IN TOUCH WITH URBAN WATER

A Report On Sustainable Water Use At Marineterrein, Amsterdam

July, 2016

Colophon

Commissioned by Bureau Marineterrein Amsterdam *20-07-2016*

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Preface

This report is the result of a project of the Tesla minor - a program at the Institute of Interdisciplinary Studies at the University of Amsterdam - in collaboration with Bureau Marineterrein Amsterdam. The Tesla minor is a five-month program for research master students with a background in beta sciences. Students work in small groups on complex projects that combine science with a business or societal challenge. Our team, consisting of three students - Evie Cox (MSc Biomedical Sciences), Maarten Erich (MSc Biological Sciences) and Merrit Beck (MSc Brain and Cognitive Sciences) - was asked by Bureau Marineterrein to investigate the opportunities for Marineterrein regarding the development of functional, sustainable and temporal innovations.

We would like to thank Anikka Fullop, project manager at Bureau Marineterrein, for her guidance during the project. Furthermore we would like to thank all other staff at Bureau Marineterrein, with a special mention for Daniëlle Willemse, for their time and enthusiasm.

We would like to acknowledge Boris Jansen for his supervision and critical notes, and for thinking along with us during the project. Furthermore, we thank Arie Vonk for his time to read and comment our draft report. In addition, the time, commitment and guidance during the project by Bertus Tulleners, Joris Buis, Tess Remmerswaal and Jarik Guijt is very much appreciated. The project would not have happened without you. Finally, a big thanks to all our fellow-Tesla students, who gave us the energy, enthusiasm and support to make this project into a success.

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Summary

Continuous growth of the number of residents in the city of Amsterdam and a rising numbers of visitors of the city bring increasing pressure on the environment and public space. The pressure is also visible on the waters and shore; therefore measures are needed to ensure sustainable utilization of the water. Marineterrein, a sheltered area in the city centre of Amsterdam, surrounded by water, forms a great location to experiment with the sustainable use of water as the area has no allocation plan until 2018.

In this project we focused on being in touch with urban water through three parts: swimming, ecology and information. We investigated if Marineterrein could become a swim spot and looked for opportunities to improve the water quality in the basin of Marineterrein by using ecology. In addition, we explored what information is needed to enable safe swimming in natural water, and ways to provide this information to the public. Our main results are the following:

- **Swimming:** Swimming in natural water is allowed anywhere unless explicitly prohibited. Usually, the water at Marineterrein is safe to swim. However, after heavy rains, the sewage system overflows excessive water into the canals, introducing high concentrations of faecal bacteria (*E. coli* and intestinal Enterococci) and potentially causing health risks for swimmers. Fluctuations of bacteria levels prevent Marineterrein to become an official swim spot. However, *Waternet* and the municipality of Amsterdam want to create 'non-official spots', where such fluctuations are not regarded. Despite these wishes, current regulations inhibit the facilitation of non-official swim spots. Marineterrein could function as a test location for new regulations. By organising a swimming competition during this project, it was demonstrated that it is safe to swim at the basin of Marineterrein.
- **Ecology:** Aquatic plants can be used to improve the quality of urban water by decreasing concentrations of heavy metals and bacteria and by competing with Cyanobacteria (blue-green algae) for nutrients. Additionally, they create a habitat for fish and macro invertebrates. A submerged garden was introduced in the basin of Marineterrein, accommodating water quality improving plants. The combination of aquatic plants and other water quality-improving organisms could be used to increase the resilience of the water quality in the basin against sewage overflow in the future.
- **Information:** At non-official swim spots, such as Amstel river, IJ or the canals, there currently exists no information or supervision regarding the safety of swimmers. An information panel was placed at Marineterrein to inform the visitors on the potential risks related to swimming in urban waters and how ecology can be used to reduce these risks. For the future, more information flows are recommended. These include information on, for example, the activity of sewage overflows and real-time measurements of the water- and bottom quality.

Concluding, direct contact with urban water through swimming could help citizens become aware of the importance of a healthy aquatic environment and how the health could be improved, while at the same time an extra recreational location in the city is provided, forming an example for sustainable water use.

1. Introduction

1.1 A short history of Marineterrein

In mid-seventeenth century, Amsterdam forms the largest harbour in the world. The extensive trading fleet of Amsterdam is protected by warships, which are made at a shipyard on the east end of the city, today known as *Marineterrein* (Navy Terrain). This shipyard houses many warehouses and workshops, and has an open connection to the *Zuiderzee*.

Almost two hundred years later, in the early twentieth century, the ships built became too large for the new locks and bridges, meaning the end of the shipyard. In 1915, the Royal Dutch Navy settles down at the complex, and builds warehouses and residences for the navy. By then, the complex is called *Marine Etablissement* Amsterdam.

In 2011, the navy decides to divest the *Marine Etablissement* due to budget cuts. Since the Navy will no longer use the premises, the location is assigned a new function by the Government and the municipality of Amsterdam, and a new name is given to the area: Marineterrein (see **Figure 1**).

Today, Marineterrein is gradually opened to the city of Amsterdam, and new users and developers are introduced to the area. In the coming two years, students and entrepreneurs are, amongst others, encouraged to use Marineterrein as a location to experiment with new ideas to help the city of Amsterdam in her sustainability goals (as described in *Duurzaam Amsterdam*).[1] By 2018, a new allocation plan will be assigned to the location, beginning a new chapter in the history of Marineterrein.

Figure 1. Map of the city centre of Amsterdam (a). Marineterrein is depicted in red; Photograph of Marineterrein (b). West of Marineterrein (at the bottom of the photograph) NEMO can be seen, the science museum of Amsterdam. In addition, the basin of Marineterrein is clearly visible in the middle right of the photograph.

1.2 Our client: Bureau Marineterrein

An explicit wish of the owners of the area (the municipality of Amsterdam and the Government of the Netherlands) is to develop Marineterrein on the basis of a gradually growing consensus. "This innovative approach has been agreed upon in an administrative agreement and will be completed by Bureau Marineterrein."[2] Bureau Marineterrein Amsterdam is the organization that steers the area's organic development. It is an independent organization that is commissioned by the Government of the Netherlands.

Key values of Bureau Marineterrein are innovation, connection and focus. With innovation is meant that there is a desire to discover, without fear for the unknown. With connection is meant the active combination of knowledge, contacts and resources, as well as innovative combinations of technology, science and entrepreneurship. With focus is meant that content is focused, goal-oriented and concentrated. Keeping their key values in mind, they started working on the following themes in September 2015: Maritime Power, Sustainability and Sport. Based on these themes, a program is developed together with renters, neighbours of Marineterrein, local residents, Ministry of Defence and external parties. In light of this program, Bureau Marineterrein commissioned us to do a project at Marineterrein.

1.3 Description of global sustainability

In 2015, the United Nations General Assembly replaced the expiring Millennium Development Goals (MDGs) with a broad set of Sustainable Development Goals (SDGs) that, contrary to their predecessors, apply to nations worldwide and not just to developing countries.[3,4] The seventeen SDGs are elucidated in the *2030 agenda for Sustainable Developments* of the United Nations, and are based on five pillars of sustainability: people, planet, prosperity, peace and partnership.[4] Despite the growing interest in, and urge to increase sustainability across the world, there is a large difference in the level of sustainability in cities worldwide.[3] This difference can mostly be ascribed to the level of development on economic, technological, scientific and medical grounds, or in other words, the difference between developing and developed countries.[3,4]

The variation in sustainability between developing and developed countries is made visible in the *Sustainable Cities Index 2015*, where 50 of the most prominent cities in the world are ranked according to the key pillars of sustainability: people, planet and profit (see **Box 1 SUSTAINABLE CITIES** for an elaborated definition).[3] This ranking shows that well established European cities come top of the overall rankings, with seven cities in the top ten (see **Figure 2**).[3] The middle part of the ranking list is occupied by North-American cities, while South-American cities are mostly found on the bottom half of the ranking.[3] The most divergence is showed by

Asian cities, with Seoul, Hong Kong and Singapore in the top ten and Manila, Mumbai, Wuhan and New Delhi forming four of the bottom five cities in the ranking.[3]

Box 1 - *Definition* SUSTAINABLE CITIES

Sustainability is often described as 'the ability to be maintained at a certain rate or level', or as 'avoidance of the depletion of natural resources in order to maintain an ecological balance'.[95] More specific, sustainable cities enable economic growth, environmental health and social inclusion for their inhabitants, their direct environment, and future generations; shortly termed as people, planet and profit. Economic growth (profit) entails the economic performance of a city, the transport infrastructure and the share in global economic networks. Environmental health (planet) includes the city energy consumption and renewable energy share, recycling rates and air- and water quality. Social inclusion (people) can broadly be grasped in the 'quality of life' of the cities' inhabitants.[3]

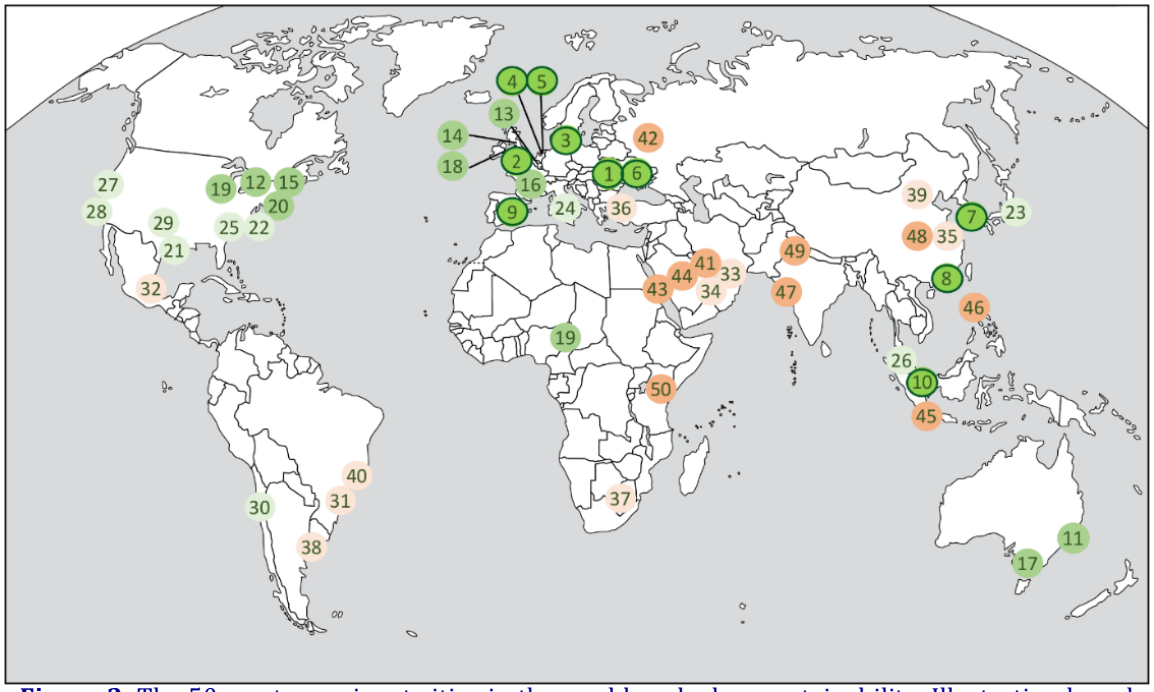


Figure 2. The 50 most prominent cities in the world ranked on sustainability. Illustration based on the *Sustainable City Index 2015*.[3]

These bottom five cities of the ranking include some of the fastest growing cities in the world. Nowadays, the majority of the world population lives in cities, and this majority continues to grow rapidly.[5] To illustrate: the amount of megacities - cities with more than 10 million inhabitants - rapidly increased from 10 in 1990, via 20 in 2005, to 28 in 2014.[6,7] This growth can be attributed to multiple causes, of which an overall growing world population, rural to urban

migration and the reclassification of areas from rural to urban are mentioned as the main determants.[5]

There is increasing evidence that the world is facing serious limits posed by nature, creating real barriers to further growth and prosperity of cities and the world population.[8] The risks to the environmental health, the depletion of natural resources, human health conditions, social cohesion, and individual rights are of particular concern.[9–11] In developing countries, attention to sustainable solutions for these problems is often, and conceivably, retained by several factors. These include the pressure to the limited available resources, the increasing demand for energy, water, and sanitation, as well as increasing need for public services, education and health care.[8] This means that often, in developing countries, attention to the immediate future is of greater urgency than to focus on the future of next generations. However, taken into account that in 2050 an estimated 80% of the world's urban population will live in developing regions, the call for sustainable solutions is increasingly urgent.[8]

Despite the fact that growing populations and urbanization mainly occur in developing countries, also developed countries experience a sharp increase in their urban populations. Today, almost three quarters (73%) of the European population lives in urban areas (data is based on the concept of urban agglomeration, specific per country).[5,7] This number will continue to increase, so that by 2050, 80% of the European population will live in urban agglomerates.[7] This is reflected in the growth of Europe's main cities. In Amsterdam, for example, the population grew from almost 700,000 people in 1990 to over 820,000 people in 2015: an increase of 17%. Since 2008, the average annual increase in population of Amsterdam even exceeds 10,000 people.[12]

In our rapidly urbanizing world, the way in which cities are planned, built, operated and redefined has a large social, environmental and economic impact.[3] Namely, cities house more than half of the population, and account for the majority of the economic output and energy consumption.[7,13] If well managed, cities offer important opportunities for innovation, economic- and social development. Nevertheless, as cities grow, managing them becomes increasingly complex.[9] To consort with the risks related to the environmental- and human health, sustainable developments are needed "that meet the needs and aspirations of the present without compromising the ability of future generations to meet their own needs".[14,15]

Sustainable cities, compared to modern industrial cities, in general show a more collective culture, which is more locally-rooted and collaborative.[16] In these cities, the quality of life of its inhabitants, as well as environmental factors like greenhouse gas emissions and pollution, but also economic performance are considered in policy-making, following the main pillars of sustainability (people, planet and profit).[3] In addition, sustainable cities increasingly embrace cyclical processes, as opposed to the normative linear and centralised processes we

have known since the 19th century (see **Box 2 CIRCULAR ECONOMY** for an elaborated definition).[16] With the rise of circular economies, and the change of focus from economic profit to societal or environmental profit, sustainable cities aim to provide a solution for the problems caused by, amongst others, the growing world population and urbanization.[17,18]

Box 2 - *Definition* CIRCULAR ECONOMY

The philosophy of a circular economy entails using components and materials at their highest utility and value, while making them as restorative and regenerative possible. In a perfect circular economy no waste exists, and every material can be re-used, re-cycled, re-purposed, or restored, bringing all materials back in the production cycle.[96]

Source: The Ellen MacArthur Foundation.[17,96]

1.4 Description of sustainability in Amsterdam

In 2015, the municipality of Amsterdam expressed the wish to compete with global players on sustainability. From then on, sustainability was seen as a starting point for the development of Amsterdam.[1] This ambition is reflected in the presence of an alternation of top-down and bottom-up approaches, which all aim to increase the environmental and human health of the city. In 2015, the municipal council of Amsterdam agreed upon an ambitious agenda for sustainability including specific goals regarding the use of renewable energy, clean air, becoming climate-neutral, and using the concept of circular economy on large scale.[1] For example, since 2016, subsidies are granted by the municipality of Amsterdam for the construction of green roofs or green facades, and the purchase and the placement of solar panels.[19,20]

Next to the top-down approaches in Amsterdam, sustainable initiatives often arise from bottom-up approaches. In Amsterdam alone, more than 300 citizens-led, neighbourhood and artist-driven initiatives were active the last five years.[16] These initiatives often start with innovative and creative ideas from citizens in the city and develop themselves when they prove to be effective. However, often there is no centralized regulation or supervision for these bottom-up initiatives, which means that exact numbers, activities and results remain unknown. Yet, there are a few examples that capture the success of some of these initiatives, for example the project *WASTED*: '*a neighbourhood laboratory for plastic waste upcycling*'.[21] *WASTED* collects plastic waste in a district in the north of Amsterdam in exchange for coins and reprocesses the plastics in new products. These coins function as an alternative local currency. Today, this local currency forms the second largest local currency in the Netherlands, with 600 households and 30 shops participating.[22]

Locally available resources often form the fundament of such sustainable developments. By using local resources, citizens of the cities support the local industries while building on the social cohesion within the community.[16] Given the central role of water in the history of the Netherlands, and the ubiquity of water in the Dutch landscape, water forms an important resource for Dutch cities. For the city of Amsterdam, water in particular is an important resource. Namely, from the Golden Age to now, the water in and around the city played a major role in its development and determines largely the identity and attractiveness of the city.[23] However, the continued growth in the number of city residents and visitors bring increasing pressure on public space, and therefore also on the water and the shore. To ensure the optimal and sustainable utilization of the water and a good organization of the increasing use of water, measures are needed.

In 2015, the board of mayor and aldermen of Amsterdam wrote a report expressing their 2040 vision on water use. The board concentrates its efforts on making the waters of Amsterdam more accessible and liveable, and on promoting the use of water more spread across the city and region.[23] As the ability to swim in the waters of Amsterdam makes the water both accessible and liveable, swimming is deliberately included in the report.[23] The goal is to increase the number of swim spots, and recreational parks next to the water, while improving and monitoring the water quality throughout the city.[23]

By closely monitoring the status of the urban water and including measures that improve the water quality, new swim spots in the city of Amsterdam will contribute to the sustainable use of water. In addition, by interacting with water, and learning about water, citizens will become aware of sustainable ways to enjoy and use the extensive aquatic resources the cities offers, and the importance of healthy ecosystems within these waters.

Marineterrein, a sheltered area in the city centre of Amsterdam, surrounded by water, forms a great location to experiment with the optimal and sustainable utilization of urban water.

2. Project

2.1 Project Aim

The aim of the project is to use Marineterrein as a location to experiment with sustainable developments. The main question of our client is:

> *What are opportunities for Marineterrein regarding the development of functional, sustainable and temporal innovations?*

Here, *functional* is interpreted in a way that the pilot of the project is not only usable at Marineterrein, but can also be scaled up to other parts of the city. In addition, *functional* is about fitting the needs of the city. *Sustainable* is about maintaining or even improving the social, environmental and human sustainability in the city. *Temporal* is about the temporary nature of the project, due to the absence of an allocation plan: all projects at Marineterrein are reconsidered in 2018, when a new allocation plan is assigned to the area.

Due to the preference of our client the focus of this project is on the sustainable utilization of urban water. Therefore, a more specified question was formulated:

> *What are the opportunities for the basin of Marineterrein regarding the sustainable use of water?*

Here, the sustainable use of water is seen as making the waters of Amsterdam more accessible and liveable. By making the waters more accessible and liveable, water is able to contribute to the limited recreational areas the city of Amsterdam offers. This will add value to the liveability of the city, and the well-being of the citizens and visitors of the city. In addition, the sustainable use of water is seen as closely monitoring and improving the water quality throughout the city, contributing to presence and health of the aquatic ecosystems.

2.2 Approach

Our five-month project was split up in five phases:

Phase 1 - Idea Generation We clarified the criteria that were given in by our client Bureau Marineterrein, through extensive conversations with them. When the question of our client was clear, we continued with the search for existing innovative and sustainable developments for inspiration, and used this as a base for brainstorm sessions. In these brainstorm sessions, at first there were no limitations taken into account. Further in the process, we briefly looked at the feasibility of our ideas: would it fit our timeframe, would it fit the wishes of the client, and did the idea appeal to us? From these sessions, we extracted three realistic ideas: Urban Mobile Garden, Floating Swimming Pool, and Swimming in the Basin (see **Appendix I**).

Phase 2 - Feasibility Check We performed a feasibility study on these three ideas (see **Appendix I**). In short, the feasibility study was based on the functionality, sustainability and temporality of the idea (see **2.1 Project aim** for an explanation of these terms) and on the SMART criteria (Specific, Measurable, Achievable, Relevant and Time-bound). The feasibility of the three ideas was presented at Bureau Marineterrein and one idea was selected: Swimming in the Basin.

Phase 3 - Development We developed and expanded the concept idea of swimming in the basin by consulting experts and reviewing scientific literature and public reports (see **3.2 Stakeholder Analysis**).

Phase 4 – Implementation We demonstrated a pilot of our idea on the open day of Marineterrein on July 3rd 2016, in the form of a swimming competition and the placing of underwater gardens and an information panel. In addition, we performed a small survey among the swimmers and other visitors of the open day.

Phase 5 - Project Evaluation A small part of the evaluation is incorporated in the survey we performed at the open day. In addition, we reflected on the project by giving a final presentation to our client Bureau Marineterrein on July 13th 2016. We gave feedback to our client and received feedback from them about the content and work.

2.3 Deliverables

In this project, we aim to attribute to the sustainable use of water in Amsterdam through the realization of a swimming spot at Marineterrein. The deliverables in this project consist of two parts: The first part is the current report. The second part is the pilot, consisting of a swimming demonstration, underwater gardens, an informational panel, and a small survey amongst the visitors of the open day of Marineterrein. The survey provides insight in the views and opinions of the swimmers and other visitors of Marineterrein on open water swimming, information and ecology.

First, the current report provides a comprehensive explanation on (the creation of) swim spots in Amsterdam, ecosystem services, and the provision of water-quality related information to the citizens of Amsterdam, including specific recommendations to our client. There is a focus on aspects involved in the creation of a natural swim spot at Marineterrein, including the legislation and regulations, due to special interest of our client.

Second, on the open day of Marineterrein on July 3rd 2016, a swimming demonstration was organized. The swimming demonstration was meant to draw attention to the basin of Marineterrein as possible swimming location in the future. In the preparation for the swimming competition, the rules and regulations regarding the creation of a swimming location were investigated. Furthermore, the water quality was, and continues to be, measured every two

weeks by *Waternet*. In addition, *Waternet* cleared the bottom of the basin of all debris, and the floating debris on the water surface was removed. By promoting the swimming competition on social media, the website of Marineterrein, among friends, and through swimming clubs in Amsterdam, a start was made to put the basin of Marineterrein on the map as a natural swimming location.

In addition as part of the pilot, three underwater gardens were placed in the basin of Marineterrein, including water quality-improving plants. Furthermore, the underwater gardens entail plants that add oxygen to the water, introducing an artificial habitat for plants and fish in the basin of Marineterrein. Since the underwater gardens are easily moved, they can function as an example of how new habitats can easily be placed in a variation of locations, offering new nature to an area and raising awareness for aquatic ecology and water quality.

As final part of the pilot, the information panel located at the side of the basin at Marineterrein, provided information on swimming and its related risks in urban open waters, water- and bottom quality, and ecology of urban waters. It appears that knowledge amongst city inhabitants on urban waters, as well as the causes and effects of water-, bottom-, and ecology quality, is limited. Therefore, by providing this information, it was aimed to enable (open water) swimmers to make a responsible and educated choice whether or not to dive into open water in the city. By doing so, the importance of a good water quality in urban waters and the importance of sustainable water use are pointed out.

3. Swimming

3. Swimming

3.1 Swimming in urban waters in Amsterdam

Amsterdam has five officially assigned swim spots at the outskirts of the city. These are Sloterplas, Gaasperplas, Amsterdamse Bos (speelweide), Nieuwe Meer en de Oudekerkerplas.[24] Furthermore, just outside of the city borders, official swim spots can be found at Diemerpark and Twiske.[24] For people living in the city centre it takes some effort to reach these spots. As an example: an inhabitant of *Kattenburg*, the district where Marineterrein is located, needs about half an hour by bike or tram to reach the nearest official swim spot (Diemerpark strand). Interestingly, a survey amongst 1040 Amsterdam inhabitants showed that only 11% of respondents knew at least one of these official spots.[25] However, 21% of all respondents indicated to swim in natural surface water in Amsterdam, including non-official spots such as the Amstel river or IJ; 5% of all respondents even indicated to occasionally swim in the canals of Amsterdam. The main reason to do so is, according to the respondents, to seek refreshment during hot weather. According to the respondents, this is rather done in surface water than a swimming pool with chlorine. Another reason to swim in natural surface water, given by the respondents, is that it is free of charge.[25]

The board of mayor and alderman of Amsterdam want to respond to the outcomes of the above mentioned survey by increasing the number of official swim spots. This plan fits with the vision regarding water creation, which was written down in the report *Watervisie 2040 Amsterdam.*[23] This report mentions the ambition to ensure the optimal and sustainable utilization of the water and a good organization of the increasing use of water. This is aimed by making the waters of Amsterdam more accessible and liveable, and by promoting the use of water more spread across the city and region.[23] As the ability to swim in the waters of Amsterdam makes the water both accessible and liveable, swimming is deliberately included in the report.[23]

The harbour of Marineterrein, located in the centre of Amsterdam, with a stunning view over the Maritime Museum (*Scheepvaartsmuseum)* and Science Museum Nemo, is a perfect location for a new swim spot. Therefore, in this chapter, an overview is given of who is involved in the development of a swim spot (see **3.2 Stakeholder analysis**), what is (legally) required for an official/non-official swim spot (see **3.3 Laws and regulations swim spot in natural surface water**), and other aspects that were considered while investigating the realisation of a swim spot. These are water and sediment quality in Amsterdam and specifically at Marineterrein (see **3.4 Quality indications for natural swim spots**), and potential health risks of swimming in

natural surface water in general and at Marineterrein specifically (see **3.5 Health risks related to swimming in surface water**).

3.2 Stakeholders analysis

Based on conversations with experts, and laws and regulations regarding swim spots in natural surface water (see 3.3 **Laws and regulations swim spot in natural surface water**), several stakeholders can be identified (see **Table 1**.). First of all, the users of the swim spot, swimmers that swim in natural surface water, are acknowledged. The creation of a swim spot has the purpose to serve the needs of these swimmers. Furthermore, authorities that are responsible for (the creation of) official swim spots are identified. These are the province of North-Holland (*Provincie Noord-Holland*) and the water board of Amstel, Gooi and Vecht (AGV, *Waterschap Amstel, Gooi en Vecht)*. Additionally, parties that are involved with both official and non-official swim spots are *Waternet* (executing AGV policy), the municipality of Amsterdam and, in the scope of this project, our client Bureau Marineterrein.

The temporary absence of a strict allocation plan at Marineterrein means that there can be experimented with different ways of using the area, for example the creation of a swim spot. However, the basin of Marineterrein forms a grey area. Marineterrein, including the basin, is owned by the state (*Rijksoverheid*) and the municipality of Amsterdam. On the other hand, *Waternet* (a semi-governmental organisation) claims to be responsible for water management in the basin, insinuating that *AGV* is owner of the waters surrounding Marineterrein, including the basin.[26] The responsibility and possession of the water in the basin by either stakeholders could have consequences for the decisions for the final utilization of the basin. After conversations with both Bureau Marineterrein and *Waternet,* it appeared that Bureau Marineterrein should be the initiator of the swim spot, and therefore should choose which type of swim spot they think would fit Marineterrein (see for an explanation of the different types of swim spots **3.3 Laws and regulations swim spot in natural surface water**). *Waternet* should only be responsible for the water quality measurements, and the clearance of the debris of the bottom of the basin. In the process of this project, this way of collaboration seemed satisfactory. The exact responsibilities of the stakeholders are elaborated on in the next section (see **3.3 Laws and regulations swim spot in natural surface water**).

Table 1. Overview of stakeholders, their organisation's role and their provided information/interest in swim spots in natural surface water, specified for Marineterrein.

Stakeholder	Personal role	Organization	Organizations' role	Provided information/Interest
Swimmers in natural surface water	Users	-	-	37 % of inhabitants swim in natural surface water in and around Amsterdam. About 5 % swims in Amsterdam' canals.[25]
Anikka Fulop and Daniëlle Willemse	Client	Bureau Marineterrein	Initiator swim spot	Want to investigate options for a swimming spot at Marineterrein (but not an official swim spot), and implement it.
Christine Kolster	Waterrecreation program - policy employee	*Provincie Noord-Holland*	Monitoring assigned swim spots, assigning new spots and providing information about these spots.	Only three categories of swim spots: a) official assigned spots, b) non assigned spots that people swim at c) spots where it's inhibited to swim. The province orders to check the water quality and the physical safety at official assigned spots.
No contact	-	Water board *Amstel, Gooi en Vecht (AGV)*	Policy making and water management. Policy is executed by *Waternet*.	*All information needed from AGV was obtained through Waternet.*
Maarten Ouboter	Responsible for Water quality in Amsterdam' canals	*Waternet*	Executive water management (commissioned by province/AVG). Checks water quality of assigned and potential spots.	*"It's not allowed to facilitate swimming* [without the responsibilities]*, but it is allowed to inform people about water quality."*
Joost Stoffels	Watersystem analyst	*Waternet*	"	Water quality data at Scheepvaartmuseum (2011 - 2015) and Marineterrein (2016)
Liesbeth Hersbach	Projectleader Water system control	*Waternet*	"	Requirements for water quality at official swim spots.
Rob Duijvis	Senior administrator (nautical terms) - mostly event related	*Waternet*	"	-

Hans Glaubitz (D66), Marianne Poot (VVD), Nelly Duijndam (SP)	Councillors of Amsterdam	Municipality of Amsterdam – Town council	Highest governing body of the city consisting of elected representatives making policy.	Initiative "*Zwemmen op Marineterrein*"[27]
Tahira Limon	Focusteam-Zwemmen	Municipality of Amsterdam – Focus team Swimming	Focus team swimming aims to increase the number of official swim spots, and looks for ways to adjust non-official swim spots to official swim spots.	The municipality of Amsterdam has a pragmatic view on the existence of non-official swim spots and recognizes them, contrary to national regulations.

3.3 Laws and regulations swim spot in natural surface water

Regarding swimming in natural swim water in the Netherlands, there is legislation on an international, national and local level (see **Table 2**).

Table 2. Overview laws and regulations regarding natural swimming water in the Netherlands. Laws and regulations depicted in **bold** are mentioned in the text. Table based on *Plan van Aanpak Zwemwater Noord-Holland 2007.*[28]

Level	Laws and regulations
International	• **Zwemwaterrichtlijn (2006/7/EG)**[29] • Kaderrichtlijn Water

National	• **Wet hygiëne en veiligheid badinrichting en zwemgeledenheden (Whvbz)**[30]
	• **Besluit hygiëne en veiligheid badinrichting en zwemgeledenheden (Bhvbz)**[31]
	  ○ **Hoofdstuk IV (Categorie C, badinrichting)**
	  ○ **Hoofdstuk V (Categorie D, zwemgelegenheden)**
	• **Werkboek Bhvbz**[32]
	• **Protocol aanwijzen en afvoeren van zwemlocaties (2009)**[33]
	• Wet verontreiniging oppervlaktewater
	• Wet op waterhuishouding
	• Besluit kwaliteitsdoelstellingen en metingen oppervlaktewater
	• NW4; 4e nota Waterhuishouding

Local	• Nationaal Waterplan 2016-2021 • Waterbeheersplannen

On European level, the directive for swimming water (*Zwemwaterrichtlijn,* 2006/7/EG) has the goal to protect the health of swimmers and aims to improve swim water quality and the provision of information to swimmers.[29] An important aspect of this regulation is that swimming in natural surface water is allowed everywhere, unless explicitly prohibited.[29]

On national level, laws and regulations are formulated to accommodate the European swimming water directive. For example, according to the law for hygiene and safety of bathing and swimming facilities (*Wet hygiene en veiligheid badinrichting en zwemgelegenheden,* Whvbz)),

Dutch provinces are responsible to assign swim water locations and withdraw locations when necessary.[30] The Whvbz and its according decree (*Besluit hygiene en veiligheid badinrichting en zwemgelegenheden,* Bhvbz) categorize swim spots into categories of 'human made' swimming pools (*Category A* and *B*) and 'natural' swimming pools (*Category C* and *D*).[31] *Category C bathing facilities (*Bhvbz, chapter IV, art. 34-43) are swim spots accommodated for swimming in surface water, with structural facilities such as showers, toilets, etc. and sufficient water quality (see **Table 3** and **Appendix II** for water quality requirements). *Category D swimming facilities (*Bhvbz, chapter V, art. 44-44-g) are locations used by a considerable amount of people to swim, but there are no or barely facilities provided.[31,32] The law provides no basis for safety requirements for this latter category, except for the requirement of sufficient water quality (see **Table 3** and **Appendix II**).[30] However, the same law (art. 10b) states that the province does have the responsibility to investigate the (physical) safety at *Category D* spots on a yearly basis, and if necessary has to inform the public about the safety regarding possible dangers.[30]

Table 3. Most important requirements of swim spots in surface water (Bhvbz , chapter IV, V).[31]

Category C - Bathing facilities	Category D - Swimming facilities
• Water quality is regularly checked and proven sufficient (for requirements, see **Appendix II**). In case the water quality is insufficient, a prohibition to swim should be imposed. • Slipperiness is prevented. • Sufficient supervision (operators' own judgement). • One toilet for every 150 visitors. • Clear boundaries of the swim area. • If depth is < 1.40 m. the steep of the bottom is < 0.06 m per meter • If depth is < 1.40 m. there are no facilities to jump. • If depth is > 1.40 m. but < 2.00 m. only starting blocks are allowed.	• Water quality is regularly checked and proven sufficient (for requirements, see **Appendix II**). In case the water quality is insufficient, a prohibition to swim should be imposed. • A yearly (physical) safety inspection at the swim spot by the province (Whvbz, article 10b)[30].

The law and the according decree are unclear about how *Category D* is enforced in practice, as it seems to have contradicting statements regarding safety requirements; the law provides no basis to require safety demands, but a yearly inspection must be done and must be acted to accordingly. Moreover, the Bhvbz states that the water quality of both *Category C* and *D* swim spots should regularly be checked, but 'regularly' is not specified in the document.[31] A revised Bhvbz with updated regulations was expected in January 2016, but the revision is postponed for unclear reasons.

For practical interpretation of the Whvbz and the Bhvbz, a handbook was written to support the Bhvbz.[32] Both Bhvbz and the handbook for the Bhvbz provide norms for the water

quality of natural surface water for swimming (see **Appendix II**). The Bhvbz has less strict norms than the handbook provides, as the Bhvbz does not mention any bacterial norms (see **3.4.1 Water quality in Amsterdam**) and mainly focuses on visible aspects such as colour, smell, foam, oil and garbage. In practice, authorities such as *Waternet* act according to the handbook and thus include also bacterial norms, to monitor health risks for swimmers as well.[34]

On a local level, water authorities (*Waterschappen*) and the government department of public works and water management (*Rijkswaterstaat*) are responsible for monitoring the official swim water locations. Furthermore, they make swim water profiles that are required for official assigned swim spots.

3.3.1 Regulations in practice

In practice, *provincie Noord-Holland* does not use the categories of the Whvbz, although this is only communicated after asking specifically about the categories of the Whvbz.[35] The reason why these categories are not used remains unclear, but instead of using the categories with its ambiguous requirements, a pragmatic policy is used.[36] The policymaking institutions (province and water board) and executive institution (*Waternet*) therefore use only one category: the official assigned natural swim spots.[37] At these official swim spots, *Waternet* regularly measures the water quality and checks all other safety requirements. The water quality norms for official swim spots that are used by *Waternet* are based on the European swimming water directive (*Zwemwaterwet*).[29] For the province, non-official swim spots are not covered by the law Whbvz, consequently safety is not monitored.[35]

There are two ways for a location to become an official swim spot: 1) When it is initiated by for example an entrepreneur, municipality or project developer; 2) When it is a 'wild' swim spot often used by swimmers. In both cases, the province starts the protocol to assign or reject swim locations (see **Table 2.**).[33] In the first case, when a swim spot is initiated, the protocol states the following regarding the responsibilities of the initiator (summary, adapted from the protocol)[33]:

> The initiator of a new swim spot (e.g. entrepreneur, municipality or project developer) will have to do research whether the norms for swimming water will be reached on a structural basis. The steps that need to be taken are described in '*Protocol aanwijzen en afvoeren van zwemlocaties*'.[33] If necessary, the initiator has to provide (furnishing-) measures, such as infrastructure, safety, hygiene and water quality. Only when these criteria have been met, a swim spot will be allocated as such, and/or the function of swimming water is assigned to the water. After the allocation to the swim spot and the assignment of swim water to the water, the Whvbz is leading to divide the responsibility with respect to e.g. monitoring and actualising the swim water profile, taking managing measures, control of safety and hygiene, and enforcement of the Whvbz and its according Bhvbz.

The regulations will have consequences for 'wild' swim spots in the centre of Amsterdam. Once the protocol to assign or reject swim locations is started, the water quality will have to prove sufficient. If the potential swim spot (initiated or 'wild) cannot meet all the requirements, it will become prohibited to swim at the spot, according to the protocol.[33] In practice, the water quality in the canals of Amsterdam often cannot meet the strict requirements to become an official swim spot (see **3.4.1 Water quality**). Consequently, it will eventually become prohibited to swim at these 'wild' swim spots.

The strict protocol that leads to an increasing number of spots where it is prohibited to swim forms a complicated issue for *Waternet*, the municipality and the province. There are many 'wild' swim spots in Amsterdam, and the wish from inhabitants as well as authorities is to increase the number of safe 'wild' swim spots, not increase the number of spots where it is prohibited to swim. It is a challenge for authorities to find a juridical and practical solution to this problem, for example by making exceptions for these locations or formulate new legislation and regulations for the realisation of more official of non-official swim spots.

Waternet has assigned Marineterrein as a potentially nominee for an official assigned swim spot, in line with the protocol.[26,33] For Marineterrein, this might have the consequence that it will become prohibited to swim, if the water quality cannot meet the requirements. Nevertheless, once there is a juridical solution for the legislative challenge, Marineterrein could function as a test location to facilitate non-official swim spots.

3.4 Quality indicators for natural swim spots

3.4.1 Water quality in Amsterdam

An important and basic requirement of swimming in natural surface water is a sufficient water quality that is not a risk for the health of swimmers. As described above (see **3.2 - 3.3**), *Waternet* monitors water quality of official assigned swim spots, but also at non-official swim spots that potentially will be nominated as official swim spots (based on the protocol).[33] The requirements for good water quality for *Category C - bathing facilities* and *Category D - swimming facilities* of the Whvbz can be found in **Appendix II**.

The requirements that *Provincie Noord-Holland* and thus *Waternet* use in practice (based on European *Zwemwaterrichtlijn*) are firstly addressing faecal contamination. The swim water parameters (levels of pathogenic faecal bacteria) that are measured by *Waternet* can be found in **Table 4**.

Table 4. Norms for different quality categories for natural surface water for intestinal Enterococci and *Escherichia coli* (adapted from *Zwemwaterrichtlijn*).[29]

Parameter	Excellent quality	Good quality	Acceptable quality	Warning threshold (***)	Reference-methods for analyses
Intestinale enterococci (kve/100 ml)	200 (*)	400 (*)	330 (**)	400	ISO 7899-1 or ISO 7899-2
Escherichia coli (kve/100 ml)	500 (*)	1000 (*)	900 (**)	1800	ISO 9308-3 or ISO 9308-1

(*) Based on rating on the 95-percentile of the probability distribution. See *Zwemwaterrichtlijn* Appendix II[29].
(**) Based on rating on the 90-percentile of the probability distribution. See *Zwemwaterrichtlijn* Appendix II[29].
(***) When warning threshold is exceeded, a negative swim advise (at official swim spots) is given by Waternet.

Official assigned swim spots need to have at least 'Acceptable quality'. Swim water is categorized 'Bad quality' when a series of swim water quality measurements is worse than the 'Acceptable quality'. Furthermore, the warning threshold is given that *Waternet* uses for measurement values for one time point (see **Table 4,** 5th column). When the values exceed the warning threshold, a negative advice to swim is given. When the measurement value no longer exceeds the threshold, the negative advice to swim is withdrawn.

Large fluctuations of measurement values at different time points result in an unstable measurements series and thus a large standard deviation from the mean measurement value. This has consequences for the measurement outcome, as calculated by the 90-percetile or 95-percentile using the mean and standard deviation. With high fluctuations, the mean concentration is more likely to exceed the norms. In simple terms, a requirement for an official swim spot is thus a stable water quality, verified by a low standard deviation.[26] One explanation for fluctuations of measurement values could be the temperature of the water. Bacterial growth is faster at higher temperatures. When *Escherichia coli* is present in the water, populations of *E. coli* rise with increasing temperature. [38] Another explanation for the fluctuations is the possible overflow of the sewage system after heavy rainfall. When the sewage system cannot handle all the incoming rainwater, *Waternet* operates overflows that drain excessive sewage into the canals. Sewage can contain human faeces, so consequently measurement values of faecal bacteria rise quickly. When this happens, *Waternet* advises to not swim in affected water for at least three days.[35]

3.4.2 Water quality at Marineterrein

W*aternet* has gathered data of the concentrations of *E. coli* and intestinal Enterococci at two locations surrounding Marineterrein (see **Figure 3.** for the locations on a map). One location is west to *Scheepvaartmuseum* (Oosterdok, measurement location OOD002, X-coordinate: 122713, Y-coordinate 487143) and in the *Nieuwe Vaart* (Nieuwe Vaart, measurement location ADM061, X-coordinate: 123099, Y-coordinate: 486928). The data, gathered since July 2011, shows that the measured concentrations of intestinal Enterococci have never exceeded the norm of 400 Colony Forming Units (CFU) per 100 ml (see **Figure 4.**). The concentrations of *E. coli* have exceeded the norm of 1800 CFU per 100 ml during two measurements (at ADM061 on July 25th 2011; at OOD002 on August 15th 2015). These measurements were done during summer months, when it is the largest change to find high bacterial concentrations. For previous years, most of the time only small bacterial concentrations were found, far below the norm. However, only three measurements per location per year were carried out, so generalization of the interpretation of the data must be careful. Furthermore, these measurements can only be taken as an indication of the water quality of the water surrounding Marineterrein.

Since April 2016, *Waternet* has started gathering data in the basin of Marineterrein. From the data in these graphs it is visible that the concentration of *E. coli* has exceeded the warning threshold by 39% on May 23rd 2016 (see **Figure 5.**).. All other measurements of *E. coli* and intestinal Enterecocci concentrations were far below the warning threshold. These measurements were at most taken once every two weeks, and not at a set time point during the day. Taken into account that there are fluctuations of bacterial concentrations in the water, the translation from these outcomes to general water quality must be done carefully. Furthermore, the collection should continue further at Marineterrein to be able to draw firm conclusions regarding the water quality, as there have only been five time points of the data collection so far.

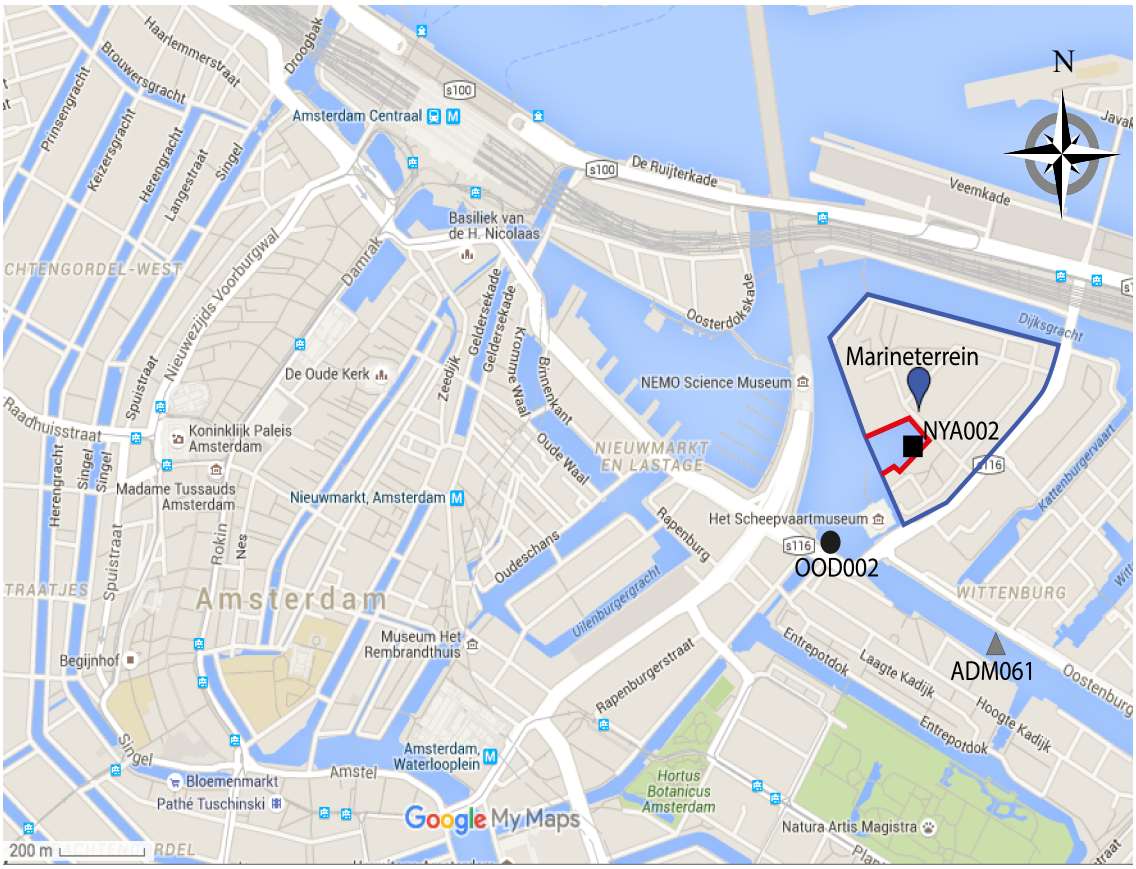


Figure 3. Map of the east centre of Amsterdam. For orientation: in the middle the entry of the IJ-tunnel, top left the central station, Marineterrein is delineated by blue and the basin by red. Three measurement sites are by figures, OOD002 (black cirkel) (x:122713, y:487143) right from the entrance of the IJ-tunnel, on the right ADM061 (grey triangle) (x:123099, y:486928) on the Nieuwe Vaart, and in the basin of Marineterrein NYA002 (black square) (x:122924, y:487333). *Data acquired from Waternet*

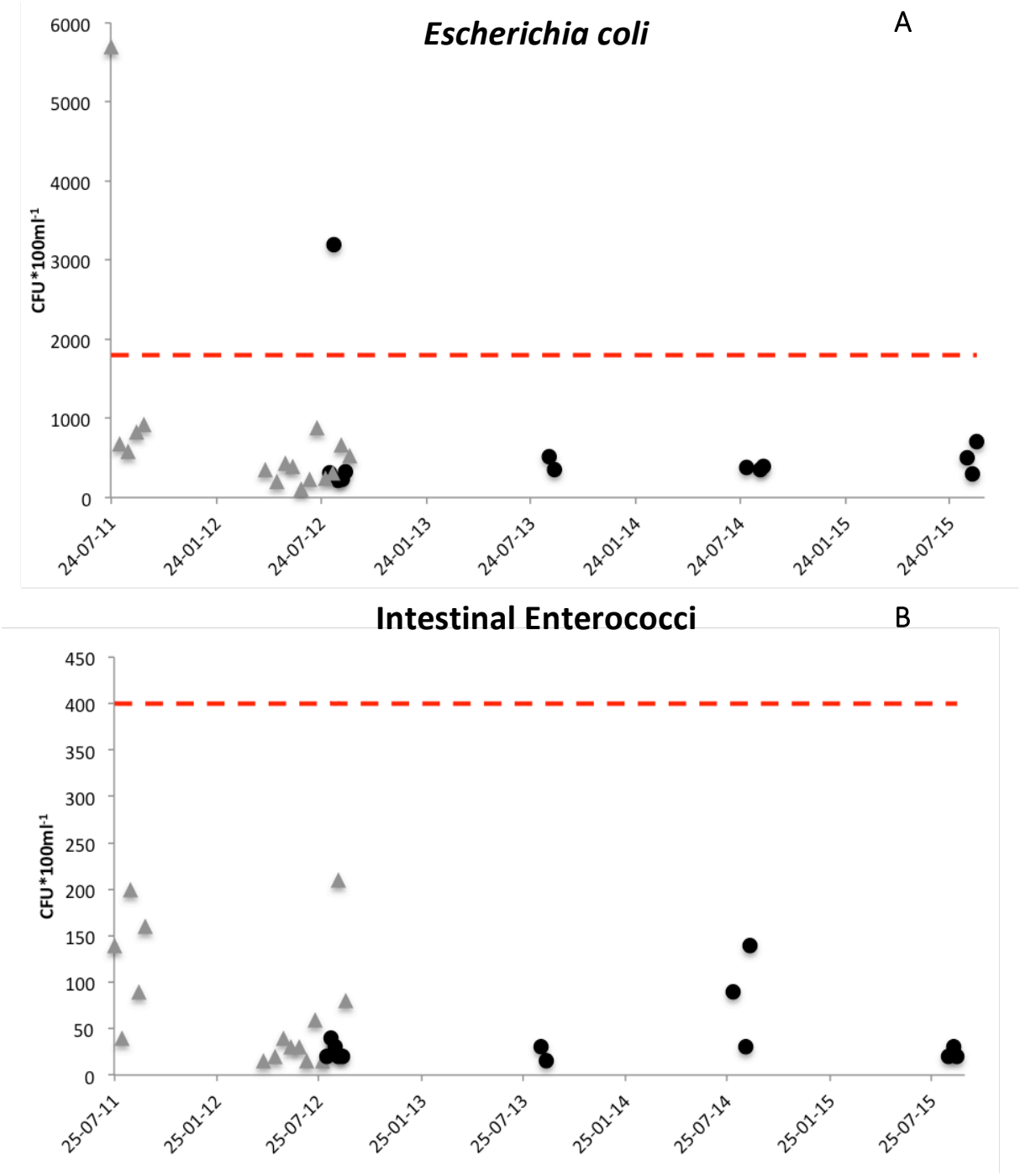


Figure 4. Measurements of concentrations of E. coli (n=30, A) and intestinal Enterococci (n=28, B) on location from 2011 until 2015 OOD002 (black dots) and ADM062 (grey triangles) with the warning threshold (red dotted line). Bacterial concentrations as Culturing Forming Units (CFU) (Kolonie Vormende Eenheden, KVE) per 100 ml. *Data acquired from Waternet*.

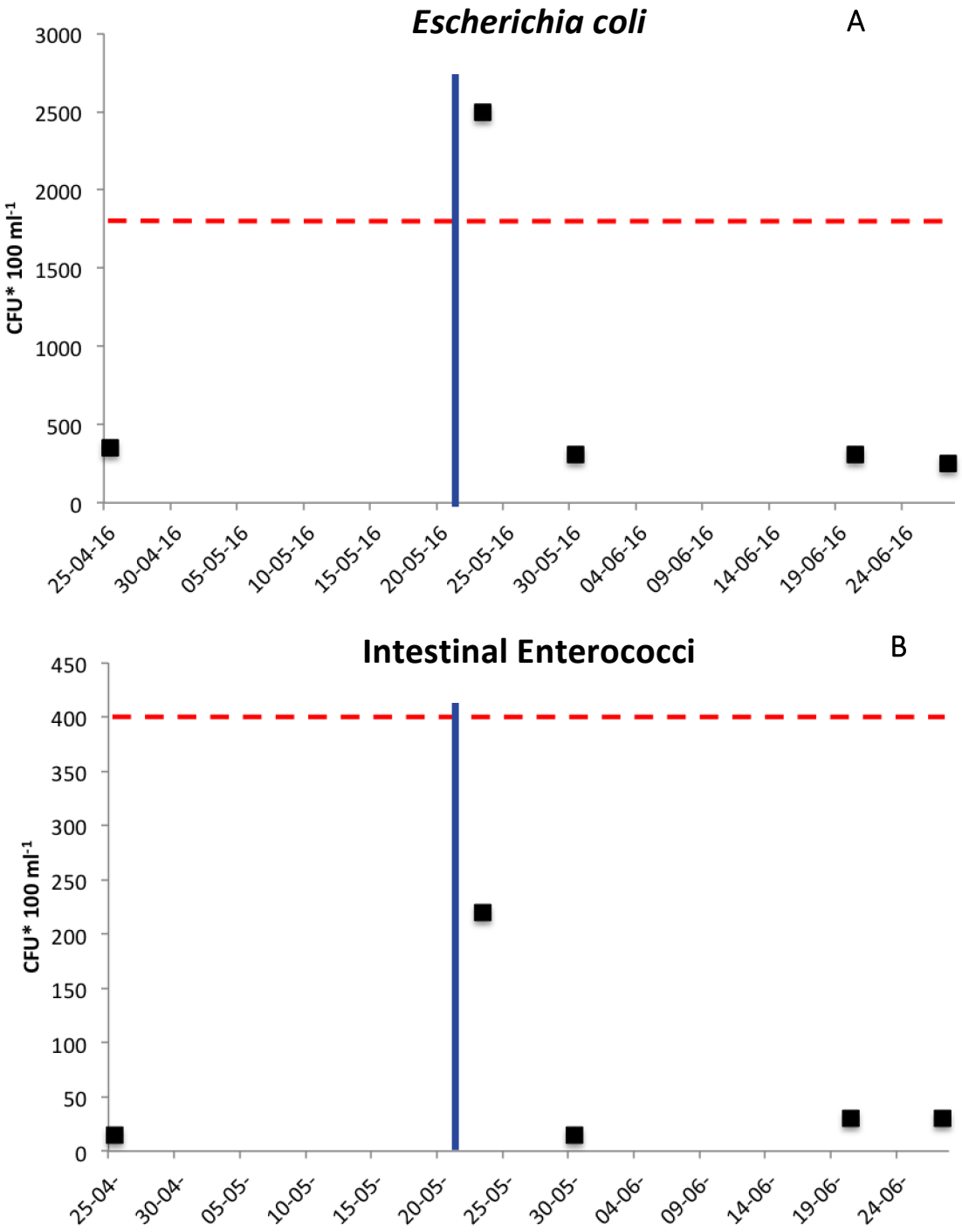


Figure 5. Measurements of concentrations of *E. coli* (n=5, **A**) and intestinal Enterococci (n=5, **B**) in the basin of Marineterrein (black squares) with the warning threshold (red dotted line). The blue line represents a day of heavy rain fall (see Appendix VIII). Bacterial concentrations are represented on the y-axes as Colony Forming Units (*Kolonie Vormende Eenheden, KVE*) per 100 ml. On the x-axes the dates are presented. *Data acquired from Waternet.*

3.4.3 Sediment quality at Marineterrein

To protect the city centre of Amsterdam (inside the highway ring A10) from the sea, the centre was built on a heightening layer, which contained contaminated heavy metals.[39] Especially the heavy metal lead is a problem, as it is diffuse throughout the soil.[39]

The area of Marineterrein has changed over the centuries, as it used to have an open connection to the Southern sea (*Zuiderzee*) in the 16th century. Over time, the area evolved, as land was reclaimed from the water, and the area of Marineterrein expanded. The final radical change was in 1962, when the IJ-tunnel was build. With the sediment from the tunnel, Marineterrein was formed to its current size. From (terrestrial) soil investigations, it can be concluded that Marineterrein was intensely used as shipyard throughout the centuries.[40] Soils that hosted shipyards are often polluted with tar and mineral oil, which can be seen in **Figure 6.** This soil quality map shows that the quality of the soil at Marineterrein is categorized as moderately contaminated.[41,42]

The basin of Marineterrein is relatively deep, with an average of about 3.5 meter (see **Figure 7.**). However, there is no (publically available) data on the exact composition of the sediment and potential contamination at Marineterrein. Furthermore, the artificial creation of land throughout the centuries makes it difficult to determine the exact sediment composition in the basin of Marineterrein on basis of archival research. Due to the lack of data regarding the sediment, the preliminary and generalized conclusion is drawn that the sediment, like the soil, is moderately contaminated.

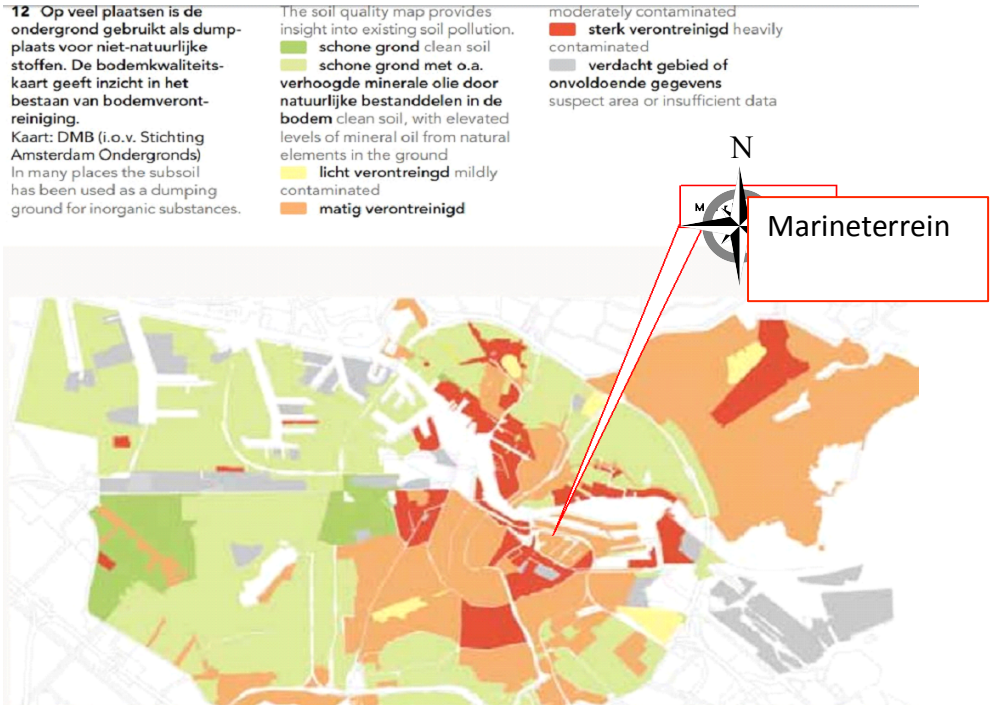


Figure 6. Soil quality map of Amsterdam. Marineterrein is moderately contaminated (orange) (adapted from [42]).

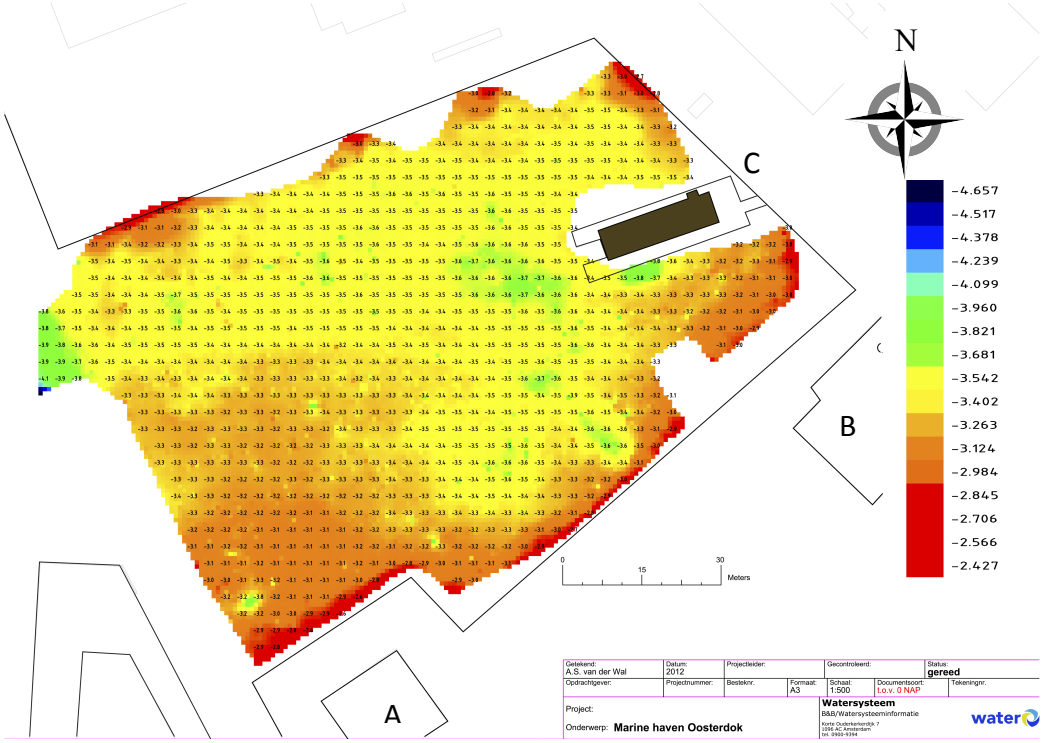


Figure 7. Map of water depth in the basin of Marineterrein relative to Amsterdam Ordance Level (AOL, in dutch: Normaal Amsterdms Peil). The average water level in the canals and the river IJ surrounding the center are -0.4m relative to AOL. Therefore, the approximate average depth is 3.5 m. With Bureau Marineterrein (A), Pension Homeland (B) and the pier of the navy (C). Data from Waternet.[34]

The question remains what should be done about the (aquatic) sediment quality. The policy of the municipality of Amsterdam regarding remediation of contaminated soil and sediment used to be sanitation of it. However, current policy is transitioning from sanitation to controlling: what is clean must remain clean, and what is contaminated should not become more contaminated.[43]

For the creation of an official assigned swim spot, the decision to remediate contaminated sediment is based on 3 types of risks: human risks and/or ecological risks and/or the risk of spreading the contamination.[44] The health risks of swimming in the basin of Marineterrein regarding the sediment quality are discussed in **3.5.1 Health risks of swimming in the basin of Marineterrein.** An investigation of the quality of the sediment at the basin should be carried out together with the consideration of the risks, before deciding whether or not remediation of the sediment is necessary at Marineterrein. This investigation should contain a prior investigation, which consists of the request of all relevant information at involved parties, a terrain inspection and archival research, regarding previous, current and future use (using protocol NEN5717[45]). Hereafter, a chemical analysis of the sediment should be done (using protocol NEN5720[45]).

3.5 Health risks of swimming in surface water

Swimming in surface water comes with certain potential health risks. Surface water naturally contains many different species of micro-organisms. Some of these could cause human health complaints. Furthermore, pathogens can be found in natural surface water from (amongst others) faecal pollution from human or animal origin, as was previously described (see **3.4.1 Water quality in Amsterdam**).[46] For an overview of pathogens (some more frequent than others), see **Table 5.** Other potential harmful substances that can be found in the sediment or in the water, such as chemicals and heavy metals (e.g. lead), could form a health risk, dependent on the severity of contamination of the sediment and the concentration in the water.

Table 5. Surface water related health complaints, described by the name of the disease, the pathogen, the transmission and the symptoms (adapted from '*Handleiding Zwemgelegenheden: Duik er eens in*'[46]).

Disease	Pathogen	Transmission	Symptoms
Several illnesses caused by **Cyanobacteria**	Cyanobacteria or blue-green algae (bacteria).	Water looks like a 'green soup'. High concentrations of toxics in floating layers of Cyanobacteria, often in stagnant water.[47]	Getting in contact with the toxics can cause headaches, skin irritation, nausea, diarrhoea and fever.
Botulism[48]	The thermo labile neurotoxin of *Clostridium botullinum* (bacteria). The most common type of botulism (type C) is not dangerous for humans.	Contact with dead water birds and fish, or in contact with infected water. In the Netherlands, the change of infection is very small.	First symptoms arise 4-14 days after infection. This starts with nausea, vomiting, tiredness, dizziness, a dry mouth and abdominal complaints. Other symptoms can follow. It is recommended to see a doctor.
Swimmer's itch	*Trichobilharzia* and *Gigantobilharzi* (*parasite*) multiplying via water snails.	These water snails can be present in submerged vegetation.	Itchy skin irritation with red bumps. After a couple of days the irritation will disappear.
Leptospirose[49] (*Ziekte van Weil*)	*Leptospira (*bacteria)	Transferred via rat's urine that contaminates surface water. In the Netherlands, the change of infection is small.	First symptoms arise between 5 to 10 days after infection. Initial symptoms are similar to flu (acute high fever, cold shivers, headache, red eyes, back pain, myalgy). Due to the seriousness of the illness, it is recommended to see a doctor.
Ear infection	*Pseudomonas aeruginosa* (bacteria), naturally occurring in water.	Increased change of infection with water temp. of 18'C or higher or with increased sensibility for ear infection.	Itch, earache, exudation and temporary hearing loss.

Gastrointestinal disturbances *(Maag-darm stoornissen)*	*E. coli* and intestinal Enterococci (bacteria), faecal bacteria from human or animal origin.	After heavy rainfall, sewage system overflow into the canals, leading to contamination of surface water. Furthermore, concentrations of faecal bacteria increase with rising water temperature.	Swallowing contaminated surface water can lead to gastrointestinal disturbances, such as spasms of the stomach, nausea, vomiting, fever and diarrhoea. Duration ranges from a couple days to the maximum of a week.

3.5.1 Health risks of swimming in the basin at Marineterrein

The current largest health risk of swimming in the basin at Marineterrein is the swallowing of water contaminated with faecal bacteria, which causes gastrointestinal disturbances (see **3.5 Health risks of swimming in surface water**).[26,34] Swallowing water only forms an enlarged risk when large faecal bacteria populations are present in the water, for example after sewage overflow or higher temperatures (see **3.4.1 Water quality)**. Human populations that have a higher risk of getting sick after swallowing contaminated water, are children, elderly and pregnant women.[50]

Regarding the mildly contaminated sediment at Marineterrein (see **3.4.3 Sediment quality at Marineterrein**), health risks for humans who occasionally swim in the water are reduced to a minimum, because the concentrations of harmful substances are most probably low.[26] Moreover, swimmers will most likely not be able to disturb the sediment while swimming, as the average depth of the basin is 3.5 m., which considerably reduces the risk for health complaints. However, motorboats are able to disturb the sediment with their motors. In this way, suspended particles can end up in the water and thus potentially create a health risk for swimmers. The risks for health complaints might increase for very frequent swimmers.

3.6 Conclusion

3.6.1 Rejection of official swim spot

To become an official swim spot, the water quality has to be monitored for at least 2 years but usually for 4 years and at least be categorized as '*Aanvaardbaar*' (acceptable).[29] Marineterrein has been assigned to be potentially nominated for an official assigned swim spot by *Waternet*, in line with the protocol.[26,33] However, after investigation of the laws and regulations (see **3.3 Laws and regulations swim spot in natural surface water**), consulting expert opinions, and analysing the data of water quality at Marineterrein (see **3.4.2 Water quality at Marineterrein**), we concluded that creating an official swim spot at Marineterrein is not an option for the coming years.[26,34] First of all, the water quality in the basin of Marineterrein has fluctuating values of potential harmful bacteria in the water (see **Figures 4.** and **5.**). Consequently, the water quality is not stable enough (yet) for an official swim spot. Secondly, at

this moment our client would not like to create an official swim spot as they do not wish to have the responsibilities that accompany an official swim spot, such as providing infrastructure and safety. Furthermore, all projects will be reconsidered in 2018 when a new allocation plan at Marineterrein is assigned. This means that within this timeframe, taking the 4 years of needed monitoring into account, no official swim spot could be created at Marineterrein.

3.6.2 Creation of 'wild' swim spot

We concluded that an official swim spot was not an option at Marineterrein, at least not in the near future. Therefore we investigated other options to make swimming possible in the natural surface water of the basin at Marineterrein. As swimming is allowed everywhere, unless explicitly prohibited, and the water quality has been shown to be good enough most of the time, we figured that stimulating people to swim at Marineterrein and hence create a 'wild' (non-official) swim spot was the best option.[29] An important aspect of a non-official swim spot is the physical safety (for example prevention of accidents with protruding objects such as bicycle wrecks at the water bottom), and subsequently sufficient water quality. The sediment quality at Marineterrein is of a lesser concern for the creation of a non-official swim spot.

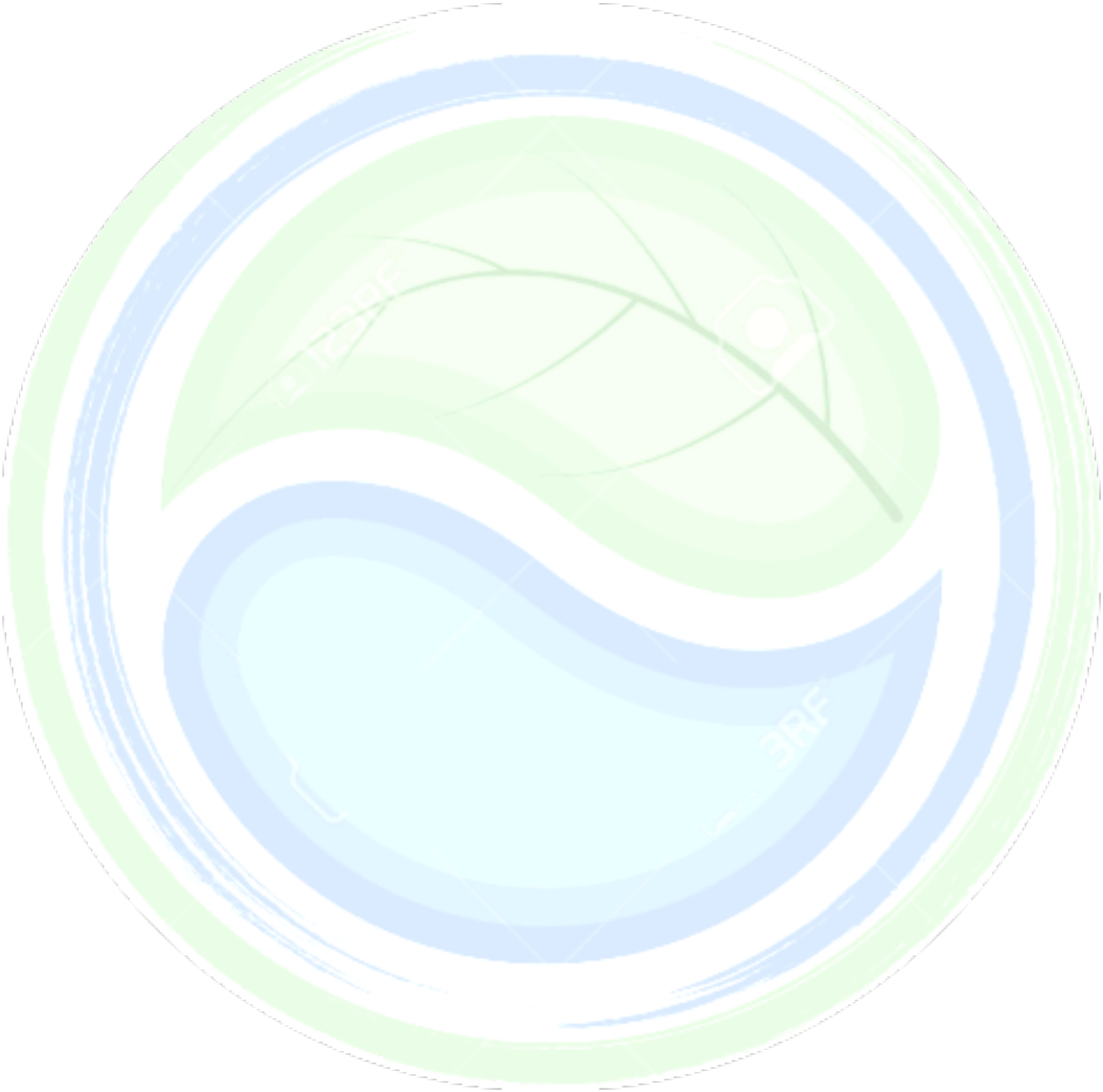
For people who want to swim at the non-official swim spot at Marineterrein, despite the assumed safety, information on the up to date water quality is needed to avoid health risks. Currently, there are websites that provide this information for potentially interested visitors of swim spots, for example zwemwater.nl.[24] This website provides quality marks for specific (official) swimming locations, and even shows full reports of *Swim-water profiles*. These profiles entail, amongst other things, all measurements that have been performed on the water quality. [29] Unfortunately, this information is only available for official swimming locations.

According to legislation, the authorities are responsible to guarantee the safety of the swimmers also at non-official locations.[31] The focus of the authorities is on direct dangers, meaning physical objects and not the chemical/biological water quality. In practice, water quality determents like *faecal bacteria* and Cyanobacteria, are not taking into account. These determents are one of the most important criteria to create an official swimming location but are neglected on the non-official places. The risks of the bacteria levels in the water surface are hard to quantify, as the implications of swimming in defiled water often are small health effects that aren't registered, like diarrhoea or infections, but worth to be recognized and known by the visitors of Marineterrein.

From conversations with Maarten Ouboter, we learned that the three governmental institutes (province North-Holland, water board AGV and municipality of Amsterdam) are open for creation of more non-official swim spots. How this should be done remains a grey area: it should be pursued by informing people about their safety and health risks, while on the other hand it is not allowed to facilitate swimming without having (legal) liability and responsibility.

Advising people (“Water quality is good enough to swim”) is thus not allowed, but informing people about the water quality is allowed (“The amount of bacteria in the water is low”).

A final point of concern is that Marineterrein is marked as a potential official spot by the province, but when the water quality turns out to be non-sufficient after four years of measurements, it will be prohibited to swim. This is the challenge authorities face in the coming years, as inhabitants of the city would like to have more safe ‘wild’, non-official swim spots. Marineterrein could function as a test location of facilitating non-official swim spots, once authorities have found a juridical solution for this challenge.



4. Ecology

4. Ecology

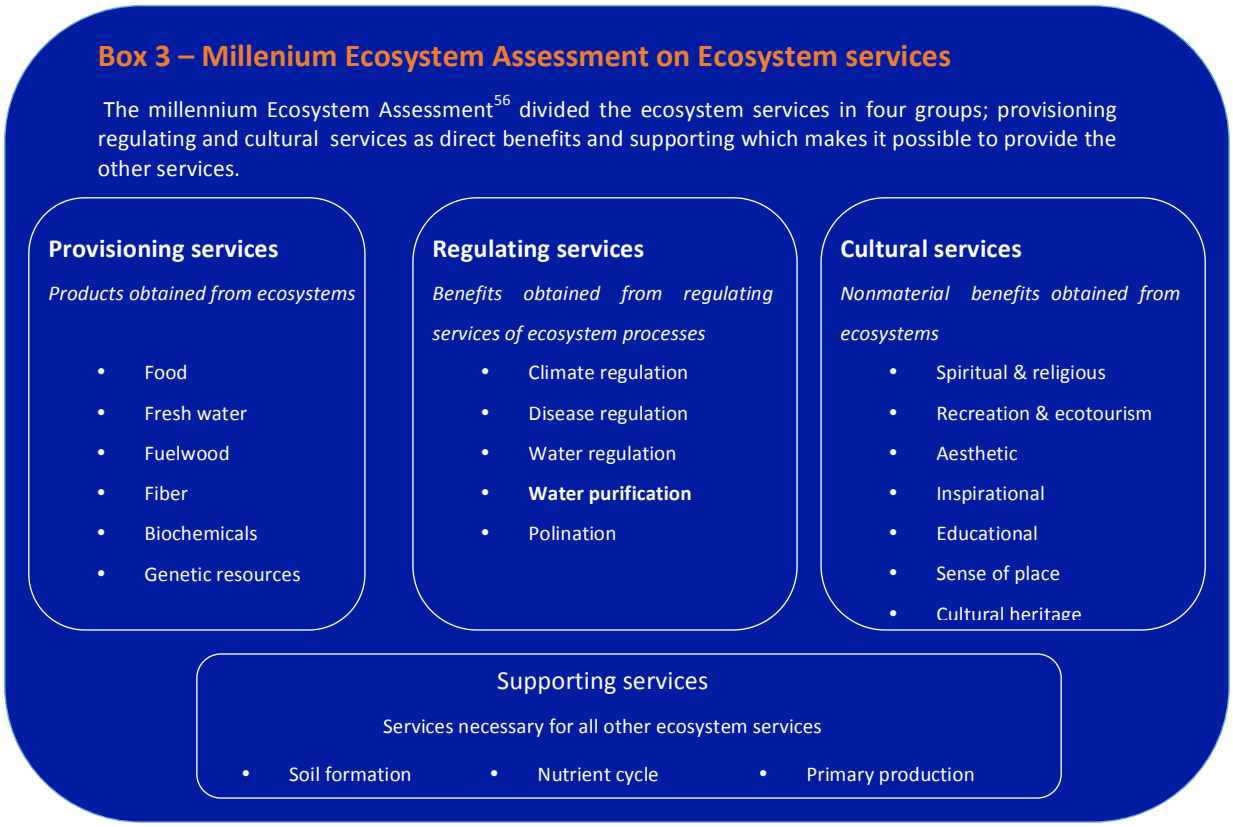
To improve the quality of urban water, and decrease the fluctuations of bacteria levels, several measures can be taken, including the use of ecology. The ability of plants to improve the water quality and at the same time increase the biodiversity, is already used by different urban applications, such as float lands. In this chapter, the concept of ecosystem services is explained, including the possibilities for the basin of Marineterrein.

4. 1 Importance of ecology

Ecology was first defined by Herewith Heackel in 1866 as: "*The entire science of the relations of the organism to the surrounding exterior world, to which relations we can count in the broader sense all conditions of existence. These are partly of organic, partly inorganic nature*".[51] In that time humans were not included in that description and ecology was therefore regarded as unimportant. This changed halfway through the 20th century when ecology got more attention in our society. Caused by a growing number of the world population, negative effects on nature became more apparent. [51] In 1958, K. Friederichs defined ecology as: "The science of the living beings as members of the whole of nature", in which he included humans.[51] Humans influence many biophysical processes on earth: from the depletion or contamination of water sources, to the removal of large areas of forest.[52] Since humans have a large impact on the environment, it is impossible to extract humans from ecology. So to work towards a more sustainable city it is important to recognize that ecology does not only exist outside the city but that ecology is also part of the city.

An important part of the study of ecology is about understanding ecosystems. Ecosystems can be described as "a set of interacting species and their local, non-biological environment functioning together to sustain life"[53]. By understanding and using the functions of ecosystems we can even profit from them, referred to as ecosystem services.[54] Ecosystem services are defined by Costanza et al. (1997) as *"the benefits human populations derive, directly or indirectly, from ecosystem functions"*.[55] In the Millennium Ecosystem Assessment (MEA) of 2005, ecosystem services are grouped into four categories: supporting, provisioning, regulating and cultural (see **Box 3.**).[56] In the MEA, it was stated that the last 50 years ecosystem services have changed all over the world. These changes contain gains and losses. The gains have been mainly on wellbeing of humans and economic growth but these gains for humans also created degradation of the ecosystem services.[56] This degradation brought risks to the human population because of the scarcity of food (provisioning) due to the depletion of fertile lands and the risk of flooding (regulating) of urban areas, due to the diminishing wetlands that could function as a buffer[56,57]. According to the MEA, the degradation involves the loss of biodiversity, which decreases the resilience of an ecosystem and increasing the likelihood of abrupt and

potentially irreversible changes.[58] This is also visible in city environments. In urban areas, ecosystem services can be used to help overcome problems, such as pollution by nutrient enrichments and other contaminant due to the water spills of cities or farmlands.[54]



4. 2 Functions of aquatic macrophytes

The functions of an ecosystem can be determent by the organisms it contains. The functions of these organisms provide services that we use. For example, wetlands are ecosystems where "*water is the primary factor controlling the environment and the associated plant and animal life*".[58] They can provide different ecosystem services such as supplying food, water purification, climate regulation, flood regulation, coastal protection, recreational functions and tourism[58,57]. These wetlands contain large varieties of aquatic organisms such as filter feeders (organisms that filter water for nutrition) and aquatic macrophytes (aquatic plants). A filter feeder with great potential regarding ecosystem services is the Quagga mussels. A short description of the developments concerning this mussel is given in **Box 4.** The remaining chapter will be focused on macrophytes.

Box 4 – Quagga mussel (*Dreissena bugensis).*

Other ways of removing particles from the water body is the use of aquatic filter feeders, such as the *Dreissena bugensis* mussel, also known as the quagga mussel.[97] These mussels are known to graze on Cyanobacteria (blue-green algae) and are proven to remove faecal bacteria such as *Escherichia coli* from the water surface.[98,99] Currently, the water board Amstel, Gooi en Vecht has started to test nets with quagga mussels to filter the water that flows towards an official swimming location (Varkensbaai) in the Sloterplas.[100] These mussels will consume large quantities of bacteria and phytoplankton, while excreting many nutrients to the water. To prevent these nutrients becoming available for other nuisances, such as Cyanobacteria, it could be combined with macrophytes which in turn extract the nutrients from the water surface.

Aquatic macrophytes are aquatic vascular plants, aquatic mosses, and larger algae with tissues that are easily visible. Aquatic vascular plants are often most abundant in wetlands.[59] The functions of these plants are the services we use. These plants have multiple growth forms: emergent, floating leaved and submerged (see **Figure 8.**). Various forms have various functions and these functions influence the environment in multiple ways. Important functions of the aquatic vascular plants are described here.

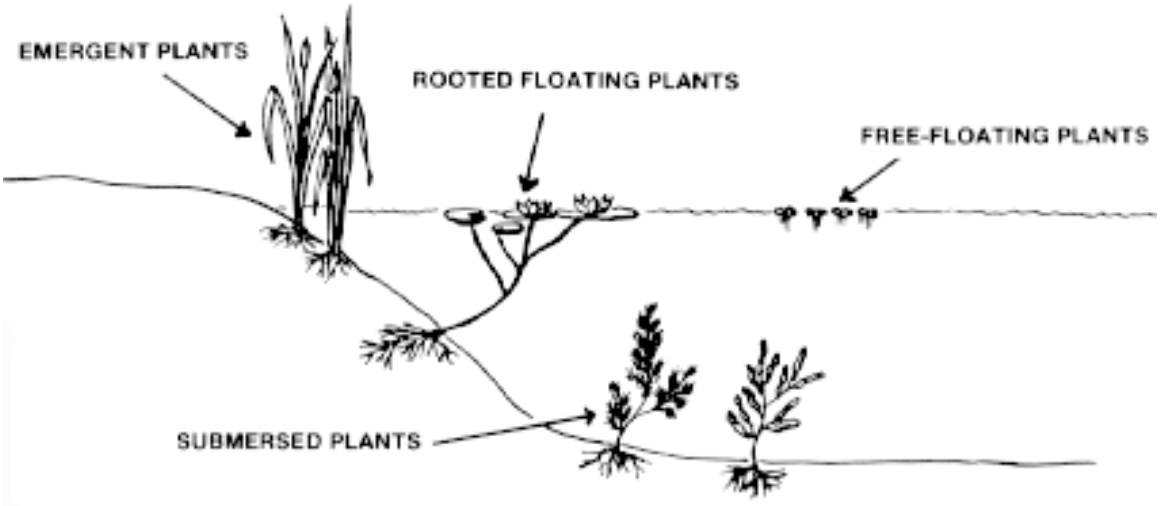


Figure 8. Aquatic vascular plants in different growth forms: Emergent plants, Rooted floating plants, submersed plants and free-floating plants.[101]

In the aquatic environment, aquatic vascular plants have a supporting function on biodiversity of fish and macro-invertebrates by introducing habitat complexity, shelter availability and feeding sites.[60] This supports a large variety of aquatic organisms and birds.[61,62] Additionally, they improve the availability of oxygen in the water, which is beneficial for macro-invertebrates and fish.[63]

Another function of aquatic vascular plants is the reduction of turbidity in shallow water bodies and maintenance of a more stable environment.[62,64–66] A way of reducing turbidity is the reduction of flow velocity, trapping sediment from the water. Another way aquatic plants reduce turbidity is by competing for nutrients with Cyanobacteria. The Cyanobacteria are free floating photosynthetic bacteria that increase the water turbidity. Negative effects of the Cyanobacteria blooms, that cover the surface of the water, are the depletion of oxygen in the water that is negative for other organisms. Furthermore, they produce bad smells and tastes, they produce toxin that can harm animals and humans, and they can disrupt food webs.[67,68] It was found that water bodies with higher density of these macrophytes have a lower chance to endure extreme blooms of Cyanobacteria.[69,70]

Finally, a function of aquatic vascular plants is that they can influence different processes that extract element from the water column. Besides reducing nutrients levels by competing with Cyanobacteria, they also reduce levels of faecal coliform bacterial concentrations or heavy metal concentrations.[71,72] Bacteria that are reduced include *E. coli* and intestinal Enterococci. They influence the swim water quality (see **3.4.1 Water quality in Amsterdam**). For example, the aquatic vascular plants reduce sediment resuspension where the bacteria and/or metals are attached, and as such reduce bacterial and/or metal concentrations in the water. [73,74] Furthermore, there are certain species of submerged plants, such as rigid hornwort, that adsorb heavy metals such as lead, copper and zinc. [75,76,77] Concluding, the functions of aquatic vascular plants described above show great potential for ecosystem services in urban waters. In the next section, the current status of aquatic ecology in Amsterdam is discussed and how the ecosystem services can be used to improve water quality to make swimming possible.

4. 3 Aquatic ecology in Amsterdam

The diversity and abundance of aquatic vascular plants in the centre of Amsterdam is not very rich.[78] In the centre of Amsterdam, terrestrial plants, such as ferns, that grow on the quaysides of the canals are monitored by an organisation called FLORON and indicated on biodiversity maps (see **Figure 9**.).[79] Unfortunately, such detailed information is not available for the aquatic vascular plants, plants that grow ín the water.

In Amsterdam, there are initiatives to improve the aquatic ecosystem using plants. One way to do this is with float lands, which are introduced on multiple canals and open water such as the IJ, and Boerenwetering.[80] These float lands form a habitat for emergent aquatic plants that have their roots in the water. These roots extract nutrients from the water and form a habitat for other organisms. This function of macrophytes is also used in the services delivered by constructed wetlands. The constructed wetlands are aquatic ecosystems that consist of aquatic plants that purify the water. This enhances the water quality so water can be reused or can be

returned to natural sources.[75] In these artificial ecosystems it is recommended to use multiple types of growth forms, as explained earlier, to target different sources of contaminants such as excessive concentrations of nutrients. [81]

The introduction of emergent aquatic plants via float lands is a good attempt to improve water quality. This way, the function of emergent aquatic vascular plants to improve the biodiversity in the canals can be used as a service to improve the water quality. This will also provide the service of improving the aesthetic view. In the next section, it will be discussed how the ecosystem services of aquatic vascular plants can be used at Marineterrein.

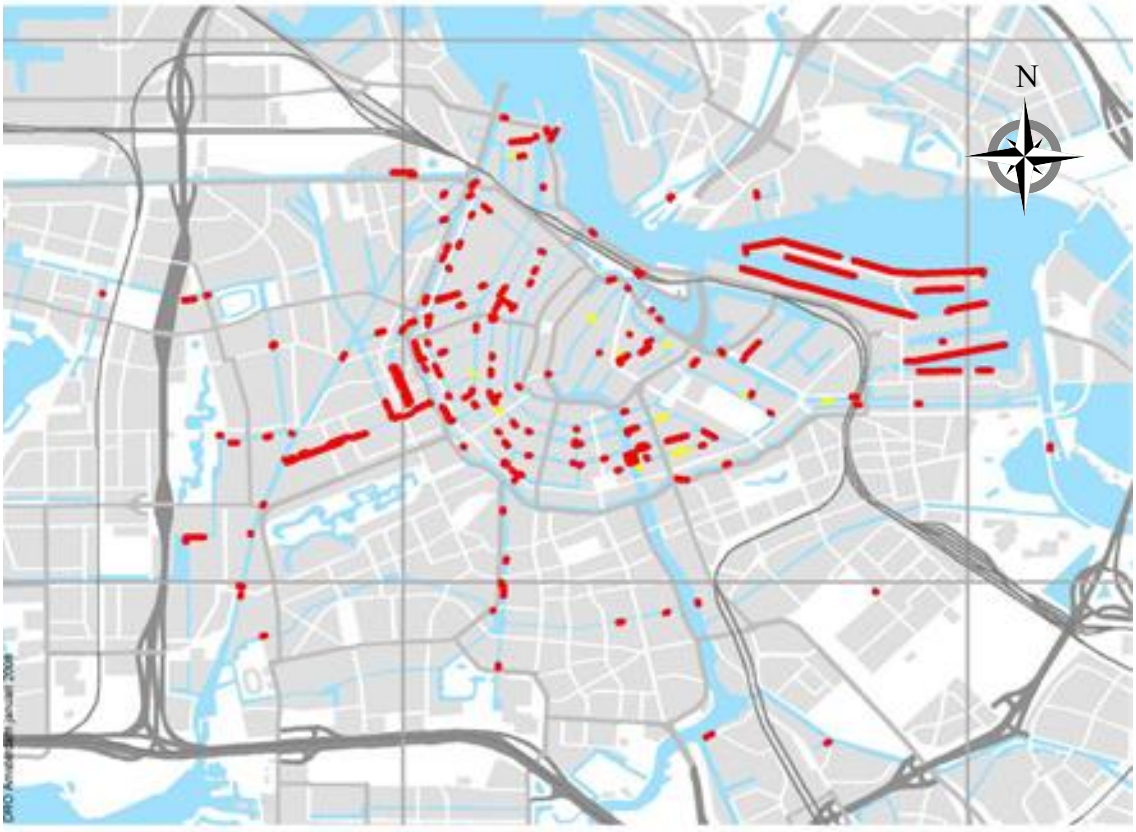


Figure 9. Vegetation on humid quaysides with protected (red) and not protected (yellow) plants species.[102]

4.3.1 Services for swimming at Marineterrein

The basin of Marineterrein is an environment made of concrete with little to no macrophytes. Understanding the functions from species we could use for ecosystem services can help to construct our own ecosystem service at Marineterrein. The positive functions of macrophytes that were discussed in previous sections include: providing habitat (complexity, shelter, and feeding sites) and thus increasing biodiversity, introducing oxygen, reduction of turbidity, nutrient competition with Cyanobacteria, and purifying from nutrients, bacteria and heavy metals. Keeping in mind that our focus is to create a swim spot in the basin of Marineterrein, we can determine what kind of ecological functions we need to turn into ecological services. Two important factors of these services that became apparent after the assessment of the water and

sediment quality of the basin is the service of purification of bacteria and heavy metals. It can be concluded from previous sections that aquatic vascular plants are able to introduce these services to the basin of Marineterrein.[82]

For the introduction of aquatic vascular plants, artificial habitats have to be created as the basin is too deep for the natural growth of macrophytes growing from the sediment. Moreover, the water flow in the basin makes it difficult for macrophytes to grow as well, as they prefer stagnant water. Therefore, artificial habitats, such as float lands, are able to introduce the macrophytes to the basin of Marineterrein.

Such artificial habitats have not been consistently investigated, causing difficulties in the assessment of the effect of the services. The effectivity of the submerged plants to purify the water in the basin of contaminants largely depends on the coverage of the plants in the basin. For quantitative and qualitative assessment of functional macrophyte coverage, research was mostly done in enclosed water bodies such as ponds or wetlands, and not in artificial habitats. This is to measure the changes over time with little to no external influences. The basin of Marineterrein is not a closed-off water body, but has continuous water flow from external water bodies. Therefore, bacterial or metal concentrations will always be influenced by the quality of external water flows.

The functional coverage of the extraction of heavy metals is debated, however some submerged species (e.g. *Ceratophyllum demersum*) can take up 70% of the metals such as lead (Pb), Zinc (Zn) and Copper (Cu) in a controlled experiment.[76,77] Mishra et al. concluded that the Ceratophyllum species show a potential as a phytotoremediator of lead in moderate polluted water bodies.[77] Phytotoremediation is the function of plants to extract heavy metals or other contaminants, used to clean the environment. This would be a good addition for the basin of Marineterrein because of the expected moderate pollution of the sediment.

When assessing the effective coverage for floating plants as well as submerged vascular plants to control toxic phytoplankton blooms, research showed that a coverage of 25-50% would be sufficient.[83–85] The 25% macrophyte coverage determined to cause a low phytoplankton concentration and the 50% coverage was determined enough for bio manipulation. Bio manipulation is an alteration of an ecosystem by humans with the goal to change it from one state to another state. For example, a pond with green turbid water that is changed into a pond with clear water with macrophytes dominating.[83] These manipulations are a controversial way of ecosystem engineering and involve far understanding of the system to get the desired goal otherwise harm can be done to the ecosystem and the surrounding ecosystems.[86]

Combining the positive functions on reducing nutrient levels, possible reduction of heavy metals, negative effect on algae bloom and reducing turbidity, will attribute to the health of the aquatic system in the basin of Marineterrein. Nevertheless, plant coverage of 50% is high for the

basin at Marineterrein, when it should also be functional for other purposes such as swimming or accessibility for boats. However, 50% coverage that would be needed for bio manipulation would alter the whole water body, is not needed for the basin because the overall water quality is good enough to swim (see **3.4.2 Water quality at Marineterrein**). A lower coverage of floating and submerged macrophytes still show a great potential for the increasing utilization of urban waters for swimming in Amsterdam. Therefore, we will set the first step in introducing an artificial habitat where macrophytes can grow in the concrete basin of Marineterrein. Hereby it is aimed to give an impulse for the use of ecosystem services throughout the urban waters of Amsterdam.

5. Future Vision

5. Future vision

In the previous chapters, **3. Swimming** and **4. Ecology,** the possibilities for the sustainable use of water in the basin of Marineterrein were investigated. In this chapter, a future vision for the use of the basin of Marineterrein is given, including the elements of swimming (see **5.1 Future swimming**), ecology (see **5.2 Future ecology**) and information (see **5.3 Future information**).

5.1 Future swimming

An explicit wish of Bureau Marineterrein, as well as many neighbours and several council members of the municipality of Amsterdam, is the possibility of swimming in the basin of Marineterrein.[27] This will involve the neighbourhood, and stimulate the social cohesion of Marineterrein and the neighbouring area. Furthermore, the possibility to swim in the basin can stimulate people to do sports, in the centre of Amsterdam, with beautiful views over NEMO, and the *Scheepvaartmuseum*. In the near future, Marineterrein will not become an official swim spot, due to the fluctuating water quality (see **3.4.2 Water quality at Marineterrein**). However, it is allowed to swim in the basin. Therefore, we organized a swimming competition to show interested visitors that it is possible to swim at Marineterrein (see **6.1 Swimming Pilot: Swimming competition**).

When in the future solutions are found to overcome the fluctuating water quality, an official swim spot at Marineterrein becomes an option. However, as mentioned in **3.6.1. Rejection of official swim spot,** all projects at Marineterrein will be reconsidered in 2018, when a new allocation plan is assigned. This means that within this timeframe, taking the 4 years of needed monitoring into account, no official swim spot could be created at Marineterrein. Thus, in the near future, a non-official swim spot is an option, as the water quality is found to be good enough to swim most of the time. When water quality is not good enough (for example when it is contaminated with faecal bacteria after sewage overflow), people need to be informed about the bad water quality (see **5.3 Future information**). In that way, people can make an educated choice whether or not to swim in the basin.

5.2 Future ecology

Nature used to be poorly represented in the concrete basin of Marineterrein. The tall quaysides prevent a natural introduction of, for example, aquatic vascular plants (or macrophytes). Introducing new ecosystems could mean great benefits for the area. For example, the ecosystem services of macrophytes can help to create a buffer against events of contamination and can help to improve the water quality by reducing faecal bacteria and reduce nutrients to compete with Cyanobacteria. This could improve the water quality, and may reduce the fluctuations in water quality in the basin of Marineterrein. Furthermore, a diverse ecosystem can be created in the

basin where different species of macrophytes can interact, and attract other organisms to this hotspot in the Amsterdam canals.

Other types of ecosystem services, such as the filtering services of the quagga mussel (*D. bugensis*) could be combined with the macrophytes to improve the effectiveness of the improvements of the water quality.

Artificial habitats such as float lands (floating treatment wetlands) can be created to help and increase the quality of the water by using the function of macrophytes as described in **4. Ecology**.[87] These float lands form a habitat for emergent macrophytes in deeper water bodies such as canals. They are mostly made from wood, styrofoam, and root nets.[88]

The basin of Marineterrein could house artificial habitats to improve its water quality and increase the biodiversity in the basin. Float lands and submerged gardens are clearly visible, and could have high esthetical value for the area. As a pilot, we introduced submerged gardens as a habitat for aquatic vascular plants into the basin of Marineterrein (see **6.2 Ecology pilot: submerged garden stimulating ecology**).

5. 3 Future information

Information availability is an essential part of increasing awareness on the sustainable use of urban waters, focusing on the opportunities of ecosystem services and the risks of swimming. Marineterrein could have a physical and notable information spot that displays the most apparent ecological characteristics, and risks of swimming in the basin of Marineterrein.

As could be concluded from chapter **3. Swimming**, most days it is safe to swim in the basin of Marineterrein. The water quality in Amsterdam has never been better, and citizens of Amsterdam regularly jump in the Amstel, IJ, canals, or other open water spots.[25,26] In the five official natural swim spots that Amsterdam knows, the water quality is monitored, and general information on water quality and provided facilities is public. This information is available on several platforms, including the website www.zwemwater.nl, the associated application for android and iOS, and the 'swimwater telephone', which is a free to dial phone number that runs in the summer months.[89]

The information regarding swimming is only available for the official swim spots. In an extensive survey on water recreation in Amsterdam, it was shown that 89% of the citizens in Amsterdam could not name any of the official open water swim spots, while 37% indicated that they sometimes swim in open water.[25] This means that many citizens of Amsterdam sometimes swim in open water, while they are not informed on the water quality and possible risks related to the swimming.

In general at non-official swim spots, a strong current and poor water quality can from risks for open water swimmers.[89] At Marineterrein, poor water quality is the main risk for the

health of swimmers. The two major causes of a poor water quality are an overflow of the sewage system after heavy rainfall, and the growth of harmful bacteria (such as faecal bacteria and Cyanobacteria) in the surface water during warm weather (see **3.4.1 Water quality in Amsterdam**). To decrease these risks, easily accessible information on the activity of sewage overflows, and the quality of water and sediment is needed. By providing this information for non-official swim spots, a definite advice that allows people to swim is not given, following the regulations that you can't facilitate swimming at non-official swim spots. Then, people are given the opportunity to deliberately choose to swim or not, at their own risk.

A new online platform (e.g. a website or application for a mobile phone), or incorporation into the existing online platform zwemwater.nl, would allow the information on non-official swim spots to be easily accessible and up to date. To give a quick insight in the complex system of urban waters and the water at Marineterrein, and give a clear picture of the level of the different risks, an online dashboard can be created. A feedback tool should be incorporated in the dashboard, so swimmers can provide feedback from personal experience (e.g. observation of Cyanobacteria). After easily assessing the risks, the swimmer can decide whether or not to dive in the urban water.

For the creation of the information panel and online dashboard, Bureau Marineterrein should consult the expertise of a group of experts, for example an ecologist, an information scientist, swimmers and a communication analyst. In conversations with *Waternet,* Joost Stoffels and Maarten Ouboter expressed their intention to consider if the data on water and sediment quality can be provided by *Waternet*, which will be needed to inform swimmers at non-official swim spots.[26,34] As a pilot, we developed an information panel in collaboration with Bureau Marineterrein (see **6.3 Information pilot: information panel**).

6. Pilot

6. Pilot

In the previous chapter, a future vision for the use of the basin of Marineterrein was given, including the elements of swimming (see **5.1 Future swimming**), ecology (see **5.2 Future ecology**) and information (see **5.3 Future information**). In this chapter, the pilots that were conducted in this project are explained. These pilots are associated with the future vision described for Marineterrein and also consists of three parts: Swimming (see **6.1 Swimming pilot: swimming competition**), ecology (see **6.2 Ecology pilot: submerged garden stimulating ecology**) and information (see **6.3 Information pilot: information panel**). On the open day of Marineterrein (03-07-2016), when all three pilots were conducted, a survey was filled in by the visitors (for the survey, see **Appendix VI**). The results of this survey, with questions on the different pilots, are shown in **Appendix V**.

6.1 Swimming pilot: swimming competition

During the open day at the 3rd of July 2016, we organized a swimming competition for open water swimmers, students, neighbours of Marineterrein and other interested visitors. The goal of the swimming competition was to stimulate swimming in the basin of Marineterrein, and show interested visitors that it is possible to swim there. In addition, attention was drawn to the fact that swimmers need to inform themselves on the possible health risks of swimming to decide for them whether it is safe to swim at Marineterrein. For a more detailed description of the open day, see **Appendix III.**

6.2 Ecology pilot: submerged garden stimulating ecology

The service of plants to improve the water quality and increase biodiversity is already used by different urban applications. An example is in the form of float lands in Amsterdam. These developments are effective, but are mainly focussed on emergent macrophytes. As discussed in **4.2 Functions of aquatic macrophytes**, the different growth forms (emergent and submergent) have different functions and therefore the focus of our pilot was on both floating- leaved, and submerged macrophytes.

Floating- leaved, and submerged macrophytes are free floating, which could cause a burden in the canals through, for example, entanglement in the motor of boats. Furthermore, some of these macrophytes have their roots in the sediment and will be removed or damaged during dredging activities to keep the waterway accessible for boats, swimmers, or others. To solve these problems, we came up with the solution: the movable submerged garden.

The goal of the submerged garden is to see if this setup is viable, displaying the possibility of combining functions: creating room for nature in urban areas; show an opportunity to improve water quality by using ecosystem services; and create awareness for the

biodiversity in urban water. This will be done without interfering the other activities in basin, such as boat traffic or swimming. Unfortunately, the change over time in water quality and biodiversity will not be included in our project due to the limited timeframe.

The submerged garden is a basket with a floating ring (see **Figure 10.**) The ring has a diameter of 100 cm and the basket had a depth of 80 cm. The meshed basket contains holes of ~1 cm by ~1 cm. The basket can be anchored to the sediment of the water body or other floating devices. The three submerged water gardens that were introduced in the basin of Marineterrein were attached to each other and anchored to the sediment by a brick. For more detailed information on the submerged garden, and the potential associated risk factors, see **Appendix IV**.

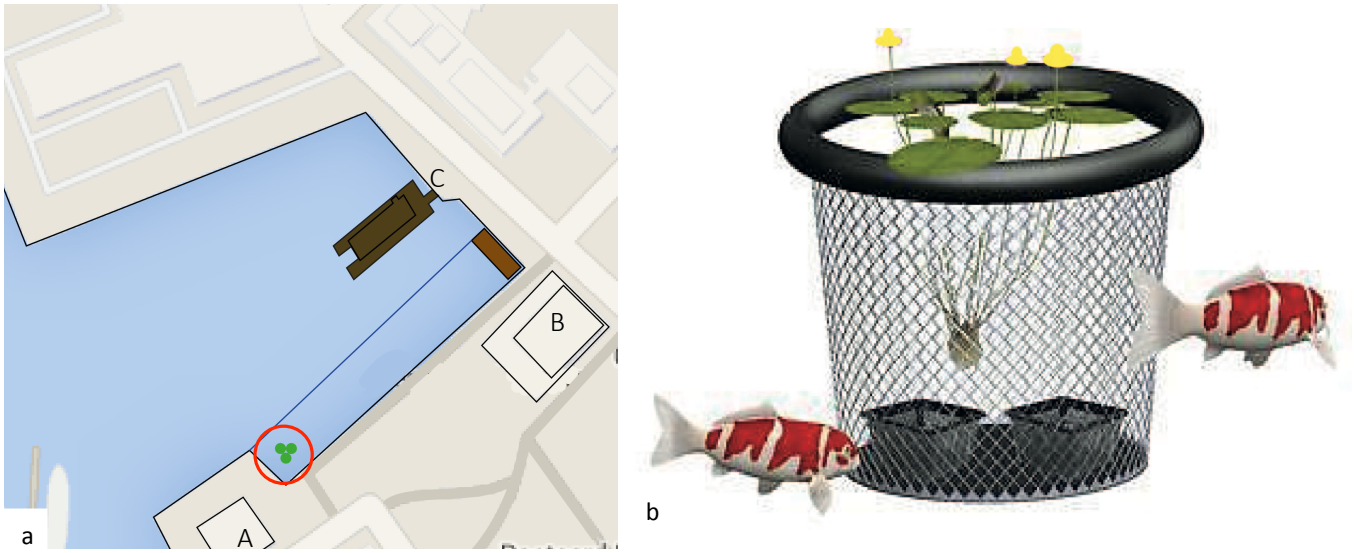


Figure 10. The map of the open day (a)(3 july 2016) with Bureau Marineterrein (A), Pension Homeland (B) and the pier of the Royal Dutch Navy (C). In the basin the ponton (brown) from the Scheepsvaartmuseum, with a buoy line. The green cirkels are the three submerged gardens (red cirkel). This location is their definite place. Three submerged gardens (b) are introduced in the basin of Marineterrein. These garden exists of a basket with a floating ring (ø 100 cm, depth 80 cm). The baskets are anchored to the sediment in the basin by a brick.

For the underwater garden in the basin of Marineterrein, two species of plants were chosen: rigid hornworts, also known as coontail (*Ceratophyllum demersum*) and yellow water-lily, also known as brandy-bottle (*Nuphar lutea*) (see **Figure 11.**). Hornwort is a free-floating macrophyte and found in lowland streams and ponds. The yellow water-lily is a floating-leaved macrophyte rooted in the sediment. These species occur naturally in the waters in and around Amsterdam and are known to have a positive effect on the water quality and biodiversity.[75] For example, both these species are used to manage water quality and can target on the risk factors of the basin: reducing concentration of faecal coliform bacteria, Cyanobacteria and heavy metal.[71,73,76,77,90]

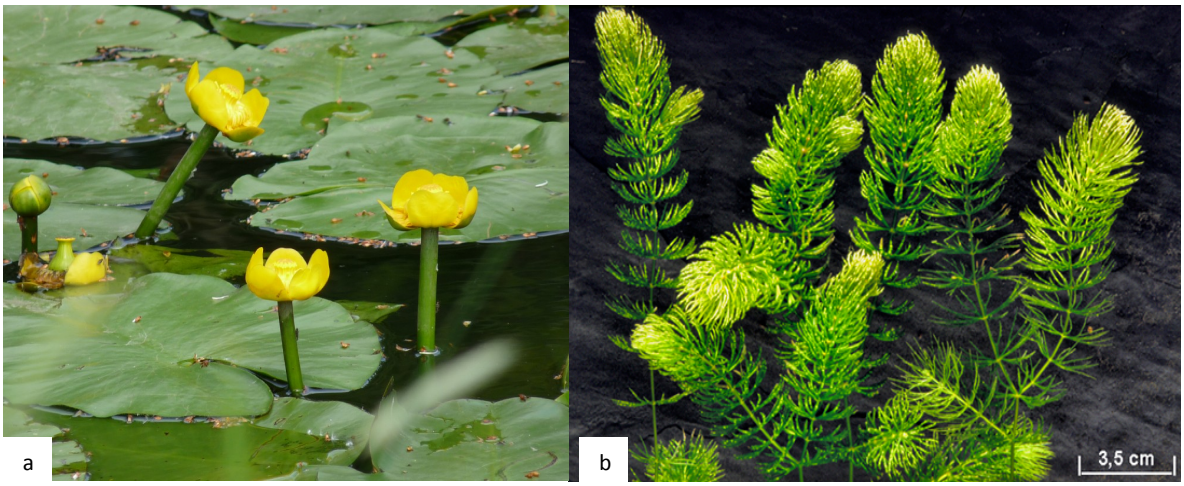


Figure 11. Two species that were introduced in the basin of Marineterrein through the submerged gardens: a) yellow water-lily (*Nuphar lutea*), also known as brandy-bottle b) Rigid hornworts (*Ceratophyllum demersum*), also known as coontail .

Furthermore, the mesh in the basket is large enough for small organisms such as fish and microorganisms to enter. Then, the garden creates a safe habitat and nurturing area for these organisms. Moreover, the yellow water-lily adds aesthetic value to the pilot by producing beautiful yellow flowers in the summer months.

When scaled up, introducing hornworts and yellow water-lilies could have a high potential to improve the water quality. But, as already stated in the goal of our pilot, we do not aim to improve the water quality with three gardens, but we aim to show the opportunities of these species to overcome the water quality fluctuations in the basin.

Finally, if the number of submerged gardens is increased, alterations to the shape of the garden or species composition can be made which can help to increase the water quality as well as the biodiversity. An alteration could be made on the holes (>1cm) in the basket to enable larger fish to enter. Another example could be alteration of the species composition, by introducing other species of aquatic macrophytes (such as *Chara* spp., *Lemna* spp., or *Potamogeton* spp).[75] These different species also have proven to provide ecosystem services to the water quality. However, their effectiveness hasn't been proven for larger volumes of water, as in the basin of Marineterrein. Therefore, Marineterrein could function as a testing area where the effects of the aquatic macrophytes on the water quality are tested and analysed.

6.3 Information pilot: information panel

To provide information about the water, sediment and ecology in the basin of Marineterrein, we developed an information panel (in collaboration with Bureau Marineterrein, see **Figure 12.**) Information is given on the risks related to swimming in natural surface water and it is emphasized that swimming in the basin of Marineterrein is at own risk. Furthermore, the

aquatic ecology in the basin is explained, including the aimed effects of the underwater gardens (see **6.2 Ecology pilot: submerged garden stimulating ecology**).

With the provision of this information, it is aimed that visitors of Marineterrein will become aware of the risks related to bad water and sediment quality, and the importance of sustainable water use. The visitors are encouraged to reflect on their own behaviour towards urban water, which could lead to small changes in behaviour: for example putting their plastic bottle in the plastics bin, instead of the canals.[91]

The information panel (119 cm x 84 cm) was placed at Marineterrein near the basin during the open day of Marineterrein at the 3rd of July 2016. The current panel was printed on non-lasting material; consequently it cannot be placed outside for a period longer than a few weeks. If Bureau Marineterrein wishes to show the information panel for a longer period of time, they can consider printing the panel on a sustainable material and place it, at least until the next allocation phase in 2018, next to the basin.

After the open day, the information provided on the panel was also published on the website of Marineterrein.[92] Through the website, the information can reach a larger public and is also available on forehand for people who intend to visit Marineterrein.

Figure 12. The information panel (119 cm x 84 cm) created in collaboration with Bureau Marineterrein. The panel was located in the harbour of Marineterrein at the open day (3 July 2016) and shows information about water- and sediment-quality, swimming and ecology. For a larger version of the information panel see **Appendix VII**.

7. Recommendations

7. Recommendations

Our concluding vision for the Marineterrein will be explained in this section, combining our project with existing projects at Marineterrein, and outside Marineterrein.
In the process of our project, we encountered many other projects that were involved in improving water quality, measuring water quality, and improving aquatic ecosystems. With many of these projects or companies, we discussed a possible collaboration for the basin of Marineterrein. Unfortunately, the time frame of five months often was an inhibitory factor, as many of the projects we encountered where still in developing phase. Sometimes, the products were already developed, but a collaboration was simply to costly. Nevertheless, to give our client a good idea of what the possibilities are for (the basin of) Marineterrein, we will elaborate on several ideas, and the combination of some:

First, the placing of a boardwalk to close off the harbour was mentioned early in our project. The original plan was to use concrete containers with wooden decking, enabling different functions (for example a terrace or a garden). Now, the *SWITCH2BLUE* project will use the original plans for a boardwalk, by using Marineterrein as a pilot study for their research project. The *SWITCH2BLUE* 'floating units' will be tested in the basin of Marinterrein for algae cultivation and nutrient recycling in fresh water systems. The aim of the research project is to achieve CO_2 capturing and to close nutrient cycles by introducing floating algae, seaweed and aquaculture systems. The activities of the submerged gardens that were introduced in the basin of Marineterrein will add to the activities of the *SWITCH2BLUE* pilot, as the submerged plants will attribute to closing nutrient cycles by extracting nutrients from the surface water. When the *SWITCH2BLUE* research project starts, this has to be taken into account. Furthermore, the *SWITCH2BLUE* project will increase the awareness on the possibilities of urban waters, which is in line with our project.

With the creation of an official swim spot taken into account, the planned boardwalk (either the original plan or the *SWITCH2BLUE* floating units) could be used for several extra applications. Submerged gardens, as we introduced in the basin during the open day, could be placed along the boardwalk. Increasing the number of the submerged gardens would increase their water quality improving effects. During our project, we spoke to the company Global Wetlands, who have a lot of expertise on floating gardens. For further contact, details are provided in **Appendix IX**.

Furthermore, Seabins could be placed along the boardwalk (see **Figure 13.**). These Seabins, created by the *Seabin Project*, are *'inwater utomated marina rubbish collectors'* that collect all floating rubbish, oils, plastics, fuels and detergents of the water surface.[93] In the beginning of april we contacted the *Seabin Project* to find out whether there was an opportunity for Marineterrein to function as a test-location to help them develop the seabin further. In their reaction they stated that they are still developing the Seabin V5, and aim to be shipping late in the year around November. They expect to have more information and a price around July or August. For further contact, see **Appendix IX**.

Figure 13. Prototype of the seabin, developed by The Seabin Project.[93]

In addition, in the beginning of our project, we come across the *Great Bubble Barrier*. The idea behind the *Great Bubble Barrier* is that two diagonal screens of air bubbles retain waste from going downstream the river, but allow fish and ships to pass. Recently, the start-up company has won the *Plastic Free Rivers Makathon* of 2016, organised by *Rijkswaterstaat.* With this price, they won €100.000 and the possibility to test their prototype in the *IJssel* river. For Marineterrein, the bubble barrier could function as a floating waste barrier. Since the planned boardwalk will not completley close off the harbour, which will still allow plastics to enter the basin, a bubble barrier could stop the overall presence of floating debris in the basin. For further contact, see **Appendix IX**.

An extra dimension of water quality, the concentration of bacteria and algae, can be improved by mussel curtains. Shortly mentioned in **4. Ecology**, mussels are able to graze on Cyanobacteria and are proven to remove faecal bacteria such as *E. coli* from the water. These mussel curtains could easily be placed under the boardwalk, which causes the majority of water that enters the basin of Marineterrein to first be purified. Mussels excrete many nutrients to the water when they puritfy the water. Subsequently, the submerged gardens will extract these nutrients from the water, and thereby prevent Cyanobacteria from growing. Marineterrein could function as a test lcoation to see whetеher the combination of the mussel curtain and the submerged gardens are able to effectivly improve the water quality.

To further improve the water quality in the basin of Marineterrein, a good start is already made by Bureau Marineterrein. Blue/groon roofs are planned to be installed by *Smartroof,* and also the sports field at Marineterrein will be serving as water storage. Water storage on roofs and on land will serve as a buffer for heavy rainfalls, which will decrease the

activity of sewage overflows and thus decrease the fluctuations in water quality. Hereby, the existing plans of Marinterrein contribute to a safer swim spot in the basin.

For the measurement of water quality in the basin of Marineterrein, we spoke with two different intititives. The first was the company of *Indymo*, a recently created start-up company that uses underwater drones to monitor water quality and ecology.[94] In may, *Indymo* offered to measure the water quality in the basin with their underwater drone and multi-parameter probe (for the measurements of oxygen levels), and to make HD film footage of the biodiversity in the basin for two days, for the total price of €1.850 (excl. BTW). At that time, we didn't think the measurements would be very useful, since we didn't take measures yet to improve the water quality or ecology in the basin. However, when in the future more measures are taken, for example more submerged gardens, and mussel curtains are placed, measurements with the aquabot would be very valuable to test their effectiveness. Moreover, the HD footage of the biodiversity would increase the visibility of the submerged garden, which in turn will increase the engagement of the visitors of Marineterrein. For further contact details, see **Appendix IX**.

The second initiative for the measurement of water quality we found is from a project group *Sensemakers*, linked to *Makerversity*, located at Marineterrein. *Sensemakers* is working to see whether it is possible to develop a buoy that is able to do real time water quality measurements. This initiative has just started, and finds itself in the brain-storm phase. For Bureau Marineterrein, it would be interesting to stay informed on the development of this initiative, as such buoy would add large value to the swim spot at Marineterrein. For further contact details, see **Appendix IX.**

To transfer the results of up-to-date water quality measurements performed in Amsterdam waters, new information streams are recommended. As mentioned in **5.3 Future Information**, websites exist for official swim spots that provide information on water quality and swim-related risks. However, for up-to-date results of non-official spots throughout the city, new applications would be needed. *Liquid Commons* is a company that aims to make the complex data of *Waternet* visually accessible. By doing so, they aim to make residents and visitors of Amsterdam aware of the water quality, and involve them in improving water quality. The project *Amsterdecks* is linked to this project, which uses information from *Waternet* to create a network of public water-measuring boardwalks located at possible swim spots throughout the city. Currently, *Amsterdecks* is still in developing phase, with a first pilot planned for the near future. Because the aim of *Amsterdecks* fits well with the aim of our project, we think that it would be a great opportunity for Marineterrein to offer the basin as a test location for the interactive boardwalk. For further contact details, see **Appendix IX**.

Concluding, with the projects mentioned above, and the expansion of the pilots executed in the current project, we think that the fluctuations of the water quality in the basin of

Marineterrein can decrease considerably, in a sustainable manner. This would decrease the risks for swimmers. Furthermore, the biodiversity in the basin would increase, while made visible, which would enlarge the awareness among the visitors of Marineterrein on the possibilities of ecosystem services within urban waters. This will raise awareness among residents and visitors of Amsterdam on the water quality, and increase involvement in improving the water quality, while enjoying a safe swim in the city centre of Amsterdam.

8. Conclusion: In touch with urban water

In this project, we investigated the possibilities of sustainable water use in the basin of Marineterrein. We approached the sustainable use of water from multiple perspectives: swimming, ecology and information. From these views, we investigated if Marineterrein can become a natural swim spot and explored opportunities to improve the water quality in the basin of Marineterrein by making use of ecological services. Additionally, we studied what information is needed to enable safe swimming in natural surface water and how to raise awareness for sustainable water use.

We concluded that it is not an option to create an official swim spot at Marineterrein in the near future, due to fluctuations of water quality. However, usually these fluctuations do not form a risk for the health of swimmers, so we recommend creating a 'wild' swim spot. The creation of a non-official swim spot happens by informing swimmers on the possibility to swim in the basin of Marineterrein and notify them about related risks, without facilitating side conditions for swimming.

Regarding the ecological opportunities, we concluded that aquatic plants could be used to improve the water quality in the basin of Marineterrein. A 50% coverage of the surface water would be needed to have a large impact. However, taken into account that the water quality is sufficient most of the time, 50% coverage is not needed. In our recommendations we suggest to use a combination of several water-quality improving measures, such as mussels and aquatic plants for optimal efficiency.

Concerning the information, we concluded that currently there is little to no information available on up-to-date water quality at the non-official swim spots of Amsterdam. We suggest creating new information channels (a panel and a website/application) that informs visitors and swimmers on the current water quality, the swim-related risks and at the same time raise awareness for the sustainable use of water.

Finally, by closely monitoring the status of the urban water in Amsterdam and introducing measures that improve the water quality, by interacting with water and learning about urban water, citizens will be ***in touch with urban water*** and become aware of sustainable ways to enjoy and use the extensive aquatic resources the city of Amsterdam has to offer.

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Appendix I. Other concepts at Marineterrein

We investigated the preliminary feasibility for three concepts. Two concepts concerned swimming: swimming in the natural surface water of the basin of Marineterrein (which is fully elaborated on in the final report "In touch with urban water") and a floating pool in the basin of Marineterrein. The third idea was to create a mobile urban garden.
Here, the floating swimming pool and the mobile urban garden are further elaborated on.*

** text adapted from our project proposal "The City of the Future" (01-04-2016)*

i. Floating pool

In a floating swimming pool, the quality of the swimming water can be controlled more easily than in the basin of Marineterrein. In this respect, the floating pool could also function as a temporary solution to the insufficient water quality in the harbour itself. It could thus serve as a swimming facility until all houseboats in the surroundings are connected to the sewage system and the levels of pathogenic faecal bacteria in the basin will be rated "good" or "sufficient". However, the floating swimming pool could also function as a lasting idea as the water quality could be better controlled and the safety of the visitors could be, to our expectations, ensured more in a closed pool.

i.i Concrete basin

Basins made of concrete are excellent options for floating swimming pools as they can harbour large volumes and are made of cheap material. In addition, these basins are easily movable, which is in line with the wishes of Bureau Marineterrein Amsterdam. Moreover, it would be easy to realize multiple floating swimming pools when the pilot is to expand across Marineterrein. Concrete basins can be made in various proportions. One size that is known by our team is a basin of 4m x 20m, and approximately 2m deep. Such a basin could function as a small pool for both swimming laps and paddling. Here are options for a floating pool basin given with the estimated costs.

- **Concrete Basin:**
  ~€25.000 (quotation Hercules bv; 20 x 4 meter**).** Low maintenance; usually can last a life-time without direct maintenance needed. A comparison with BadBuiten shows that a pool of 20 x 4 could hold maximum 35 people in it.
- **Cargo Ship:**
  ~€100.000 (barge;25 x 7.50 x 2.02) Too expensive.
- **Flexible Drum:**
  ~€100 (PVC canvas 10 x 15 meter). Never used as a partition wall for a pool. Would be very expensive and unhandy to apply this in the harbour as a swimming pool. The canvas could be applied to the bottom of the harbour to keep it in place, but it is expensive and may not be hufter-proof. Also the idea is not temporal as the huge secluded pool probably cannot be used elsewhere or with another purpose.
- **Aqauglide Ocean Pools:**
  ~€15,599.85 (3 x Aqauglide Ocean Pool; 6 x 5 x 2,4 meter) Not handy; three small pools connected. Pools are able to separate swim water from the harbour water.

i.ii Sustainable water filter with a helophyte filter

A helophyte filtering system is able to filter wastewater with the use of plants and microorganisms that live around the roots of these plants. These microorganisms are able to convert waste into nutrients, which are then used for themselves and for the plants.[1]

This allows the water to be purified in a natural way, without any substances to be added. In the scope of the floating swimming pool, water would be collected from the basin of Marineterrein and possibly from the (planned) blue/green roofs of the buildings at Marineterrein. The collected water would be pumped through a system that is driven by a vertical wind turbine, possibly in combination with a small solar panel. After the water is collected above the ground, it would follow a gradual downwards system of filtering levels consisting of crane and microorganism-rich soil until clean water will eventually reach the concrete basin. The pump will create a continuous flow of water, which will increase the water quality even further.

The structure of different levels that are needed for the filtering system allows the incorporation of the filtering system in a larger structure. This means

that we could create a stand next to the basin where people are able to relax, and enjoy the view over the Marineterrein and the surroundings. A structure that combines a helophyte filter with a stand will result in a visible pilot that could also serve an educational value, as visitors will come in direct contact with the filtering system. It is also possible to make the construction movable to ensure the mobility of the entire floating swimming pool-system. If necessary, this pilot could also be copied at different spots on Marineterrein.

For the application of a water filtering system, it is crucial that there are periodical water quality checks to realize safe swimming water. This applies to the inflowing water but also the basin water. For the water quality, the EU guidelines regarding bathing water are followed.[2]

- **Helophyte filter**

  -Size: 2,5-5 m2/IE (International Unit - *Internationale Eenheid*)

  -Depth: ± 100 cm

  -Costs: Installation ~€600/IE (at 4IE) | €400/IE (at 4000 IE)

  -Energy consumption (1 €/IE/yr)

  -Personnel costs (0.5 h/wk x 220 d/year x 25 €/h): 590 €;

  -Maintenance (0.5 % of investment or €4/IE/m2)

  -Remaining questions: how much litre water fits in a pool of 20 x 4 meter? How much litre is filtered per IE, per week/year?

i.ii Alternative filter

An alternative way to filter natural water can be seen in Natural Swimming Pools (NSPs). Here, specific filtration substrate and flora can filter the water in a natural way. We will study examples of NSPs and look at potential applications for the floating swimming pool. Another idea to filter the water is the use of mussels.

- **Natural Swimming Pool:**

  For a true natural pool with no help from ultraviolet light or other such technology**,** the requirement is half swimming area, half regeneration area. Expect to pay $1,000 to $1,200 for a quality underwater aeration system. Needs a closed pool.

- **Mussels:**

  Each mussel filters between 50 and 300 liters of water a day, this depends on mussel size and other factors. Mussels work immediately. Mussel plants both purify water for nitrogen and phosphorus and make the water clearer. When harvesting mussels, the nutrients are thus removed from the water. Quagga mussel or Zebra Mussel (driehoeksmossel), both exotic species, are already used in projects to filter water. Point of discussion: it is not desirable to introduce new species of mussels, but it is possible to collect mussels from waters in Amsterdam. In addition, fresh water mussel filters are used in aquaponics systems but never in pools. Could cause harmful growth in ponds when not controlled. They clear all food for the fish, which is not a problem in our pool.

i.iv Pump

A *Beregeningspomp* could be used, together with a *aanzuigslang (*max. 9 meters). Futhermore, a *voorfilter* is needed if the pump doesn't pump tapwater. If the pump is in continuously use (> 3 hours in a row), a DAB pump is necessary. When the pump is not continuously in use, as cheaper but same quality pump (TIP) can be used.

Remaining question: How much litre would be pumped through the pump?

- **Prices:**

  ranges between 200-600 euro.
- **Capacity:**

  The pump has a capacity of 3300-7200 liters per hour.

i.v Heating system

Options for a heating system are:

- **Sun**:

  Shallow planting helps to absorb warmth from the sun and keep it in the water.
- **Covering:**

  Solar covers cost £10 – £15,000. Hand reel-out black bubble covers are about £2,500 as a budget option.
- **Heat pumps**:

Pools are most efficiently heated by an air source heat pump, which can be run off solar panels. The swimming area should be covered to make it viable. Costs are between £6 – £12,000 for heater and £6 – £12,000 for an insulation cover. There are lower budget covering options available. (These costs exclude solar panels).

Yearly average water temperature is 10.5-10.7 degrees Celsius. In the summer this can rise up to 25 degrees Celsius at the bottom of the canals, which have an average depth of 2 meters. High temperatures are harmful for hazard factors (bacteria, viruses, protozoa, and fungi). Hazardous bacterial growth already starts at temperature above the 20 degrees Celcius. Few of these organisms are included in the bathing water directive (*Pseudomonas aeruginosa* en *Vibrio* spp.). However, many frequently occuring pathogens are not included (*Leptospira* (bacteria for Weil desease), Clostridium botulinum (bacteria causing botilusm) en *Trichobilharzia* (parasites causing swimmers itch). Therefore, heating the swimming pool would not be an option.

i.vi Concerns

Facilitating a swimming location at the basin of Marineterrein raises a few concerns that have to be taken into account. The first concern is the temperature of the swimming water. The Netherlands is not known for its hot summers and we have to think about whether it is worth the effort to realize an outdoor swimming location when it will attract visitors for only a few weeks a year. However, we are convinced that these few weeks a year will leave such a positive memory with the visitors that this will positively affect the visitor numbers the rest of the year. Outside the swimming season, Marineterrein offers, amongst other things, a beautiful location for walks, and visits to restaurants Homeland and Zeekameel. In addition, the helophyte filter of the floating swimming pool will work throughout the seasons and will maintain its educational value. Moreover, we could think of possibilities to heat the water in the floating swimming pool, for example by letting the water circulate through tubes that are painted black. This way, sunlight might be enough to increase the water

temperature with a few degrees and expand the swimming season with a few days.

The second concern is the safety of the visitors. When a floating swimming pool is created, Marineterrein will have the responsibility to guarantee physical safety, by providing lifeguards and other safety-ensuring methods.

ii. Mobile Urban Garden

At the moment in the city of Amsterdam garbage is burned for the purpose of central heating. Nevertheless, our piles of waste contain high amounts of energy.[3] A large part of our garbage, the biodegradable waste has high amounts of valuable nutrients such as phosphates and nitrates.[3] The waste treatment destroys valuable energy in the form of these nutrients that are essential for plants and can therefore be used more effectively. These waste streams can be altered and the biodegradable waste can be collected separately. This concept will use these waste streams to reduce the total waste produced by Marineterrein and produce food for the community in an urban garden. This urban ecosystem will help to reduce the environmental pressure on the environment and increase the environmental sustainability by the reduction of waste streams. Furthermore, these gardens can function as one of the few safe havens for biodiversity in urbanized area for example bees.[4]

Compost can be made from biodegradable waste, which in turn can be used in the production of plants in local gardens. Local gardens can have two important roles in a community; releasing pressure on expenses and function as a social gathering place. Our idea is to use Marineterrein as a case for a circular urban ecosystem by introducing the urban mobile garden.

ii.ii Idea: the urban mobile garden

The urban mobile garden has the purpose serving seasonable fruits and vegetables to the community on Marineterrein while reusing the energy from the waste of the community. The urban mobile garden will be part of Marineterrein and reuses the biodegradable waste by turning it into compost for the garden. The gardens will be in movable (flexible) containers and produces vegetables,

fruits and herbs, which can be shared by organizing leaseholder lunches. The leaseholders will in return bring their biodegradable waste to the compost installation. The garden will become a central point on Marineterrein and will increase the cohesion of the leaseholders on Marineterrein. Increased awareness of food production by urban gardening with the urban mobile garden will give insight to the leaseholders where food comes from and how it is produced.[4] The urban mobile garden will reduce the amount of waste on Marineterrein and in return produces fruits and vegetables, and functions as a central gathering place for the community. There are different techniques for composting like; traditional composting where biodegradable waste is transformed into nutrient under the right pH and temperature,[3] vermicomposting where worms are used to transform biodegradable waste and heavy metals are also extracted, [3] integrated composting is similar to traditional composting but integrated in the grow bed of the crops (inspired by Noocity growbed[5]), and there are many more. Here are some factors described that we checked in the feasibility analysis.

- **Mobile garden:**
  -1 bak 750dm3 (1.45*1.45*0.36) → ~ € 166.5,- (hout = 24, zeil= 16-24, wielen 31 (pp.7.80), potgrond 1l:142,-; 0.75l:106.5, schroeven = 5)

- **Amount of compost:**
  -Compost duurt 3-9 maanden afhankelijk van system
  -200-400 m2 garden: 290 litre compost system → €25
  -40% (1.000 kg GFT-afval → ~ 400 kg compost)
  -Two systems closed system(small) / open system (large)

- **Crops:**
  -Approximately: 4kg/m2 → on 40-50m2 → 160-200kg vegetables/fruits (varying from 1-10kg/m2)
  -Choice of crops: One harvest / season round picking
  -Herbs?
  -Intensivity of workload → 100m2:half day/week or large garden 10 hours/week

- **Involvement of community on Marineterrein:**

  -Via composting (for example Pension Homeland):

  1. Weekly: 20 kg VFG waste. (8 kg gft per day)
  2. Yearly compost of 52*20*40% → ~ 416kg
  3. 2-8 kg/m2 → 52 m2

  -Other individual companies

  -If it will result in too much VGF(GFT) → can it be traded?

ii.iii Potential up scaling to larger circular urban ecosystem

Our idea of urban mobile garden has the potential for expansion and up scaling by adding extra ecological elements or extra modules of reusing material. The ecological harbour for species that is created with the urbanized environment can be enhanced with the addition of a beehive and an urban beekeeper. Furthermore, adding extra modules of reusing material such as plastic (such as WASTED[6]) or paper (such as Makerversity[7]) could upscale the idea of a circular urban ecosystem on Marineterrein. This will neutralize extra waste streams and create products for the community. This flexible addition of modules makes the idea also suitable for upscaling across the borders of Marineterrein, by cooperating with neighbours such as Mediamatic, Hanneke's boom, Nemo, neighbours living in Kattenburg, etc.

iii. References Appendix I

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Appendix II. Bhvbz Bijlage II; Werkboek Bhvbz Bijlage II

Besluit hygiëne en veiligheid badinrichtingen en zwemgelegenheden

Geldend van 01-07-2011 t/m heden

Bijlage II. bij het Besluit hygiëne en veiligheid zweminrichtingen

Normen voor zwem- en badwater in badinrichtingen ingericht voor het zwemmen of baden in oppervlaktewater en andere op grond van artikel 10b van de wet geïnventariseerde plaatsen

Normen voor zwem- en badwater in badinrichtingen ingericht voor het zwemmen of baden in oppervlaktewater en andere op grond van artikel 10b van de wet geïnventariseerde plaatsen			
parameters	eenheid	norm	door de houder van een badinrichting in oppervlaktewater dagelijks uit te voeren onderzoek
doorzicht	meter	≥ 1,0[1]	X
kleur	–	een niet anders dan door natuurlijke omstandigheden veroorzaakte kleur	X
geur	–	afwezigheid van rottingsgeuren of andere geuren die algemeen als hinderlijk worden ervaren, in het bijzonder de geur van fenolen	X

schuim	–	een niet anders dan door natuurlijke omstandigheden veroorzaakte schuim	X
olie	–	geen zichtbare hoeveelheid olie op het wateroppervlak	X
vuil	–	afwezigheid in of op het water en op de bodem van afvalstoffen en dode organische materie in aanmerkelijke hoeveelheid	X

[1] Overschrijding van de norm als gevolg van de natuurlijke gesteldheid van de bodem en de invloed daarvan op het water worden niet beschouwd als overschrijding.

Bijlage II. bij het Besluit hygiëne en veiligheid zweminrichtingen

Normen voor zwem- en badwater in badinrichtingen in oppervlaktewater

Normen voor zwem- en badwater in badinrichtingen ingericht voor het zwemmen of baden in oppervlaktewater en andere op grond van artikel 10b van de wet geïnventariseerde plaatsen			
Parameters	**Eenheid**	**Norm**	**Door de houder van een badinrichting in oppervlaktewater dagelijks uit te voeren onderzoek**
1. Bacteriën van de coligroep	aantal per 100 ml	≤ 10.000	-
2. Thermotolerante bacterieën van de coligroep	aantal per 100 ml	≤ 2.000	-
3. Doorzicht	meter	≥ 1,0[1]	X
4. Zuurgraad	pH	6,0 ≤ pH ≤ 9,0[1]	-
5. Kleur	–	een niet anders dan door natuurlijke omstandigheden veroorzaakte kleur	X
6. Geur	–	afwezigheid van rottingsgeuren of andere geuren die algemeen als hinderlijk	X

		worden ervaren, in het bijzonder de geur van fenolen	
7. Schuim	–	een niet anders dan door natuurlijke omstandigheden veroorzaakte schuim	X
8. Olie	–	geen zichtbare hoeveelheid olie op het wateroppervlak	X
9. Vuil	–	afwezigheid in of op het water en op de bodem van afvalstoffen en dode organische materie in aanmerkelijke hoeveelheid	X
10. Salmonellae	-	niet aantoonbaar in 1 L	-
11. Entero-virussen	-	niet aantoonbaar in 10 L	-
12. Faecale streptokokken	aantal per 100 ml	≤ 300 (de mediaanwaarde van de uitkomsten van het onderzoek)	-

X= dagelijks door de houder van de badinrichting in oppervlaktewater uit te voeren (en vast te leggen in logboek).

Voorschriften ten aanzien van de toetsing

De toetsing van de hoedanigheid van het zwem - en badwater aan de normen verloopt als volgt.

1. Er wordt uitgegaan van de gegevens uit het onderzoek dat wordt verricht ingevolge artikel 4, eerste lid van het Besluit kwaliteitsdoelstellingen en metingen oppervlakte wateren.

2. Het zwem- en badwater wordt geacht overeen te stemmen met de in deze bijlage gegeven normen indien blijkt dat van de monsters, genomen op een

zelfde plaats van monsterneming, volgens de in bijlage II van het Besluit kwaliteitsdoelstellingen en metingen oppervlaktewateren aangegeven frequentie:
bij de parameters "bacterieën van de coligroep" en "thermotolerante bacteriën van de coligroep" 95% in overeenstemming is met de normen voor de betreffende parameter.
bij de overige parameters, met uitzondering van faecale streptococcen, 95% in overeenstemming is met de normen voor de betreffende parameter. Voor de (maximaal) 5% van de monsters die niet conform de norm zijn, mag deze afwijking niet meer bedragen dan 50% van de normwaarde voor de betreffende parameters, waarbij een uitzondering wordt gemaakt voor pH en opgeloste zuurstof.

[1] Over (of onder-) schrijdingen van de norm als gevolg van de natuurlijke gesteldheid van de bodem en de invloed daarvan op het water worden niet beschouwd als overschrijding.

Appendix III. Pilot: Swimming competition

Detailed description of the organization of the swimming competition

For the swimming competition during the open day of Marineterrein, we had to apply for a permit at the municipality of Amsterdam. Fortunately, we received a positive recommendation about the swim water quality from *Waternet* and thus a permission to go through with the swim competition. We arranged a floating pier (borrowed from *Scheepvaartmuseum*) and had the Amsterdam rescue squad (*Amsterdamse reddingsbrigade*) supervise during the competition to guarantee safety of the swimmers. We asked a fellow Tesla student (Marijn van Doorn) to provide commentary for the public during the competition. After the copmetition all swimmers received a goodie bag to thank them for their participation, including some snack, drinks, and a booklet about Marineterrein

The swim competition took place in the basin along the south quay of the basin. The start was in the southeast corner of the basin (next to Pension Homeland), and participants swam to the southwest corner of the basin, where they turned around the underwater garden (that functioned as a buoy). The finish was at the start again. The total distance was about 200 meter. There were four teams of 2-3 people, and each team swam in relay against another team. Two swimmers with the fastest time raced in a final against each other. The winner of the competition was a 61-year old neighbour of Marineterrein.

Due to the bad weather forecast, there were some withdraws from the competition. Nonetheless, the competition was a great success. The swimmers showed their best swimming skills and the public on the quay showed much enthusiasm. We received many compliments from neighbours who came to support the swimming competition and expressed their interest in swimming in the basin (see **Appendix IV**).

Appendix IV. Pilot: submerged garden

Details of submerged garden

For the element of the submerged garden three large *koilelie* were ordered at *Nikoi online vijver winkel*. Furthermore, the plant were ordered at *Directplant*, twelve of the Rigid Hornwort (*Ceratophyllum demersum*) and six of the yellow water-lily (*Nuphar lutea*) which were delivered at Dubbelgroen at the Czaar Peterstraat in Amsterdam. This resulted in a total of €756.70 for the submerged garden. Eventually the yellow water-lily appeared to be too small therefore we collected some of the yellow water-lily from one of the canals surrounding Marineterrein.

Item	Price (€)	Number of items	Total price (€)	Delivery time (Days)	Shop/Website
Submerged garden					
Koilellie (basket)	€229,95	3	€689,85	4-10	https://www.nikoi.nl/koilelie
Anchor line	€6,19	1	€6,19	0	Praxis
Anchor Block	€0	1	€0	0	
Macrophytes					
Rigid hornwort	€2,13	12	€25,56	3-5	http://www.directplant.nl/hoornblad-ceratophyllum-demersum.html
Yellow Water-lily	€5,85	6	€35,10	3-5	http://www.directplant.nl/gele-plomp-nuphar-lutea.html
Total			**€756,70**		

As stated earlier these species occur in natural waters surrounding Amsterdam. However, it is not determined that they can survive in the submerged gardens and the plants in it. Multiple factors could play a role determining the life time of the pilot. A few of these factor will be elaborated.

- Herbivory by water bird– there is an Eurasian coot (meerkoet) couple in the basin nesting on the boat platform form the navy. They showed interest in the

submerged gardens in the first week. After two weeks they started to forage on the leaves of the plants to feed their young. Time has to show what will happen to the plants and the coots.

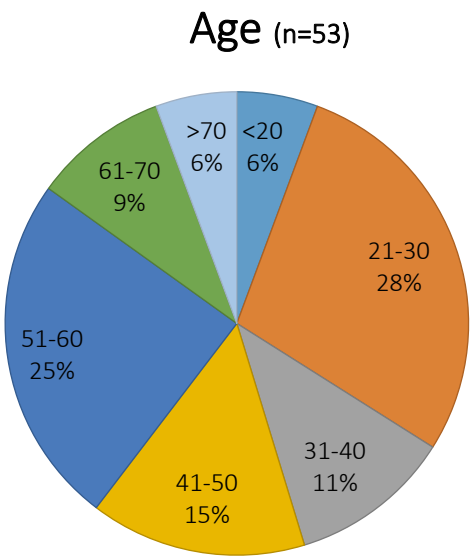
- Swimmers could form a risk for the plants by climbing on the ring. The ring are strong enough to help a person float and can not easily be broken. Nevertheless, extreme behaviour can harm the plant significantly and when people stand in the ring it will eventually break. When plants grow in the gardens people will probably stay out of the basket.
- Another risk for the plant could be formed by the large waves in the water. Extreme waves can disturb the submerged gardens. The basin is not extremely susceptible for these big waves but to prevent to much disturbance we placed the garden in a corner with little waves (**see picture**).
- Lastly, winter can form a risk. The chance of the water freezing over in the winter is small nevertheless this could damage the floating ring. Low temperatures could also damage the plants, however the plants also exist in the shallow waters with less current therefor this would not be a big problem.

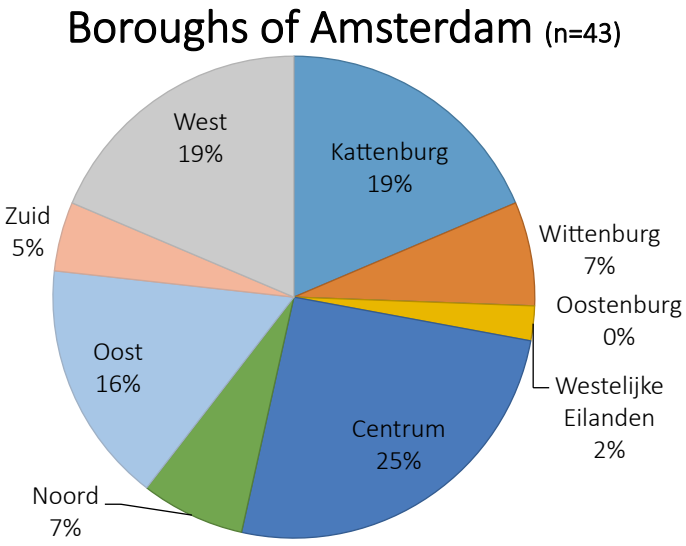
Appendix V. Survey outcomes

The survey was performed among a number of the visitors (n=54) at the open day of Marineterrein on the 3 July 2016. Not all the questions were filled in by all the respondents and some questions were answered with multiple answers. Furthermore, there has to be taken into account that 7 participants of the swimming competition filled in the survey. This may interfere with the results since this is almost 13% of all the participants. For an example of the questionnaire see **Appendix VI**.

General information

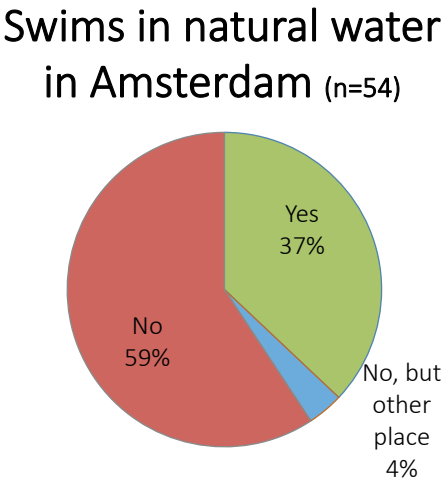
All different age groups among the respondents was represented, with a majority for the group 51-60 (29%) and group 21-30 (28%). We asked the respondents in which borough they lived and specified that for the neighbourhood. Among the respondents from Amsterdam the largest part lived in the city centre (25%). The next best represented were the city borough *West* (18%), *Kattenburg* (18%) and *Oost* (16%). No respondents were from *Oostenburg*.

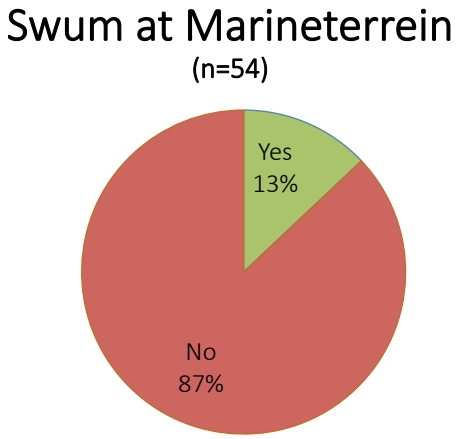




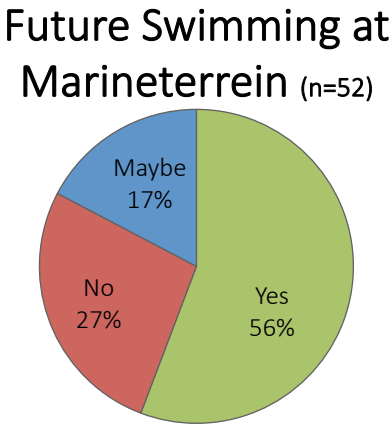
Swimming

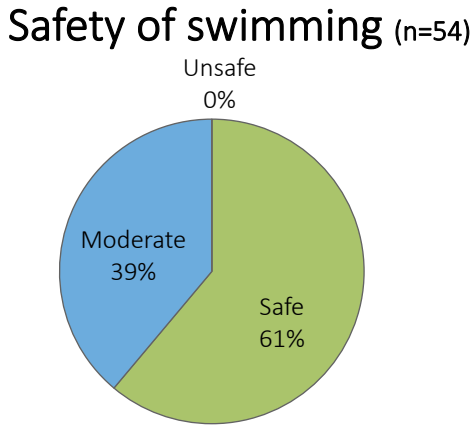
Among the respondents, 13% participated in the swimming competition on that day (n=7). Among all the respondents, 37% answered that they swim more often in natural water in, or surrounding Amsterdam, 4% does not swim in natural water surrounding Amsterdam but somewhere else. The remaining 59% answered that they do not swim in natural water.

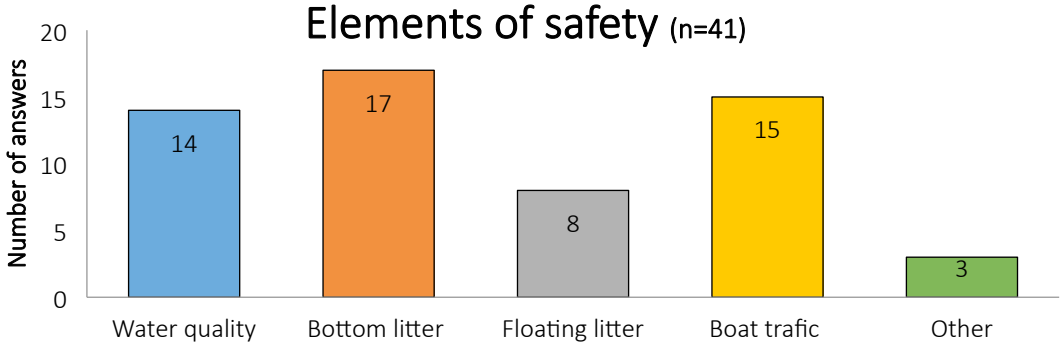




Of the respondents (n=52) 56% answered to want to swim at Marineterrein in the future, when a pier is provided. Of the remaining respondents 17% answered *maybe* on the question to swim in the basin in the future and 27% answered *no*. Two answers were left out the result because of answering *yes* and *maybe* at the same time.





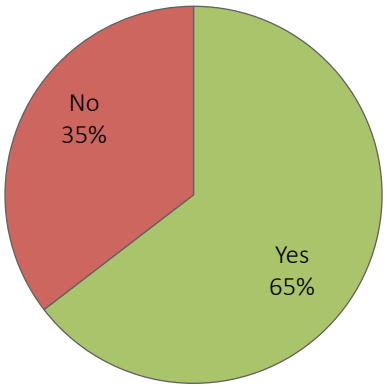


On the question concerning the safety of the water none of the respondents answered *unsafe* (Moderate: 39%, Safe: 61%). This is probably influenced by the organisation of a swimming competition. The element determining the safety of swimming differed between the participants. They could give multiple answers in the survey but not everybody answered this question. The element mostly chosen is the *litter on the bottom* (17), such as bike wrecks. But *boat traffic* (15) and *water quality* (14) were also viewed as important element of safety.

Information

Of the respondents (n=48), 65% would like to have *more information* concerning safety, ecology and swimming and 35 % in *not interested* more information. The following question about the location of the information (n=45) the majority, 35 answers, would like to find this information on a *website* and only 16 answered they would like to see the information *at Marineterrein*.

More information about safety, ecology, swimming (n=48)

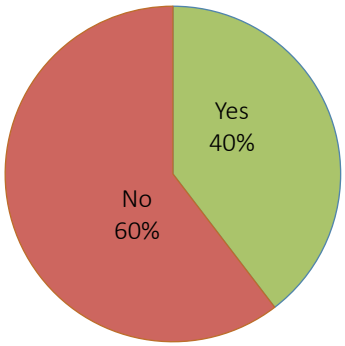


Information medium (n=45)

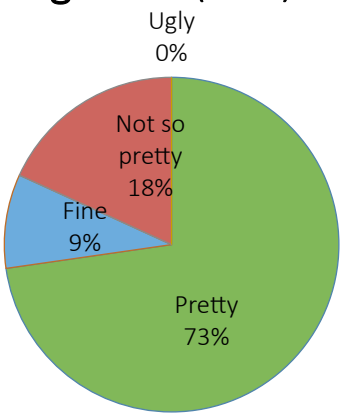
Submerged gardens

Of the respondents (n=53) answering the question if they had seen the submerged garden, 60% answered that they did *not see* the garden and the remaining 40% *did*. When the respondents were asked the follow-up question, what they think of the appearance of the submerged garden 73% answered *pretty*, 9% answered *fine* and 18% answered *not so pretty*. 0% of the respondents thought the submerged gardens were *ugly*.

Have you seen the submerged garden (n=53)



Appearance of the submerged garden (n=22)



Appendix VI. Survey open day Marineterrein

Ecologie

Heeft u de onderwatertuinen in de haven van het Marineterrein gezien?

Ja ------

Nee ------

Zo ja, wat vindt u van de onderwatertuinen?

Mooi ------

Prima ------

Niet zo mooi ------

Lelijk ------

START

Zwemmen

Heeft u gezwommen tijdens de open dag van het Marineterrein?

Ja -------

Nee -------

Zwemt u vaker in openwater in Amsterdam (of omstreken)?

Ja -------

Nee -------

Nee, maar wel op andere plekken dan Amsterdam en omstreken -------

Zou u in de toekomst gaan zwemmen in de haven van het Marineterrein als er een steiger ligt?

Ja -------

Nee -------

Misschien -------

Vul in: Volgens u is het … om te zwemmen in de haven van het Marineterrein

Veilig -------

Matig veilig -------

Onveilig -------

Wat zijn volgens u de oorzaken van een onveilige/veilige zwemplek op het Marineterrein?

Slechte waterkwaliteit ------

Afval op de bodem ------

Afval op het water ------

Bootverkeer ------

Overig ------

MARINETERREIN *Amsterdam*

Scheur enquête

Scheur uw antwoord op de stippellijn en vul hier uw gegevens in als u er mee instemt om benaderd te worden voor meer vragen:

Naam: ……

Email adres:……

Hartelijk bedankt

namens het Tesla team:

Evie Cox
Maarten Erich
Merrit Beck

UNIVERSITEIT VAN AMSTERDAM

TESLA
connecting science,business and society

Uw bezoek

Wat is uw leeftijd?

< 20 ------

21 – 30 ------

31 – 40 ------

41 – 50 ------

51 – 60 ------

61 – 70 ------

70 ------

Als u uit Amsterdam komt, uit welke buurt komt u dan?

Kattenburg ------

Wittenburg ------

Oostenburg ------

Westelijke eilanden ------

Centrum Overig ------

Noord ------

Oost ------

Zuid ------

West ------

Informatie

Zou u meer informatie willen krijgen over het water, de ecologie en (de veiligheid van) zwemmen in de haven van het Marineterrein?

Ja -----

Nee -----

Op welke manier kan deze informatie het best gedeeld worden volgens u?

Informatiebord in de haven van het Marineterrein -----

Website -----

Appendix VII. Information panel open day Marineterrein

MARINETERREIN *Amsterdam*

Zwemmen in de binnenhaven?

Open dag

Water heeft altijd een centrale rol gespeeld op het Marineterrein Amsterdam: als scheepswerf voor de Admiraliteit van Amsterdam en later als logistiek centrum voor de Koninklijke Marine. Net als in de rest van de stad werd het water niet alleen gebruikt voor transport maar ook voor het lozen van afval. De gevolgen daarvan merken we nog steeds. Maar er is goed nieuws: de kwaliteit van het Amsterdamse water verbetert elk jaar.

Zwemmen op eigen risico

Waternet monitort sinds het voorjaar 2016 de waterkwaliteit. De binnenhaven is de komende jaren nog geen officiële zwemplek vanwege strenge regelgeving en fluctuaties in de waterkwaliteit. Toch mag je hier zwemmen, maar dan wel op eigen risico. Studenten van de UvA hebben de waterkwaliteit, de bodemgesteldheid en de ecologie van het water onderzocht, zodat je een weloverwogen keuze kunt maken voor je het water in gaat om een baantje te trekken.

Hoe schoon is het water?

De waterkwaliteit in de Amsterdamse grachten is meestal goed. Maar soms, bij langdurige regen en hoosbuien, kunnen de riolen zó vol raken dat er rioolwater in de grachten stroomt. Dan komen er bacteriën in het water terecht. Bij warm weer vermenigvuldigen bacteriën zich bovendien snel. Zwemmers die dan water binnenkrijgen, kunnen last krijgen van buikpijn, braken of diarree. Kinderen en ouderen hebben een verhoogd risico.

Wat ligt er op de bodem?

De bodem is door de eeuwen heen vervuild geraakt met zware metalen en olieresten. Als de bodem wordt omgewoeld, kunnen deze stoffen vrijkomen. Dat zal niet snel gebeuren als er wordt gezwommen, want de bodem ligt op 3 tot 4 meter diepte, maar wel als er veel schepen varen. In de toekomst kan de bodem bedekt worden met een schone laag zand, zodat het vuile slib minder snel in het water komt.

Wat leeft er in het water?

Het Marineterrein is jarenlang afgesloten geweest, ook voor biologen en ecologen. Daardoor weten we nog niet veel over de natuur op het land en in het water.
Wat we wel weten is dat de hoge stenen wallen weinig kansen bieden voor waterplanten en vissen om zich te nestelen. Het is zinvol om in de binnenhaven alternatieve leefomgevingen te creëren, want een goed ecosysteem is de beste manier om helder en schoon water te krijgen.

Onderwatertuinen

Om de waterkwaliteit te verbeteren hebben de studenten onderwatertuinen aangelegd: drijvende korven met diverse waterplanten zoals grof hoornblad, gele plomp en kranswieren. Deze planten voegen zuurstof aan het water toe en ze gaan de groei van blauwalgen tegen. Jonge visjes vinden bovendien beschutting tussen de planten. Zo verbetert de waterkwaliteit op natuurlijke wijze.

Colofon

Studenten van de Tesla-minor (Universiteit van Amsterdam) voeren het onderzoek uit in opdracht van Bureau Marineterrein Amsterdam en in samenwerking met Waternet. In de zomer van 2016 wordt het onderzoek afgerond en gepubliceerd op marineterrein.nl.

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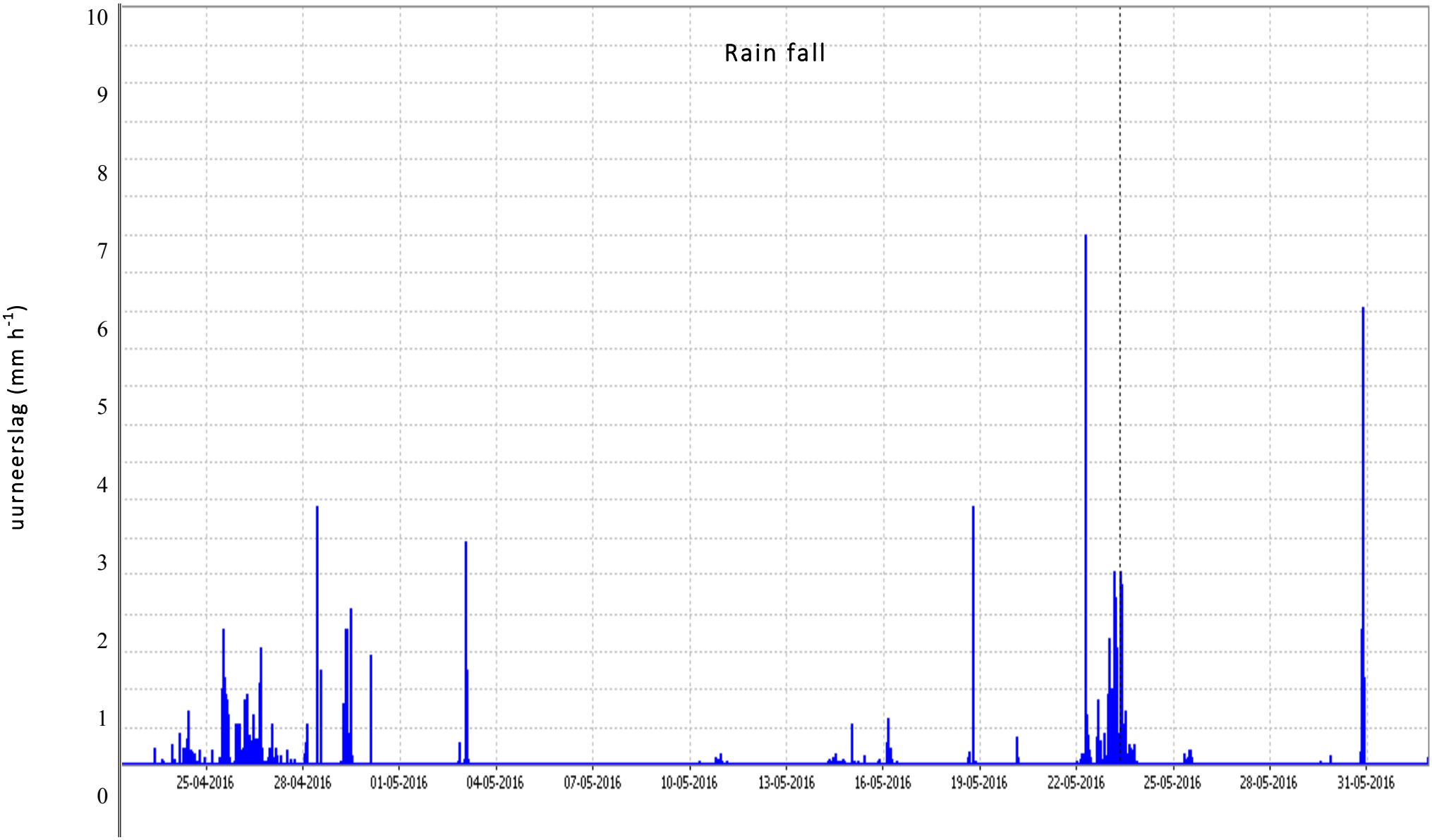
Appendix VIII. Rain fall in Amsterdam

Data about the rain fall between 23-04-2016 until 02-06-2016, acquired from *Waternet*.



Appendix IX. Recommendation contact details

In this table the contact details from the extra companies, initiatives and projects we have spoken to during our project next to the stakeholder analyses.

Project	Company	Contact	Contact details
Floating gardens	Global Wetlands	Jonas Pelgröm	jonas@globalwetlands.com
Seabins	The Seabin Project	Pete Ceglinski	pete@seabinproject.com
Floating waste barrier	Great Bubble Barrier	Francis Zoet	thegreatbubblebarrier@gmail.com
Aquabot	Indymo	Rutger de Graaf- van Dinther	rutger@indymo.nl
Interactive buoy	Sensemakers	Ted van der Togt	ted@vandertogt.nl
Amsterdecks	Liquid Commons	Christopher de Vries	info@rademacherdevries.com

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20-07-2016