and seafloor, consists mostly of the beach. (green)
- Outer protection zone landside: Additional buffer zone where any form of activities with potential of posting a treat to the flood defences are prohibited. (yellow)
- Outer protection zone seaside: This zone goes as far as -20NAP or 20 kilometres out of the coast. Also here the main purpose of this zone is to create a buffer to have minimal disturbance that could damage to the integrity of the coast. (yellow)

3.4.3 Areal distribution

Figure 15 shows that the protection zone, as well as the outer protection zone can be found on both sides of the core zone, resulting in a total of five zones that make up the complete barrier against the North Sea. The outer protection zone on the landside does not go any further as 700 metres land inwards, see Figure 15. As a result the primary water barrier only

takes in a very small portion of the surface area of the AWD and the dunes in general in this area.

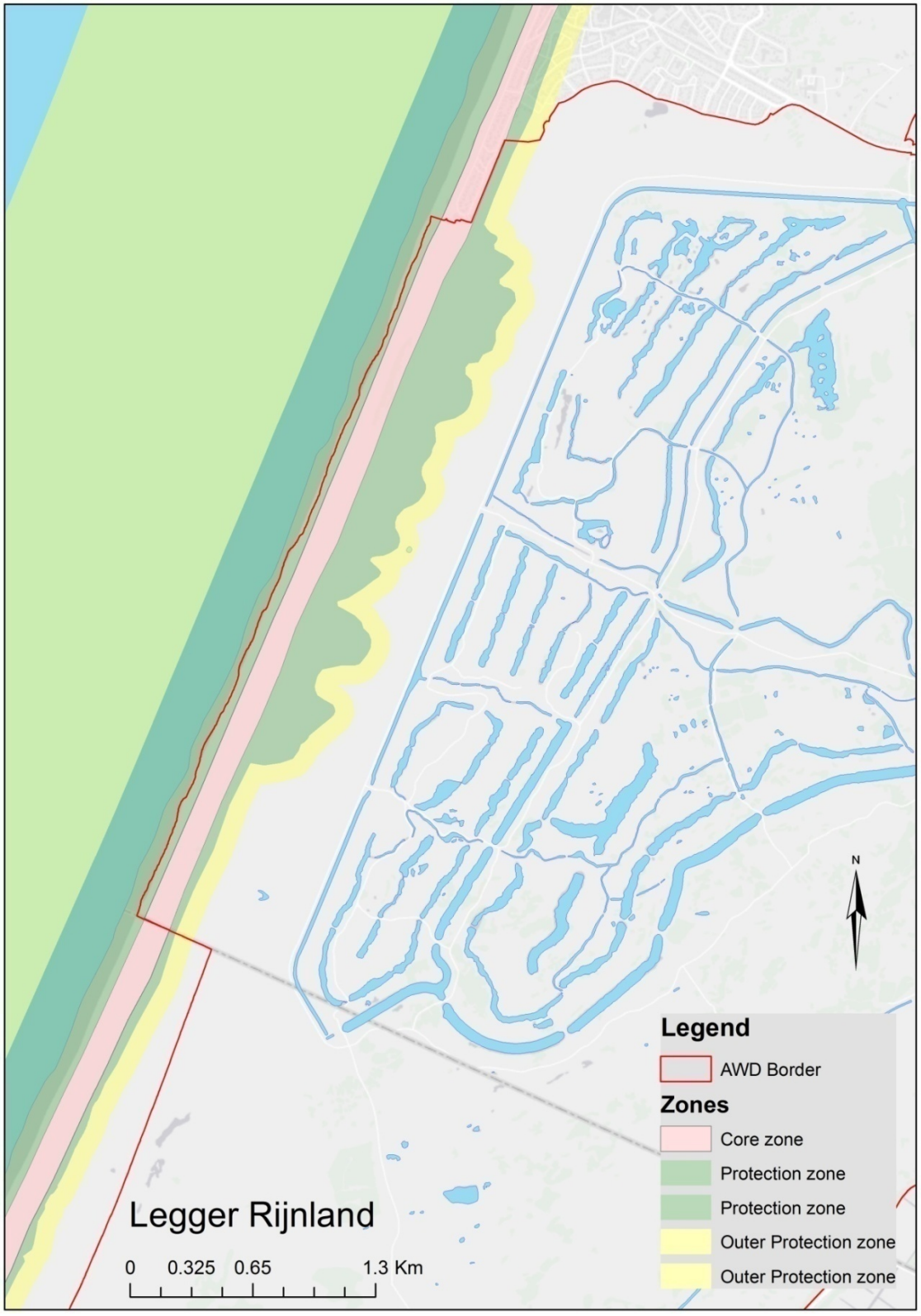

Figure 15: The spatial distribution of the primary barrier along the coast of the AWD.

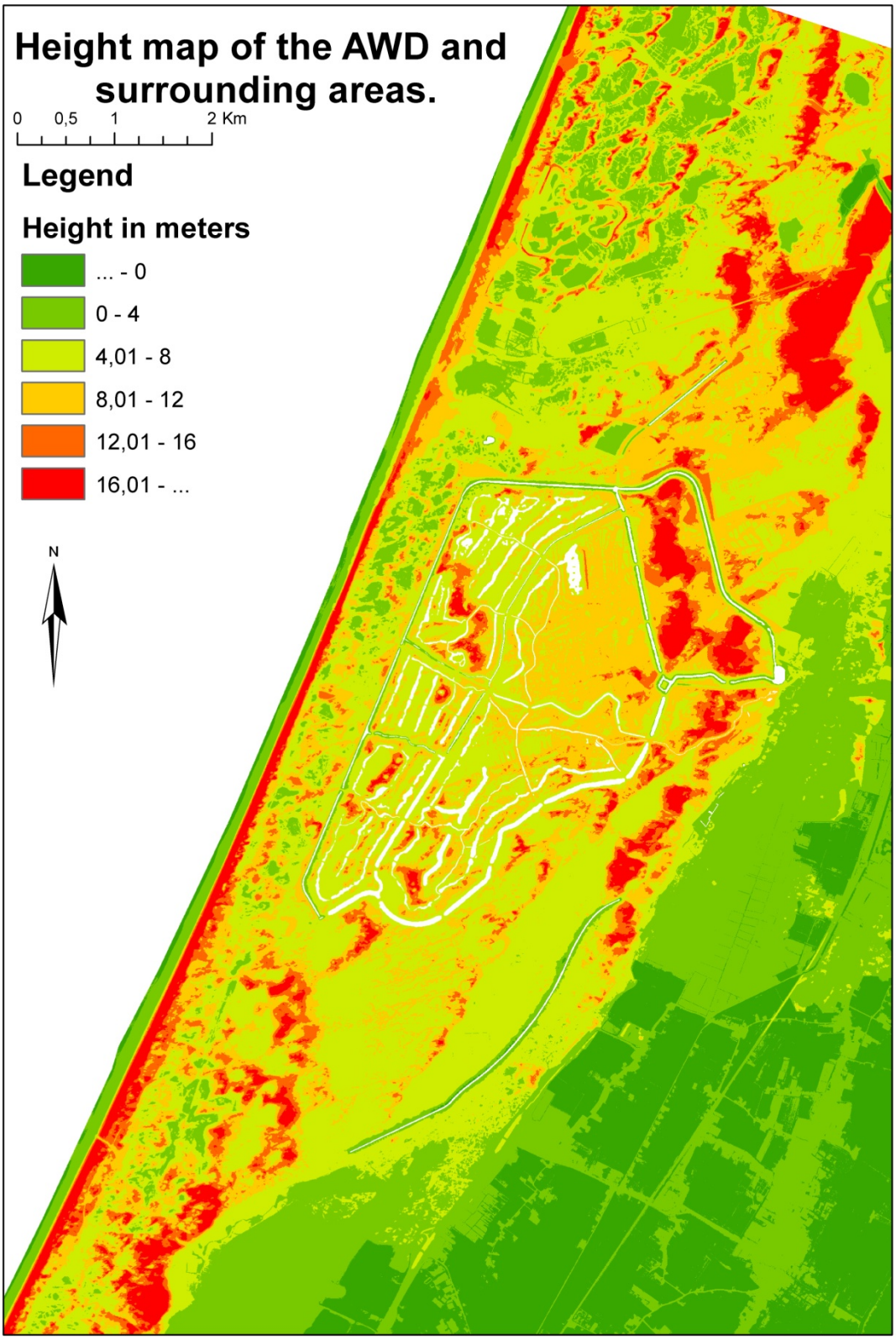

Figure 16: Height map of the AWD and surrounding areas in metres above sea level or NAP (Normaal Amsterdamse Peil) with on the left the sea.

In Figure 16 it becomes clear, when comparing to Figure 16, that the core zone of the primary barrier consists of an unbroken dune ridge higher than 16 metres, some dunes in this ridge will go over 30 metres high. Remarkable is that in the AWD itself the height of the terrain never goes below zero. In fact; it rarely goes below 4 metres above sea level. This is

caused by the bulging groundwater table, wet sand does not suffer from wind erosion so the surface level of secondary dune slacks is about the same as the groundwater table. With this information it becomes clear that the area behind the primary barrier seen in Figures 15 and 16 certainly can serve a purpose as a secondary barrier against the sea in the case of a breakthrough in the primary barrier as the height of the land (almost) never goes below sea level.

3.4.4 Financial aspect

The total surface of the primary water barrier may not take in too much space, however, the role it fulfils is enormous. Appendix 10 shows that most part of dyke ring 14 is well under NAP and is therefore in danger of being flooded in the case of a breach of the primary water barrier. The Central Bureau for Statistics Netherlands made an estimate of how much Dutch wealth was protected by the dyke rings system. This resulted in a unfathomable total of €1800 billion of Dutch wealth protected by the dyke ring system for 2007. As this is nine years ago, this number should have increased quite a bit. On top of this comes a possible economic damage as a result of a flooding for all dyke rings that was estimated at €190billion (Stive et al., 2011). 65% of the Dutch BNP is made in dyke ring 14. As a result the average damage in case of a total flood of dyke ring 14 is estimated at €4.7billion along with 1500 casualties. The chance of failure for the primary water barrier in dyke ring 14 was estimated at <1/16.000 however (Vergouwe, 2014).
In addition to this report by Vergouwe a follow up is being made. In this concept report not only the damages are taken into account but also the victims and death toll have been monetized. Furthermore the area that is evaluated is more precise than the complete Dyke ring 14. Instead, smaller parts of the Primary barrier looked at separately. For the part of the primary barrier that is adjacent to the AWD the costs of a catastrophic breakthrough and an expected flooding that is the result of that the cost have been calculated/estimated at €14.486 billion for the year 2016 with a 1/30,000 chance per year of occurring (DPV, 2014). When multiplying these two numbers with each other the value per year can be calculated. This results in €482,866 per year.

3.5 Raw materials and food- Provisioning

3.5.1 Plant material

As the AWD is a Natura2000 area, the main goal, besides the filtration of water, is the preservation and improvement of the ecosystem. Due to this policy there is no active logging in the AWD. The only scenario where trees or plants are cut down is for the betterment of the ecosystem. Dead plant biomass is usually left on the ground, not removed and sold. (awd.waternet.nl,(2)). The reason for this is that dead plant material, in this case mainly wood, is a huge natural component of an ecosystem. Dead wood has a whole ecosystem of its own and houses a huge variety of species that live off the dead biomass, such as Fungi (Figure 17) and Arthropods which, in turn, serve as a food source for other organisms. Furthermore the soil fertility receives large benefits from the presence of dead wood and even the water quality of surrounding water bodies is positively affected (Evans, 2016). There are exceptions where it is beneficial to remove the dead wood and other plant materials from the area. This can be sold as wood chips or fire wood, depending on the quality and thus becoming a possible source of income. There are other dead plant materials that exit the AWD as a result of mowing activities and the dredging/cleaning of the waterways. These, however, do not create income and are rather likely to form an expenditure instead (awd.waternet.nl,(2)).

Figure 17: Dead wood with Fungi growing on it in the AWD. (Source: awd.waternet.nl)

3.5.2 Animal products

Comparable to the benefits that dead plant material has to an ecosystem; carcasses of animals also provide a vital role in ecosystems. Both vertebrate and invertebrate scavenger and/or carnivore species rely on this food source. Removing carcasses would not only take away the food source from the ecosystem, causing wood webs to collapse, but can also have negative effects on nutritional value of soil(Fielding et al., 2013).
Deer that die due to natural causes are not removed from the area but are left on the spot where they died. An exception is made when a deer dies on or right next to a path or a road or have fallen into a water body. The carcass will then be moved a bit more out of sight and away from water. The only measure that is always taken when a dead deer is found is the removal of the antlers, if present, to avoid people from taking them themselves. This method is applied to all other animals in the AWD.
Now that active control of the Fallow deer has started an extra way of handling dead deer has begun. All Fallow deer that are shot will not be left in the area but removed and used as much as possible. The antlers are sold in the visitor centre in the AWD and the meat is sold to various butchers. A part of the meat is even given to goodwill. This all according to forester and coordinator Gerard Griffioen, employee of Waternet.

3.5.3 Financial aspect

In 2014 Waternet made a total profit of €2,734 for sales of fire wood or wood chips, the only plant materials that serve as a source of income according to Gerard Griffioen and Martijn

van Schaik. This income before costs per year is expected to increase rapidly in the coming years. The reason behind this expectation is the start of the control of the Fallow deer (Dama dama) and with that the sales of the meat and other products derived from the animals (awd.waternet.nl,(3)). However, according to forester and coordinator Gerard Griffioen the costs of the deer control process far outweighs the total income.
Another factor that can be a source of fluctuation in the yearly income is the weather. For instance; a heavy summer storm hit the Netherlands in July 2015. As a result an abnormal number of trees fell and needed to be cleared from paths and in general to prevent smothering of plants and trees that withstood the storm but now had a tree lying on or against them (awd.waternet.nl,(2)). Here a lot of extra wood was removed and made available for sale. Due to this storm a total of 700 tons of woodchips and 120 tons of solid wood was sold that made a total profit of €14,000 according to Martijn van Schaik. Once again, as the yearly income is rather small the relative fluctuation due to events as these can be quite large. However, compared to the annual turnover and/or other ecosystem services the AWD and Waternet the difference is negligible, as should become clear in the financial overview in the conclusion.

4. Discussion

The Results section shows five large ecosystem services that have been prioritized in this report. Naturally there are many other ecosystem services in the AWD, be they large or small. However, these have been deemed less relevant to the goal of this report and the request from the EU.

4.1 Spatial conflicts

With the exception of the raw materials and food service where information lacked to create any type of mapped distribution, the spatial distribution of the individual services in this report have become apparent in the Results. When reading the Results it becomes clear that most services overlap with others and through this overlap have potential conflicts with one another. These overlaps and potential conflicts that can be observed with the data gathered and presented in this report will be discussed below.
A first interesting point is a contradiction within one service that deserves attention before comparing services with one another. This regards the conservation service. There is a high concentration of Red List species (Figure 5) that mostly consists of plant species in areas that score a low score in the THUMB rating (Figure 6) specifically on the East side of infiltration areas four and five (Figure 9). Remarkable is that THUMB is a rating for vegetation types. It would be expected that vegetation types that harbour Red list species would score high in the THUMB rating. However this seems not to be the case and the valuation of THUMB rests on other factors. In order to find the cause of this contradiction further insight into the THUMB rating is required.
The conservation service is in possible conflict with both the water and recreation services to a large extent. When comparing the conservation and water aspects more overlap and with that possible conflicts can be observed. In the five infiltration areas there are very high THUMB ratings as well as (mostly in infiltration area five) a high concentration of Red List species sightings. However the Red List species is not a good measure for this conflict as infiltration areas one, two and three do not allow recreation and with that little to none

possible observations. Interesting is the high THUMB rating of a large portion of the waterways, Figure 6. This data does not show that there is a conflict or problem but does clearly indicate that these two factors are closely intertwined in these areas.
When comparing the density and intensity of the recreation (Figure 12) with the THUMB ratings there is a clear correlation to be seen. Especially at the Oranjekom entrance where the intensity of the recreation is at its peak the THUMB ratings are very low for most of this area. However, as described earlier, in this same area the concentration of Red List sightings is high. So these two aspects also contradict each other in light of possible conflict with another service.
The Conservation service does overlap with the coastal defence but the THUMB rating for the primary barrier area is very low and there are barely any Red List species found. From this two possible conclusions can be drawn. First, these two services do not seem to be in conflict with each other according to this data as one service (the Coastal protection) is dominating this area. However, it could be that the THUMB values and Red List species counts are low as a result of the Primary barrier, in this case it would certainly be a conflict. Further research should give clarity on this matter. Concerning the height map (Figure 16) of the AWD and its possible extra protection against the sea, it stands to reason that when the primary barrier fails due to a storm the storm that causes this failure is so severe that it will go along with such high waters for an extended period of time that the sea will eventually find its way through the area via lower parts, perhaps with the help if the waterways in the AWD. As extreme as this might sound, this is the only expected way that the primary barrier would fail; a super storm with abnormal high sea levels that lasts for multiple days. Taking this into consideration the Coastal defence is limited to the legger shown in Figure 15.
As a last point and perhaps the only certainty of actual conflict in light of the available data is the presence of the restricted areas (infiltration areas one, two and three). These restricted areas form a clear separation between the water and recreation services, completely excluding recreation from these areas.

4.2 Economical evaluation

It was not possible to find a monetary value for the conservation service and therefore will not be discussed any further here.
For the remaining four services that are described in this report it was possible to find monetary values. To give a clear overview to summarize these values can be found in the table below.

Table 11: Economical value of services per year and for what year they have been calculated.

Service	Value per year in €	Year	Method
Recreation	596,541	2014	Income before costs
Drinking water	11,036,930	2014	Separate values of water
Coastal defence	482,866	2016	Prevention of damages
Raw materials	2,734	2014	Income after costs

From Table 11 alone it becomes clear that the water service is, by far, the most valuable ecosystem service of these four. However comparing these values with each other in this way is not completely justified. The reason for this is that, aside from the fact that not every service is done for the same year, the methods of calculating the values is not the same for each service. For instance, the recreation service is before costs and the raw materials is

after costs. However both come directly from the administration of Waternet. For the drinking water a new method of calculating had to be created and therefore stands aside from the recreation and raw materials. The last service, coastal defence, not only has its own method of calculation but is also not measured in income but rather in the value that it protects. Furthermore, the coastal defence number seen in Table 11 is the result of dividing the actual number by the yearly chance of the primary barrier failure (1/30.000) in order to obtain a value per year.

Due to limited resources a separate way of valuating services had to be applied, as became clear in the above paragraph. In order to gather more insight in the financial aspect of the ecosystem services in the AWD more research is necessary in combination with the creation of a uniform method of valuating ecosystem services.

4.3 Implications for the AWD

To complete the spatial distribution section it needs to become clear that, aside from the last point, no actual clear conflicts have been identified in the AWD. All the described points above can only be seen as spatial overlap of services that suggest or indicate possible conflicts between the present depicted services. In order to identify actual (possible) conflicts between ecosystem services further research is required where, for instance, actual field work can provide new data. This report can serve as a foundation of such research and an indicator of what possible conflicts could be the most interesting to study in the AWD. During these, possible future, studies other ecosystem services of interest could, and most likely will, arise that deserve to be looked individually. An example of this is the breakdown of the water supply service. Here the water stock, mixing of water and temperature regulation are example that could be services of interest to study.
Once the actual conflicts have been studied and indentified action plans can be formed. Ultimately possible conflicts between ecosystem services in the AWD could be solved resulting in a better functioning ecosystem if this is deemed necessary.

4.5 Implications and applications of this methodology for other areas

While this report has been done for a N2000 area that also provides drinking water, is located along the coast and consists mostly of dunes this methodology would, if unaltered, apply the best to ecosystems that share these traits. Other Dutch drinking water companies as PWN and Dunea are good examples. However, with alteration of the methodology this same process of identifying and mapping ecosystem services could be applied to any ecosystem. Once this method is applied to, a selection of, services in another ecosystem the same implications apply that have been described in the section above of identifying and improvement of the working of ecosystems.

5. Conclusion

In order to answer the main question of this report: *What are the main ecosystem services that the AWD provides and how are they currently located/distributed throughout the area?* Five generalized ecosystem services have been covered in this report: Water extraction, conservation, Recreation, Coastal protection and Raw materials. These fist four are considered to be the ecosystem services of the AWD that combined form the main functions of the AWD as an ecosystem. Even though many others are present and can fulfil major roles. In this report the location of ecosystem services has been identified and through this overlaps in several services and possible conflicts in the AWD. One certain conflict, between the Water extraction and Recreation services, has been found. The economical valuation shows large stakes for the four major services with the Water extraction service being the largest by far and Raw materials having little to none economical value in terms of income after costs.

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Instances: Waternet, CML, Hoogheemraadschap Rijnland,

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8. Appendix

8.1 Appendix 1

MEA

The Millennium Ecosystems Assessment (MEA) was initiated in 2001 in response to the request of United Nations Secretary-General Kofi Annan in 2000. The MEA set the goal to assess the consequences of ecosystem changes for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. The MEA was coordinated by the UN Environmental Programme and was governed by a board of a large variety of stakeholders(Duraiappah et al., 2005).

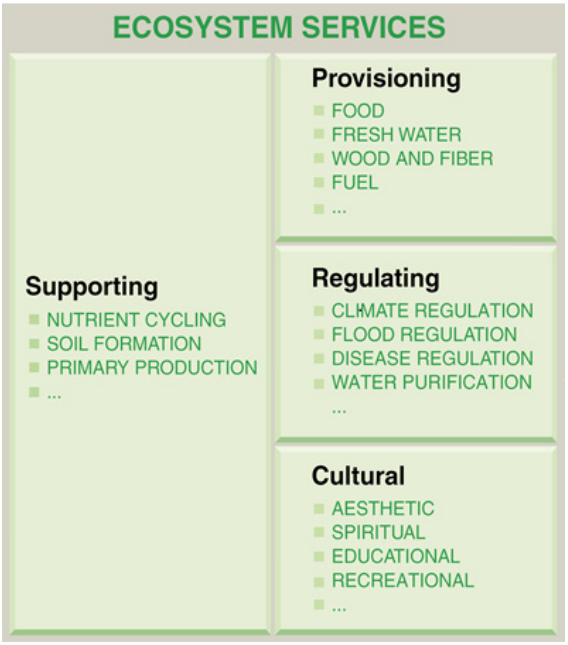
Among the results of this assessment where four main findings:

- Ecosystems have changed more in the last 50 years due to humans than in any time period before. Mostly due to rapid increase in demands for products by humans. This has resulted in a large loss of biodiversity and loss of natural habitats.
- The changes made on ecosystems have resulted in a large increase is human welfare and economic growth at the cost of many ecosystem services. This causes the threat of sudden, irreversible changes and/or collapses of ecosystem services .
- The negative changes to ecosystems could become substantially worse in the next 50 years.
- Reversing the negative effects on ecosystems requires the changing of many laws and policies. (Duraiappah et al., 2005)

The MEA largely popularized the term "Ecosystem services", made the first categorisation of ecosystem services and was the basis and/or catalyst for a multitude of other studies such as TEEB.

What is TEEB?

TEEB is short for The Economics of Ecosystems and Biodiversity. This is an initiative that started in 2007 commissioned by the G8+5(currently G7+5) consisting of an international team of experts led by Pavan Sukhdev that has set the goal to find the values present in nature and make them visible. This has led to several publications on different aspects(teebweb.org). TEEB initiative has sparked a whole range of studies based on their findings and models(e.g. Hendriks et al., 2014).



MEA Ecosystem Service classification. (Source: Duraiappah et al., 2005)

Comparing MEA and TEEB classification

The classification of TEEB, shown below, that was published five years after the MEA is for the most part the same. The Three classes Provisioning, Regulating and Cultural can be found in both classifications. However the supporting class is removed and replaced by

Habitat in TEEB containing additional services.The services in the Supporting class in the MEA are moved to the Regulating class as they are seen as a subset of ecological processes in TEEB(Groot et al., 2010).

TEEB ecosystem services classification:

	Main service types
	PROVISIONING SERVICES
1	**Food** (e.g. fish, game, fruit)
2	**Water** (e.g. for drinking, irrigation, cooling)
3	**Raw Materials** (e.g. fiber, timber, fuel wood, fodder, fertilizer)
4	**Genetic resources** (e.g. for crop-improvement and medicinal purposes)
5	**Medicinal resources** (e.g. biochemical products, models & test-organisms)
6	**Ornamental resources** (e.g. artisan work, décorative plants, pet animals, fashion)
	REGULATING SERVICES
7	**Air quality regulation** (e.g. capturing (fine)dust, chemicals, etc)
8	**Climate regulation** (incl. C-sequestration, influence of vegetation on rainfall, etc.)
9	**Moderation of extreme events** (eg. storm protection and flood prevention)
10	**Regulation of water flows** (e.g. natural drainage, irrigation and drought prevention)
11	**Waste treatment** (especially water purification)
12	**Erosion prevention**
13	**Maintenance of soil fertility** (incl. soil formation)
14	**Pollination**
15	**Biological control** (e.g. seed dispersal, pest and disease control)
	HABITAT SERVICES
16	**Maintenance of life cycles of migratory species** (incl. nursery service)
17	**Maintenance of genetic diversity** (especially in gene pool protection)
	CULTURAL & AMENITY SERVICES
18	**Aesthetic information**
19	**Opportunities for recreation & tourism**
20	**Inspiration for culture, art and design**
21	**Spiritual experience**
22	**Information for cognitive development**

TEEB Ecosystem Service classification. (Source: Groot et al., 2010)

Important to note is that these four classes of services are not strictly separated but categorized artificially to help structuring the information. In reality these four categories can be interlinked, if a product occurs in one class that does not automatically exclude it from others. For instance, a Fallow deer (*Dama dama*) can be seen as a cultural aspect, to be seen by hikers in nature (cultural). However, when shot the meat begotten from the animal becomes a material output and falls under the provisioning classification. This way the provisioning can overlap with the cultural aspect.

8.2 Appendix 2

Drinking water

The AWD has been the result of a gradual expansion of land used to gather drinking water that started in 1851. Until 1853, Amsterdam mainly got its drinking water from the river Vecht and imported water with boats. This process was very inefficient, labour intensive and would not be able to keep up with the growing population of Amsterdam. The quality of the water obtained from the Vecht was not of good quality either. In the Dunes West of Heemstede, the area that currently is the AWD, existed a natural reservoir of high quality fresh water. In 1851 the "Duinwater-Maatschappij" was founded and a six meter deep lake called the Oranjewater(currently called Oranjekom) was dug. A 3550 meter long canal connected to it to the West of Heemstede and Vogelenzang. This would be the beginning of the extended system of canals that are present in the AWD today. From this canal the water was transported by pipeline directly to Amsterdam (Groen, 1978). Through the years the amount and total length of the canals in the area were expanded and with this the total surface area of the dune terrain. The land was mostly bought or leased from large-land owners (Baeyens, 1991). In 1896 the city of Amsterdam took over the ownership of the Duinwater-Maatschappij and with this all the land became municipal property. Through this the entire area became one whole instead of fragmented between different land owners. Gradually farming, cattle breeding and hunting came to an end, this cleared the way for the area to become what it is today (van Til, 1999).

The canals in the AWD (Source: Waternet)

Protection from the sea

The Natura 2000 area that the AWD is part of contains the Natura 2000 habitat type H2120 (White Dunes). These dunes form the most outer dune ridge and are the first natural barrier against the sea, to make sure these dunes remain intact they are being maintained artificially(Synbiosys.alterra.nl(2)). Combined with the rest of the dunes that lay behind this first ridge they are a part of the protection against the sea. As over two-thirds of the Dutch population lives below sea level it is of great importance that the line of defence against the sea remains intact, be it in the form of the Delta works (Deltawerken) or natural dunes (Stive et al., 2011).

8.3 Appendix 3

Natura 2000

Natura 2000 is based on two directives:

- The Birds Directive, that aims to protect all the naturally occurring birds in the European Union.
- The Habitats Directive, that aims to protect rare, threatened or endemic plant and animal species. In addition the protection and conservation of 200 types of rare and characteristic habitats falls under this directive.

Through these two directives the Natura 2000 strives to safeguard different aspects of European nature and has become a network of core breeding and resting grounds for rare and protected species with a total of more than 18% of all EU land area and close to 6% of the EUs marine territory, spread over all 28 EU member states.

Important to note is that Natura 2000 areas are not just Nature reserves that are government controlled. Most of the areas are privately owned and/or are open to public access (ec.europa.eu). This way the Natura 2000 network does not only protect nature but also allows the general public to enjoy it. The AWD falls under this description; while it is government controlled it is(for the most part) assessable to the public for leisure purposes and at the same time it is a highly valued nature area that harbours a variety of species that are rarely found in the Netherlands.

8.4 Appendix 4

Below is a list and description of all the habitat types found in the AWD, based on the inventarisation of 2007(Oosterbaan et al., 2010). Given is the Habitat type code, the name, and a description(EC, 2013)(synbiosys.alterra.nl).

H0000: No habitat type

H2110: Embryonic shifting dunes. Formations of the coast representing the first stages of dune construction, constituted by ripples or raised sand surfaces of the upper beach or by a seaward fringe at the foot of the tall dunes.

H2120: Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes). Mobile dunes forming the seaward cordon or cordons of dune systems of the coasts.

H2130: Fixed coastal dunes with herbaceous vegetation (grey dunes). Fixed dunes, stabilised and colonised by more or less closed perennial grasslands and abundant carpets of lichens and mosses.

H2130A: Fixed coastal dunes with herbaceous vegetation (grey dunes), calcium rich. Young dune grasslands with calcium rich soils.

H2130B: Fixed coastal dunes with herbaceous vegetation (grey dunes), calcium poor. Due to lower calcium this subtype can harbour lichen well.

H2130C: Fixed coastal dunes with herbaceous vegetation (grey dunes), nardus. Soil is more humid and contains more humus compared to subtypes A and B.

H2150: Atlantic decalcified fixed dunes (*Calluno-Ulicetea*). Decalcified dunes of France, Belgium and Britain, colonised by heaths of the alliances *Calluno-Genistion* or *Ulicion minoris*, and of Iberia, colonised by heaths of the alliance Ericion umbellatae.

H2160: Dunes with Hippophae rhamnoides. Sea-buckthorn formations of forest colonisation in both dry and humid dune depressions.

H2170: Dunes with *Salix repens ssp. argentea* (*Salicion arenariea*). *Salix repens* communities (*Salicion arenariae*), colonising wet dune slacks. Following the lowering of the ground water table or accumulation of drift sand, these communities may develop into mesophilous communities as the *Pyrolo-Salicetum* (with *Pyrola rotundifolia*, Viola canina, *Monotropa hypopitys*) or, into *xerophilous Salix* communities (with *Carlina vulgaris*, *Thalictrum minus*) or into *Salix repens* communities with Mesobromion elements.

H2180: Wooded dunes of the Atlantic, Continental and Boreal region. Natural or semi-natural forests (long established) of the Atlantic, Continental and Boreal region coastal dunes with a well developed woodland structure and an assemblage of characteristic woodland species. It corresponds to oak groves and beech-oak groves with birch (Quercion robori-petraeae) on acid soils, as well as forests of the *Quercetalia pubescenti-petraeae* order. Pioneer stages are open forests with *Betula spp*. and *Crataegus monogyna*, mixed forests with *Fraxinus excelsior*, *Quercus robur*, *Ulmus minor* and *Acer pseudoplatanus* or, in wet dune slacks, pioneer forests with *Salix alba* which develop into humid mixed forests or marsh forests.

H2180A: Wooded dunes of the Atlantic, Continental and Boreal region, dry. Most nutrient poor and driest subtype. Mostly *Betula spec*. and *Quercus* forests. Mostly found on old dunes, higher areas of shorelines and the most calcium low inner dunes edges of the young dunes. Soil relatively acidic.

H2180B: Wooded dunes of the Atlantic, Continental and Boreal region, wet. Mostly in wet dune valleys with groundwater levels that reach the ground level during winter. Relatively protected from the sea wind.

H2180C: Wooded dunes of the Atlantic, Continental and Boreal region, inner dune edge. Forests highly influenced by humans. Mostly part of 18th century estates build on the inner dune ridge. Due to digging that brought up deeper, calcium rich, soil this soil is more calcium rich than subtypes A and B. Also lower groundwater levels and humus rich soils.

H2190: Humid dune slacks. Humid depressions of dunal systems. Humid dune-slacks are extremely rich and specialised habitats very threatened by the lowering of water tables.

H2190A: Humid dune slacks, open water. Fresh-water aquatic communities of permanent dune-slack water bodies. Almost never fall completely dry, found in the lowest parts of the dune area. Within this subtype there is a large variation of ecological circumstances. Slacks can be fresh or slats water, nutrient rich or poor, acidic or basic.

H2190B: Humid dune slacks, calcium rich. Mostly freshwater slacks in primary dune valleys. Usually fall dry in the spring.

H2190D: Humid dune slacks, high swamp plants. Mostly calcium rich dune areas with a lot of Reed (*Phragmites australis*) and Carex plants. These dense vegetations function as breeding grounds for a lot of swamp birds.

H7140: Transition mires and quaking bogs. Peat-forming communities developed at the surface of oligotrophic to mesotrophic waters, with characteristics intermediate between soligenous and ombrogenous types. They present a large and diverse range of plant communities. In large peaty systems, the most prominent communities are swaying swards, floating carpets or quaking mires formed by medium-sized or small sedges, associated

with sphagnum or brown mosses. They are generally accompanied by aquatic and amphibious communities. In the Boreal region this habitat type includes minerotrophic fens that are not part of a larger mire complex, open swamps and small fens in the transition zone between water (lakes, ponds) and mineral soil. These mires and bogs belong to the *Scheuchzerietalia palustris* order (oligotrophic floating carpets among others) and to the *Caricetalia fuscae* order (quaking communities). Oligotrophic water-land interfaces with *Carex rostrata* are included.

H7140B: Transition mires and quaking bogs, peat-moss-reed lands. More stabilized peat layer with a closed moss layer, dominant peat moss species, rich in ferns and a thin reed layer.

8.5 Appendix 5

Red list species present in the AWD in the last three years. Taken from www.NDFF.nl.

Mammals:	6 species	151 sightings
English	**Dutch**	**Scientific**
Pine marten	Boommarter	*Martes martes*
Harbour seal	Gewone zeehond	*Phoca vitulina*
Serotine	Laatvlieger	*Eptesicus serotinus*
Common noctule	Rosse vleermuis	*Nyctalus noctula*
Water shrew	Waterspitsmuis	*Neomys fodiens*
Weasel	Wezel	*Mustela nivalis*

Birds:	50 species	23549 sightings
English	**Dutch**	**Scientific**
Northern Harrier	Blauwe Kiekendief	*Circus cyaneus*
Barn swallow	Boerenzwaluw	*Hirundo rustica*
Common ringed plover	Bontbekplevier	*Charadrius hiaticula*
Eurasian hobby	Boomvalk	*Falco subbuteo*
Common goldeneye	Brilduiker	*Bucephala clangula*
Tawny pipit	Duinpieper	*Anthus campestris*
Yellow wagtail	Engelse kwikstaart	*Motacilla flavissima*
Bull-headed wagtail	Gele kwikstaart	*Motacilla flava*
Golden plover	Goudplevier	*Pluvialis apricaria*
Meadow pipit	Graspieper	*Anthus pratensis*
Red-backed shrike	Grauwe klauwier	*Lanius collurio*
Spotted flycatcher	Grauwe Vliegenvanger	*Muscicapa striata*
Green woodpecker	Groene specht	*Picus viridis*
Great black-backed gull	Grote mantelmeeuw	*Larus marinus*
Sandwich tern	Grote stern	*Sterna sandvicensis*
Great egret	Grote zilverreiger	*Casmerodius albus*
Black-tailed godwit	Grutto	*Limosa limosa*
House sparrow	Huismus	*Passer domesticus*
House martin	Huiszwaluw	*Delichon urbicum*
Barn owl	Kerkuil	*Tyto alba*
Great grey shrike	Klapekster	*Lanius excubitor*
Little egret	Kleine zilverreiger	*Egretta garzetta*
Linnet	Kneu	*Linaria cannabina*
Cuckoo	Koekoek	*Cuculus canorus*
Fieldfare	Kramsvogel	*Turdus pilaris*
Red-breasted merganser	Middelste zaagbek	*Mergus serrator*
Nightingale	Nachtegaal	*Luscinia megarhynchos*

Common sandpiper	Oeverloper	*Actitis hypoleucos*
Winchat	Paapje	*Saxicola rubetra*
Grey partridge	Patrijs	*Perdix perdix*
Anas acuta	Pijlstaart	*Anas acuta*
Purple heron	Purperreiger	*Ardea purpurea*
Raven	Raaf	*Corvus corax*
Long-eared owl	Ransuil	*Asio otus*
Tree sparrow	Ringmus	*Passer montanus*
Eurasian bittern	Roerdomp	*Botaurus stellaris*
Peregrine falcon	Slechtvalk	*Falco peregrinus*
Northern shoveler	Slobeend	*Anas clypeata*
Savi's warbler	Snor	*Locustella luscinioides*
Icterine warbler	Spotvogel	*Hippolais icterina*
Northern wheatear	Tapuit	*Oenanthe oenanthe*
Redshank	Tureluur	*Tringa totanus*
Skylark	Veldleeuwerik	*Alauda arvensis*
Short-eared owl	Velduil	*Asio flammeus*
Common tern	Visdief	*Sterna hirundo*
Common snipe	Watersnip	*Gallinago gallinago*
Golden oriole	Wielewaal	*Oriolus oriolus*
Teal	Wintertaling	*Anas crecca*
Garganey	Zomertaling	*Anas querquedula*
Tortle dove	Zomertortel	*Streptopelia turtur*

Reptiles: 1 species 896 sightings

English	**Dutch**	**Scientific**
Sand lizard	Zandhagedis	*Lacerta agilis*

Amphibians: 2 species 1633 sightings

English	**Dutch**	**Scientific**
European tree frog	Boomkikker	*Hyla arborea*
Natterjack toad	Rugstreeppad	*Bufo calamita*

Fish: 0 species 0 sightings

English	**Dutch**	**Scientific**
none		

Butterflies: 8 species 9604 sightings

English	**Dutch**	**Scientific**
Grizzles skipper	aardbeivlinder	*Pyrgus malvae*
Brown argus	bruin blauwtje	*Aricia agestis*
Niobe fritillary	duinparelmoervlinder	*Argynnis niobe*
Large skipper	groot dikkopje	*Ochlodes sylvanus*
Dark green fritilary	grote parelmoervlinder	*Argynnis aglaja*
Grayling	heivlinder	*Hipparchia semele*
Silver-washed fritillary	keizersmantel	*Argynnis paphia*
Queen of Spain fritillary	kleine parelmoervlinder	*Issoria lathonia*

Moths: 0 species 0 sightings

English	**Dutch**	**Scientific**
none		

Dragonflies: 5 species 817 sightings

English	**Dutch**	**Scientific**

Common winter damselfly	Bruine winterjuffer	*Sympecma fusca*
Large white-faced darter	Gevlekte witsnuitlibel	*Leucorrhinia pectoralis*
Hairy dragonfly	Glassnijder	*Brachytron pratense*
Small spreadwing	Tengere pantserjuffer	*Lestes virens*
Green-eyed hawker	Vroege glazenmaker	*Aeshna isoceles*

Insects: 18 species 14182 sightings

English	Dutch	Scientific
Grizzles skipper	aardbeivlinder	*Pyrgus malvae*
Blue-winged grasshopper	Blauwvleugelsprinkhaan	*Oedipoda caerulescens*
Brown argus	bruin blauwtje	*Aricia agestis*
Common winter damselfly	Bruine winterjuffer	*Sympecma fusca*
Niobe fritillary	duinparelmoervlinder	*Argynnis niobe*
Hairy dragonfly	Glassnijder	*Brachytron pratense*
Large white-faced darter	Gevlekte witsnuitlibel	*Leucorrhinia pectoralis*
Large skipper	groot dikkopje	*Ochlodes sylvanus*
Dark green fritilary	grote parelmoervlinder	*Argynnis aglaja*
Grayling	heivlinder	*Hipparchia semele*
Silver-washed fritillary	keizersmantel	*Argynnis paphia*
Queen of Spain fritillary	kleine parelmoervlinder	*Issoria lathonia*
?	Kustbehangersbij	*Megachile maritima*
sickle-baring bush-cricket	Sikkelsprinkhaan	*Phaneroptera falcata*
Small spreadwing	Tengere pantserjuffer	*Lestes virens*
European mole-cricket	Veenmol	*Gryllotalpa gryllotalpa*
Green-eyed hawker	Vroege glazenmaker	*Aeshna isoceles*
?	Zilveren fluitje	*Megachile leachella*

Arthropods: 0 species 0 sightings

English	Dutch	Scientific
none		

Vascular plants: 44 species 41543 sightings

English	Dutch	Scientific
Common hedgenettle	Betonie	*Stachys officinalis*
Quaking-grass	Bevertjes	*Briza media*
Henbane	Bilzekruid	*Hyoscyamus niger*
Downy Hemp-nettle	Bleekgele hennepnetel	*Galeopsis segetum*
Wild basil	Borstelkrans	*Clinopodium vulgare*
Wild strawberry	Bosaardbei	*Fragaria vesca*
Pondweed	Brede waterpest	*Elodea canadensis*
Carline thistle	Driedistel	*Carlina vulgaris*
Small cudweed	Dwergviltkruid	*Filago minima*
Purging flax	Geelhartje	*Linum catharticum*
Keelen-fruited Cornsalad	Gegroefde veldsla	*Valerianella carinata*
Common Moonwort	Gelobde maanvaren	*Botrychium lunaria*
Agrimony	Gewone agrimonie	*Agrimonia eupatoria*
Common milkwort	Gewone vleugeltjesbloem	*Polygala vulgaris*
Smooth cat's-ear	Glad biggenkruid	*Hypochaeris glabra*
Common twayblade	Grote keverorchis	*Neottia ovata*
Broad leaved thyme	Grote tijm	*Thymus pulegioides*
Pyramidal orchid	Hondskruid	*Anacamptis pyramidalis*
Heath dog-violet	Hondsviooltje	*Viola canina*
Common wintergreen	Klein wintergroen	*Pyrola minor*
Little yellowrattle	Kleine ratelaar	*Rhinanthus minor*

Lesser meadiw-rue	Kleine ruit	*Thalictrum minus*
Basil thyme	Kleine steentijm	*Clinopodium acinos*
Sticky stork's-bill	Kleverige reigersbek	*Erodium lebelii*
black bog-rush	Knopbies	*Schoenus nigricans*
Cross-leaved gentian	Kruisbladgentiaan	*Gentiana cruciata*
Marsh helleborine	Moeraswespenorchis	*Epipactis palustris*
Mossy stonecrop	Mosbloempje	*Crassula tillaea*
Spanish catchfly	Oorsilene	*Silene otites*
Grass of parnassus	Parnassia	*Parnassia palustris*
Round-leaved wintergreen	Rond wintergroen	*Pyrola rotundifolia*
Round-leaved sundew	Ronde zonnedauw	*Drosera rotundifolia*
Dandelion Sub sp.	Schraallandpaardenbloem	*Taraxacum celticum*
Knotted pearlwort	Sierlijke vetmuur	*Sagina nodosa*
Autnumn gentian	Slanke gentiaan	*Gentianella amarella*
Wild primrose	Stengelloze sleutelbloem	*Primula vulgaris*
Rigid Eyebright	Stijve ogentroost	*Euphrasia stricta*
Bog pimpernel	Teer guichelheil	*Anagallis tenella*
Tower mustard	Torenkruid	*Arabis glabra*
Spring sedge	Voorjaarszegge	*Carex caryophyllea*
Cat-mint	Wild kattenkruid	*Nepeta cataria*
Swallow-wort	Witte engbloem	*Vincetoxicum hirundinaria*
Kidney-vetch	Wondklaver	*Anthyllis vulneraria*
Sea spurge	Zeewolfsmelk	*Euphorbia paralias*

Mosses: 18 secies 6366 sightings

English	**Dutch**	**Scientific**
Bluish veilwort	Blauw boomvorkje	*Metzgeria fruticulosa*
Tree-moss	Boompjesmos	*Climacium dendroides*
Wrinkle-leaved Feather-moss	Buizerdmos	*Rhytidium rugosum*
Minute pouncewort	Dwergwratjesmos	*Cololejeunea minutissima*
Tamarisk Scalewort	Flesjesroestmos	*Frullania tamarisci*
Wall scalewort	Gewoon pelsmos	*Porella platyphylla*
Glittering wood-moss	Glanzend etagemos	*Hylocomium splendens*
Lustrous bog-moss	Glanzend veenmos	*Sphagnum subnitens*
Racomitrium moss	Grijze bisschopsmuts	*Racomitrium canescens*
Maidenhair moss	Groot vedermos	*Fissidens adianthoides*
Side-fruited Crisp-moss	Hakig kronkelbladmos	*Pleurochaete squarrosa*
Bendy ditrichum	Kalksmaltandmos	*Ditrichum flexicaule*
Imbricate Bog-moss	Kamveenmos	*Sphagnum affine*
Rustwort	Krulbladmos	*Nowellia curvifolia*
Large-leaf/felted Thyme moss	Kwelviltsterrenmos	*Rhizomnium pseudopunctatum*
Awl-leaved Screw-moss	Langkapselsterretje	*Tortula subulata*
Larger Mouse-tail Moss	Recht palmpjesmos	*Isothecium alopecuroides*
Rose-moss	Rozetmos	*Rhodobryum roseum*

Lichen: 20 species 2935 sightings

English	**Dutch**	**Scientific**
?	Boomsuikerkorst	*Fuscidea lightfootii*
Rim lichen	Bosschotelkorst	*Lecanora argentata*
Cowpie lichen	Duindaalder	*Diploschistes muscorum*
Baglietto's dotted lichen	Duinknoopjeskorst	*Bacidia bagliettoana*
Reindeer lichen	Gebogen rendiermos	*Cladonia arbuscula*
Dust lichen	Gele poederkorst	*Chrysothrix candelaris*

?	Gelig baardmos	*Usnea flavocardia*
Nit beard lichen	Gewoon baardmos	*Usnea subfloridana*
Dog lichen	Groot leermos	*Peltigera canina*
Cartilage lichen	Groot takmos	*Ramalina fraxinea*
Elf ears	Hamsteroortje	*Normandina pulchella*
Beard lichen	Ingesnoerd baardmos	*Usnea cornuta*
?	Kaal leermos	*Peltigera hymenina*
Felt lichen	Klein leermos	*Peltigera rufescens*
Scribble lichen	Kort schriftmos	*Opegrapha varia*
?	Parasietkorst	*Normandina acroglypta*
?	Sierlijk rendiermos	*Cladonia ciliata*
Cartilage lichen	Waaiertakmos	*Ramalina lacera*
Yellow bloodstain lichen	Witgerande stofkorst	*Haematomma ochroleucum*
Black-saddle pelt lichen	Zwart leermos	*Peltigera neckeri*

Algae: 0 species 0 sightings

English	Dutch	Scientific
none		

Fungi: 53 species 1276 sightings

English	Dutch	Scientific
Scarlet bonnet	Adonismycena	*Mycena adonis*
Red-banded cortinarius	Armbandgordijnzwam	*Cortinarius armillatus*
Striate earthstar	Baretaardster	*Geastrum striatum*
?	Blauwgroen trechtertje	*Omphalina chlorocyanea*
?	Bleke borstelkurkzwam	*Coriolopsis trogii*
Elegant earthstar	Bruine aardster	*Geastrum elegans*
Honey pinkgill	Dennensatijnzwam	*Entoloma cetratum*
Herald of winter	Dennenslijmkop	*Hygrophorus hypothejus*
Sand stinkhorn	Duinstinkzwam	*Phallus hadriani*
Dune waxcap	Duinwasplaat	*Hygrocybe conicoides*
Butter waxcap	Elfenwasplaat	*Hygrocybe ceracea*
?	Forse aardster	*Geastrum coronatum*
Handsome club	Fraaie knotszwam	*Clavulinopsis laeticolor*
Larch bolete	Gele ringboleet	*Suillus grevillei*
?	Gesteeld mosoortje	*Arrhenia spathulata*
Reishi mushroom	Gesteelde lakzwam	*Ganoderma lucidum*
Yellow morel	Gewone morielje	*Morchella esculenta*
Lion shield	Goudgele hertenzwam	*Pluteus leoninus*
?	Klein oranje zandschijfje	*Byssonectria aggregata*
Tiny earthstar	Kleine aardster	*Geastrum minimum*
?	Kleine kop-op-schotel	*Disciseda candida*
King Alfred's cakes	Kogelhoutskoolzwam	*Daldinia concentrica*
Copper spike	Koperrode spijkerzwam	*Chroogomphus rutilus*
?	Melige bovist	*Bovista aestivalis*
Weeping bolete	Melkboleet	*Suillus granulatus*
?	Mestnestzwammetje	*Cyathus stercoreus*
Jewelled amanita	Narcisamaniet	*Amanita gemmata*
Sulphus knight	Narcisridderzwam	*Tricholoma sulphureum*
Earpick fungus	Oorlepelzwam	*Auriscalpium vulgare*
?	Papegaaizwammetje	*Hygrocybe psittacina*
Pepper pot	Peperbus	*Myriostoma coliforme*
Crimped gill	Plooivlieswaaiertje	*Plicaturopsis crispa*
Lion's mane	Pruikzwam	*Hericium erinaceus*

?	Puntmutswasplaat	*Hygrocybe acutoconica*
?	Rode plakkaatzwam	*Meruliopsis taxicola*
Grey milkcap	Roodgrijze melkzwam	*Lactarius vietus*
Dappled webcap	Roodschubbige gordijnzwam	*Cortinarius bolaris*
Field earthstar	Ruwe aardster	*Geastrum campestre*
?	Ruwstelige stuifbal	*Tulostoma fimbriatum*
Meadow coral	Sikkelkoraalzwam	*Clavulinopsis corniculata*
?	Slijmwasplaat	*Hygrocybe laeta*
?	Sneeuwzwammetje	*Hygrocybe virginea*
Pale stagshorn	Spatelhoorntje	*Calocera pallidospathulata*
Waether earthstar	Tepelaardster	*Geastrum corollinum*
Papillate pinkgill	Tepelsatijnzwam	*Entoloma papillatum*
Bicoloured bracket	Tweekleurig elfenbankje	*Gloeoporus dichrous*
?	Vale schijnridderzwam	*Lepista panaeolus*
Apricot club	Verblekende knotszwam	*Clavulinopsis luteoalba*
?	Viltige aardster	*Geastrum saccatum*
Fenugreek milkcap	Viltige maggizwam	*Lactarius helvus*
Thimble morel	Vingerhoedje	*Verpa conica*
Dune cup	Zandtulpje	*Peziza ammophila*
Blue edge pinkgill	Zwartsneesatijnzwam	*Entoloma serrulatum*

Molluscs:	2 species	190 sightings
English	**Dutch**	**Scientific**
Crested vertigo	Dwerg-korfslak	*Vertigo pygmaea*
Burgundy snail	Wijngaardslak	*Helix pomatia*

8.6 Appendix 6

volg	vegty	DVN	Habtype_09	Thumb
1	W0	Open water		0
2	W1	04BA02	H2190_A	6,36
3	W2	04BB01	H2190_A	5,19
4	W3	04RG01	H2190_A	4,53
5	W4	04BA03	H2190_A	6,98
6	W5	05BC03		9,07
7	W6	05BC		0
8	W7	08AA	H2190_D	1,69
9	W8	08AA		0
10	P	Strand		0
11	P0	31BA01A	H2130_A	7,31
12	P1	23AB01B	H2120	3,37
13	P2k	14CA01A	H2130_A	7,01
14	P2z	14AA02	H2130_B	6,11
15	P3	27AA02	H2190_B	21,47
16	M1	14CA02	H2130_A	9,60
17	M2	14CA01B	H2130_A	7,01
18	M3	14CA01B	H2130_A	7,01
19	M4	14AA02B	H2130_B	6,11
20	M5	14AA02A	H2130_B	6,11
21	M6	20AA01A	H2150	4,07
22	M7	09AA02	H7140_B	16,41
23	G0		H2120	0
24	G1	14CA02	H2130_A	9,60

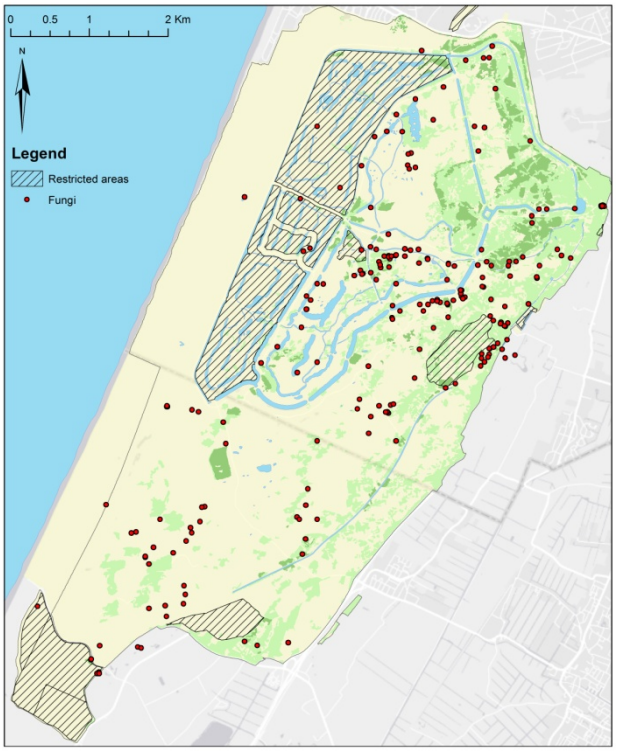
25	G2	14CB02		H2130_A	19,29
26	G3	14BB02B		H2130_A	6,81
27	G4	14CA01B		H2130_A	7,01
28	G5	14CB01A		H2130_A	17,18
29	G6	14CB01C		H2130_A	17,18
30	G7	14CB01B		H2130_A	17,18
31	G8	14CB01B		H2130_A	17,18
32	G9	14CB01A		H2130_B	17,18
33	G10	14CB01C		H2130_B	17,18
34	G11	14AA02B		H2130_B	6,11
35	G12	14BB02A		H2130_B	6,81
36	G13	14BB02A		H2130_B	6,81
37	V1	14BB02A		H2130_B	6,81
38	V2d	14CB01B		H2130_A	17,18
39	V2v	19AA03		H2130_C	27,11
40	V3		14	H2190_B	0
41	V4		33		0
42	V5t	09AA		H7140_B	16,41
43	V5je				0
44	V6t	09BA04		H2190_B	54,93
45	V6js			H2190_B	17,14
46	V7	08AA		H2190_D	1,69
47	V8		33		0
48	V9	08RG03		H2190_D	5,01
49	R0	31BA01A			0
50	R1	23AB01		H2120	3,37
51	R2a	23RG01		H2120	4,43
52	R2r	23RG01		H2130_A	4,43
53	R3	31AB03B		H2130_A	5,15
54	R4	31BA01A		H2130_A	7,31
55	R5	14CB		H2130_A	17,18
56	R6ce	14RG09		H2130_B	5,17
57	R6ca	14RG01		H2130_B	3,12
58	R7	37AA		H2130_B	5,4
59	R8	18RG01		H2130_B	5,42
60	D0			H2160	0
61	D1	14CB02		H2130_A	19,29
62	D2	37RG02		H2160	10,47
63	D3hr	37AC02A		H2160	11,84
64	D3rf			H2160	11,84
65	D4	37RG03		H2160	9,29
66	D5	37RG02		H2160	10,47
67	K1	37AC02A		H2160	11,84
68	K2k	14CB01C		H2130_A	17,18
69	K2z	14CB01C		H2130_B	17,18
70	K3	37AC02A		H2160	11,84
71	K4	37RG04		H2160	3,56
72	K5k	14RG10		H2130_A	8,83
73	K5z	14RG10		H2130_B	8,83
74	K6	14CB01B		H2130_A	17,18
75	K7	14CB		H2160	17,18
76	K8	20AB04		H2170	32,26
77	K9	37AC02B		H2160	11,84
78	H1	37AC01		H2160	7,52
79	H2	37AC03		H2160	12,52
80	H3s	37AC03		H2160	12,52

81	H3b	37AC03	H2180_A	12,52
82	H4	14AA	H2130_B	2,63
83	H5	33AA	H2160	2,79
84	H6	40AA02	H2180_B	7,75
85	L1	43AA03A	H2180_A	11,02
86	L2	43AA03B	H2180_B	11,02
87	L3	43AA03B	H2180_B	11,02
88	L4	37AC03	H2180_A	12,52
89	L5	42AA02	H2180_A	4,15
90	L6	42AA02	H2180_A	4,15
91	L7	33	H2180_A	2,79
92	L8	33	H2180_B	2,79
93	L9	43AA01	H2180_C	9,52
94	N1	14CB		2,69
95	N2	41DG03		2,69
96	N3	41DG03		2,69
97	T	30B		0
98	O	Niet gekarteerd		0

8.7 Appendix 7

The locations of sightings of Fungi (1), Lichen (2), Mosses (3), and Vascular plants (4).

1



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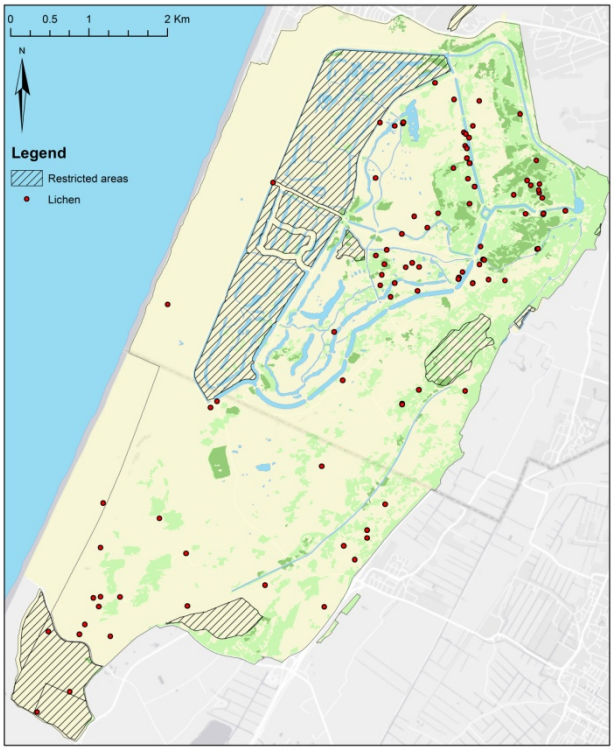
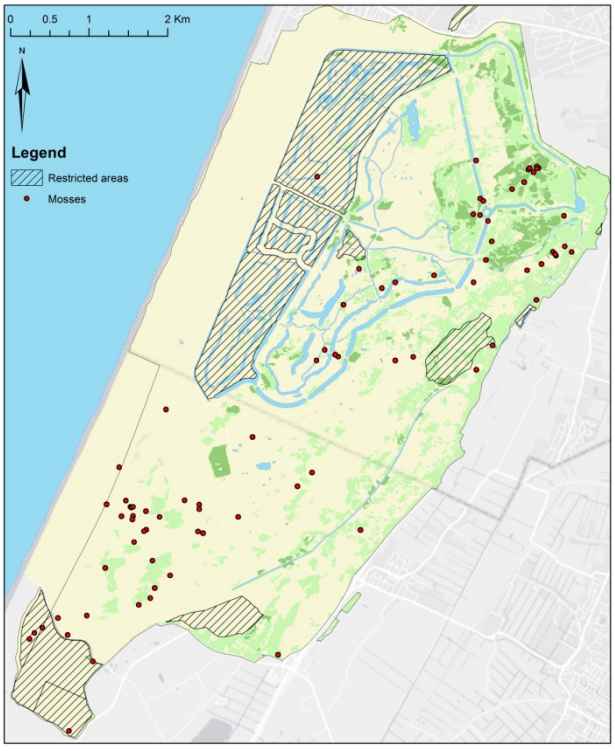
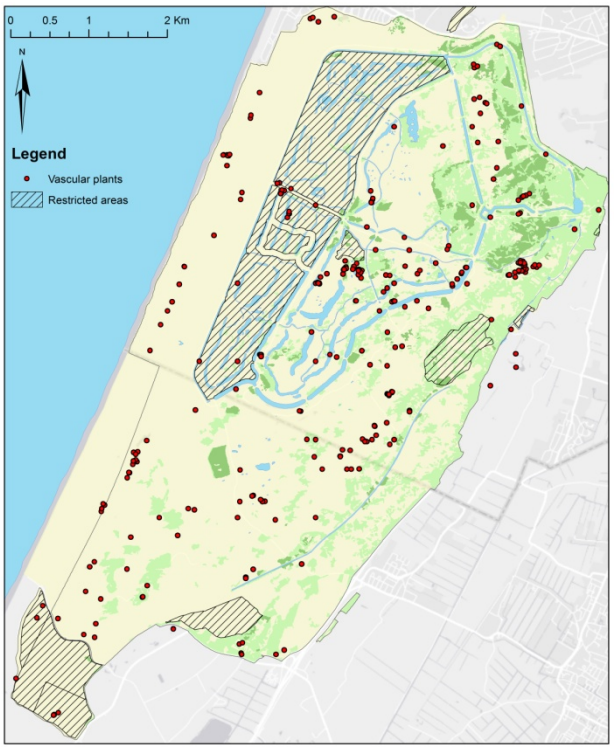


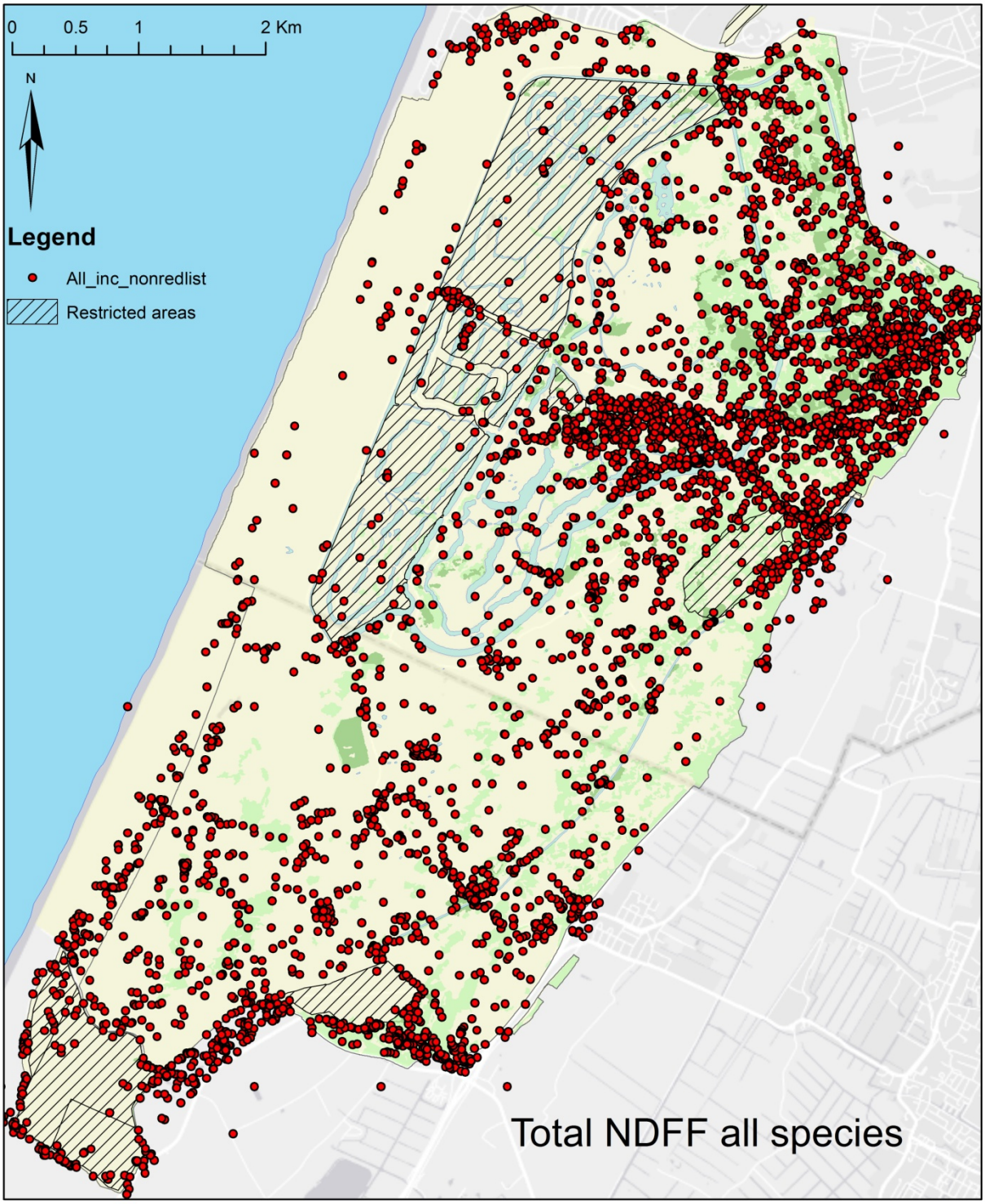
3



4

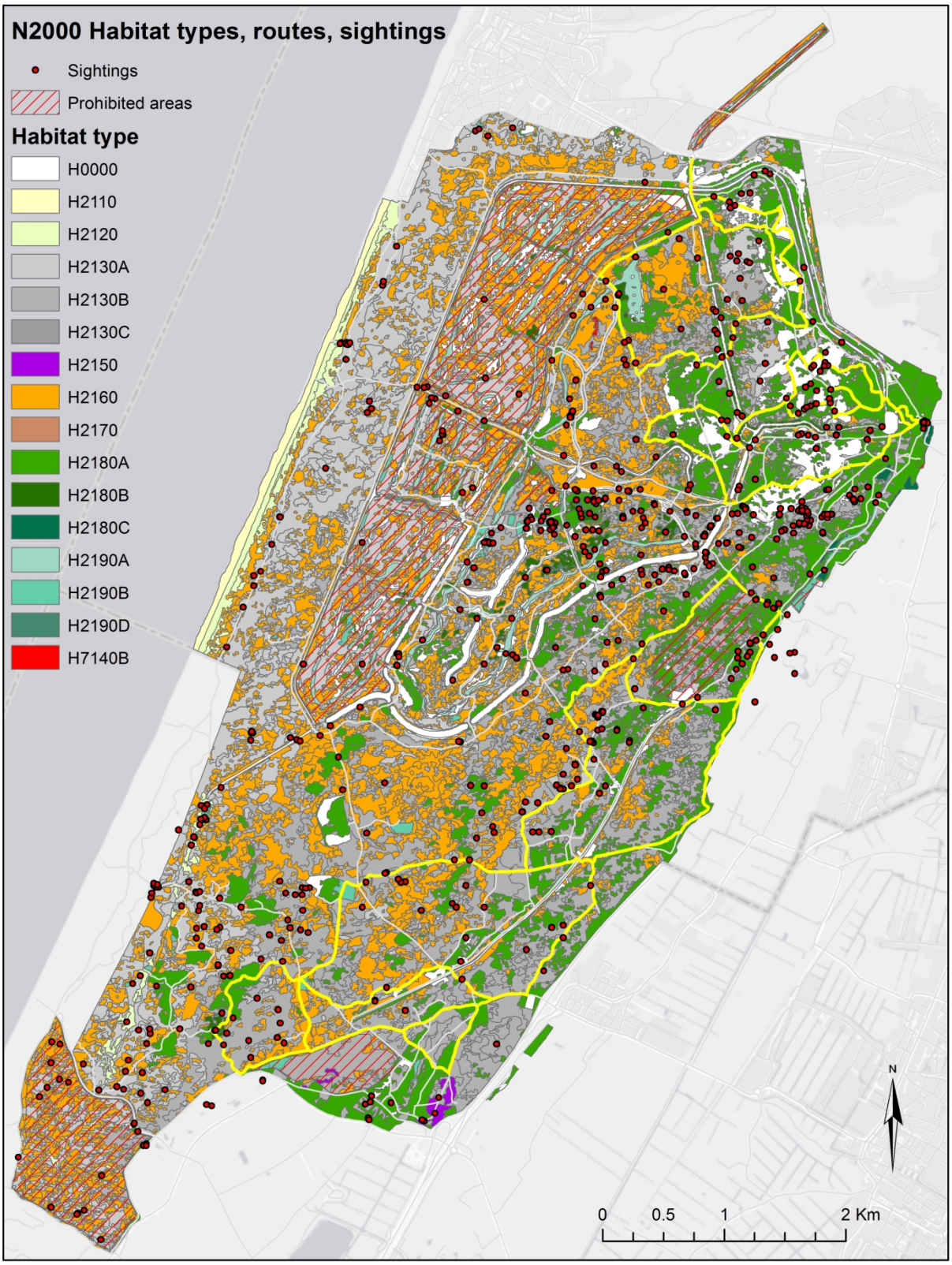


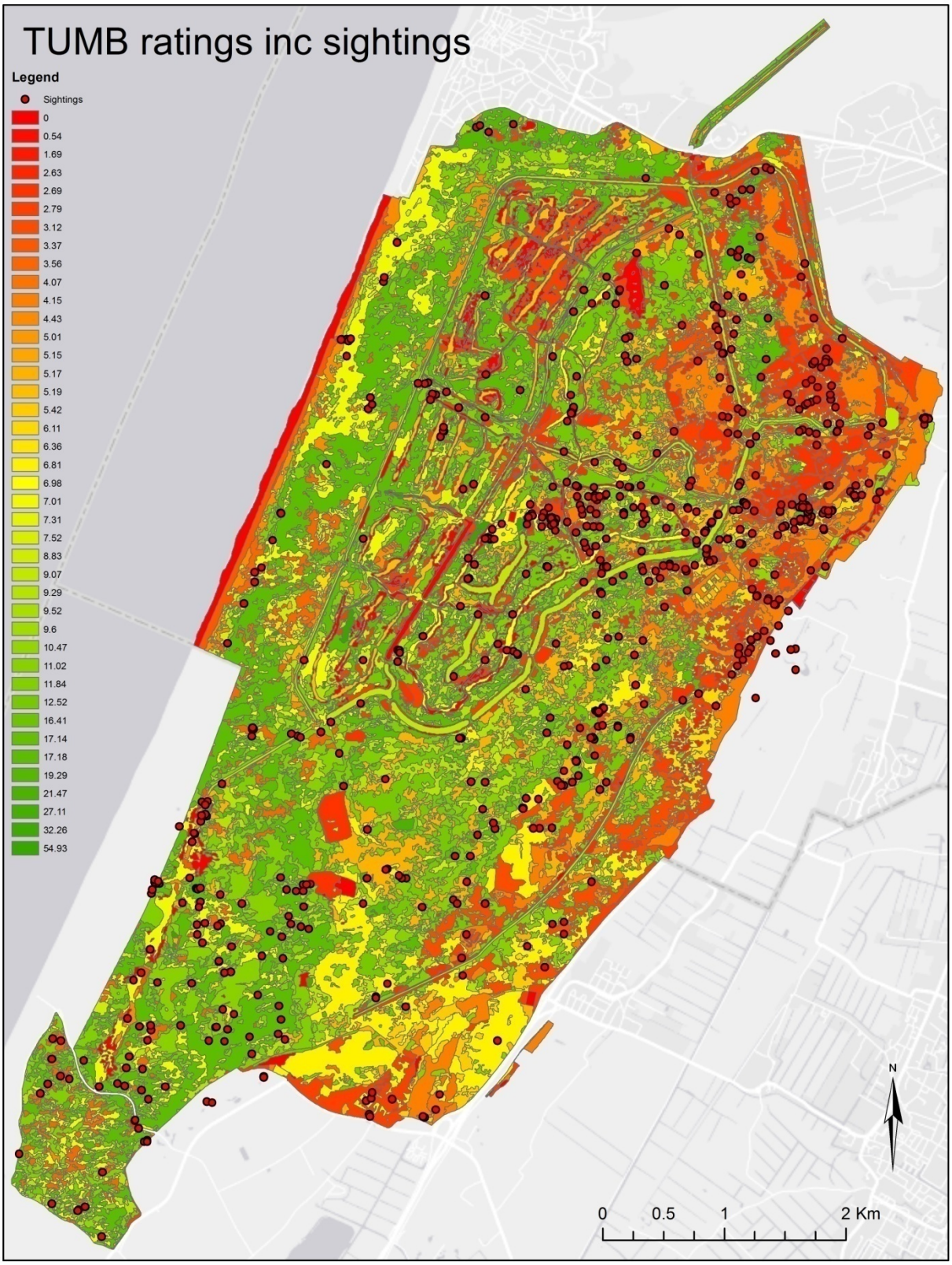
8.8 Appendix 8



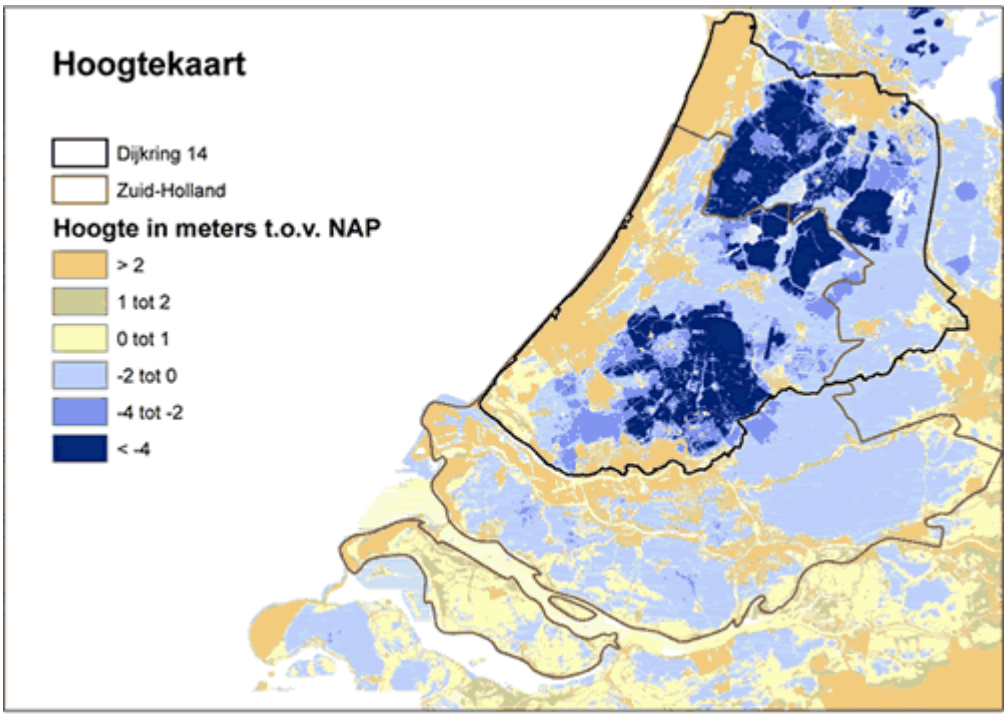
The locations of sightings of Fungi, Lichen, Mosses and Vascular plants combined including non-red list species. This figure shows a clear bias towards certain parts of the AWD.

8.9 Appendix 9




TUMB ratings inc sightings
Legend
Sightings
0
0.54
1.69
2.63
2.69
2.79
3.12
3.37
3.56
4.07
4.15
4.43
5.01
5.15
5.17
5.19
5.42
6.11
6.36
6.81
6.98
7.01
7.31
7.52
8.83
9.07
9.29
9.52
9.6
10.47
11.02
11.84
12.52
16.41
17.14
17.18
19.29
21.47
27.11
32.26
54.93
N
0
0.5
1
2 Km

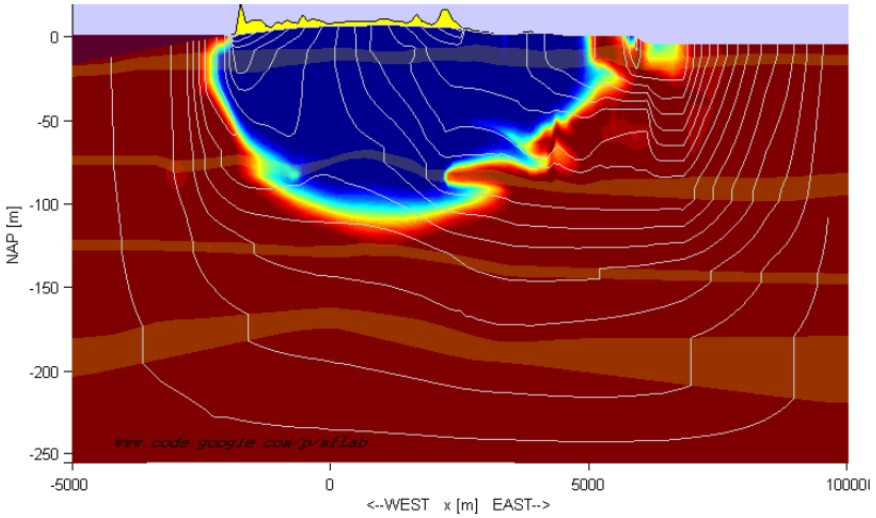
8.10 Appendix 10



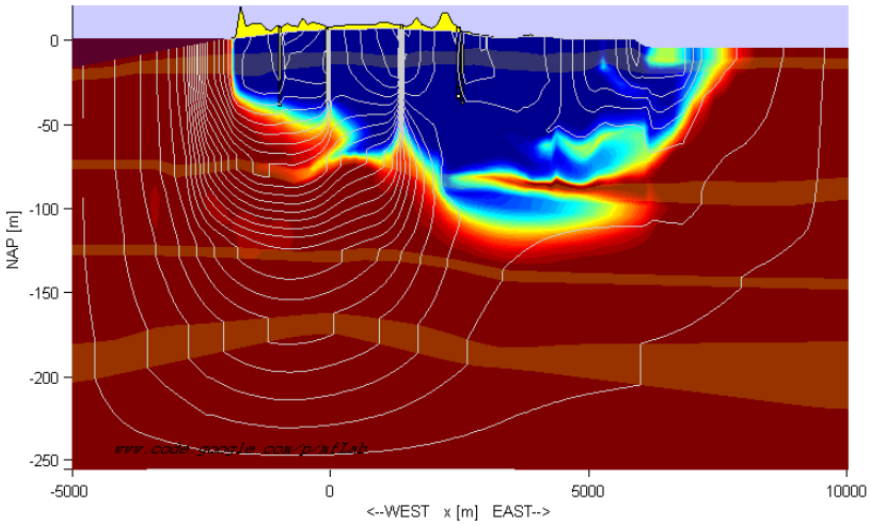
The surface of dyke ring 14 and the amount of meters below NAP the land is. (Source: waarheenmethetveen.nl)

8.11 Appendix 11

The naturally occurring water was for a long time the only source of water used for the production of drinking water in the AWD. Due to an increase in population, overall use of drinking water and increase of the area the drinking water was delivered to, the aquifer of the dunes was diminishing, depicted in blue. As a result the saltwater(red) underneath took its place up to the point where salt water was pumped up instead of dune water.



The simulated state of the natural dune aquifer (blue) and salt ground water(red) underneath the dunes(yellow aboveground) of the AWD in 1853. (Source: Waternet)



The simulated state of the natural dune aquifer (blue) and salt ground water(red) underneath the dunes(yellow above ground) of the AWD in 1957after 100 years of overexploitation. (Source: Waternet)

8.12 Appendix 12

The suggested walking routes in the AWD for each starting/end entrance. N.B.: Colours do not correspond with colours in figures concerning recreation. Source: Wandelkaart, 2016.

Entrance	Yellow	Blue/green
Zandvoortselaan	3,6km	6,7km
De Oase	3,6km	6,8km
Panneland	3,8km	7,8km
De Zilk	4,8km	9,3km

8.13 Appendix 13

17/3/2016
Time: 8:00-12:00
Waternet employee: Peter Jongeneelen (Dune operator)
Transport: car
Activity: Daily measuring of the water levels throughout the AWD. General control/observing of the waterways in the AWD. Mostly remained in the infiltration areas.
Notes: Lots of birds' nests in the infiltration areas. Swans, ducks, cormorants.

23/3/2016
Time: 13:00-16:00
Waternet employee: Martijn van Schaik (Overseer / Coordinator NT projects)
Transport: car
Activity: Visiting LIFE projects, keeping tabs on their progress. Mostly South and East part of the AWD. Checked new fence in the North.
Notes: - Lots of grounds have had their top soils and with that the plants removed (plaggen). This was done for the betterment of the ecosystem. More diversity and dynamic nature.

- Whole area of the AWD is, to some extent, affected by the extraction of drinking water.

5/4/2016
Time: 13:30-16:15
Waternet employee: Alfons Daniëls (Forester)
Transport: car
Activity: Visiting the most Southern part and Eastern parts of the AWD. General patroliing of the area, checking entrance cards, talking with cyclist.
Notes: - Mostly just 3 entrances and mostly the suggested routes are being used. This is by experience and/or feeling not confirmed by actual numbers.
- Income from hikers: entrance fee, parking fee, maps. And indirect the food service industry, not for Waternet.

31/5/2016
Time: 14:30- 15:30
Rijnland employee: Joost Veer
Activity: Appointment at offices of Rijnland in Leiden. Gathering additional information on the primary barrier and its costs/values.
Notes: - Obtained document with information on the primary barrier (factsheets technische uitwerking).
- Budget of maintaining 41 km of coast: €80,000 ,-

1/6/2016
Time: 10:00- 11:00
Waternet employee: Geurt Rombach
Activity: Appointment at the offices of Waternet in Amsterdam. Consultation on the value of water that flows out of the AWD.
Notes: - Directed to a 20 year old document by Gerlof and Buurman: "Kosten verdeel staat".
- Notified of Staatsbosbeheer waardering.
- Discussed ways of capturing the value of the AWD concerning the filtration of water.

15/6/2016
Time: 10:30- 12:00
Waternet employee: André Burgers
Activity: Tour of the production process of the industrialized filtration/purification of water at the Leiduin location. These are the stages between the Oranjekom and the transport to the consumer.
Notes: - Not directly related to the report, but gave insight in the stages that the water undergoes when it leaves the AWD.

Mentioned above are the actual appointments I have made with people in order to obtain information for services or general knowledge of the AWD and/or Waternet. Not listed here are the numerous times I have spoken with Waternet employees for other matters. This concerned mostly small questions to clear something up or the general gathering of information. This was either done via e-mail or in person at the Waternet offices in Vogelenzang or "Leiduin". All employees of Waternet and other instances that I came into contact with and have contributed in some way to this report are listed in the acknowledgements. The method can be consulted as a source for which persons were

contacted for what purpose and service although not all names listed in the acknowledgements will be listed here.