Sound Water Retention Strategies for The Municipality Borsele

Freshwater retention within de subsurface of North Sea Port

Final Thesis Report
05/08/2020

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Preface

With this thesis report "Sound Water Retention Strategies for the Municipality Borsele" I conclude my bachelors program Delta Management at the Hogeschool Zeeland. My time spent following this bachelor program has made me increasingly interested in the topic of water retention to combat climate change. The knowledge and experiences gained working on my report have given me valuable skills for my future career.

This report was written for public and private parties within Zuid-Beveland who are involved in the agricultural, local governance or water utility service fields. This report attempts to provide an insight into the ever-growing impacts of climate change within Borsele whilst providing a solution which can help reduce the effects drought periods have. This report was written in assignment for the municipality Borsele, it provides the project owner with an overview of risks and solutions that can help in reducing detrimental impacts on the agricultural field.

I would like to thank my internship supervisors Miora Maat-Rijk, Jan Joosten and Remy Lemmens for the time they spent providing me with feedback and guidance throughout the process of writing my thesis report. Furthermore, I would like to acknowledge the time spent by countless farmers, contractors and representatives of agricultural organizations for the time they spent answering my questionnaire.

Mart Scheers
20/06/2020

Summary

The municipality of Borsele as well as other municipalities are dealing with water shortages as a result of a changing climate. This water deficit is likely to become an increasingly pressing issue as climate change further develops. This growing shortage of water will threaten urban zones as well as the widespread agricultural sector of Borsele. This report aims to provide the reader with an insight into ways that Borsele can be prepared for climate change. The primary research question is to assess a method in which a larger irrigation water quantity can be created by either creating new water storage locations or by altering the usage of existing networks.

The primary research method used to perform this research report was the analysis of quantitative and qualitative information via desk research. The qualitative information provided an insight into what methods are available to store water whilst the qualitative data provided and insight into the specific threats Borsele will face relating to climate change and its current agricultural situation. Furthermore, interviews where used to attain a significant portion of the data required. The insights created using desk research and the inquiries held where tested in workgroups which allowed for the assessment of the most suitable retention method and the further development of a strategy.

By performing this research, the following conclusions have been established. Firstly, the current water use by the agricultural sector in Borsele is high. In the months June, July and August a minimum of 0,57 million cubic meters of water is used monthly. Secondly, current water usage will rise due to climate changes. Thirdly, crop types and fruit varieties grown in Borsele are not drought and salinity resilient climate change will likely have a significant impact on harvests if methods are not altered or crops grown changed.

The most suitable method of optimizing water retention in Borsele is large-scale subsurface water retention within the substrate of the Port Facility “North Sea Port”. To achieve this a number of zones within the northern and central (Scaldia Terminal) of North Sea Port can be adapted with measures to improve percolation. At these suitable storage locations water can be extracted from the substrate and used for industrial purposes or used locally by some industries. By using water locally, the industrial water supply coming from “North Brabant” 1200m^3 / hour can be utilized by agricultural businesses increasing water availability during dry months providing up to 864,000m^3/month. This is upwards of more than half the monthly requirement for irrigation needed during dry summers.

Validity of results in this research is achieved by using literature and statistics from well-established organizations and institutions. The findings are discussed with the work field in order to establish wat strategies are available, and which are most suitable.

The report has led to the following advices; the implementation of a channel grid in the northern portion of North Seaport Vlissingen. Additionally, further utilization of the Evides Industrial water grid needs to be assessed. To do this price research needs to be performed in order to determine utilization willingness. Finally, additional research is needed to determine the water retaining capacity of NSP by assessing dock wall characteristics.

1 Table of Contents

List of Abreviations

Abreviation	Definition	Notes
IPCC	Intergovernmental panel on climate change	
KNMI	Koninklijk Nederland Metereologsch Institute	
GIWR	Gross Irrigation Water Requirement	
NIWR	Net Irrigation Water Requirement	
WTP	Water Treatment Plants	
SAZ+	SAMENWERKING (AFVAL)WATERKETEN ZEELAND	*A project managed by the Waterboard Scheldestromen to improve water system circularity within the sewage grid system.*
RIVM	Rijksinsititute voor Volksgezondheid en Milieu	
MER	Milieueffectrapport	
ZSP	Zeeland Seaports	
NSP	North Sea Port	
Ha	Hectare	*A measurement unit containing 100 meters*
M	Meter	
NAP	Normaal Amsterdams Peil	*Amsterdam Ordananence Datum*
STOWA	Stichting Toegepast Onderzoek Waterbeheer	*Knowledge institute of waterboards and provinces*
IRN	Net Irrigation Requirement	
IRG	Gross Irrigation Requirement	
GW	Available Groundwater	
WB	Available Soil Moisture	
PE	Effective Precipitation	
ETC	Crop Evapotranspiration	
ETO	Reference Crop Evapotranspiration	
RA	evaporation equivalent of extraterrestrial solar radiation	
TD	the difference between average daily maximum and minimum temperatures for the period	
T	Average Temperature	
EA	Application Efficiency	
EC	Canal Conveyance Efficiency	

1 Introduction

1.1 Problem Statement

The effects of prolonged drought have led to significant impacts within Borsele in recent years. In 2018 a severe dry spell caused widespread loss of harvests especially amongst union harvests. For a municipality such as Borsele which is largely agricultural this will have far reaching impacts on the livelihoods of its inhabitants if no action is taken to reduce the risks of drought.
This has forced the municipality Borsele to make assessments of climate vulnerabilities for its urban and rural zones. From the assessments thus far, it has become evident that drought is one of the primary threats for the near future. Prolonged drought will bring with it severe water shortages which primarily threaten the agricultural sector. Climate change induced drought and heat will become an ever-increasing threat for the municipality of Borsele. The resulting freshwater shortages are likely to have detrimental impacts on harvests and the livelihoods of the many agricultural communities the municipality is home too.

1.2 Research Goal

To improve the supply of freshwater, possibilities of storing large quantities of water in surface water bodies and the sub-surface need to assessed.
Initially this research will investigate the current water use situation in Borsele. After which it will assess all the possibilities for storing large volumes of water in or in de direct vicinity of Borsele. For the most suitable retention measure an area analysis and design proposal will be constructed. This thesis report will provide the municipality of Borsele with a clear assessment of its possibilities for preparing for prolonged drought strengthened by ongoing climate change.

1.3 Primary Research Question

How can large quantities of freshwater best be stored within or in the direct vicinity of the municipality of Borsele? Or how can existing waterbodies or networks be used more effectively as to insure a larger supply of Irrigation water during dry months?

1.4 Sub-Research Questions

1. What are known water retention strategies for urban and rural areas which are applicable to Borsele?
2. What is the total average annual quantity of freshwater used in dry and wet months within de municipality Borsele by agricultural businesses requiring water for irrigation purposes?
3. What stake- and shareholders are involved in freshwater retention strategies? Which of these actors are essential to realizing a strategy?
4. What is the most viable retention measure('s) for the municipality Borsele, what known and proven retention methods can be used?
5. What legislative steps or physical alterations need to be made in order to ensure that the most promising measure can provide the maximum amount of freshwater for agriculture?

2 Theoretical Framework

In the following chapter relevant definitions, theories, methods and organizations are discussed that are applicable for a water retention strategy in Borsele. This framework aims to form a foundation for the results of this thesis report.

2.1 Climate Change

A climate is defined by the average weather over a period of 30 years. To determine a climate barometric pressure, temperature humidity, wind, precipitation and cloud cover are considered. Additionally, extremes such as heatwaves, extreme precipitation and flood events are considered (KNMI, 2019). The Average weather over a period of 30 years is called a climate (KNMI, 2019). If two 30-year periods show sufficient variation climate change is occurring. Climate change has occurred a great multitude of times since the formation of civilization, however now it has become evident that the most current changes are driven by human activity. The primary cause being the expulsion of large quantities of greenhouse gasses since the start of the industrial revolution (Senge, 2019). The industrial revolution began in 1750. From this point on our planet has been warming up (Senge, 2008). This is caused primarily by using fossil fuels, first the burning of coal and later other hydrocarbons. From the combustion process carbon dioxide is expelled into the atmosphere. Due to industrialization the concentration of greenhouse gases has grown exponentially since the start of the 20th century.

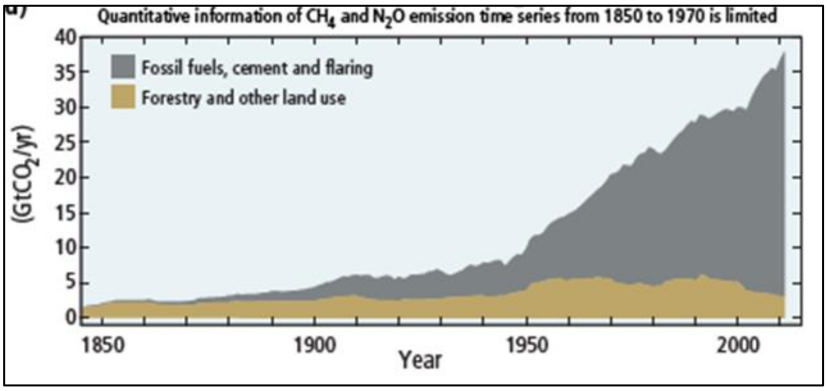

Figure 1: Global emission increase. Received From: https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

Greenhouse gasses can be characterized by their ability absorb and contain solar radiation. As solar radiation (Heatwaves) no longer escape from the earth's atmosphere the average global temperature will rise (Senge, 2004). As a result of this greenhouse effect mean global temperatures are expected to rise by 0,9 to 4,0 degrees by 2100.

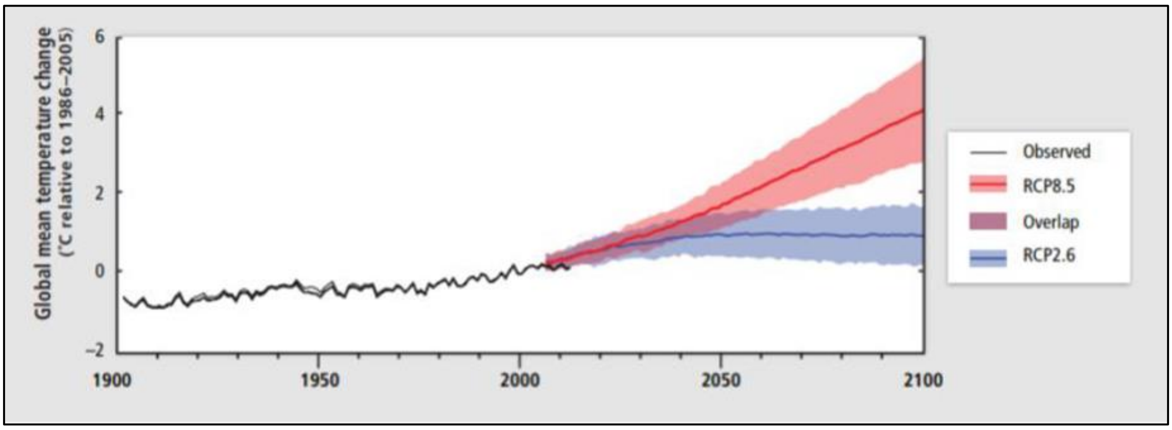

Figure 2; Climate Rise Predictions. Retrieved From: https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

The figure shown above from the AR5 2014 IPCC report represents two scenarios. The RCP 2.6 prediction is a moderate representation of the future climate. It assumes that industrialized nations have taken substantial mitigation measures to mitigate their impact on the climate. If no mitigation measures are taken scenario RCP 8.5 could become reality this would bring with it substantially higher temperature rise than scenario RCP 2.6. The RCP 2.6 predicts a mean rise of 0,9-1,9 C° whilst the RCP 8.5 assumes a temperature increase of up to 4,0C ° by 2100. The average mean temperature rise discussed in the previous paragraph can have a severe impact on human populations and the biosphere. Rising temperatures can cause prolonged drought extreme heatwaves and an increase in the frequency of intense precipitation events this in turn increasing flood risks (KNMI, 2019).

Climate change is likely to lead to a steep increase in the amount of extremely hot days during summer months and less cold days in the winter (Tank et al, 2015).The occurrence of extremely hot days will result in short periods of extreme weather, storms with high winds and hail will become a more common occurrence. The annual precipitation totals will rise until 2050 however due to increased evaporation rates the chance of drought will continue to rise.

2.2 Extreme Weather Patterns

Figure 18 shows a slight increase in the amount of annual precipitation in the Nederland's since 1957. From this figure drought should occur less and become a rare occurrence as average precipitation rates are rising. This is however not the case. Much of this precipitation which falls in summer months falls in short intervals. Precipitation which falls in short periods does not percolate into the subsoil effectively. Much of this water will run into waterways and be removed from agricultural fields. Extreme precipitation is expected to become more prominent as mean temperatures become higher. Additionally, evaporation rates become higher as solar energy increases partially induced by climate change. As this trend continues it will become very likely that less of the net irrigation requirement is available to crops meaning the gross irrigation requirement becomes larger. Crops will have to be irrigated more to insure proper crop development.

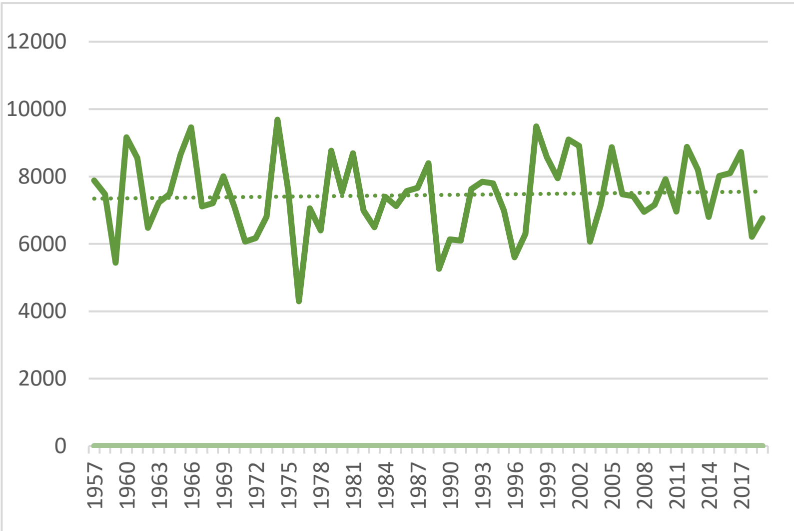

Figure 3, Precipitation Trends in the Netherlands. Source KNMI

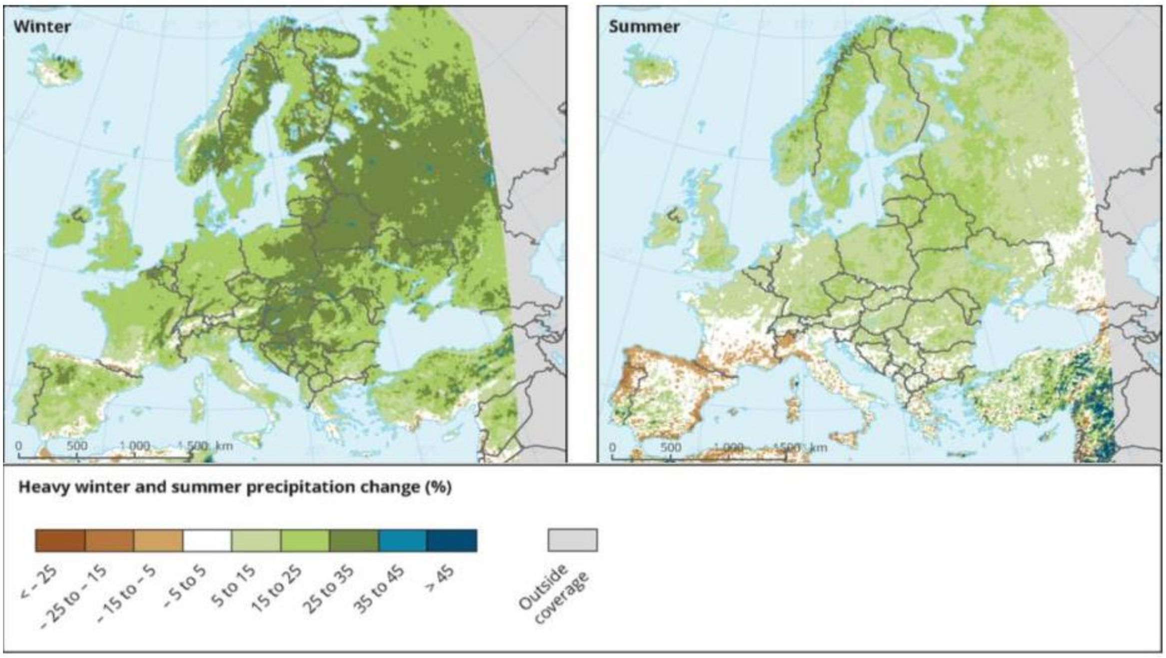

Figure 4, European Precipitation Changes until 2100 RCP8.5 Retrieved From: https://www.eea.europa.eu/data-and-maps/indicators/precipitation-extremes-in-europe-3/assessment-1

The figure above shows how heavy precipitation events are likely to become more frequent throughout most of northern and central Europe. The Netherlands is likely to experience a 15-25% increase in heavy precipitation events compared to the period 1971-2000 (IPCC.2016). When large amounts of precipitation fall in short periods the ability of fields to store water is decreased this will further lower the amount of groundwater as effective precipitation is reduced.

The temperature throughout europe has risen considerably in the last decades. With both winter and summer temperatures rising by 0.4-0.6 in the Netherlands in the past 30 years (IPCC. 2016). This increase in temperature will lead to higher levels of evapotranspiration as it brings with it higher rates of solar radiation. In time this will result in increasing crop evaporation rates and a higher irrigation requirement.

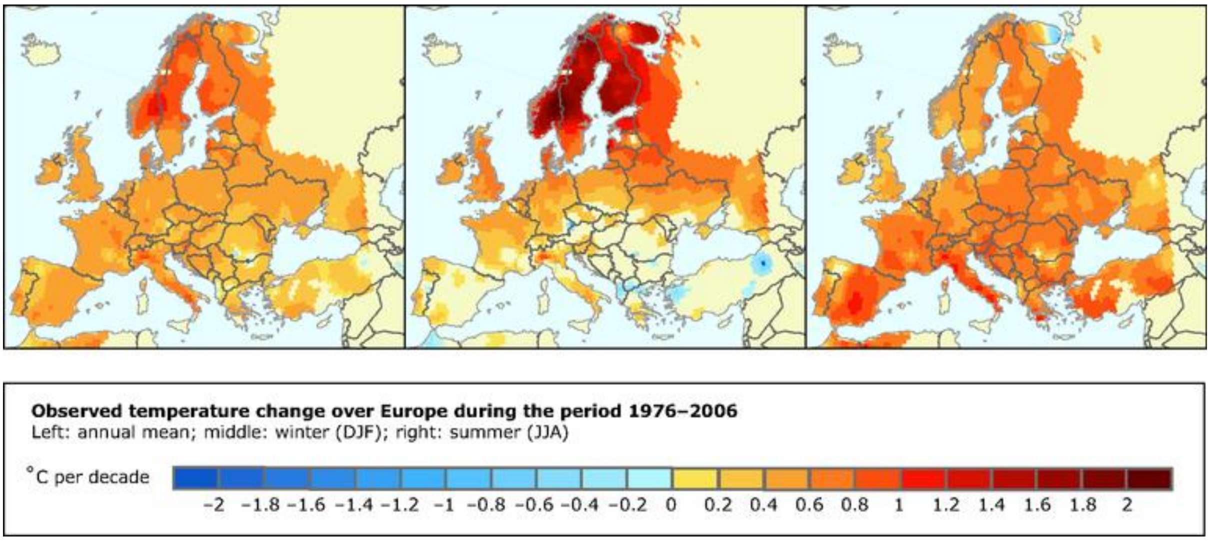

Figure 5 European Average Temperature Changes. Retrieved from: https://www.eea.europa.eu/data-and-maps/figures/observed-temperature-change-over-europe-1976-2006

2.3 Impacts on Crops

Elevated levels of salinity alter the development of plants (Grattan. 1999). Due to the location of Borsele close to the North Sea drought quickly leads to the intrusion of salts. In soils with high ion concentrations plants are unable to properly absorb water due to differences in ion concentrations within and outside cell structures (osmotic effect). Additionally, high Na+ ions can cause harm to cells when toxic levels are reached. This results in the crop yields being reduced or even the complete wilting of a crop. Soil salinity is often measured by measuring soil electroconductivity expressed in (ECe, in dS/m). The following table expresses salinity classes which intern relate to the tolerances of specific crops.

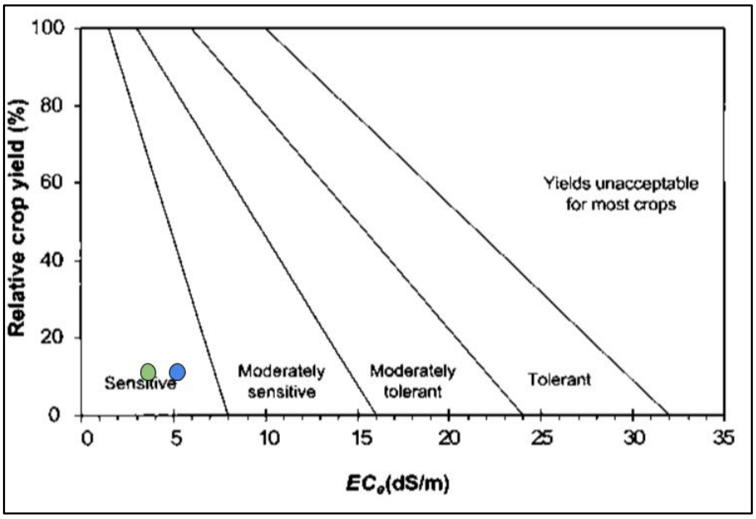

Figure 6, Crop Salt Tolerances, Potatoes Blue, Onions Green: Source Salt Farm Tezel

Al crops have different salt tolerances, with some losing almost all yield at low levels of salinity whilst others are able to tolerate very high salinity levels with almost no yield loss. Knowing how changes in salinity levels effect crops grown in an area is of vital importance as it has great effect on total crop yield.

Table 1, Salinity Tolerance Classification. Source: Salt Farm Texel

Soil-Salinity Class	EC (in dS/m)	Effects on Crops and Plants
Non-Saline	0-2	Very small effects on Yields
Slightly saline	2-4	Yields of sensitive crops restricted
Moderately saline	4-8	Yields of most crops restricted
Strongly saline	8-16	Only suitable for salt tolerant crops
Very strongly saline	>16	Tolerable for but a few plant types

The potato is considered a salt intolerant crop. It losses 10 percent of its yield between 3.6-4.6 in dS/m and 50% loss at 11 in dS/m (Hoffman. 2000). In recent years as drought has become a growing issue worldwide attempts have been made to create more tolerant variants; these initiatives have gained success with successful trials being performed in a number of third world countries (A de Vos. 2016). To increase potato harvest resiliency farmers can grow potatoes with higher salt tolerances such as the 927 USDA. It should be noted that these crops have different shape and textures as the established varieties grown in the Nederland's. Much like the potato unions are considered by most standards as a salt sensitive crop. Unions loss 10% yield at 3,7-4,7 in dS/m and 50% yield at 8,6-8,9 in dS/m (Hoffman .2000). Unions therefor are a poor choice of crop when low salinity levels cannot be maintained in summer months.

Pear and apple trees are both considered a salt sensitive wooded crop (Ivanov.1970). Studies assessing the impact of saline soils have been performed using young trees however information on adolescent trees is missing (Boland.1990). Field experiments on apple trees have shown that Na+ ions are stored within the woody mass of trees. At first the impact to the plant is minimal but once thresholds are reached the plant will become incapable of absorbing and transporting water. Due to this trait it could seem that trees are capable of dealing with higher salt concentrations. However once ion storage capacity exceeds its limit the plant will die within a short time span.

In 2018 the province of Zeeland completed a cartography project in which soil salinity was measured. This research has shown that on both the island of Walcheren and the island of Noord-Beveland moderate ion concentrations can be found at relatively shallow depths. The following image shows at what depth concentrations of 1500 mg Cl /L can be found in soils. 1500 mg Cl /L translates to an electroconductivity of just over 8 in dS/m (Texel Salt Farm. 2014). This means that in the south of Borsele soils can be considered saline at a depth between 0-2.5m. It is likely that irrigation channels in the south of Borsele regularly contain high salinity levels.

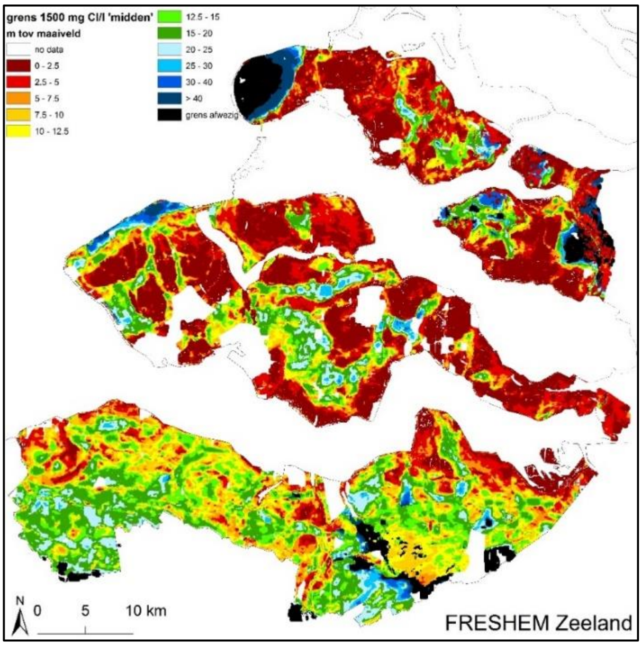

Figure 7, Freshen Map Zeeland, Retrieved From: https://kaarten.zeeland.nl/map/freshem

The majority of modern potato varieties are considered to be a drought sensitive crop (American Society of Plant Biologists. 2008). A shortage of available soil moisture will quickly lead to a halt of photosynthesis within the potato plant and greatly reduced internal cell signaling this is likely to result in the yield and quality of the potato to be significantly altered although the extent of the damage is greatly dependent on the species of potato grown. Unions are also a crop with a low drought tolerance however they are more likely to wilt and die as a result. This correlates with drought events in the province of Zeeland primarily effecting the union harvests. The effect on tree's must also not be underestimated. Trees are better equipped to deal with restricted water availability due to the wood mass being suited to retain moisture under evaporation stress. Additionally, deeper and extensive root systems allow for more sub terranean water sources to be utilized. Despite this prolonged water stress greatly effects the development of fruit and can affect harvests of the upcoming year (University of Missouri. 2016).

2.4 Soil Mechanics & Irrigation Requirements

Al soil types are able to hold considerable amounts of water within their granular structures. This water moves through soils following capillary pull and gravity, this results in water flowing towards lower layers of soil or flowing into lakes, rivers or oceans. Some of the water will be lost to evaporation. Percolation is the process in which fluids move through soils following gravitational pull and capillary pull as described in Darcy's law. The speed at which fluids move through the pore space is determined by the size of the pores (Newman.2000). Larger pore spaces generally allow for faster percolation then smaller pore spaces, it is for this reason that sand is suitable for quick infiltration and storage of water whilst clay soils allow for only slow percolation. If a lot of water is applied to a soil the field capacity can be reached. The field capacity is the amount of water left in a soil structure after all the excess water is drained and no evaporation has occurred. Field capacity is strongly dependent on grain size and the ability of a soil to create a capillary pull. Sand generally has a poor field capacity whilst clay soils have a high field capacity.

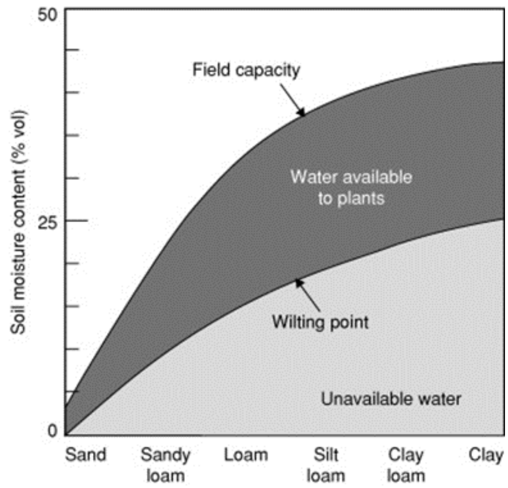

Figure 8; Field Capacity and Wilting Point, Retrieved From: https://www.researchgate.net/post/How_to_maintain_100_and_50_field_capacity_in_tomato_grown_in_poly_grow_bags

The curve shown right represents the relationship between the energy of water (pressure) in the pore space and the degree of soil saturation. Figure 4 shows that Clay can hold more water within its structure then sand and loam soils. The gross irrigation equation is commonly used in agriculture in order to properly irrigate crops (Peace Corps, 1994). The formula to determine gross irrigation requirement is as follows. This formula incorporates irrigation efficiency water loss.

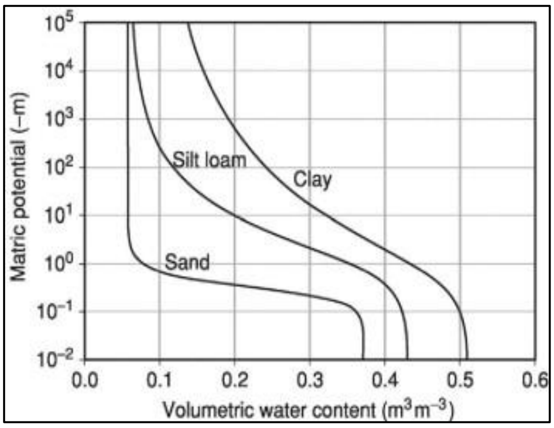

Figure 9; Soil Water Characteristic Curve, Retrieved From: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/soil-water-characteristic

$$Irg = \frac{Irn}{Ea \times Ec}$$

Irg=Gross irrigation requirement
Irn=Net irrigation requirement pre day
Ea=Farm application efficiency
Ec=canal conveyance efficiency

The net irrigation water requirement is the volume of water which needs to be applied to a soil in order to compensate the soil water which is consumed by a crop and evaporation. Maintaining net irrigation water requirement is necessary to achieve full crop yield (Peace Corps, 1994).

$$IRN = ETc - Pe - Gw - Wb$$

IRN=Net Irrigation Requirement
ETc= Crop evapotranspiration under no stress
Pe= Effective Precipitation
Gw=Groundwater Contribution
Wb=Stored soil water at the beginning of a period

2.5 Water Retention Methods

In recent years retaining water within the urban and rural environment has become an increasingly discussed topic as the risks continue to grow. The following paragraphs provide an overview of retention methods for rural landscapes within the Netherlands listed by STOWA.

Using irrigation channels to increase agricultural plot retention capacity.

Irrigation channels running along agricultural plots are the smallest components of most freshwater networks. In periods of high precipitation rates water can be stored in these channels. This reduces pressure on downstream water networks and allows for more water to infiltrate into the subsurface surrounding fields this in turn combats rising saline water lenses. A widespread method of retaining water locally is placing a weir to control water levels. Weirs allow farmers to adjust the height of water in channels the use of so-called smart weirs such as the SAWAX system is becoming increasingly common. Reducing the depth of irrigation channels can also be a method used to store water in the soil of fields. Diep channels pull water out of the surrounding soils whilst still allowing to be expelled when necessary. Finally, a way freshwater lenses can be strengthened is by increasing the length of irrigation channels. Reinstating of meandering waterways will increase the time water can infiltrate. These methods can be applied on the local scale by farmers personally as well as by municipalities and waterboards. Additionally, the implementation of adjustable weirs does not require considerable financial investment (Stowa.2015).

Figure 10, Adjustable Weir, Retrieved From: https://www.stowa.nl/publicaties/zelfvoorzienendheid-zoetwater-zoek-de-mogelijkheden

Above ground water storage methods.

The principle of above ground water storage is a widespread practice in greenhouse horticulture (Altera. 2014). In this industry closed loop systems are created in which rainwater and other runoff is collected and stored in large tarp lined basins. Costs of these methods are however relatively high and are often only used when other freshwater sources are scarce or costly. It is for these reasons that open ground agriculture rarely uses above ground storage methods. Above ground water basins are measures which are taken on the local scale. Water can also be stored above ground by applying multiple spatial land use methods. This entails that natural areas such as wetlands and fields can be used to temporarily store water for use in agriculture. A prerequisite for such a measure is that very high-water levels don’t harm ecosystems. This method has undergone multiple promising field trials. However, it is applied on a wider spatial and organizational scale and thus requires more cooperation between actors it is because of this that it has not seen widespread practice.

Figure 11, Above Ground Water Basin, Retrieved From: https://www.stowa.nl/publicaties/zelfvoorzienendheid-zoetwater-zoek-de-mogelijkheden

Sub terranean storage of freshwater.

Water can be stored in underground layers by artificially increasing the amount of water which infiltrates into the ground (Stowa. 2015). This method creates larger aquifers by deepening freshwater lenses and is often called artificial storage and recovery (ASR) or managed aquifer recharges (MAR). ASR methods focus on allowing for rapid percolation of excess water from above ground sources such as rainwater or treated effluent. This water is often brought deep into the subsurface via vertical drains. Water infiltration can also be increased by making changes in the natural landscape and agricultural zones. Water which is stored for longer periods in surface waterbodies is allowed more time to infiltrate into the underground. Using underground aquifers has the additional advantage that it prevents the stored water from evaporating. Finally, water which percolates through the ground is of excellent quality meaning that when it is extracted it is of excellent quality and usable for many different purposes. Subsurface water storage is a widespread practice worldwide particularly in the drink water sector it is also used to some extent in greenhouse horticulture in the Netherlands.

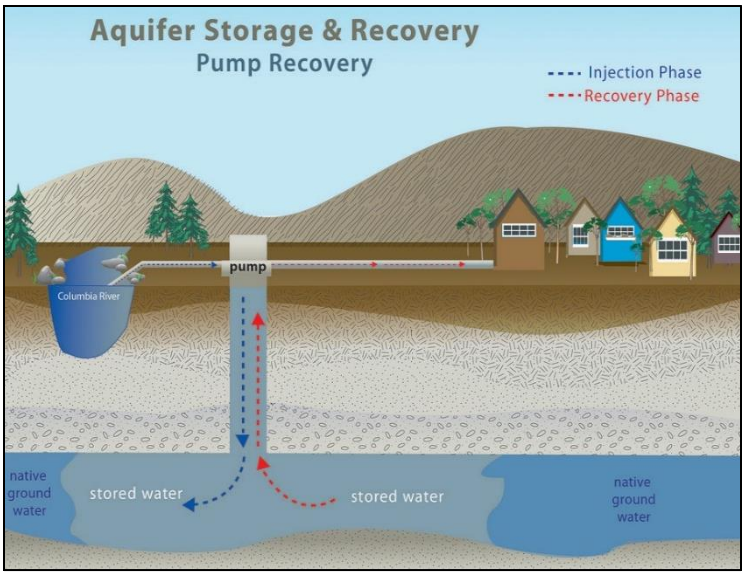

Figure 12, Aquifer Recovery, Retrieved From: https://www.flickr.com/photos/ecologywa/33116969814/in/photostream/

Water storage in creek ridges is similar in strategy to storage of water in deep water aquifers. Creek ridges are however sandy zones which are located at the surface or close to the surface this allows for easy infiltration and extraction. The figure shown right provides an overview of what locations are suited for this form of retention. Throughout Borsele a patch network of suitable locations is visible.

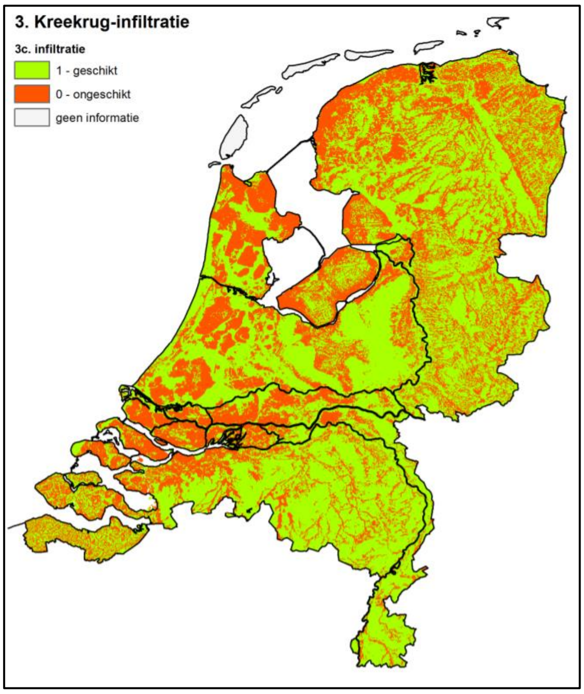

Figure 13, Locations Suitable for Creek Ridge Infiltration, Retrieved From: https://library.wur.nl/WebQuery/wurpubs/fulltext/329919

Increasing water use efficiency.

A direct method water can be retained is by increasing water use efficiency (Stowa. 2015). By applying irrigation water in precise amounts little runoff is created and less evaporation occurs. This increase in efficiency leads to a lower gross irrigation requirement meaning farmers need a smaller volume of water. Al water use efficiency are implemented on the most local level this being the individual field level. One such way water use efficiency can be increased is by implementing drop irrigation. In this irrigation method tubes provide individual plants with a steady supply of water. This irrigation strategy is used worldwide and is proven worldwide in the Nederland's it is however only used occasionally in horticulture and some forms of fruit cultivation. In Borsele this method is common practice amongst farmers of Apples and Peers. Sub surface irrigation is a method in which water is applied in the root zone of a crop. Due to the moisture being focused below ground there is very little evaporation. Sub surface irrigation is a proven method in the Nederland's (Reindsen, H. 2015). It is very effective in sandy soils, but clay soils limit its percolation capacity. The moisture content of soils can also be increased by increasing the amount of organic matter in soils. This requires farmers to apply some form of mulch onto fields. A final method of improving water use efficiency is by making use of precision irrigation methods. This irrigation method uses sensors and precipitation predictions in order to optimize soil moisture. This reduces water requirement and also reduces the amount of fertilizer required as there is less runoff. It is however a new technic which requires large financial investment.

Figure 14, Tree Drop Irrigation, Retrieved From: http://www.oxfarmorganic.com/our-products/agri_news/drip-irrigation-in-fruits/

Drainage methods to increase percolation.

On the scale of the individual agricultural plot infiltration systems can be applied as to store more freshwater. In the east of the Nederland's this can be used to prevent desiccation whilst in the west it can prevent salinization of the root zone. An adjustable drainage system is one which manages a certain water table in the vicinity of agricultural fields. Whilst allowing for the removal of water in periods of heavy precipitation. The Dutch term for such drainage systems is "Peil Gestuurde Drainage". By utilizing this method, the duration of water staying in the soil is increased this allows for a better absorption of nutrients by plants. This system is being applied more and more in the Netherlands and has proven to be effective. Intensive draining is a system in which a pipe grid is used to bring water from the surface into soil layers. The difference with aquifer restoration is that water is brought down only a few meters. Field trials have shown that this system can provide a valuable contribution to raising freshwater lenses (Stowa. 2016).

Figure 13, Adjustable Drainage System, Retrieved From: http://www.gebr-emonds.nl/site/drainage/peilgestuurde-drainage.html?showall=1

Using alternative water sources for irrigation purposes.

Figure 15, WTP Settling Tank. Retrieved From: http://blogs.edf.org/growingreturns/2015/09/01/why-wastewater-treatment-plants-are-investing-in-farmers/

In the vast majority of cases irrigation water comes from rivers, lakes or aquifers. However, there are alternatives available in some locations which can be considered for use in agriculture (STOWA. 2015). One such an alternative is the use of effluent from wastewater treatment plants. Most treatment plants have a fairly standardized throughput meaning they can supply a constant quantity of water. However, the effluent will usually contain some form of nutrients and trace amounts of medicines. A secondary treatment phase will have to be added to remove medicine traces and nutrients will have to be recovered. Another alternative water source is the desalinization of water lenses containing elevated ion concentrations. One such a process is called capacitive deionization (Cap-DI) which is currently being tested in the southwest of the Netherlands. Capacitive deionization works by pushing saltwater between two membranes these membranes are both situated on either a positive or negative charge. These charges pull charged ionic compounds through the membranes away from the water. This process does require large amounts of energy as well as high upfront investments.

Altered flushing regimes to remove soil salinization.

In many parts of the Western Nederland's water lenses with relatively high salt concentrations are located close to surface (STOWA. 2015). Water layers with high concentrations of ions form a threat to agriculture as swell as most natural ecosystems. In order to reduce concentrations of ions, freshwater is often pushed through irrigation systems as to dilute salt concentrations. The process off flushing out saltwater is a new principle and has only been tested on a small scale. The most assessed method is by separating the in and outputs of freshwater sources as to keep freshwater retained in a specific area and allow for more dilution of ion concentrations.

3 The Methodology

3.1 Research Design

The following chapter describes the methods and research strategies used to attain the answers to research questions. The research process for this thesis report will be built up of three primary phases. The first step being performing desk research in order to answer basic questions and form an understanding of the project location. This first phase will aim to gather understanding to perform workgroups. The second research phase will be performing two workgroups and conducting interviews. The first workgroup will be held within the municipality this workgroup will be meant to form an accord over the most suitable retention measure. The second workgroup will focus on filling in details of the most suitable retention method. The third and final research phase will be the retention strategy design phase, for which, additional interviews will be held, and desk research performed.

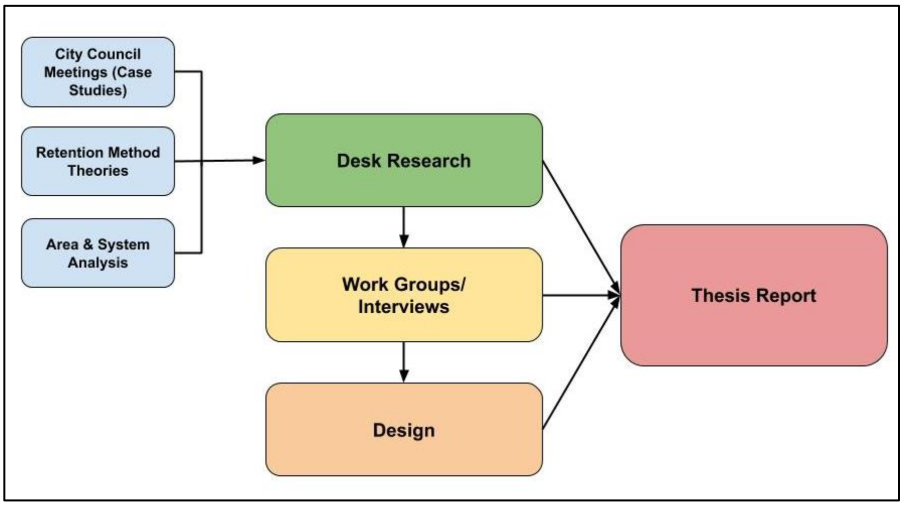

Figure 16, Research Design

3.2 Research Methods

This report makes use of both quantitative and qualitative research methods. In the first phase of this research meteorological, spatial and geographic information specific to the municipality and the province of Zeeland will be assessed this is done to help define the current situation and better understand the problems urban and rural zones are facing.

Qualitative data used in this report will be in the form of known and proven water retention methods. Literature surrounding these cases will be interpreted in order to determine what methods are available for Borsele. The retention methods which will be interpreted are provided by STOWA, a knowledge platform established by waterboards and provinces which provides an overview of water retention methods for the Netherlands every couple years. These strategies provided by STOWA will be further assessed for suitability within Borsele. This will provide a list of measures for which location specific strategies will be developed which will be further analyzed in the first workgroup.

In order to assess water usage within Borsele during dry months two calculation approaches will be utilized. Firstly, the gross irrigation requirement will be used and secondly interviews will be held

This report assumes climate change based on reports presented by the IPCC and the KNMI. The IPCC 2016 synthesis report provides an overview of possible degrees of climate change. This Provides evidence that climate change is imminent, and preparations are required. Meteorological data such as temperature trends and average rainfall used in order to calculate water usage using the gross irrigation requirement will come from data provided by the KNMI. Before the first workgroup is held an inventory will be made of the actors which are involved in retention methods. This inventory is the result of assessing water users and supply sources as well as governments which hold authoritative positions. When the available methods are established, water usage and risks known the first work group will be held.

3.3 Interviews & Inquiries

In order to develop an overview of land usage and water use in the months with highest water demand. Interviews will be held amongst crop and fruit farmers operating in Borsele additionally representative organization such as NFO and ZLTO will be interviewed. All interviews were held via phone as the current pandemic (Covid-19) did not allow for face to face interviews. These interviews are held in order to determine the amount of water which is given to a hectare of land on a daily basis. Furthermore, the interviews aim to determine water sources, water use efficiency and used irrigation methods. The interviews held where semi structured, a list of questions was prepared in advance which was used to create a pathway through the interview. This question list provided certainty that all questions where addressed during the interview whilst providing sufficient space to the interviewer to ask further unscripted questions. Some questions asked during the interview where changed or removed from the question list when representatives from ZLTO and NFO were interviewed. Initially two crop farmers as well as two fruit cultivators where interviewed. These interviews focused on acquiring quantitative data surrounding land use, water use and irrigation methods. Interviews were held anonymously no names, phone numbers or emails from the interviewed will be made public in this report. The initial plan was to establish a large selection group from which interviews where to be held however the preparedness to participate is limited. Some farmers that were interviewed lacked specific knowledge surrounding their average water use and these interviews were not used. After the farmers and fruit cultivators where interviewed the organizations ZLTO and NFO were interviewed this was done in order to check the results gained from the limited source group. ZLTO and NFO have conducted their own research into water usage and water use efficiency however these reports were not completely available to me. In the interviews finding from the interviews where corroborated.

3.4 Workgroups

When desk research concerning available retention methods, water use, and actors is completed a work group will be held to determine which method is most effective. For each STOWA retention strategy a specific strategy for Borsele is given. A total of six strategies are available, which were established during a council meeting held by the municipality Borsele on January 16th 2020. This meeting aimed to find strategies for local water retention. Before the workgroup was held the retention capacity, installation utilization, risks and opportunities were already assessed. These where first presented in a presentation after which the established criteria were discussed. For each retention strategy the criteria were rated. Based on these criteria the most suitable strategy is decided. The final phase of this research will consist of a design phase. This phase will firstly asses characteristics of the chosen retention strategy in order to understand the location as well as the method used to store water. This information will play an important role in the final work group which is to be held towards the end of this research. The first workgroup was held internally within the municipality Borsele with only four participants.

The final workgroup is held amongst actors involved in the chosen retention strategy. During this work group a general introduction is provided on the topic after which a dialogue is to be formed in which limitations and opportunities pertaining to total water storage quantity, water quality and distribution of established sources is to be discussed. As the water retention within North Sea Port was chosen as the most suitable method parties involved within this location where invited. Firstly, North Sea Port itself was contacted to partake furthermore Evides, the local Waterboard and the Province were to participate. Once this final workgroup is held a proposal can be developed which assists in the storage of water. This proposal will contain physical adjustments or policy changes.

3.5 Validity of Information

Several guidelines are followed to ensure validity of results. Desk research performed will make use of reports by established organizations and avoid any questionable sources. Interviews will be done using a sizeable group of individuals from one specific work field. During the interview process 8 farmers were interviewed. After removing invalid interviews two crop farmers and two fruit farmers were interviewed. Finally, the workgroups provide a moment to test findings using experts. In these meetings data is represented if mistakes are made or invalid assumptions used this can be addressed during these sessions

3.6 Conceptual Model

The following conceptual model shows the relationship between climate change and how this is to affect factors which will in turn lead to failed or successful harvests.

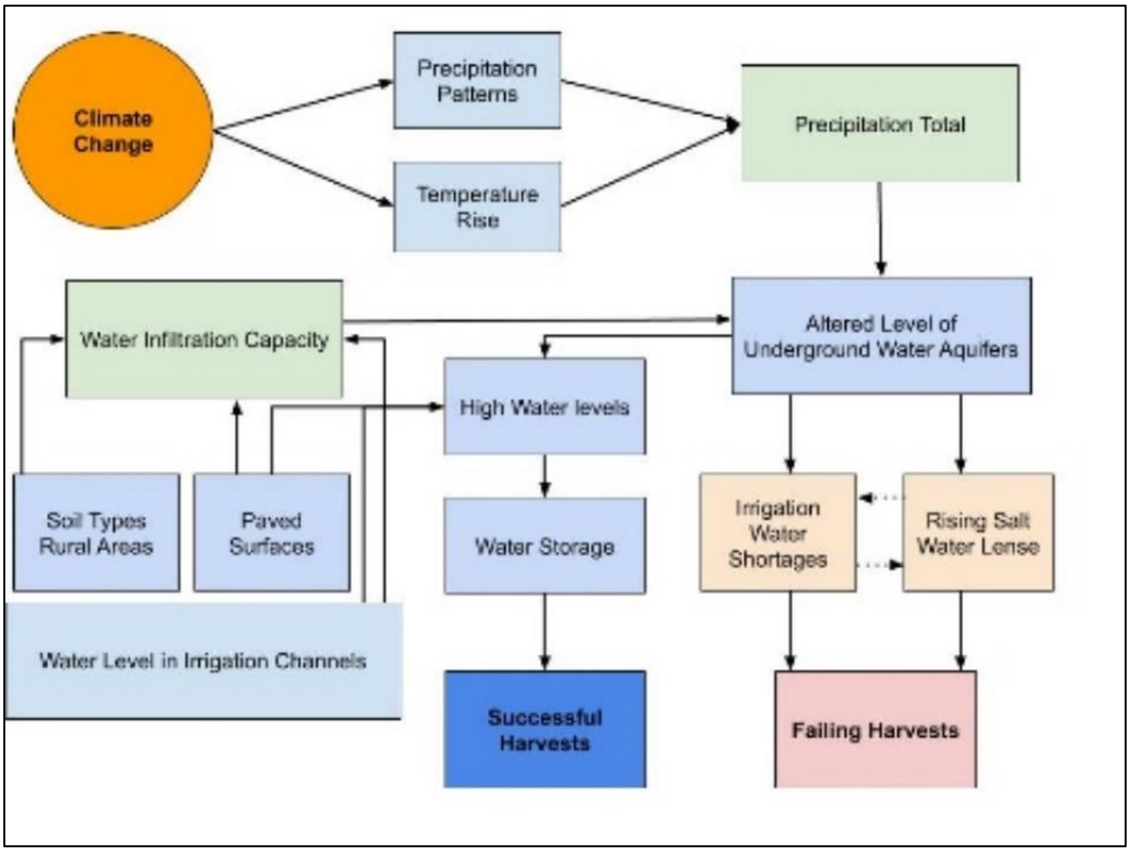

Figure 17, Conceptual Model Climate Change and harvests

4 Results

The following chapters show the results for each sub-question. Every sub research question is assessed in an individual chapter. The first three questions assessed will provide a systems analysis of the municipalities; hydrological, meteorological and geographical situation. Whilst the final chapters assess the most suitable retention case and provides a concept design.

Part 1

Situation Analysis

4.1 Suitable water retention strategies in urban and rural areas.

The following chapter discusses suitable water retention strategies for urban as well as rural zones. The retention methods discussed in this chapter will be combined with the measures discussed in council meetings of the municipality Borsele.

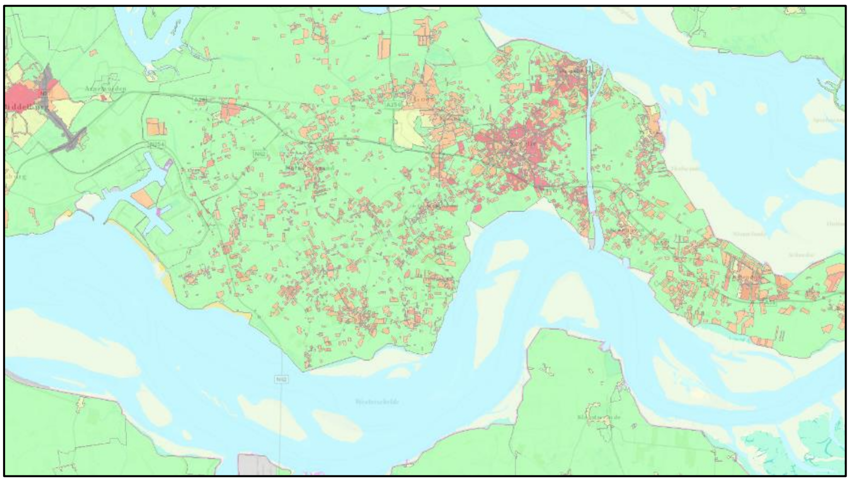

Figure 18 Rural and Urban area distribution Borsele

Borsele is largely an agricultural municipality with 22,800 inhabitants, its rural zones outnumber its urban zones greatly. As of today, Borsele has 15 registered urban areas with an average population of 1286 inhabitants and a population density of 1792 inhabitants per square kilometer within these urban centers. The total surface area of the urban space is 920.7 hectare whilst the total surface area of the municipality is 14,000 hectares. This in turn means the land surface available to apply urban retention strategies is limited compared to that land available for rural measures. The total volume of water which can be stored in rural zones will therefore be considerably larger than that of urban areas.

Borsele has been making assessments of measures which can reduce the effects of changing precipitation and temperature patterns for its urban areas ''Klimaatstraten". One of the goals of these measures is to ensure that periods of intense precipitation don't lead to localized flooding and ensure that sufficient water is available for the flora of urban areas. The Klimaatstraat Nieuwdorp held in 2019 concluded that in order to reduce the risk of flooding, infiltration in urban zones needs to be optimized. It was proposed to activate inhabitants to reduce the number of hard surfaces present in gardens and driveways. This can be done by removing tiles with gravel or increasing the number of vegetated surfaces as to increase rainwater percolation. Another proposed method was to connect water collected in streets with green zones and irrigation channels as to reduce the amount of grey sewage. In the Nederland's a multitude of measures are currently being implemented to retain water in agriculturally zoned areas. These measures can be put into three categories; measures that are proven and practiced, measures which have undergone field trials and measures proposed in desk research. This report will assess both proven methods as well as retention methods proven in theory.

Table 1: Retention Measure Analysis, Source: STOWA & ZLTO

	Scale	Costs	Law & Regulations
		-: Low Cost o: Neutral + High Cost	-: Restrictive o: Neutral +: Stimulating
Proven Retention Methods			
Utilizing irrigation channels to improve plot retention.	Individual Plot Level	-	+
Above ground storage methods (Basins)	Individual Plot Level	+	-
Methods proven in case studies			
Subterranean Storage of a Water supply	Regional Level	o	-
Increasing water use efficiency	Individual Plot Level	+	o
Drainage Methods to improve percolation	Individual Plot Level	+	o/+
Measures Proven in Literature			
Utilizing alternate water resources for irrigation	Local-Regional Level	+	o
Altered flushing regimes to reduce salinization	Local-Regional Level	o	o

The majority of retention methods listed are applicable at the most local level this being the individual agricultural plot. This entails that farmers and the municipality can play an important role in setting up retention strategies. Most measures require substantial investment this report will assume cost effectiveness based on the cost of creating one cubic meter of stored water. A number of measures are negatively affected by existing laws and regulations particularly above ground water basins and subterranean water storage are restricted by permit requirements in Borsele. By reducing the amount of restrictive legislation, the implementation of measures can be encouraged. A possibility could be that local governments support farmers by reducing regulations or by providing subsidies where possible, total available subsidy is limited due to limited resources within local government. From the seven measures assessed there are two measures that are less suitable to this project. These are increasing water use efficiency on agricultural plots and implementing altered flushing regimes to reduce salinization. Water use efficiency is currently being optimized in Borsele by fruit producers the fast majority of these currently use drip irrigation (ZLTO. 2020). For farmers of ploughland this is however not viable as the cost per crop is high and the installation would need to be rebuilt after each plough period. Implementation of such a measure would require substantial subsidies. Altered flushing regimes whilst a valuable tool in insuring quality of water sources is a task of the Waterboard Scheldestromen. The municipality manages waterways in urban areas whilst the waterboard manages rural waterways and irrigation channels. The five remaining strategies will be assessed further in this report. On the 16th of January 2020 a city council meeting was held to further asses which of the following solutions could be applicable to Borsele.

1. Utilizing irrigation channels to improve plot retention.
2. Above ground storage methods (Basins)
3. Subterranean Storage of a Water supply
4. Drainage Methods to improve percolation
5. Utilizing alternate water sources for irrigation

4.2 Land use in Borsele

This report will calculate the quantity of irrigation water used in Borsele by the agricultural sector for the months June, July and August. This is done using two methods the first being by taking inventory of interviews held amongst farmers and assessing water use per acre of land per crop type. The second method will be by calculating gross water loss over the entire surface area of land used for cultivation of crops and fruits. This is done by using the gross- and net irrigation requirement.

The amount of agricultural businesses within Borsele has been on the decline since the year 2000 likely driven by the economic recession of 2008 and increasingly strict agriculture regulations. A reduction of 35.1% has occurred between 2000 and 2019 (CBS, 2020). This curve seems to be halted as in the last couple years no more businesses have closed.

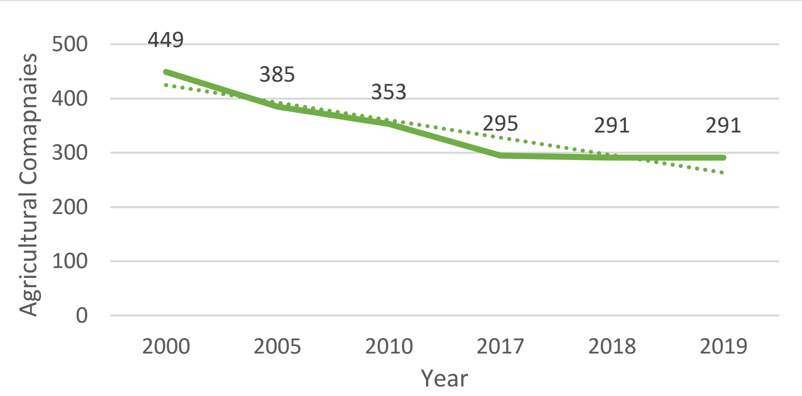

Figure 2. Trend Agricultural Businesses Borsele, Source CBS

In the last 19 years 158 agricultural businesses have closed within the municipality (CBS, 2019). With the closing of these businesses a considerable sum of arable land has gone out of service. The total area used within the municipality for the purpose of agriculture has decreased by 14%. The decrease of used arable land is lower than the amount of businesses that have closed, this could be the result of land being bought and used by other agricultural businesses. 25% of this land is used for fruit cultivation despite fruit farms being considerably smaller in surface area then crop farms, these being 20 to 100 hectares on average respectively. The trend of less companies operating within the agricultural field and less land used for this purpose could be the result of climate change or economical activities making it difficult to be economically viable.

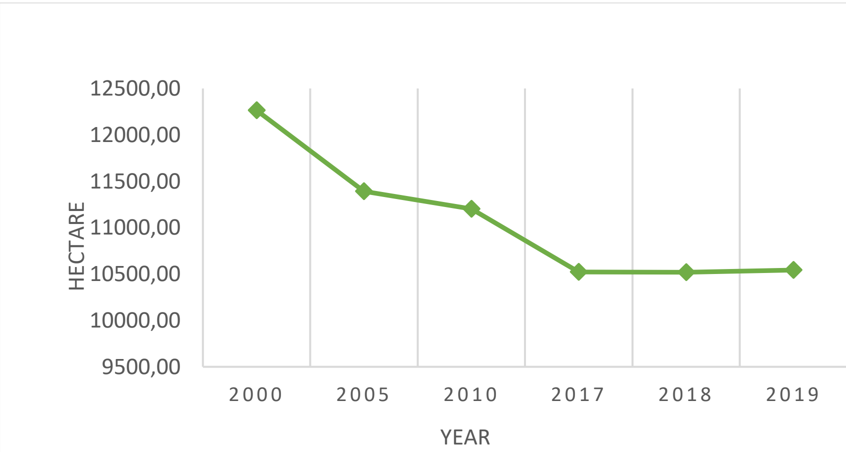

Figure 3 Trend land area owned by agricultural businesses in Borsele, Source CBS

The municipality of Borsele has de largest number of hectares used for the cultivation of fruit of the Nederland's (NFO. 2019). As of today, the municipality is home to 1.630 hectares of land for fruit cultivation. Besides fruit; vegetables, grains and flower buds are also cultivated in addition a sizeable surface area of grassland is maintained as food source for livestock. Al of these different agricultural products have different irrigation requirements. The Following circle diagram shows the distribution of agricultural land use in Borsele. It is evident that grain consumes the highest amount of surface area within Borsele followed by fruit orchards and vegetables. The vast majority of vegetables produced are unions and potatoes (ZLTO. 2020) both are drought intolerant meaning they will require regular irrigation in periods of drought. Including fruit orchards close to 43% of agriculture in Borsele will require irrigation in periods of limited rainfall and or high evaporation rates.

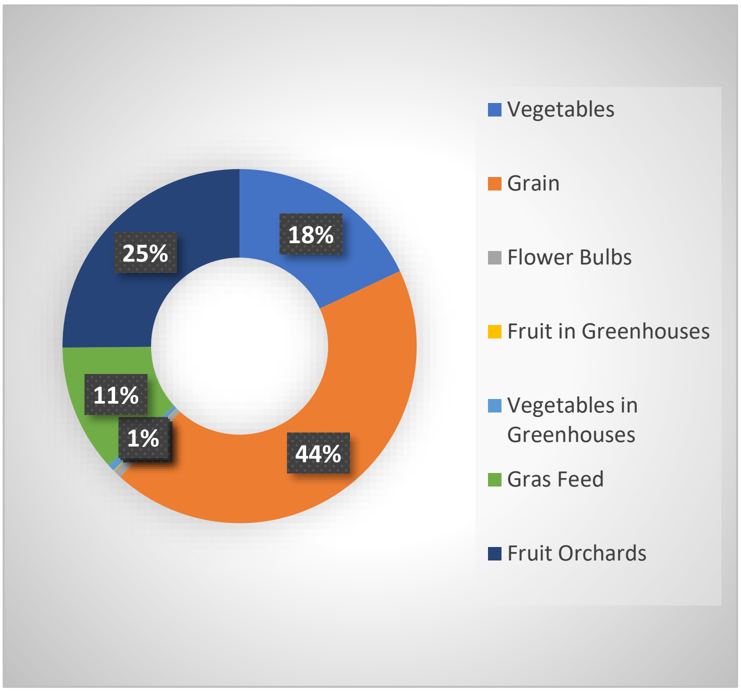

Table 1, Land use Distribution Borsele 2020, Source: ZLTO, NFO & CBS

Tabel 2, Agriculture Distribution Borsele

Surface In Hectares	2000	2005	2010	2017	2018	2019
Vegetables Surface Area	690.38	910.17	1038.84	1262.82	1308.60	1148.93
Vegetable Producers	120	101	102	137	136	125
Grain Surface Area	3143.96	3494.05	3416.10	2559.62	2450.82	2785.42
Graan Producers	282	258	216	176	170	174
Flower Bulbs Surface Area	58.84	61.50	61.85	53.56	74.67	50.05
Flower Bulb Producers	11	7	5	8	13	10
Fruit in Greenhouses	24.20	0	5.00	5.00	5.00	5.00
Fruit in Greenhouse Porducers	2	0	1	1	1	1
Vegetables in Greenhouses	101.05	118.40	72.08	73.58	40.86	40.86
Vegetable Producers (Greenhouses)	3	3	1	1	1	1
Gras Feed Surface Area	874.92	1104.03	814.65	727.84	713.17	739.93
Gras Feed Producers	180	147	150	127	132	139
Total Ploughland	**4869.15**	**5688.15**	**5403.52**	**4677.42**	**4588.12**	**4765.19**
Fruit Orchards Surface Area	-	-	-	-	-	1630.00
Fruit Producers	-	-	-	-	-	≈60-

4.3 Water Use in Borsele During Dry Months

Analysis

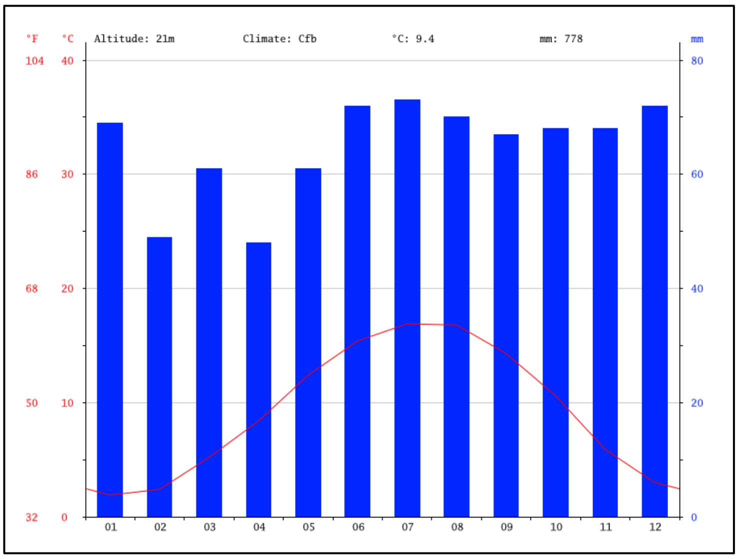

Figure 4,Annaul Temperature and Precipitation, Retrieved From:

The demand for freshwater within the municipality of Borsele reaches its peak during periods of high evaporation. This high evaporation is caused by high temperatures and elevated levels of solar energy when this occurs farmers are forced to irrigate to ensure wilting points are not reached and crops have access to enough water as to allow for proper development. The summer months June, July and August are considered the most demanding months for irrigation systems according to local farmers, ZLTO and KNMI statistics. During these months large quantities of water are expelled onto agricultural lands in order to ensure the wilting point of plants is not reached. This is done despite the average monthly precipitation being high at upwards of 70mm in recent years. During periods of extreme heat farmers occasionally spray a mist on fruit trees to prevent the heat from damaging the cellular structure of the developing fruit. This activity requires large quantities of freshwater (ZLTO.2020).

In summer months large quantities of water are required to fight high evaporation rates. In winter months evaporation rates are merely a fraction of what they are in summer months additionally during the winter only few crop types remain on the fields. However, water is used in a different way to protect crops and fruit. It is sprayed onto the surface of developing fruit in order to protect them from frost. This protection measure requires large amounts of water to be discharged via a mist throughout the fields in a short time period. If temperatures rise during the day and the ice layer thaws the process will have to be repeated. The quantities of water required to perform this form of frost protection are very large. According to local farmers for the protection of 20 hectares upwards of 4000m3 of water is required in a 24-hour period. Farms which supply this water from local above ground water storage say the deficit caused can be restored before the end of the winter season. The majority of water applied during the winter will percolate back into the soil as evaporation is limited meaning on a small portion is effectively lost.

The following paragraphs asses the amount of water required based on inquiries held amongst farmers and organizations which represent farmers interests. A total of 4 completed interviews were held amongst farmers with two fruit farmers and two crop farmers being interviewed. Due to the lack of participants NFO and ZLTO were interviewed to confirm the established water use per hectare.

Question 1) What kind of agricultural business those the farmer operate?
This question was asked solely to establish the type of crop or fruit grown by a farmer. Al crop farmers interviewed answered to growing potatoes and unions, one farmer also stated to growing beets and carrots. All interviewed fruit cultivators are growing either apples, pears or both. One retired fruit cultivator did claim to have grown blackcurrant and cherries in the past.

Question 2) What is the surface Area of agricultural land used by a farmer?
Al companies interviewed had a total land area between 20 and 100 hectares. It became evident that crop producing companies where considerably larger than fruit producing companies.

Question 3) In which months do the crops or fruit trees require the most irrigation?
To this question al answered the months June and July, a considerable majority of farmers also answered the month of August as a month requiring daily irrigation. One farmer stated that he starts irrigating in the months may and April though water requirement is considerably lower than in summer months.

Question 4) During the period when increased irrigation is required wat water source is used?
The most common irrigation water source used by crop producing farmers was water from irrigation channels. One crop farmer also stated that when salinity levels in channels would become too high, he would use groundwater as a secondary water source. Fruit producers stated to use water from irrigation channels as well as water from Evides as their primary water source. One fruit farmer also claimed to utilize an 8000 cubic meter above ground basin.

Question5) How often is an agricultural plot irrigated during the most water demanding period?
Al fruit farmers stated that during months with high evaporation rates (June, July and August) orchards are irrigated on a daily basis. Crop producers move a reel system along fields which pump water from channels and propels water through the air to cover a wider area. One farmer stated that this is relatively inefficient but allows him to cover the 100 hectares of land he maintains.
Fruit cultivators al stated to use some form of drip irrigation which generally waters trees for a couple of hours a day in the morning or later in the afternoon.

Question6) What is the daily water requirement for your agricultural plots during the dry period?
The majority of farmers could not provide an accurate estimate of their daily water use for dry periods. Only four of the interviewed individuals provided an estimate of their water use. Others stated that this water us depended a lot on the temperature over a period of time and the rainfall.

Question7) Does the farmer monitor the quality of used water sources?
Al farmers stated that they regularly check the salinity levels of used water sources. One farmer also stated that in 2018 he was unable to water unions as a result of elevated chloride concentrations. Farmers stated that elevated ion concentrations where primarily an issue within irrigation channels.

Question7) Does de salinity concentration create problems for irrigation?
Al farmers stated that occasionally salinity levels create problems when irrigating in summer months. This has led to farmers withholding from applying irrigation or using a different source for irrigation. Farmers that stated problems with salinity levels mentioned irrigation channels as the source of high salinity levels.

Question8) Does the farmer apply water to his plants as to avoid frost damages?
Fruit farmers stated that it is common practice to apply water to fruit trees when frost is predicted. Al fruit cultivators stated doing this. Of the interviewed crop farmers non claimed to have used this form of crop protection.

The interviews concluded that two methods of irrigation are used within Borsele by farmers to apply water to crops and fruit trees. These are the reel irrigation system and the drip irrigation system. The reel irrigation system is an inefficient system used by crops producers which allows them to cover a large surface area in limited time. The second irrigation method commonly used is the drip irrigation method. This method has a higher water use efficiency and provides the farmers with some form of automation as less labor is required. The drip irrigation system most used is the point source emitter which emits drops under the soil surface. By means of reel (sprinkler) irrigation up to 40% of water can be lost by evaporation depending on evaporation rates. When a form of drip irrigation is used no more than 10% of applied water is lost (Bajwa.2018). Besides water usage the reel irrigation requires diesel to run pumps adding to the cost of the method.

From the interviews three primary water sources where determined. These are water from irrigation channels, water from subterranean aquifers (relatively shallow) and water from a specialized agricultural water grid operated by Evides. Water from subterranean aquifers is always of good quality however elevated iron ion concentrations make usage difficult in drip irrigation systems. The interviews held amongst farmers concluded that the months June, July and August whereby far the months that required the most irrigation. Farmers stated that this is the result of high temperatures. However, the interviews did not give a definitive answer to the amount of water used for irrigation as most farmers did not have a clear insight into water used throughout this entire period. From the interviews it could be concluded that the irrigation methods in fruit cultivation lead to higher water use efficiency then the irrigation methods of the crop (Union & Potato) producers. Interviews also confirmed that agricultural businesses are already experiencing the effects of drought and saltwater intrusion as irrigation is a fulltime job in the months June, July and August for farmers and water sources have to be checked regularly for salinity levels.

The most common types of cultivated fruit within the municipality Borsele are apples and pears. Adolescent peer trees require 15-25m^3/ ha per day depending on evaporation rates whilst apple trees require 12-20m^3 per hectare every day (NFO, 2020). The efficiency of water used in the cultivation of fruit is relatively high as drop irrigation is a very common method in this field. For the calculation the assumption will be made that half of the fruit orchards are used for apple trees and the other half is used for peer tree's other fruit types are left out of the calculation as no conclusive information is available on these fruit types and these crops represent but a relatively small portion of surface area used for the cultivation of fruit.

When assessing the irrigation requirement of crops, one needs to assess the drought tolerance of a plant type. Drought tolerance is the ability of a plant to maintain biomass production during periods drought (Ashraf M, 2010). Some crops have gained a high level of drought tolerance as the result of selective breeding and genetic engineering, especially crops like corn, wheat and some rice varieties are capable of retaining turgidity despite a lack of irrigation. However, the majority of the crops cultivated in Borsele are not drought resistant and require regular irrigation in dry periods (ZLTO, 2020). The most common vegetable crops cultivated in Borsele are potatoes and unions (ZLTO,2020). These are usually irrigated by means of a reel system. Reel systems are moved around by farmers over fields, every field is generally irrigated for one hour every four days by a reel with a capacity of 30-60m3 per hour. The cultivation of wheat and corn is also performed within Borsele. Due to their drought tolerance they are however only rarely irrigated (ZLTO, 2020). As grains are but rarely irrigated these will not be considered in irrigation requirement calculations.

Table 2, Water Requirement Interview Findings

Agriculture Type	Daily Water Requirement (Per Hectare)	Area used for Cultivation (Hectare)	Daily Volume	Monthly Irrigation Requirement
Apple Tree's	5-25m^3	815 ha	4,075-20.375m3	
Pear Tree's	5-20m^3	815 ha	4,075-16.300m3	
Sub-Total Fruit		1.630 ha	8,150-36.675m3	
Unions	≈8.33m^3	574 ha	4.781m3	
Potatoes	≈8.33m^3	574 ha	4.781m3	
Sub-Total Crop		1.148 ha	9.562m3	
Total		2.778 ha	17,712-46.237m3	531,360-1.387.110m3

Total water requirement for fruit and vegetable cultivation will average between 0.53 and 1.39 million cubic meters per month assuming irrigation is required daily. This is water which is applied to fields by farmers and does not take into consideration any water which reaches crops by natural processes. 1.39 is the absolute maximum amount of water which can theoretically be applied this is however unrealistic as it is very unlikely that an entire month requires such high irrigation amounts.

Water Requirement Calculations

Net Irrigation Requirement (Irn)

The net Irrigation requirement will calculate the average Irrigation requirement for the months June, July and August. As these are the months in which water systems in Borsele are under the most pressure. In order to make this calculation individual components of the formula will be determined by assessing meteorological and geological data for components see paragraph 2.8.1.1. and 2.9.1. 1..

$$IRN = ETc - Pe - Gw - Wb$$

Reference Crop Evapotranspiration (Eto)

By assessing meteorological information, the reference crop evapotranspiration can be calculated. This refers to the amount of water which is lost to the atmosphere via evaporation.

$$Eto = 0.0023(Ra \times (Td)^{0.5}) \times (T°C + 17.8)$$

The following table shows annual average evaporation rates since measurements started in the Nederland's till the year 2000. The table is divided into five types of cloud cover the left being very cloudy whilst the right shows evaporation on very clear days. When looking at the average evaporation rates it becomes evident that the months may, June, July and august are the months with the highest levels of evaporation. This corresponds with the experiences of local famers. The average evaporation ration rate for the months June, July and August is 2.88mm/day. Realistic evaporation rates are however considerably higher on vegetated surfaces as plants create a higher surface area per square meter. For the Northern hemisphere at 50° longitude the months June, July and August have an Ra of 15,87mm/day, See Appendix.

Table 3.Evaporation averages in mm until 2000. Source: KNMI

Maand	30% Cloudy	10% Coudy	Partialy Cloudy	10% Sunny	30% Sunny	Average
Jan	8	7	8	8	9	8
Feb	14	12	15	16	18	15
Mrt	28	24	31	34	38	31
Apr	50	44	55	58	64	54,2
Mei	76	66	83	90	100	83
Jun	80	69	87	94	105	87
Jul	85	74	92	99	110	92
Aug	75	67	80	85	93	80
Sep	45	40	48	51	56	48
Okt	25	23	27	29	31	27
Nov	10	9	11	12	13	11
Dec	6	5	6	6	7	6
Totaal	525	500	543	559	584	542,2

Average Temperature (TD)

The following graph shows average monthly maximum and minimum temperatures measured by the KNMI offer a period of the last 100 years. The Average temperature difference between low and high temps for June, July and August is 8.96C°. And the average temperature for these months is 15,73C°.

Table 4, Min, Max and Average Temperatures in Celsius. Source: KNMI

	Januari	Februari	Maart	April	Mei	Juni	Juli	Augustus	September	Oktober	November	December
gemiddelde Temperatuur (°C)	1.8	2	4.6	6.8	11.7	14.7	16.2	16.3	13.9	10.4	5.9	3
Min. Temperatuur (°C)	-0,90	-0,90	1,30	3,60	7,30	10,20	11,90	11,80	9,70	6,80	3,20	0,60
Max. Temperatuur (°C)	4,50	5,00	8,00	10,10	16,20	19,30	20,60	20,90	18,20	14,00	8,60	5,50
Min. Max. Difference	5,40	5,90	6,70	6,50	8,90	9,10	8,70	9,10	8,50	7,20	5,40	4,90

Crop Evaporation (Etc)

Using crop coefficients which can be found in literature Crop evapotranspiration can be calculated. Using the following formula.

$$Etc = Kc \times Eto$$

The crop evapotranspiration gives the amount of water in mm which is lost from a unit of surface area per day by accounting the water lost via plant mass. The table below shows the resulting crop evaporation rates for the most common fruits and crops of the municipality. The lower coefficients of the fruit types represent the higher water use efficiency of the fruit cultivating sector.

Table 5, Crop Evaporation Rates Source: FAO

	Crop Coefficients	***Crop Evapotranspiration***
Potatoes	1,00	0,39
Unions (Green)	1,00	0,39
Orchard Apples	0,95	0,37
Orchard Pear's	0,95	0,37

Net Irrigation Requirement (Irn)
With the crop evaporation known the amount of water which needs to be applied as irrigation can be determined. This is done by subtracting the water sources which are available to a field from the crop evaporation rate. Net irrigation will be determined for both crops and fruits as these have different Evaporation rates.

$$IRN = ETc - Pe - Gw - Wb$$

Effective Precipitation (Pe)
Effective precipitation represents the water which falls on agricultural plots and becomes available to plants in the root zone. Water which forms runoff or evaporates needs to be subtracted from the total evaporation amount. For most soils which are not considered to be heavy effective precipitation is generally assumed to be 80% of total precipitation (Peace Corps. 1994). The average effective precipitation for the months June, July and august is 54,29mm. This translates to 1,81mm daily.

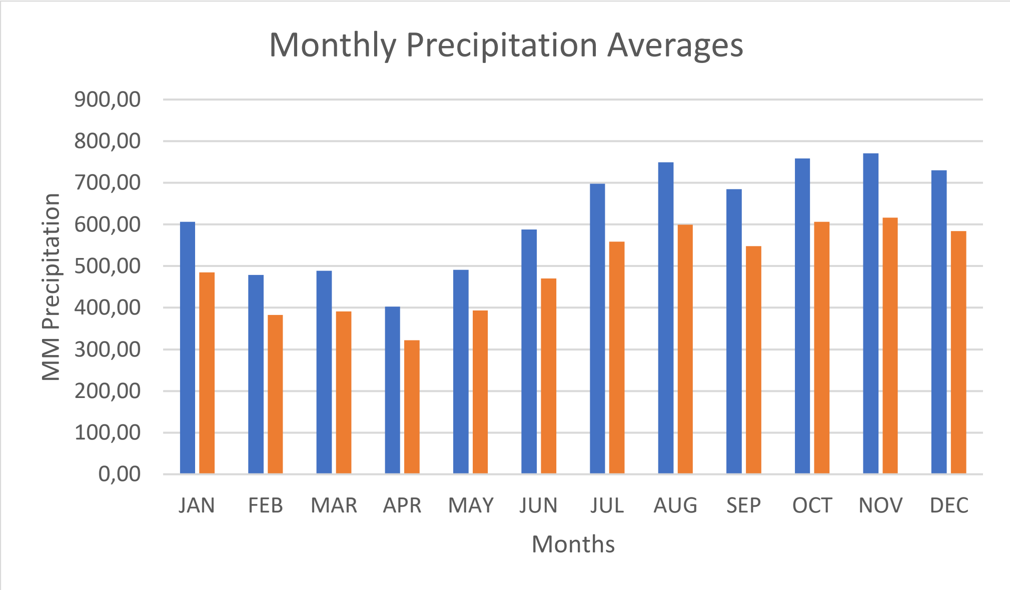

Figure 19, Monthly Precipitation, Total Precipitation (Blue), Effective Precipitation (Orange). Source: KNMI

Available Ground Water (Gw)
During recent summer months existing groundwater tables have dropped dramatically leaving a ground water table deficit of upwards of 180mm (Scheldestromen. 2018). This deficit has been filled my means of irrigation and irrigation channel level management. Potatoes and Unions have a maximum root depth of 60,0 centimeters (Bernstein *et al.* 1951) due to this shallow root depth no groundwater is available to crops in summer months. Fruit trees have much deeper roots then most crop types. Both pear and apple trees can have roots at a depth of 2.0 meters. This allows them to utilize groundwater even in dry months. However, in some places throughout Borsele even relatively shallow groundwater is unsuited for most plants due to high ions concentrations (Freshem. 2018). As a result, groundwater has become an unreliable water source to lower the saltwater lenses farmers must irrigate heavily to lower this lens. It is for this reason that for both crops and fruit no available groundwater will be assumed.

Soil Water at the Start of a Period (Wb)

The majority of soils in Borsele can be defined as moderate to heavy clay soils. The highest concentration of these clay soils can be found along the coast of the Western Scheldt where long stretches of sulfur rich clay grounds can be found running from west to east. Grounds containing sulfur have a lowered PH as sulfur is an acidic compound. Crops grown in Borsele benefit from a moderately acidic soil both Potatoes and Unions grow best in soils with a PH of 6.0 (Harvest To Table. 2016). Towards the center of Borsele surrounding Heinkenzand numerous large deposits of sandy soils can be found. The 2018 Freshem project performed by the province of Zeeland has shown that these sandy soils contain larger freshwater lenses than clay rich soils.

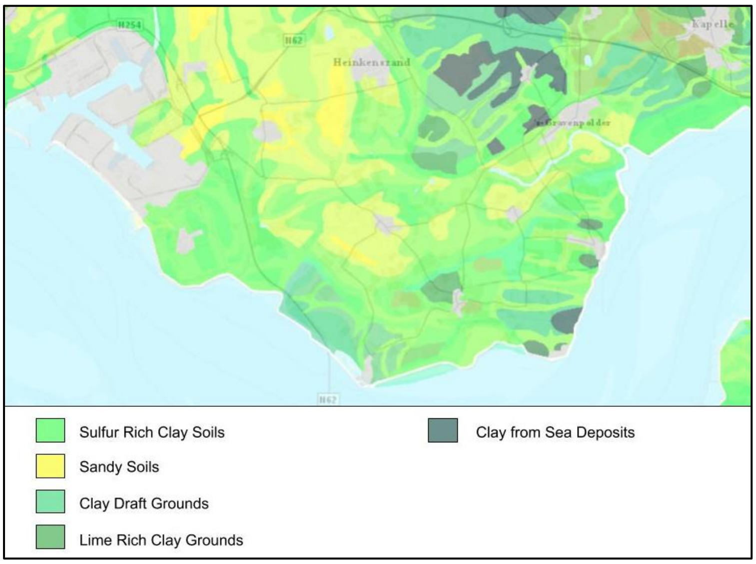

Figure 5, Soil Types of Borsele. Source: Provincie Zeeland

Soils act as a buffer which have a temporary storage capacity for water which is later returned to plants (FAO.2018). During wet periods this is sufficient to fulfill plant water requirement however in dry periods irrigation is required to compensate for evaporation (crop transpiration and soil evaporation). The Gross irrigation requirement assumes soil moisture if the water requirement is determined for a short period of time. When looking at monthly requirements with elevated evaporation rates the soil moisture is not considered.

Figure 20, Soil Type Distribution Borsele

Net Irrigation Requirement Calculation (Irn)
The following table shows the daily net irrigation requirement in mm per unit of surface area. Crops require the largest amount of irrigation in the months July and August as groundwater sources have been largely depleted. Whilst the month of June shows that no water is required for fruit trees as sub surface water should be available however due to salinity already being a year-round issue farmer are likely to irrigate as to lower salinity levels in the root zone. Furthermore, if the months preceding June have a rainfall deficit soil moisture could be insufficient therefore water requirement is equal in al months.

Table 3, Net Irrigation Requirement Crops & Fruit

	Net irrigation Requirement June	Net irrigation Requirement July	Net Irrigation Requirement August
Unions	0,92mm/day	0,92mm/day	0,92mm/day
Potatoes	0,92mm/day	0,92mm/day	0,92mm/day
Peers	0,82mm/day	0,82mm/day	0,82mm/day
Appels	0,82mm/day	0,82mm/day	0,82mm/day

Gross Irrigation Requirement (Irg)
The gross irrigation requirement formula for any crop or fruit is built out of two main components. These being the net irrigation requirement and two efficiency constants based on irrigation efficiency of the farms ability to retain water.

Application Efficiency (Ea)
The application efficiency of water used during the irrigation process has a large influence on the total quantity of water required to achieve maximum crop yield. This efficiency is influenced by a multitude of factors the first being the method used to apply water to a crop, the soil type and the climate of a location. In Borsele two methods of irrigation are applied, the first being the reel irrigation system which is the most common method of irrigation amongst crop farmers. In this method water is either pumped from channels or aquifers and distributed offer fields using a large sprinkler which is moved along the fields. The second method used is the drip irrigation method this is used by the fruit cultivators. These farmers have networks of plastic pipes which provide each individual fruit tree with a steady supply of water. Reel irrigation has an efficiency factor of 0.60 whilst drip irrigation has an efficiency of 0.90.

Table 6, Application Efficiency. Source: Peace Corps

Irrigation System	Application Efficiency (Fraction)
Surface Methods	
Light Soils	0.55
Medium Soils	0.70
Heavy Soils	0.60
Sprinkler	
Hot,Dry Climate	0.60
Tempered Climate	0.60
Cool Climate	0.60
Drip Irrigation	0.90

Canal Conveyance Efficiency (Ec)

This factor represents the efficiency of a waterway to supply a field of water without loss to evaporation and percolation. Soil type and channel length are the primary factors which determine the efficiency of a canal. The vast majority of channels in Borsele have length no longer then one kilometer meaning they are of medium length. Not all water used for irrigation reaches fields through channels for aquifer water use and the industrial water grid 100% channel conveyance efficiency will be assumed.

Table 7, Canal Efficiency. Source: Peace Corps

Earthen canals				
Soil type	**Sand**	**Loam**	**Clay**	**Lined Canal**
Canal length				
Long (> 2000m)	60%	70%	80%	95%
Medium (200-2000m)	70%	75%	85%	95%
Short (< 200m)	80%	85%	90%	95%

Gross Irrigation Requirement (Irg)

The gross irrigation requirement calculations show similar results to the interviews held. Efficiency is higher in fruit production than in crop cultivation. The total monthly irrigation requirement is 1.11 million m^3per month. This is assuming normal summer conditions.

Table 7, Gross Irrigation Requirement Total

	June	July	August
Irg Crops	1,55mm/day	1,55mm/day	1,55mm/day
Irg Fruit Trees	1,18mm/day	1,18mm/day	1,18mm/day
Daily Irrigation Requirement Crops/ Hectare	15,51m^3/day	15,51m^3/day	15,51m^3/day
Daily Irrigation Requirement Fruit/ Hectare	11,80m^3/day	11,80m^3/day	11,80m^3/day
Monthly Irrigation Requirement Crop Land Borsele	534,049m^3	534,049m^3	534,049m^3
Monthly Irrigation Requirement Fruit Land Borsele	576,874m^3	576,874m^3	576,874m^3
Total Monthly Irrigation Requirement Borsele	**1,110,924m^3**	**1,110,924m^3**	**1,110,924m^3**

4.4 Impacts

Current Water Use

The Gross Irrigation requirement calculation shows clear correlation with the results from the inquiries held amongst the fruit and crop producing sector. The gross irrigation requirement shows that 1.1 million cubic meters of irrigation water is required monthly during the months requiring large quantities of irrigation water. 5.34 million m^3 is required for water demanding crops whilst 5.76 million m^3 is used by fruit trees. The irrigation requirements found by the performed interviews came out lower and higher than the gross irrigation requirement. This was predicted as the gross irrigation requirement uses averages to determine water usage. The interview calculation asses extremely high and low water demand situations. 5.3 million cubic meters therefor represents water usage in very wet months when farmers have but to irrigate intermittently. The high-water requirement of 1.37 million cubic meters from the interviews represents water usage in months with very little to no precipitation and high temperatures.

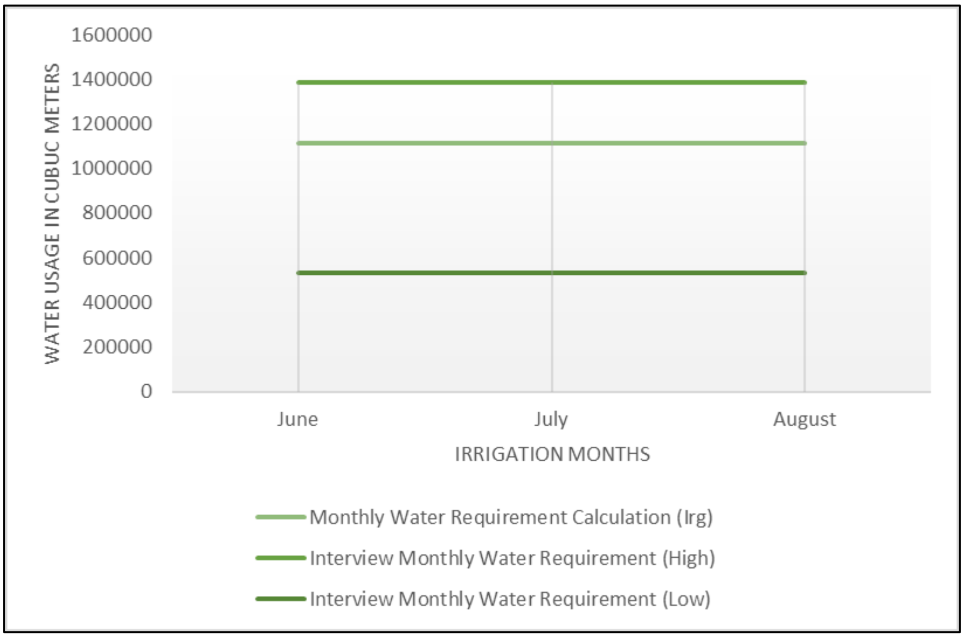

Figure 21, Monthly Water Requirement Borsele

Future Impacts

Water usage is very likely to increase in de near future. The net irrigation requirement is set to increase as the average temperature (TD) rises by at least 1,0 ° Celsius by 2100 according to RCP 2.6 predictions from the IPCC. It is also likely that as the temperature on earth rises that the reference crop evapotranspiration will rise. Furthermore, the gross irrigation requirement will increase as efficiency coefficients drop due a change in extreme precipitation patterns.

4.5 Actors

In the municipality of Borsele a number of Private and Public organizations are involved in managing or providing freshwater for irrigation purposes. Private parties focus on delivering water to costumers and consuming it for industrial and agricultural purposes whilst government entities focus on maintaining natural supply sources and treating used effluent.

Municipality Borsele, Kapelle And Vlissingen

The municipality of Borsele like al municipalities in the Netherlands is de most local form of government within Borsele. It holds a wide portfolio of tasks ranging from public order to environmental regulation. In recent years municipalities have started to take inventory of climate change threats the primary topics are urban adaptation measures for drought and heat whilst water availability is the primary concern for the agricultural zones. The primary activities municipalities take to actively influence available freshwater for agriculture are zoning schemes and infrastructure projects. Municipalities can appoint locations as water retention locations. Furthermore, it is manages ground water levels and infiltration in urban zones.

Waterboard Scheldestromen

The Waterboard Scheldestromen has a large impact on available freshwater and the delivery process of freshwater to farmers. The Waterboard Scheldestromen manages most secondary freshwater ways, weirs, pumping stations and water treatment plants present in Borsele and surrounding areas. It therefor directly impacts the amount of water stored on the surface and in the sub-surface. Furthermore, Waterboards manage permits for water extraction and manage prices for water used by the agricultural sector. In the "Water Beheerplan 2016-2021" the Waterboard Scheldestromen expresses its intention to secure freshwater as it is a vital resource under threat of climate change. It will perform this goal by improving management and increased implementation of circular water systems. These goals are also laid out in a number of laws "Waterwetten" these water laws state that a Waterboard ensures the water quality of water networks in its domain and manages WTP Facilities.

The Province of Zeeland

When it comes to assessing groundwater and other geographic risks provinces are an important partner. Provinces make assessments for floods and other area specific risks. Additionally, provinces provide permits for largescale groundwater extraction of upwards of 150,000m3/ annually. Provinces are also involved in the zoning and planning of industrial zones such as ports and other industrial facilities. Furthermore, the province plays an important part in regulating the activities of waterboards and municipalities as it checks expenditure of municipalities and checks the activities of the Waterboard.

Evides (Evides Industrie Water)

Evides is a utility company which provides water to customers throughout the provinces of Zuid-Holland, Zeeland and parts of Noord Brabant. It has approximately 2.5 million customers making it the second largest water utility company in de Netherlands with Vitens being the largest. Evides has separated its civil and industrial service branches. In the annual report of 2018 Evides states that it aims to grow its industrial water provisioning capacity whilst increasing the circularity of their water systems. Evides also acknowledges that it has an important social task within its zone of operation. This task is particularly important in Zeeland as Evides is the sole water utility provider.

North Sea Ports

North Sea Ports was established by means of a fusion between the ports of Vlissingen "Zeeland Seaports", the port of Terneuzen and the port of Gent on the 29th of June 2018. This fusion made it the third largest European port. Together these three port facilities provide upwards of 44,000 jobs and almost 55,000 jobs indirectly (North Sea Ports. 2017). The port provides an economic value of 13.5 billion euros annually. The port has a wide variety of shareholders, the province of Zeeland holds a 25% share, the municipalities of Vlissingen, Borsele and Terneuzen have a 8.33% share with the remaining 50% share being spread between the city of Ghent and de municipalities Evergem and Zelzate. Property Within the port North Sea

Port Vlissingen is largely owned by private companies undeveloped property and networks are property of North Sea Port. For retention methods for the island of Walcheren and Zuid-Beveland the port facility of the former Zeeland Seaport is of interest. As this facility is located between the municipalities of Borsele and Vlissingen. In the current configuration this facility requires water from Evides for many companies operating on the premises. There are however possibilities of storing water within the substrate which could make it a water supplier. Many companies have contracts with Evides which entitles them to a set volume of water.

DNWG (De Netwerkgroup)
DNWG is a company specializing in the maintenance, construction and management of water networks. It was originally part of the Delta utility company however new laws required the company to separate its maintenance and commercial branches. As of today, DNWG is part of the Stedin group which serves roughly 200.000 households in the province of Zeeland. DNWG is a vital knowledge partner as they have insight into al pipeline related water grids in Walcheren and Zuid Beveland.

NFO (Nederlandse Fruitelers Organisatie)
NFO is an organization that represents the interests of the Dutch fruit cultivation sector. It focuses on insuring crop protection, social economic strength of the sector and promotion of a suitable market climate. Approximately 80% of fruit farmers is associated with FNO (FNO.2019). The organization is divided into 20 separate departments each representing a specific region. On the Island of Walcheren and Zuid Beveland NFO Zeeland represents the interests of local fruit cultivators.

ZLTO (Zuidelijke Land- en Tuinbouworganisatie)
ZLTO has a similar role as NFO however it represents the interests of the crop producing agricultural sector as well as Horticulturists. As of 2019 the organization represented the interest of 13.000 farmers throughout the southern Netherlands.

Demand and Supply

The relationship between demand and supply is an important factor when it comes to the availability of irrigation water in Borsele. If the preparedness to pay is high this could lead to new water sources and supply methods being created by farmers as well as by water suppliers such as Evides. Currently the industrial and agricultural water grids run well below capacity throughout most of the year. Especially the agricultural grid is currently only used very limitedly and only reaches capacity halfway through June till September. As effective precipitation is expected to decrease in the coming one hundred years and evaporation rates rise. The demand for irrigation water is going to rise, if no new supply sources are created the price per unit of water will rise. Higher water prices in turn can have a detrimental effect on the longevity of agricultural business in Borsele.

Water Supply Source	Cost	Authorized supervision
Groundwater	0,025-0,029€/m^3 *no Cost if extraction is below 10m3/uur	Waterboards
Surface water	Dependent on Location 40-13€/hectare of land owned per season	Waterboard
Water Evides Pipe grid	>0,55€/m^3	Evides Industrie Water
River Water (Transported Via Boat)	≈5.00€/m^3	-

	Primary Activities	Position (*Influence on Decision Making)*	Impact (*Contribution to the successful outcome of the project*)
Municipalities Borsele & Vlssingen	• Establishing Zoning Schemes • Zoning related Permit Approval • Managing urban groundwater levels	The municipality Borsele plays an important role in managing urban freshwater levels whilst designating above ground storage locations.	Organizer of retention methods which fall within its operational domain.
Waterboard Scheldestromen	• Water Level Management Secondary Channels • Wastewater Treatment • Managing rural groundwater levels	The waterboard manages water levels in many secondary waterways. Whilst it also manages water extraction by selling extraction permits. Waterboards also have the mandate to manage rural groundwater tables.	Organizer of retention methods which fall within its operational domain. Implementing water network regime changes in order to increase water supplies.
Evides "Evides Industrie Water"	• Supplying Drinking Water (Contractual obligation) • Suppling Industrial Water (Contractual obligation) • Supplying Irrigation Water	Evides owns an extensive water network grid for both private, industrial and agricultural purposes. As it is the sole supplier of water it has a significant impact on freshwater availability.	Investor in retention methods involving circular water networks.
Province of Zeeland	• Risks analysis's • Large scale water extraction permit approval • Industrial and agricultural Zoning • Regulating and controlling other institutions	Provinces have a monitoring function in which they supervise the activities of Waterboards and Municipalities. In addition, it manages environmental regulation and industrial zoning schemes. Combine this with its ability to decline large scale water extraction it can greatly impact water availability.	For projects involving industrial zones and large-scale water extraction the province needs to grant permission. The province of Zeeland will therefor play an important approving role.
North Sea Port	• Port Infrastructure Management • Port Real-estate management	North Sea Port manages the future development of the port facility. It can incorporate a strategy which improves percolation and manages water extraction from the sub-surface.	Crucial partner for implementing measures that manage water levels and extraction within the Sub-state of the port facility.
NFO	• Informing fruit farmers on market and cultivation trends • Representing Member Interest	Inform members of cost-effective retention methods and change member perception of retention methods.	Informing member base on retention method possibilities. Assessing preparedness amongst members to partake in measures.
ZLTO	• Representing Member Interest • Promoting Innovation	Inform members of cost-effective retention methods and change member perception of retention methods.	Informing member base on retention method possibilities. Assessing preparedness amongst members to partake in measures.

5 Suitable Retention Methods

The Municipality of Borsele has been assessing its options in fighting the ever-growing effects of climate change. It has done this by performing climate stress tests and organizing meetings between the local city council and inhabitants. Out of these council meetings the following six retention cases have come forward. The following paragraph assesses the potential of these measures to provide water retention for Borsele. Note that these six cases have been altered using the findings of chapter one and do not strictly represent the ideas shared in initial council meetings.

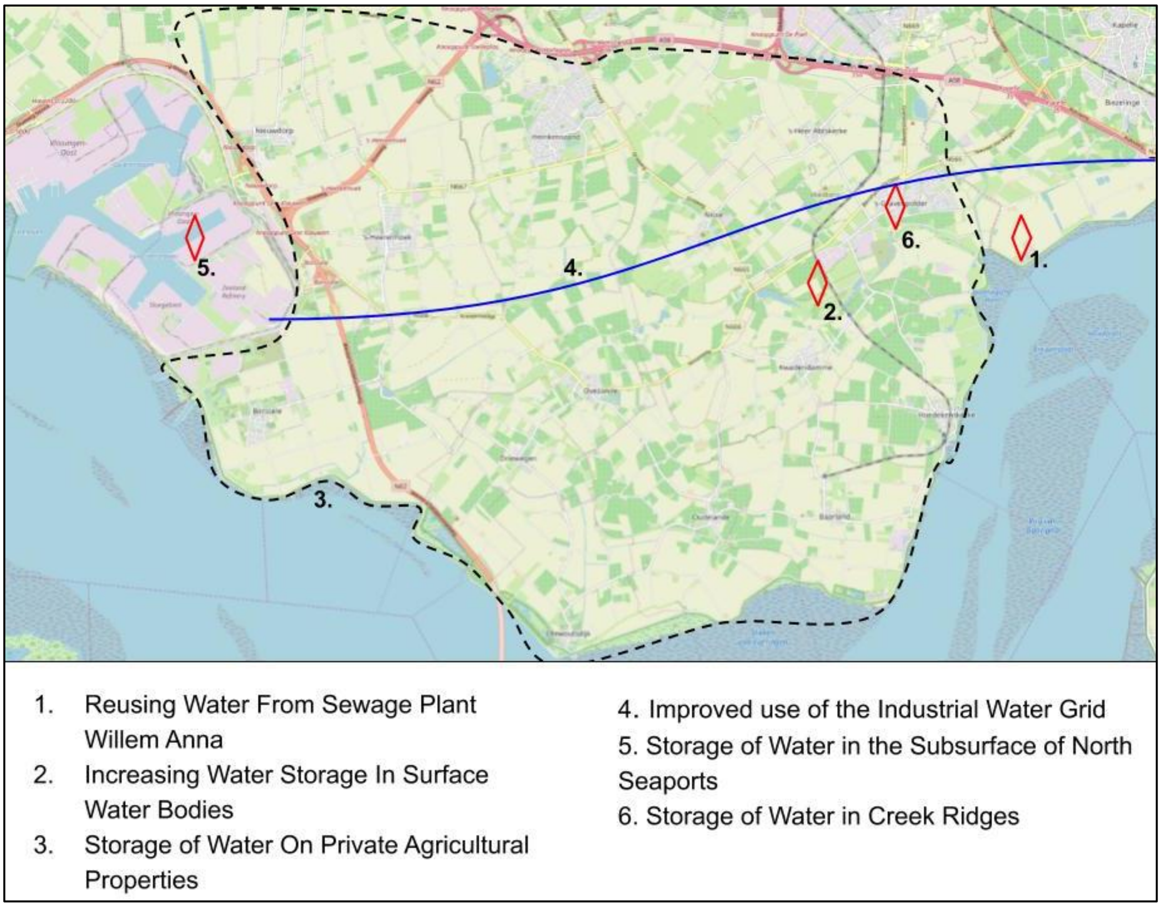

Figure 6, Retention Case Locations

5.1 Reusing Treated Sewage Effluent from RWZI Kapelle

Using alternative water sources for irrigation purpose

The municipality of Kapelle is situated to the east of Borsele. This municipality is home to the ''RWZI Willem Anna'' this sewage treatment installation leis close to the border of Borsele. Currently the treated effluent is transported through the local surface water network towards the ''Maelstede'' pumping station from where it is transported through the "Sint Jansdijk" into the Westerschelde. The treatment plant is operated by the Water Authority Scheldestromen. Currently the installation treats 1200m^3 to 1400$m^3$of sewage daily. This treated effluent can be used by the agricultural sector to water crops and fruit trees if this effluent is treated in a secondary treatment phase. The effluent will have to adhere to European standards concerning trace concentrations of medicines. To ensure this an additional treatment phase will have to be added to the current process. For this second phase two methods are available, a mechanical phase can be used which will require a large capital investment and maintenance cost. The second method is a natural wetland which has lower construction costs but requires increased space to build.

If all the treated effluent is reused in the agricultural sector 12 hectares of land can be irrigated daily assuming an irrigation rate of 12mm and normal summertime evaporation rates (ZLTO. 2020). This is however still a relatively small contribution to the total water demand as the municipality has 1.630 hectares of fruit orchards and 4.765 hectares of ploughland. Less than half a percent of total arable land can thus be irrigated using this retention strategy.

Figure 21, Location Treatment plant Willem Anna Kapelle

Figure 22, RWZI Kapelle, Retrieved From: https://www.pzc.nl/zeeuws-nieuws/rioolwater-bron-van-de-toekomst~ac7d1431/

Restrictions	Opportunities
The addition of a treatment phase to remove trace amounts of medicine makes this a costly measure.	If water scarcity continues the measure could become viable in the future if water prices rise.
Capacity is limited compared to total monthly demand	Effluent which is not consumed will be additionally purified before entering the natural environment.
-	A natural wetland filtration process could lower second filtration step costs.
-	Surrounding agricultural plots are of poor quality, these could be turned into freshwater retention locations increasing total provisioning capacity.

5.2 Retention in Existing Waterbodies

Above ground water storage methods

Figure 23, Location Zwaakse Weel

This retention method involves al surface waterbodies of the municipality Borsele. These include but are not limited to ponds, lakes and channels. A location within the municipality which shows proper characteristics for such a retention method is the Zwaakse Weel. The Zwaakse Weel is a small nature reserve managed by "Nature Monumenten" most of the surface area consists of grass or wetland. As of today, the water level in the area is low this can be raised to allow the location to retain a larger water volume. Another location which could be made suitable for above ground water retention is a small bird sanctuary in the Hoedekenskerkepolder. This wetland of 65 hectares is currently classified as a bird sanctuary however it has not yet managed to attract the desired bird species water in this location could also be raised as to increase water retention. Additionally, primary waterways in the municipality can be widened to allow for more water storage. In winter months water levels within surface water bodies can be elevated. This can be done by raising the height of wears and pumping less water towards the Westerschelde. Additionally, water can be moved by using the excess capacity of the industrial water grid to bring water into the Zwaakse Weel. This stored water can be used in dry periods. Both the Zwaakse Weel and the nature reserve near Hoedekenskerke have a relatively low elevation of -0,50-meter NAP for this reason water can only be distributed to a limited number of polders within Borsele using passive transport methods. Retention Methods in Urban zones need also be assessed. Whilst rural retention capacity is likely to exceed the urban capacity there are many water features in urban areas in which water can be stored by utilizing all of these a respectable contribution can be formed.

The Zwaakse Weel has a total surface of 670.000m^2or 67 hectares. If the average water level was to be raised by ten centimeters this would allow for 67.000$m^3$of water to be stored the total capacity is lower due to the slop of surrounding land. Further water level elevation would increase storage capacity however it would alter the natural environment and recreational capacity of the area severely. Water lost to evaporation lowers the total amount of water that can be stored.

Restrictions	Opportunities
Changes in Fauna and Flora will occur when water levels are raised substantially.	Higher water levels can lead to increased biodiversity.
The owner of the location "Natuur Monumenten" needs to consent to changes. Changes might not match their plans or visions.	-
Water distribution to and from retention locations is limited by gravitational transport.	-
Water tables can only be raised limitedly as surrounding wears and waterways are not built for high water tables.	-

5.3 Retaining water on Private Property

Above ground water storage methods

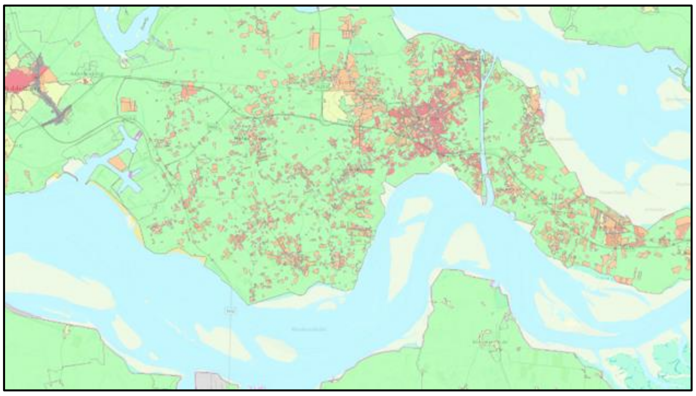

Figure 24 Rural & Urban areas of Borsele Green rural, Orange urban

This retention case involves the private properties owned by agricultural companies within Borsele. The total surface area of such land is 10.541 hectares as of 2019 (CBS. 2019). Owners of the 291 agricultural businesses in Borsele can implement a form of above ground water storage on private property. Currently eight farmers within Borsele have created some form of local water retention on their property. The properties of agricultural businesses will be transformed in a way as to create a considerable local water storage. This can be done by implementing different strategies, one way is to apply better soil management. More organic matter can be mixed in with soils as to allow soil to hold more groundwater. Secondly farmers can place a wear in channels bordering their property. Wears can be used to elevate the water tables increasing the water stored in the sub-surface this should be done in accordance with the waterboard. Finally, a basin can be established on the property of farmers this basin is to be filled during winter months and depleted during summer months. This measure can be reinforced by applying price differentiation of the Evides water grid between summer and winter months. Additionally, the provincial government can incentivize this basin storage by reducing permit requirements. The total water retention capacity of this measure is difficult to determine as it is completely reliant on the preparedness of farmers to invest in such measures. A retention estimate can be given once preparedness to participate has been assessed. Currently this method of water retention is used only limitedly in Borsele. An orchard farmer has implemented a basin with a capacity of 8000m^3 to irrigate peer and apple trees. This provides a sufficiently large freshwater reserve for when he cannot use water from other sources. The capacity is sufficient to irrigate half of his 20 hectares of land during a prolonged dry spell. As of 2019 the municipality was home to a total of 291 agricultural businesses and 4765 hectares of land used for agricultural purposes. If all businesses where to apply the method discussed 2.3 million cubic meters of water would be stored enough to fulfill irrigation requirements in most years if basins can be refilled to some extent during the months of June. July and August. It is likely that this method will only be used by businesses with high water efficiency these being the fruit producers. Implementation is only realistic by 55-60 businesses.

Restrictions	Opportunities
By increasing the water table in agricultural fields, the occurrence of ''brown rot'' is likely to increase. This disease spreads through water and will threaten a limited variety of crops.	This measure can be strengthened by applying price differentiation of ''Evides Industry Water''. This would form an incentive for farmers to store water in winter months for use in summer
Willingness to participate is the limiting factor of this measure. This in turn is strongly affected by cost effectiveness.	Future water shortages could make this measure economically viable. Prices are likely to rise when de supply decreases.
Freshwater basins are not allowed to have a height exceeding 3.0 meters as laid out in rural zoning rules.	-
Basins are expensive measures with basins of an 8000m^3capacity costing upwards of €100,000	-

5.4 Using Evides Agricultural Water to Facilitate Water Storage

Using alternative water sources for irrigation purposes

Figure 25 Industrial Water grid Location, Source: DNWG

The municipality of Borsele is home to an industrial water network which runs from the east of the municipality towards the west and ends in North Sea Ports. The water comes from the ''Hollands Diep'' in the province of Brabant. The product is unfiltered and carried in two separate pipelines, one is used for agricultural purposes whilst the other is used for industrial applications. The network has many secondary arms which reach into the municipality of Borsele as of today the grid is used by 340 farmers within "Zuid-Beveland" during dry periods. The agricultural network has a water provisioning capacity of 800m^3/ hour. The water is sold at a price of 0,50€-0,65€/m^3. Demand peaks during summer months whilst usage throughout the rest of the year is severely limited this results in the grid not being profitable for Evides. It is possible that the use of this water network can be optimized to enable freshwater storage within the municipality of Borsele. This can be done by ensuring that the grid is used both during winter and summer months. This can be done by maintaining different prices for water in winter and summer months. Low prices in winter months can incentivize the agricultural sector to store water for use in the summer. If this practice became widespread it could provide a significant water buffer. In order to achieve this method of storing this water need to be assessed. Currently water prices in winter months are slightly lower than summer months however from interviews with farmers it was concluded that this does not incentivize storage.

The capacity of this measure to provide freshwater is dependent on two variables. The first being the maximum throughput capacity of the grid. And secondly the willingness of farmers to invest in local private storage measures. If the agricultural water network was to run at maximum capacity upwards of 7 million cubic meters of water could be supplied annually. However as of now no means of storing this water is available. If all farmers had a storage basin of 8000m3 up to 2,3 millionm3 of water can be stored. Monthly 567,000 m3 can be refilled in summer months 4,0 million m3 can be made available using this method.

Restrictions	Opportunities
The preparedness of farmers to invest in local retention strategies is a key limiting factor.	Integration with retention cases that involve local water storage can strengthen the effects of the measures 3A.
The capacity of the water grid to supply water. A limited throughput capacity could form a limiting factor in supplying water.	-
The cost of small-scale water retention methods compared to their relative effectiveness.	-

5.5 Retaining water in the sub-surface of North Seaports

Sub Terranean Storage of Freshwater

The port facility of North Sea Port is located in the northwestern most portion of Borsele. Half of port property is located Within the municipality of Borsele whilst the other half is within the municipal borders of Vlissingen. North Seaports is the second largest port of the Western Scheldt with the port of Antwerp being the largest. The facility has an estimated economic value of 13.5billion euro's annually making it vital for the economy of the province of Zeeland. The port has a circumference of 18 kilometers and a total surface area of 1.181 hectare. Of this total surface area 166 hectares is currently not in use and could be used for industrial purposes or retention strategies. North Seaports was formed in 2017 by means of a fusion of the ports; Zeeland Seaports, The port of Terneuzen and the port of Ghent. North Seaports was built by creating a large mound of sand with a height of approximately 5 meters in most places. This large sand substrate can be used to store large quantities of water. Water which infiltrates into the sub-surface during the winter months can be extracted in summer months. Retention methods can be implemented on port property as to increase percolation rates.

Figure 26 Division of the Port Between Vlissingen and Borsele

North Sea Port has a total surface area of 1,181 hectares this translates to 11,8 million cubic meters of substrate. NSP was created by applying large volumes of sand from the western Scheldt, the elevation was raised by approximately 5 meters. This creates a volume of 59,1 million cubic meters of substrate available for the retention of water. Sand generally has a water retention capacity of 10-12% per volumetric unit (Shirsat. 2019). Theoretically the sub-surface of NSP can retain between 5,9-8,9 million cubic meters if the entire area is used for water storage.

Restrictions	Opportunities
A potential limiting factor could be the quality of the stored water. Are there harmful trace elements from industrial activities present in the soil?	For a project that promotes circularity a European Interreg subsidy could be applicable.
Infiltration of seawater into the freshwater layer could degrade water quality and usability.	Increasing above ground water storage as to increase total stored water and percolation.
Are farmers prepared to utilize water from North Seaports?	Redistributing "Evides Industrie Water" to increase available supply to agriculture whilst using stored water within NSP for industrial purposes.
The large volume of available water needs to be distributed throughout Borsele.	-

5.6 Storing Water in Creek Ridges and other Sandy Substrates

Sub Terranean Storage of Freshwater/ Drainage methods to increase percolation

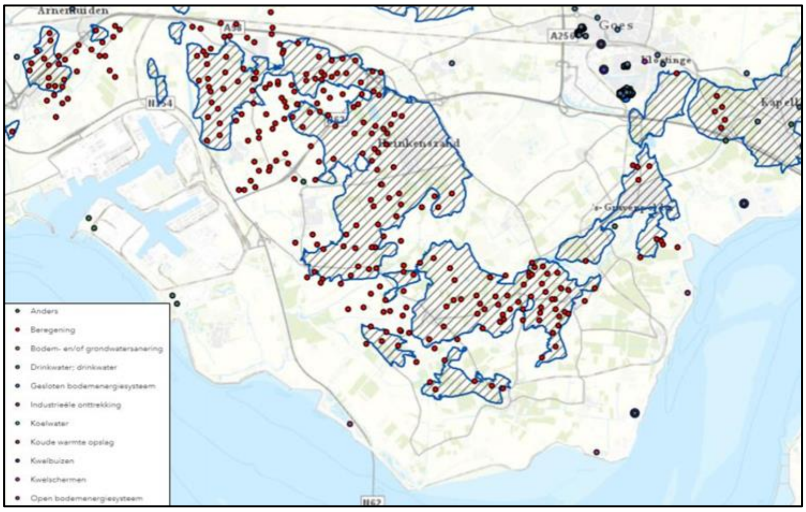

Figure 27. Subterranean Water Supply and Pumping locations. Source: Waterschap Scheldestromen

A creek ridge is a sandy elevated landmass which protrudes from the surrounding landscape (Delta Werken Online. 2004). Such a landmass is formed by the filling of creeks with sandy sediments. Overtime the natural channel will become filled until no water is able to pass through it. The surrounding land can decline overtime if water tables drop. The sandy soil layers will not decline when water is removed this results in the creek retaining its elevation whilst the surrounding land drops resulting in an elevated ridge. As of today the Municipality of Borsele is home to a number of locations with characteristics of creek ridges. Many towns are built on the remnants of creekridges as these where once locations of higher elevation. Two towns which are surrounded by the remnants of creek ridges are Heinkenzand and s'Gravenspolder. Creek ridges are built up of sandy substrates, sand can allow for fast percolation of water into the subsoil during periods of increased precipitation. If this layer of sand contains sufficient water, it can be utilized via extraction to water fields in periods of drought. As of today, water tables in rural areas are managed actively by the Waterboard. These water tables can be managed by maintaining water levels in irrigation channels and by applying intensive drainage. The application of intensive drainage is a method which can be done by farmers and the municipality.

Half the municipalities surface area ≈8.500 hectare can be divined as having sandy soils. Despite the surface area suitable for retention being known the depth of the sandy substrate has not yet been determined precisely. A prediction can however be made by looking at the Freshem project. Areas with good percolation characteristics are at least 12.5-15 meter in depth in central Borsele. Plotting the largest freshwater lens in the Freshem project ≈<53 million cubic meters of water is stored. However not all this water mass is available as the removal of water will lead to a rise of the saltwater lens. The water which is extracted must therefore be balanced with the amount that percolates. Water present in the subsurface is property of the landowner once it is brought to the surface by means of a pump as stated in the Civil Code article 20. Water which moves freely through soil layers is not property of anyone party. For extraction of groundwater a permit from the local waterboard is required.

Restrictions	Opportunities
The total volume of water retaining sand needs to be further assessed.	Water stored in creek ridges is of good quality as water that infiltrates during winter periods and does not contain pesticides.
Water extracted needs to be refilled as to prevent intrusion of saltwater. This requires active management.	Applying for a European Interreg Subsidy is a possibility as the project promotes circularity.

5.7 Analysis Criteria First Workgroup Session

A workgroup was held on the second of April 2020 with members of the municipality Borsele. The first step of this meeting was to discuss each of the six cases and increase understanding of characteristics. The second step was to discuss each case's ability to fulfill the six established criteria. This was done in order to fill out a matrix which aids in determining the most suitable retention method.

The Measure Provides a calculable water provisioning capacity

Using information available on a measure a calculation can be made which provides an insight into how many cubic meters of suitable freshwater can be stored. In order to make this calculation the surface area and depth of the storage substrate can be determined. The field capacity of the substrate is known in order to determine pore space available for water.

The freshwater provisioning capacity is of sufficient quantity

Borsele has a large portion of arable land, this land requires large volumes of suitable water to irrigate. A company cultivating peers and apples will require $100m^3$ of freshwater per day in the months June, July and august to irrigate just 20 hectares of land. The entire municipality is home to more than 6.300 hectares of arable land a suitable retention method must therefore be able to store many thousands of cubic meters. A retention strategy must provide a significant portion of the total water requirement of 1,4 million cubic meters a month if the strategy requires substantial investment.

The retention measure doesn't alter existing zoning plans

Zoning schemes are established by municipalities usually for an undetermined period of time. These plans determine how specific locations can be used by both private and public organizations. Zoning schemes are legally binding for all parties altering these takes time and can result in opposition. A retention method which fits within existing zoning plans would be preferable.

The retention measure will not alter existing infrastructure

Measures can require the construction of new forms of infrastructure this causes for additional levels of complexity. These new networks will have to be connected to existing systems which requires additional funding and planning. It is preferable that measures make use of existing networks and require little new hard infrastructure.

This measure does not require a large Kapital investment

Some retention measures will require large capital investments by either businesses or government. Costs should be kept low when possible as this is an important part of cost effectiveness. Measures with high costs but limited water retention capacity are unlikely to find support. Cost effectiveness for retention capacity must therefore be assessed.

Water stored by utilizing this retention method is of suitable quality

Water suitable for irrigation cannot contain high concentrations of ions. Potatoes and most union varieties are considered a salt sensitive crop (Arjen de Vos. 2016). Furthermore, the concentrations of nitrogen containing compounds such as nitrite and nitrate need to be considered as this can harm plant development and harm aquatic live. Substrate quality of the location needs to be assessed to determine if stored water is usable. Pollutants from industrial activity should also be considered, for industry the presence of heavy metals need to be considered.

5.8 Discussion per Case

Case 1A, Reuse Effluent Water Willem Anna (Using alternative water sources for irrigation purposes)

During the discussion concerns surrounding the cost effectiveness of this measure where raised. The water provisioning capacity is known and limited to 1400m^3/ day whilst the costs for establishing and maintaining a secondary treatment phase is high. As the water treatment plant is located in the neighboring municipality of Kapelle it is unlikely that all treated effluent will become available in Borsele the water will likely be distributed throughout Zuid-Beveland. Initiating this measure leis outside the means of local municipalities as they do not have ownership of the installation or relevant waterways. Additionally, it was brought up that the Waterboard Scheldestromen would play a crucial role in this measure. The installation "RWZI Kapelle" is operated by the waterboard any projects altering its operation must be undertaken by the waterboard these decisions are out of the influence sphere of the municipality Borsele. Adjusting operation of the WTP to retain freshwater fits the SAZ+ project of the Waterboard Scheldestromen.

Case 2A, Increasing Water Storage in Surface Water Bodies (Above Ground Storage Methods)

Initially this measure seemed promising however the municipality of Borsele has a lack of suitable above ground retention locations. There are but few locations within Borsele which can be expanded using water table alteration or expansion. A location which has the spatial capacity to store large quantities of freshwater is the Zwaakse Weel this is a nature reserve managed by ''Natuur Monumenten''. In its current state this location has a shallow water level elevating it would likely reduce this locations recreational and particularly ecological value furthermore Natuur Monumenten needs to consent to any changes made at this location. The measure of storing water in irrigation channels was also assessed however a multitude of drawbacks where stated. High water levels could harm certain crops "Bruinrot" whilst if channels where deepened this would lead to more water lose in periods of drought as more groundwater is removed from surrounding fields whilst widening fields would often cut into properties privately owned.

Case 3A, Storing Water on Private Property (Above Ground Storage Methods)

Storage on the agricultural plot level by private parties could provide a substantial buffer as proven by eight farmers in Borsele as of today. Currently there are a number of restrictions surrounding the construction of new above ground storage basins. Permits are required for the construction of the object which may not exceed 3 meters height. Additionally, ground may not be excavated deeper than 40 centimeters without proper permits. The cumbersome construction process tied with high costs makes this measure unsuitable for most forms of agriculture. Only businesses which can achieve high water use efficiency consider such measures. This measure however, leis well outside of the influence sphere of local municipalities as it is up too private partners to develop this measure. The municipality can still partake in a supporting role the process of acquiring proper permits can be made easier and the cost for these permits can be dropped or nullified.

Case 1B, Optimized use of Evides Industrie Water Network (Using Alternative Water Sources)

Utilizing the "Evides Industrial Water network" to improve water storage throughout the municipality proved to be a measure which could strengthen or facilitate measure 3A. This could be achieved by establishing a price difference between the price of water in summer and winter months. In its current state the agricultural water network has a maximum throughput of 800 cubic meters an hour. In summer months this network is at the peak of its capacity whilst during the winter use is limited. Lower winter prizes can incentivize famers to establish retention basins on their property as cost effectiveness is increased. The industrial and agricultural water grid is property of Evides, as this network is private property altering prices is not within the ability of government to change consumer behavior without subsidizing a seasonal price difference. A subsidy is however unlikely as financial resources of municipalities are limited.

Case 2B, Storing Water in the "Substrate" of North Sea Port (Sub-surface Freshwater- Storage)

During the first workgroup this measure proved to be the most promising retention method. Storing water in the substrate of North Seaports is a measure which provides a predictable volume of water of considerable size. Another advantage of this measure is that it will not alter the existing functionality of the port. Due to the innovative nature of the retention method the possibility exists to apply for a European Interreg subsidy this could substantially improve the cost effectiveness. De combination of a large retention capacity and the availability of subsidies results in a low cost per stored cubic meter of water. The quality of stored water is a factor which needs to be assessed. The port is home to a number of industrial sites such as Thermos, Total terminal and EPZ Zeeland these locations could have polluted substrates, further research is required to determine if this is the case. North Sea Port is located in the western most portion of the municipality Borsele moving stored water to fields that require irrigation will require waterways or water networks. To facilitate this a new pipe grid or channel will have to be constructed adapting existing waterways is a possibility which must be assessed.

Case 3B, Storing water in Kreek Ridges and Sandy Soils (Sub-surface Freshwater Storage)

Kreek ridge water storage could provide substantial freshwater retention as the municipality Borsele has substantial sandy substrates. Currently the sandy northwestern half of Borsele stores large amounts of water of suitable quality for irrigation. This becomes apparent by looking at the results of the Freshem project. This measure despite utilizing some form of natural infiltration capacity will require substantial financial investment as on the local scale numerous measures will have to be taken to increase infiltration to optimize water storage. Managing groundwater tables in rural areas is a task currently performed by the Waterboard Scheldestromen. Therefor this retention method would best be further developed by the Waterboard with an assisting role left to the municipality Borsele and other local municipalities.

5.9 Discussion

Table 4, Criteria Assesment

	Case 1A	Case 2A	Case 3A	Case 1B	Case 2B	Case3B
The Measure Provides a calculable water provisioning capacity	✓	✓	X	X	✓	✓
The freshwater provisioning is of sufficient quantity	X	X	-	-	✓	✓
The retention measure doesn't alter existing zoning plans	✓	X	X	✓	✓	✓
The retention measure will not alter existing infrastructure	✓	✓	X	X	✓	✓
This measure does not require a large Kapital investment	X	✓	X	X	-	X
Water stored by utilizing this retention method is of sufficient Quality	✓	-	✓	✓	-	✓
Criteria Sum	4	3	1	2	4	5

✓: The Measure Fulfils the Criteria, X: The Measure Does not meet Criteria, -: Cannot be determined

Retention method 1A provides a predictable but low freshwater storage capacity. The cost of this retention measure is also high this results in a low expected cost effectiveness. Due to a large amount of uncertainty surrounding measures 1B and 3A that pertain to retention capacity the freshwater provisioning capacity of these two retention methods cannot be given. The primary factor that leads to this uncertainty is the willingness of private parties to participate in the retention strategies. The market price of water, crops and fruits is an important factor in determining whether farmers will implement basins and winter month storage. From the six cases assessed two fulfill both the predictability and storage provisioning criteria. These are criteria 2B and 3B, storage in North Sea Port and creek ridges respectively. Despite the costs of applying these methods being high the very large retention capacity and the possibility of spreading costs through use of subsidies makes both measures good retention strategies.

Both 2B and 3B provide good retention capabilities. Method 3B is however already being applied to a certain extent within Borsele and many other municipalities in the Netherlands as waterboards already actively implement measures that allow for percolation and sub-surface water table restoration and farmers already extract water from shallow aquifers this is also managed by waterboards. As this measure fits the task of the Waterboard it should be further assessed by the waterboard.

Case 2B, of storing water in de sub-surface and surface of North Sea port is a measure that would create access to a sizeable water quantity which has the capacity to largely reduce the impact of dry periods. The municipality Borsele is one of the eight public shareholders of the port facility. A partnership between the Province, the municipality Borsele and North Sea Port would create a strong opportunity to counter climate change effects.

Part 2

Location Analysis & Alteration Proposal

6 Water Storage North Sea Port (Sloegebied, Vlissingen Oost)

The Location

North Seaport consists of a network of four separated port facilities with a total surface area of 9.300 hectare. This report focusses on the port facility of North Sea Port Vlissingen also known as “Vlissingen Oost” and “Sloegebied”. These two names refer to the portion of the port facility within the municipal boundaries of Vlissingen and Borsele respectively. The port property has a total surface area of 1.781 hectares and is home to approximately 90 businesses.

Figure 28, Location North Sea Port. Source: Qgis Edited

The port is located strategically at the entrance of the Western Scheldt. Despite being located close to the open sea it is still relatively close to inland ports such as Gent and Antwerp. The port is a deep-water port with its deepest channel being 16.5 meters deep and its entrance being 360 meters wide. This feature coupled with its gateway location gives it a vital regional infrastructural and economical role.

6.1 The History of North Sea Port

Figure 29, Sloehaven 1962. Retrieved Source: https://www.zeeuwsarchief.nl/onderzoek-het-zelf/archief/?mivast=239&miadt=239&mizig=261&miview=gal&mizk_alle=sloe gebied

The current location of the port known as the "Sloe Gebied" is the location of the old Middelburg harbor from where at one point in time 4.700 VOC ships would start their journey during the 16th century. At this point in time Walcheren was an island and was not yet connected to Zuid Beveland. The period between 1572-1795 is considered to be the golden age of the port of Middelburg with the end of the 19th century being a period of stagnation as a result of the construction of the "Kanaal door Walcheren". This period of decay ended with the construction of the railway connection between Bergen op Zoom and Vlissingen. In 1964 the construction of the "Sloe Gebied" was completed on September second. After the construction of this facility many industrial companies including the EPZ nuclear power plant would move into the port. Throughout the coming years numerous new inland port channels and docks would be constructed. As of today, the port handles all cargo types with wet bulk goods (Chemicals) being de largest portion of its transferred goods. It is also apparent that containers form but a small portion of total goods mass handled. Besides the transfer and transport of goods the offshore construction industry is an ever-growing industry in the port as offshore wind parks continue to develop along the western edge of the territorial waters of Zeeland.

Table 1. Goods Transfer Dutch Ports (1000 tons) Source: https://www.portgdansk.pl/about-port/cargo-statistics

	North Sea Port "Vlissingen"	Port of Rotterdam
Total Mass	22.822	291.955
Total Mass dry bulk goods	9.042	79.971
Total Mass wet bulk	13.780	211.984
Containers	815	122.607
Roll on/ Roll off	1.024	17.906
Other General Cargo	9.485	22.000

Area analysis Sloegebied

The port is home to a wide variety of industries. Ranging from roll on and off cargo, chemical storage, offshore construction and energy production. The industries present in the port impact the amount of percolation and the quality of stored water. For each location the surface area, soil profile and industries that can affect groundwater will be assessed in order to determine location suitability.

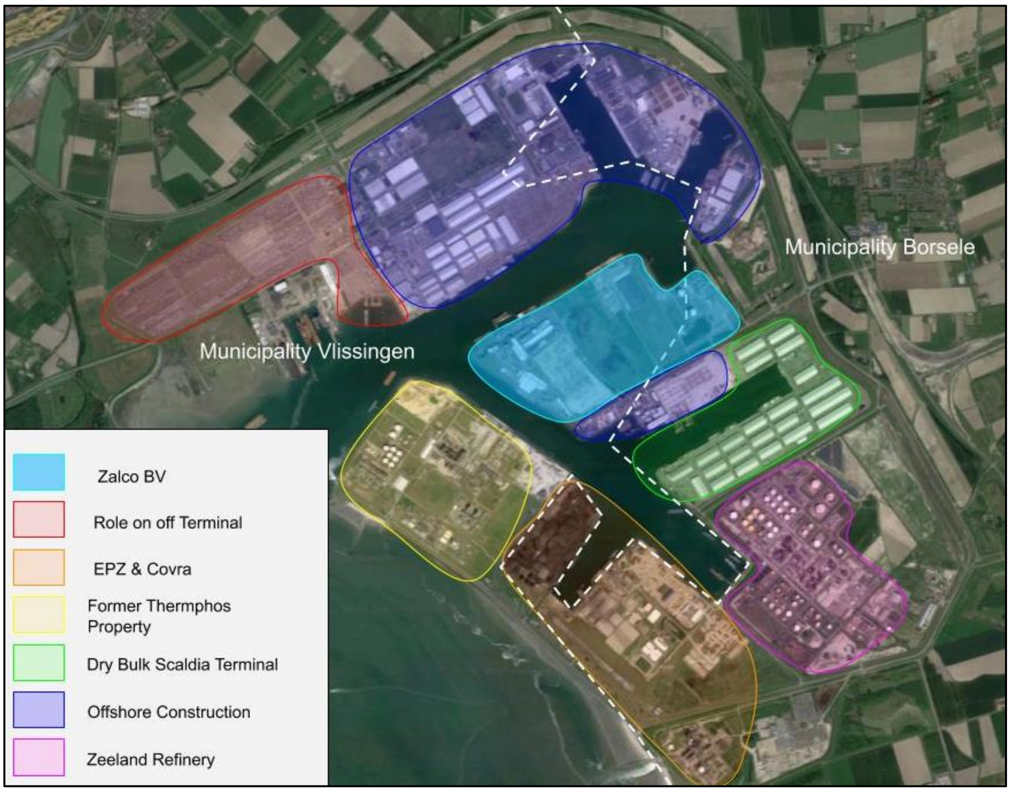

Figure 30, Port Zoning

Role on roll off cargo terminal (Sloehaven)

The north west of the ''Sloe gebied'' is home to a large terminal which deals in the transport of vehicles. The area consists of large paved surfaces for the storage of vehicles this area has a total surface area of 140 hectares.

Figure 28, location Car Terminal Sloe gebied (Left) Soil Profile (Right). Source: https://www.dinoloket.nl/ondergrondgegevens

The majority of surface area of this location is covered by extensive parking lots depending on the type of concrete used the percolation can be greatly reduced negatively affecting groundwater lenses. Additionally, the surface substrate consists of a layer of clay with a thickness of 40 centimeters. This clay layer can further reduce the amount of percolation which can take place.

Offshore Construction (Quarleshaven, Bijleveldhaven and Westhofhaven)

The northern most part of North Sea Port is home to an extensive network of docks and industrial fascilities for the construction of ofshore stuctures such as windmills and drilling platforms. This zone has a total surface area of 290 heactares. Besides paved docks there is also a substantial amount of surface area which is not paved. These unaltered locactions could be valuable in increasing infilatration capacity the majority however has been maintained by private parties. The majority of the substrate beneath this zone can be defined as sand however there are patches of clay.

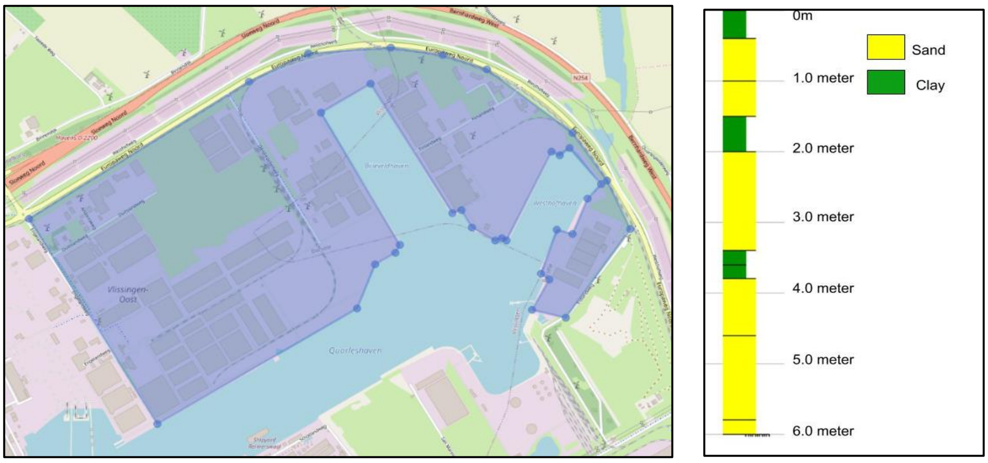

Figure 31, Location Offshore construction zone (Left) Soils Sample (Right). Source: https://www.dinoloket.nl/ondergrondgegevens

Zalco BV Property (Quarleshaven)

The southern dock of the Quarleshaven is home to two sizable aluminium factories. The western most portion is home to the Zalco plant and the northen part Is home to the Century Aluminium Plant with the eastern part of the terminal being home to the Vopak terminal. The middel of this area is largely unused and consists of unbuilt surface area. This port location has a surface area of 135 hectares.

Figure 32, Location Zalco Property (Left) Soil Sample (Right). Source: https://www.dinoloket.nl/ondergrondgegevens

The substraat of this location consists largely of sand making it suitable for water retention and infiltration. The presence of barren stretches of land in the centre of this location further increases percolation and provides an oppurtinity for active infiltration methods. The Hall-Héroult-proces used to produce aluminium from cryolite can produce the dangerous compound (F-).

Dry Bulk Terminal (Scaldiahaven)

The Scaldia terminal is the largest dry bulk terminal within North Sea Port it is located within the municipality of Borsele. It has a surface area of 110 hectares, this surface is covered by asphalt but also a high density of roofs. This high density constructed area reduces the amount of rain which can infiltrate. Water from roofs is caught in gutters from where it enters the grey sewage grid and is effectively lost as most runoff is released into the Western Scheldt.

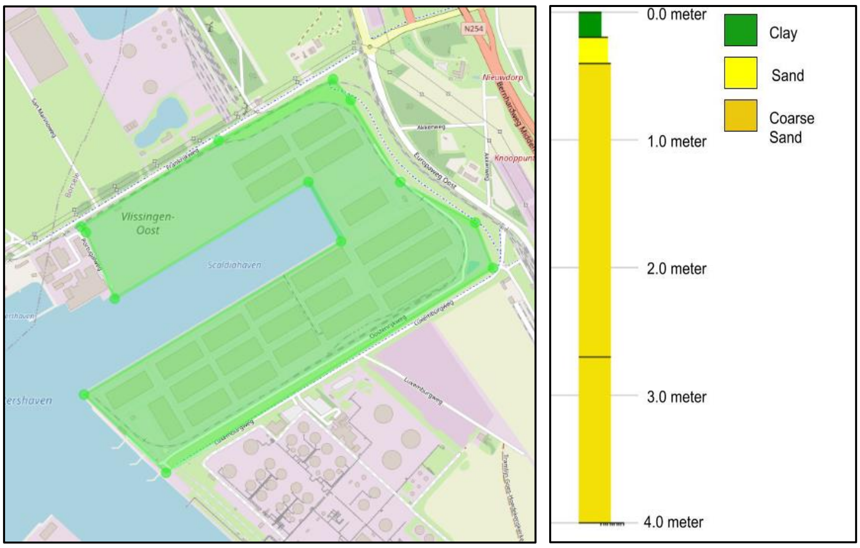

Figure 33, Location Scaldia Haven (Left) Soil Sample (Right) Source: HTTPs://www.dinoloket.nl/ondergrondgegevens

Soil samples from the Scaldiahaven taken in 1996 show that the substrate of this port facility consists primarily out of sand with only the top layer consisting of a thin layer of clay. The sand beneath this facility is of a larger grain size with a cone resistance MPa of upwards of 20 MPa. Coarse sand negatively effects the retention capacity of a substrate (Bal. 2001) as it can retain less water than fine sand. Percolation can also be slowed due to the grain size gradually becoming larger at lower ground levels.

Zeeland Refinery (Citterhaven)

Zeeland Refinery was established in 1972. The facility is a crude oil refinery where; LPG, Gasoline, Kerosene, Diesel and Fuel Oils are produced. The facility has a wide array of large fluid storage tanks and distillation towers. The surface area adds up to 230 hectares a substantial portion is not paved or occupied a portion of this unused land is currently being covered with solar panels.

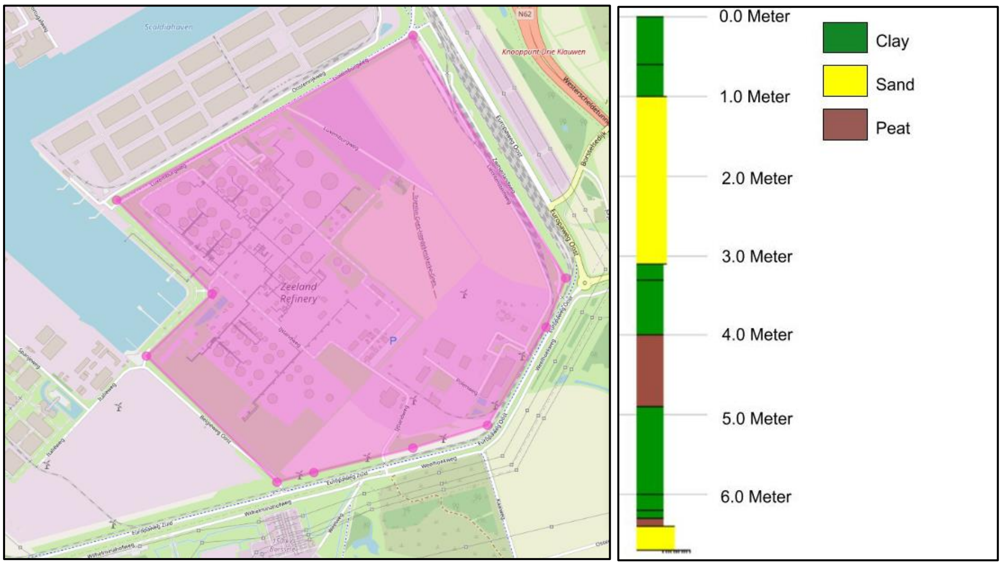

Figure 34, Location Zeeland Refinery (Left), Soil Sample (Right). Source: https://www.dinoloket.nl/ondergrondgegevens

The substraat below Zeeland Refinery contains significantly larger layers of clay then most port zones. This negatively affects infiltration rate and excessable groundwater. The presence of a peat layer makes water extraction unsuitable to this area as it could cause for ground subsidance which inturn could affect structures and port fascilities. The petroleum industry produces a number of by products which could be present in the fascilities surface soil layers though generaly soil pollution is considered as less of an issue then air pollution in this field (HAZARDOUS SUBSTANCE RESEARCH CENTER. 2001). It is however a possiblity that past spills have created pollution of numerous hydrocarbon varieties which can be present in the topsoil of the fascility.

EPZ & Covra (Kaloothaven)

The Kaloothaven is home to the Covra a facility designed for the long-term storage of nuclear waste and the coal terminal operated by the Elektriciteits Produktiemaatschappij Zuid-Nederland. This portion of port property has substantial stretches of vegetated surface area. Additionally, there are a number of surface waterbodies surrounding the Covra Facility the total surface area is 177 hectares. The substrate of the Kaloothaven consists largely of clay and peat layers with only small amounts of sand being present. This is due to the elevated level of this area at the start of port construction in 1962 at that point in time this area

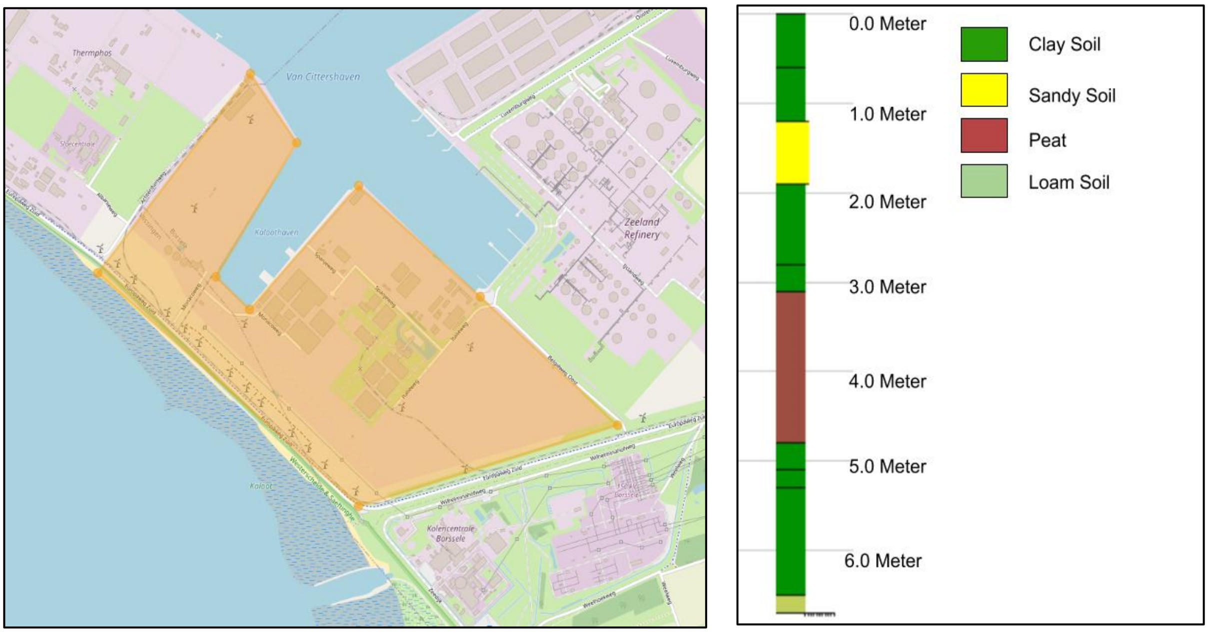

Figure 35, Location Kaloothaven (Left), Soil Sample (Right). Source: https://www.dinoloket.nl/ondergrondgegevens

was a saltmarsh running along the dyke protecting Borsele. This salt marsh created large layers of clay and additionally a considerable layer of Peat. The presence of large clay layers and a sizeable peat deposit negatively affects the retention capacity of this zone. Whilst the clay layer reduces retention and extraction speed of water the peat layer can cause for a drop-in port elevation when water is extracted. This greatly reduces this locations water storage capacity. The Kaloothaven is home to a number of industries which can negatively affect the quality of stored water. The Covra is the largest storage facility of nuclear waste in the Netherlands. furthermore, the nuclear powerplant of the EPZ is located at approximately 100 meters of the port. Due to the presence of these installations it is possible that increased levels of background radiation are present in this part of the port and possibly other port zones. Frequent measurements from the RIVM have shown that radiation levels are well within save boundaries.

The outdoor storage of coal in large coal piles is well known for producing significant contamination of surrounding soils and waterways especially in the direction of the prevailing wind direction (A. Cicek. 2004). The presence of coal storage sites generally causes for an increase in soil acidity due to the presence of sulfur which can react with water into an acid. Sulfides present in coal can be bound to heavy metals which in turn can contaminate the soil, waterways and groundwater.

Thermphos & SloeCentrale (Sloehaven)

The port zone of the Sloehaven containing the former Thermphos property and the Sloecentrale has a surface area of 144 hectares. The entire property is located within the municipality of Vlissingen. Besides the powerplant and the former Thermphos plant the northwest of this zone is home to a small chemical terminal and a polyester producing facility.

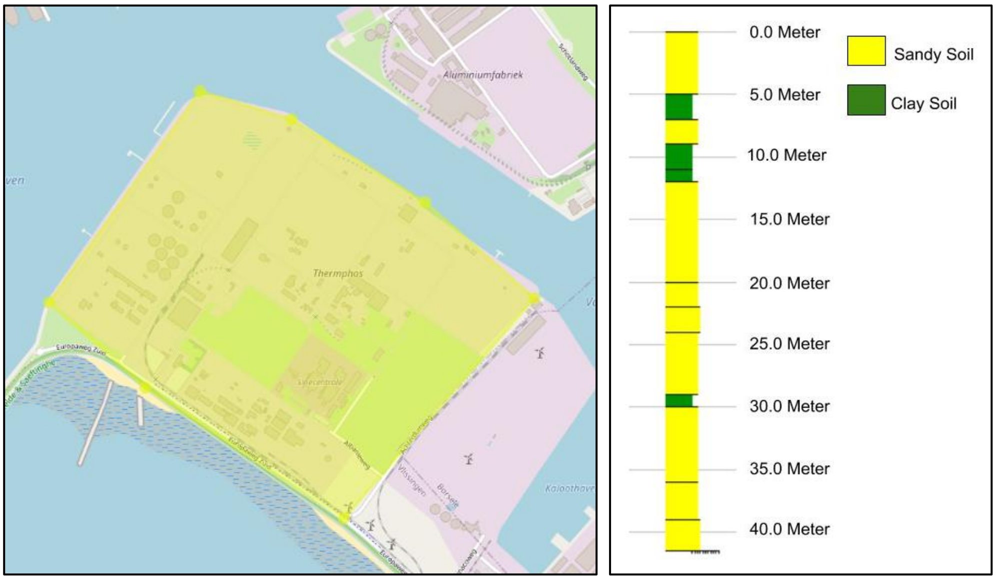

Figure 36, Sloehaven location (Left), Soil Profile (Right). Source: https://www.dinoloket.nl/ondergrondgegevens

The soil profile of the Sloehaven shows a very large deposit of sand with a number of small clay layers. The Sloehaven was once a diep open waterway which led to the port of Middelburg in the 16th century. Intinitialy this location was reclaimed from the sea as part of the Delta Werken resullting from the 1953 “Watersnood Ramp”. After 1964 this location would be further heightened inorder to creat dokes as seen today. The presence of large volumes of sand allows this zone to easily store large volumes of water. The Sloehaven zone is home to the former Thermphos production plant site which was part of the German Hoechst-concern. This factory was once used to produce Fosfor products this process turned phosphate rock and coke into Phosphoric acid. During this process heavy metals such as lead, kopper and nikkel where expelled into the air. Overtime these metals would pollute the soil of the property. The presence of heavy metals can greatly impact the quality of stored water.

Other Port Zones & Areas available for improved percolation

Besides zones voor logistics and industry NSP is home to stretches of land classified as green zones. These zones can be found primarily along the outskirts of the port between the "europaweg" and the N254. In 2018 the construction of a sizable solarpark was initiated within this zone currently large areas are covered with solar panels. These green zones are built outside of the primary seadikes on clay rich grounds. Combind with the presence of an extensive solar park this makes existing green zones unsuitable for water retention or increased infiltration.

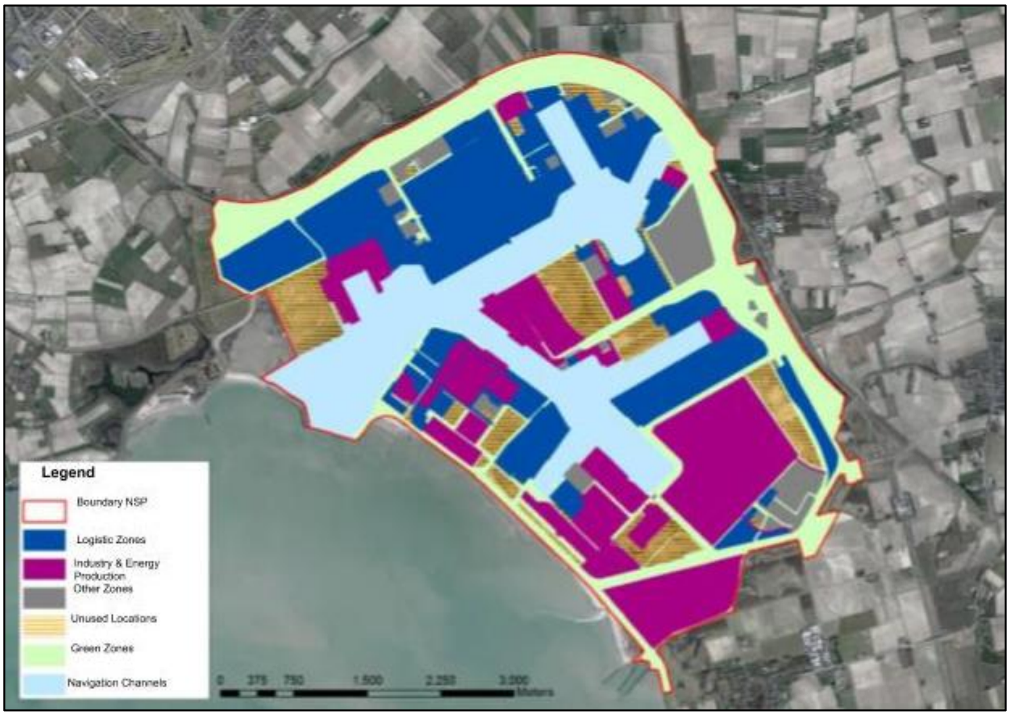

Figure 37, Port Zones NSP. Retrieved From: https://www.vlissingen.nl/fileadmin/user_upload/Plan-MER_Bestemmingsplannen_Sloegebied_21_april_2016.pdf

Besides the green zones a number of port locations are currently unused, these locations are owned by North Sea Port and could be implemented for above ground water retention or percolation methods. In 2016 186 hectares of land was available within North Sea port (Zeeland Sea Port. 2016).

Ground Water Tables & Elevation

Between 1970 and 1982 regular measurements of groundwater tables were taken between the property of Zeeland refinery and the Liechtensteinweg. These measurements show yearly fluctuations in water table levels. In winter months water tables regularly exceed +0.60-meter NAP whilst during the summer the water table drops to under -0.30-meter NAP. This is likely the result of considerably lower infiltration rates during the summer which leads to water tables loss either as water percolates away or evaporates as currently no water is extracted.

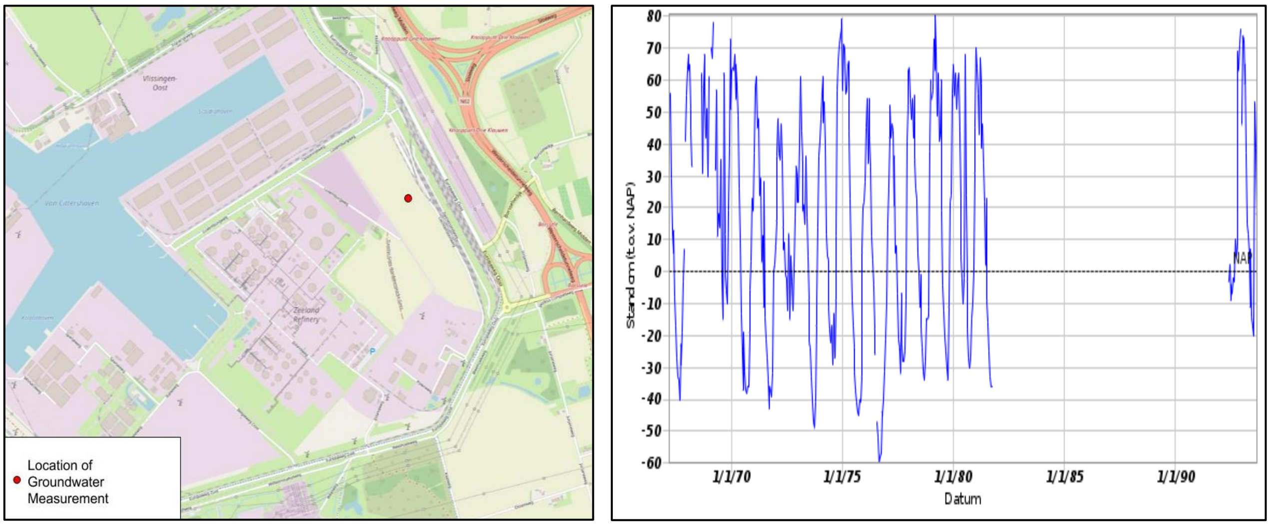

Figure 38. Groundwater measurement location (Left) Water Table Measurement 1970-1995 (Right). Source: https://www.dinoloket.nl/ondergrondgegevens

The annual rise and fall of ground water tables provides evidence that the sediment of North Seaport has the ability to retain a freshwater lens for some time. The elevations of port facilities in North Sea Port vary slightly throughout the port most docks have an elevation varying between 4,80 and 5,50. NAP (Scheldestromen. 2018). Zeeland refinery has a lower elevation than the surrounding port properties. This entails that less substrate is present which can hold water, additionally if high water lenses are maintained in neighboring port properties Zeeland Refinery could experience hydraulic seepage. This seepage could be drained using existing channel networks. The depth of the freshwater lens drops to -0,30m NAP water below this point can be assumed to be under control of tidal regimes therefor being of considerably higher ion concentrations. The maximum storage capacity of a port zone can be determined by adding 30 centimeters to its elevation compared to NAP. By counting in a locations surface area and the water retention capacity of a substrate type the amount of water which can be stored in a zone can be determined. Currently the water lens is limited to enlarge this percolation of precipitation needs to be increased.

Figure 39. Elevation North Sea Port. Source: Waterschap Scheldestromen

Port Freshwater Networks

North Sea Port is home to a variety of water networks maintained by a number of different actors. The majority of grey sewage networks are managed by North Sea Ports and private companies which operate these facilities the majority of runoff produced is expelled into the Westernscheldt where it is essentially lost. Most properties manage their own water household however Zeeland refinery has an above ground channel network which is managed by the Waterboard Scheldestromen. Water within Zeeland refinery is occasionally expelled into the western Scheldt. Due to the fact that only a small portion of channels along Zeeland Refinery are connected to the channel network of Borsele and Vlissingen moving water from North Sea Port to agricultural plots will require an additional water grid either above or below ground.

Evides Industrie Water provides water for use in industrial applications. This network can be found primarily in the southern portion of North Sea Port where it provides filtered water to the Zalco plant, Zeeland refinery and EPZ. This network is similar to the network providing water to agricultural businesses in Borsele as it shares the same water source and largely runs perpendicular to this agricultural grid. The water brought in through this grid is filtered in a facility within the municipality Kapelle "De Wranghe". This grid has a maximum capacity of 1,500m^3/hour. Under normal circumstances water usage averages approximately 500m^3/hour this entails that two thirds of the total provisioning capacity goes unused. Usage trends have shown that water usage by the industrial sector has little fluctuation (Evides .2020) Additionally, the Ph of the water is lowered to make it more suitable for use in industrial installations.

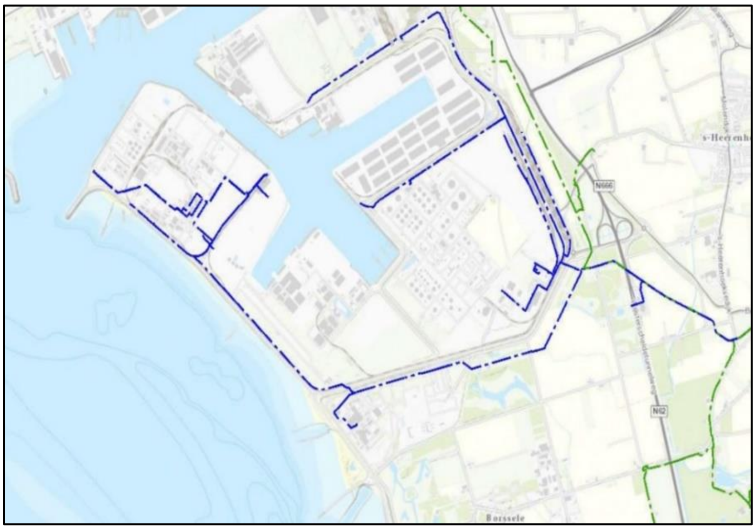

Figure 39, (Left) Surface Waterways, Source: Waterschap Scheldestromen Figure 40, (Right) Evides Industrial Water grid, Source: DNWG

Dikes & Hydrological Zones

Within North Sea Port three hydrological zones can be identified. These zones are created by the primary sea dikes which run through the location. These zones are likely to experience limited mixing of groundwater between zones as the dikes create a clay boundary of a depth of upwards of 10 meters.

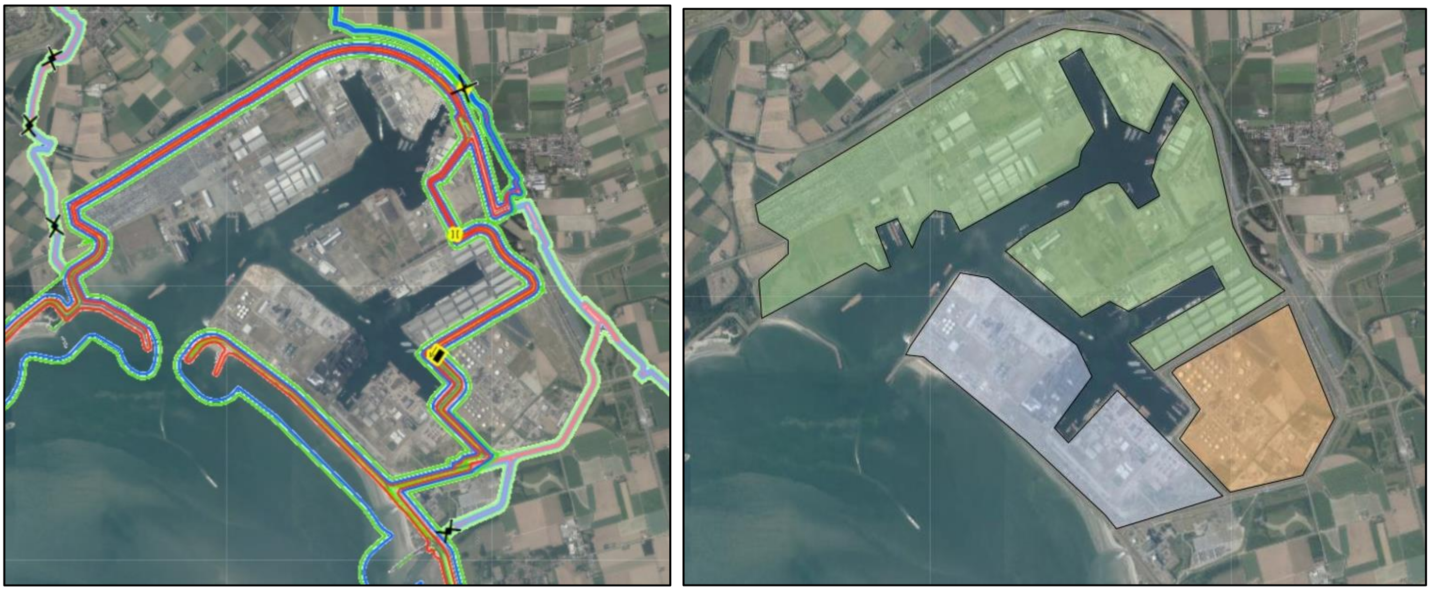

Figure 41, Sea Dikes (Left) Source: Waterboard Scheldestromen, Hydrological Zones (Right)

Currently percolation levels within North Sea Port are influenced by the building density soil types present and water loss through docks and saltwater lens mixing. In order to make water storage effective the amount of water that enters the substrate needs to be increased where possible. Northern port zones consist primarily out of sand, sand has an excellent percolation rate at upwards of 8 inches of water per hour (Kirby. 2017). The center of the port "Scaldia Haven" consists of a substantial sand layer however the entire area is covered with asphalt and warehouses. Southern port zones are home to considerable layers of clay soils. Water infiltration rates will be higher in the northern portions of the port.

Above Ground Percolation Methods

A basin can be established on land currently not used privately. Such a basin will not be used itself to store water it will however be used to allow water to percolate at increased rates. A sandy gully can be drawn below the basin if this gully is filled with sand of a large grain size the speed at which water moves from this large saturated layer into finer sands and even clays can be optimized (Basavaraj. 2019). A location where space is available for such a method and the substrate is suitable is the property east of the Zalco plant. Additionally, channels can be dug along roads were space is sufficiently available.

Active Percolation

Active percolation methods are available which can assist in bringing precipitation into the sub-surface. One such a method is bringing water into lower soil layers by means of a pipe grid which can be pressurized enough as to overcome pressure in the soil layers (sand). This network could be used to apply a portion of the over capacity of the Evides Industrie water grid into soil layers.

Analysis Second Work Group session

On the 17th of June a meeting was organized between representatives of the Municipality Borsele, North Sea Port, The Province of Zeeland, Evides, and the Waterboard Scheldestromen. The goal of this meeting was to map the port facility, characterize the existing water grid and define opportunities and limitations.

Work Group Findings

The zoning scheme created of North Seaport was agreed upon by all participants. No new findings or limitations where found concerning land surface area, land usage and substrate type. Contamination of the subsurface was also discussed the contamination of the Thermphos site was the only location where some form of pollution was confirmed pollution of the other three sites was stated as being possible. The land available for increased infiltration was also limited only some barren unused land east of the Zalco plant could be confirmed. Furthermore, concerns were raised about the cost of percolation methods. No participant thought this could be done cost effectively at the current price point of groundwater.

The discussion found that the gray water sewage grid in Zeeland Refinery is currently being expelled into the "Schelde". As this grid is connected to the rest of the municipality it could be used to move rainwater into agricultural zones however water quality would need to be assessed. The capacity of the industrial water grid was listed as an opportunity currently $1000m^3$/h is not being used. This water could be used in different ways firstly this water could be actively put into the subsurface as to create a buffer. This water could then be pumped up during dry periods. A second method could be to make this water available to farmers when an irrigation water deficit is imminent. Farmers would be able to pick up this water by means of tank trucks.

Conclusion

The workgroup concluded that further steps are required in order to determine the water retaining capacity of the port. An important factor which needs to be assessed is the extent that dock walls can retain water and the amount of mixing that will occur between fresh and saltwater layers. These aspects are to be further researched in order to determine capacity and water quality. The northern portion was labeled as preferable for water storage. Finally, research into price preparedness needs to be further assessed in order to determine viability of measures.

Tabel 8, Assement Sloegebied Second Workgroup

	Municipality	Surface Area (Hectares)	Substrate Type	Presence of Contaminants	Land Available for active infiltration
Role on roll off cargo terminal (Sloehaven)	Vlissingen	140	Primarily Sand	Unlikely	-
Offshore Construction (Quarleshaven, Bijleveldhaven and Westhofhaven)	Vlissingen	290	Primarily Sand	Unlikely	-
Zalco BV Property (Quarleshaven)	Vlissingen/ Borsele	135	Primarily Sand	Possibly Fluor Ions and reactants	Yes
Dry Bulk Terminal (Scaldiahaven)	Borsele	110	Primarily Sand	Unlikely	-
Zeeland Refinery (Citterhaven)	Borsele	230	Clay with Peat	Possibly Hydrocarbons, Metals & Cyanide	-
EPZ & Covra (Kaloothaven)	Borsele	177	Clay with Peat	Possibly Sulfuric Acid	-
Thermphos & SloeCentrale (Sloehaven)	Vlissingen	144	Primarily Sand	The presence of Heavy Metals has been confirmed	-

The Suitable Retention Location

The location determined as being the most suitable for water retention is the northern most hydrological zone of NSP. This is due to the limited presence of possible pollutants, the primarily sandy substrates and some space available for percolation methods. Within this zone alterations are to be made to the existing water grid as to increase infiltration and allow excess water to be moved into the dike rings of Borsele and Vlissingen.

Figure 40, Suitable Retention Location NSP

Channel Design

The channels constructed within NSP will be based on a standardized profile with a slope gradient of 1:2 utilized by the waterboard Scheldestromen. The total channel width will be 8,5 meters where possible. It is unlikely that in all locations this maximum channel width can be achieved if maximum width is very low an underground culvert must be established. The maximum water table depth is to be 1,7 meters as to prevent flooding. The maximum flowrate of the channel is 0,6m/s as to prevent erosion. The maximum throughput capacity of this channel profile is 4,58m^3/s. The channel has a lengthy wetted perimeter of 9,2 meters when the max water table is reached.

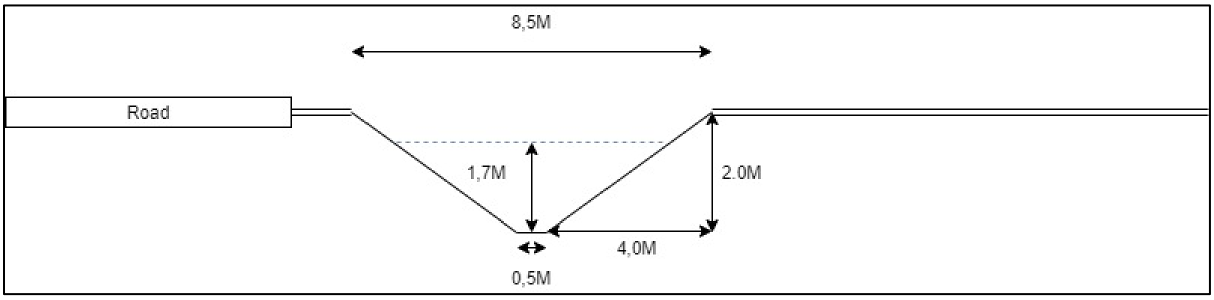

Figure 7, Standardized Channel Profile

Channels are constructed using clay soils as to prevent erosion this does slow down the maximum infiltration as there is no direct connection with sandy soils. Water infiltration rates for channels is set at 0,050m/day as a mixture of sandy clay soils can be assumed.

Alterations Car terminal

Figure 41, Water grid Proposal Role on Off Terminal

Within the role on off terminal a series of irrigation channels with a total length of 1,900 meters is to be established. The total surface area of this location is 700,000m^3 during periods of the maximum intense rainfall (25mm/h) upto 4,6 cubic meters of water falls on the location per second. This total throughput however is the maximum capacity of clay linned channels as only a flowrate of 0,6m/s can reliably be established (Nvl. 2014). The space available for channels is limited primarily along the Europaweg west. Not al the water from the terminal will therefor be moved by means of the new channel instead a substantial portion of water will still be discharged by means of the existing subteraneean grid which expels into de westernscheldt. A series of culverts is to be established inorder to connect irrigation channels. Two culverts are to be built below the Ritthemstraat and the Europaweg West near the busstation Vlissingen-Oost, Scheldepoort. A third culvert is to be established through the dike in the north of therminal this culvert allows water from the port to move into the dikering Rithem. An overflow channel with a wier is to be built running from the Rithemstraat towards the south through this channel water will be discharged into the westerschelde as to prevent channel overflow.

An alternative is to establish a pipe capable of carrying 4,59m3/s beneath the Europaweg West. To achieve this a concrete pipe with a diameter of 1,50 meters and a drop of >2,5 meters needs to be established. Applying such a culvert would remove water from the channels quickly and not allow for optimized infiltration. It is preverable to establish a culvert with a drop of 1 meter this would allow 0,70 meters of water to remain in channels. This would greatly reduce the flowrate and limit throughput to the dikering Rithem.

Table 5, Rainfall Discharge Roll On & Off Terminal

	Formula	Normal Heavy Precipitation 25mm
Total Surface Area	$A = Width \times Length$	700,000$m2$
Maximum Rainfall Intensitity	$r = \frac{Xl}{s}/ha(\frac{mm}{h})$ (25mm/h)	66,66L/S
Drain Coeficient	Ψ=1,0	Ψ=1,0
Draingage Requirement	$Q = \frac{A \times r}{10000} X\Psi$	4,666L/S

Alterations Vlissingen Oost Terminal

In the the center of the northern half of NSP three new above ground channels are proposed. The centre of this location is currently home to a barren stretch of land which has been acquired by a private party for development. Along the frindges of properties some land currently unsused can be transfomed into a temporary or permanent waterway. Along the ''Engelandweg'' a wide stretch of grassland is available on which a channel can be establlished. The total drainage area of this location is large upwards of 200 hecatres it will therefor not be possible to move al rainfall during periods of extreme precipitation despite roughly halve the surface area being permeable. it is for this reason only a limited portion of properties wil divert there current grey water networks into this system roughly 34 percent of the total surface area. A final channel is to be established along the Europaweg Noord this channel will run just south of the railroad running parallel to the Europaweg Noord.

Figure 42, Proposed Watergrid Vlissingen Oost Terminal

Table 6, Rainfall Discharge Vlissingen Oost Terminal

	Formula	Normal Heavy Precipitation 25mm
Total Surface Area	$A = Width \times Length$	2,000,000m^3
Maximum Rainfall Intensitity	$r = \frac{Xl}{s}/ha(\frac{mm}{h})$ (25mm/h)	66,66L/S
Drain Coeficient	Ψ=1,0 Ψ=0,5	Ψ=1,0 Ψ=0,5
Draingage Requirement	$Q = \frac{A \times r}{10000}$XΨ	13,333L/S

Alterations Northeast Terminal

Figure 43, Proposed Watergrid Vestas & Kloosterboer

In the northeast of NSP north of Vestas offshore and the Kloostboer docks a series of channels are to be created with a length of 740 meters. To the north of the Vestas terminal a stretch of baren land owned by North Sea Port is available for the implementation of three stretches of channels. Water will be moved from the port in Northeastern direction through the Europaweg Noord and the Westhofweg from here water can be moved into the Sloekreek. This zone has a total drainage area of 61 hectares roughly half is paved with the other half being open land. Under intense rainfall conditions the maximum throughput capacity is not reached. This entails that al water can move into dikerings or percolate. This can be done if existing grey water nertworks can be adjusted.

Table 7, Rainfall discharge Northeast Terminal

	Formula	Normal Heavy Precipitation 25mm
Total Surface Area	A=Width×Length	610,000m^3
Maximum Rainfall Intensitity	r=Xl/s/ha(mm/h) (25mm/h)	66,66L/S
Drain Coeficient	Ψ=1,0 Ψ=0,5	Ψ=1,0 Ψ=0,5
Draingage Requirement	$Q = \frac{A \times r}{10000}$XΨ	4,066L/S

Alterations Zalco & Century Aluminum

Figure 44, Proposed Water grid Zalco & Century Aluminium

To the east of the Zalco aluminium plant a stretch of sandy barren land is avaialbe for the implementation of retention methods as of today this land is owned by North Sea Port. By constructing a channel network with a total length of 2,800 meters water can be diverted through this zone where it is given increased time to percolate. At the end of the designed channel grid a wier is to be built which is set to maintain a high water table in the established network. With a surface area of 137 hectares not al water will be able to be held temporarily to allow percoalation even with the high infiltration rates of the sandy soil. Water can not be moved into Borsele and Vlissingen as a lot of infrastructure is located between the closest channel maintained by the waterboard and this port zone.

Table 8, Rainfall Discharge Zalco Aluminium

	Formula	Normal Heavy Precipitation 25mm
Total Surface Area	$A = Width \times Length$	$1{,}370{,}000m^3$
Maximum Rainfall Intensitity	$r = \frac{Xl}{s}/ha(\frac{mm}{h})$ (25/h)	66,66L/S
Drain Coeficient	Ψ=1,0 Ψ=0,5	Ψ=1,0 Ψ=0,5
Draingage Requirement	$Q = \frac{A \times r}{10000} X\Psi$	9,132L/S

Artificial Aquifer Restoration

In the most northern port location the Evides industrial watergrid services is the Zalco Aluminium plant. To the east of this location a sizable stretch of land (69 hectares) is available for percolation methods. Besides the redirection of surface water water can be redirected from the industrial watergrid into the soil. The first 3,5 meters of soil consist of sand below which clay layers can be found. This location could serve as the site for an active percolation methode. However it must first be determined if the substrate can produce a water table of sufficient hieght for this additional research is required into the movement of water through the substrate.

Figure 45, Locations Suitable for active Infiltration Strategies

Conclusion

By answering the five sub-research questions answers were created which lead to a proposal that allows for a large quantity of irrigation water to be stored within Borsele. Once the final sub-research was answered the main research question was concluded.

What Retention Strategies Are Available to Borsele?

From the strategies available to Borsele listed by STOWA five proofed to be suitable for implementation in Borsele. These are; utilizing irrigation channels to improve plot retention, above ground storage methods (Basins), subterranean storage of a water supply, drainage methods to improve percolation and utilizing alternate water sources for irrigation. In a city council meeting these strategies were further developed to specifically fit Borsele. This provided six specific cases that could provide Borsele with an increased freshwater supply.

What is the average Quantity of Irrigation water used in a summer month in Borsele?

Interviews and area analysis's has shown that current water demand in Borsele is high at upwards of 1.1 million cubic meters a month during normal summers and upwards of 1,38 million cubic meters during months of extreme drought. This water demand is set to increase as climate change alters temperature and rainfall patterns this will have a detrimental impact on crops and fruit trees currently grown in Borsele as these are not suitable for dealing with these changing conditions.

What actors are involved in Water Retention within Borsele?

By analyzing the actors involved in the consumption and supplying of irrigation water it was determined that the agricultural sector is the primary consumer of fresh water within Borsele whilst Waterboards and municipalities as well as the utility company Evides are involved in the provisioning and maintaining of water sources. Furthermore, the province is involved in supplying freshwater as it is an important supplier of large-scale water extraction permits furthermore the province is an important knowledge institute. In developing strategies, the Waterboard, the local Province and Evides are important partners. Additionally, North Sea Port must be involved in strategies involving the Port location. It was the result of this analysis that these parties were invited to participate in the final work group.

From the developed retention Strategies, which is Most Suitable for Borsele?

By assessing the possibilities of storing water within Borsele six retention cases could be established. From the measures available for retaining more water within the general vicinity of Borsele retention within the substrate of North Sea Port is a measure which provides a large capacity at an acceptable price point. Only two of the discussed measures are expected to provide a predictable and large quantity of water. As the municipality is a shareholder of NSP creating cooperation would be an opportunity for preparing for climate change the measure of storing water in "Kreekruggen" .

What Physical or Legislative Alterations Need to be made to facilitate the preferable retention strategy?

An analysis of North Sea Port has shown that the Northern portion of the port can be used to store up to a maximum of 3,2million cubic meters of water. Furthermore, water from Zeeland Refinery needs to be redirected in northern and eastern direction through existing water ways managed by the Waterboard Scheldestromen as to ensure this water is no longer lost to the Western Scheldt. In the northern part of NSP a series of three separate channel grids is to bring water into dike rings 29 and 30. In order to deliver this water outside of NSP, channels and culverts need to be established within NSP. These established irrigation channels can also assist in increasing percolation rates. Another way percolation can be increased is by using the excess capacity of the industrial water grid owned by Evides to apply artificial aquifer restoration in the vicinity of the Zalco Plant. If a channel network is established and a form of ASR applied a water source can be maintained within NSP which fights the detrimental effects of climate change and helps Borsele prepare for the future.

Discussion

The findings of this thesis report where established by creating a dialogue between different work fields involved in agriculture, governance and water utility. By doing so a proposal for alterations has been created which will aid in retaining water within Borsele. By performing desk research into methods to retain water within the Netherlands an overview of available strategies was established. These strategies where made location specific through analyzing the results of focus groups. After a set of measures was created the most suitable method was chosen using a set of criteria which was discussed within a workgroup. A second workgroup created an insight into opportunities and limitations for the most suitable method. The quantitative data used in this report came from established sources such as the IPCC and the KNMI. For the information surrounding water usage the agricultural sector was interviewed. This provided an understanding of the current water use situation and an understanding of future threats.

The qualitative data analysis has shown that water storage within NSP is the most suitable method to store water for Borsele. That this method was proven to be the most suitable did not come as a surprise as the method had proven it could retain a very large amount of water. The quantitative analysis has shown that large quantities of water are needed for irrigation within Borsele. This water requirement is set to rise as climate change further develops. That this method was chosen as the most effective measure could be largely the result of the fact that this water source is currently not used for irrigation in any way. Al other methods are used in a way al be it limitedly. By applying this method, a sum of water is essentially used which would otherwise be lost to the Western Scheldt. By further assessing a retention strategy within North Sea Port it was discovered that the industrial water grid owned by Evides could provide a significant amount of water suitable for crop irrigation. This measure can be used as a separate water source or combined with subsurface methods.

A number of unknown variables however do limit the accuracy of the listed retention capacity. Information surrounding characteristics of dock walls is not available this greatly impacts the amount of water which can be stored. Furthermore, the research itself was wide and only narrowed down when a location and method was determined there for further research is required to accurately provide a total water retention quantity. This report provides a set of follow up research questions which will allow for these uncertainties to be further determined. This thesis research was performed during the Covid-19 pandemic. Because of this it was difficult to establish contact with some companies additionally the workgroups where held with less representatives. Whilst the most vital parties did participate the amount of possible feedback was limited because some actors could not attend.

Recommendations

After performing this research, a number of uncertainties still remain these need to be answered before any form of water retention and extraction within NSP is to be implemented. Some results have proven that by implementing alterations within current water networks more water can be stored. These recommendations are provided as to give the municipality Borsele an overview of activities which need to be performed to achieve a successful retention strategy within NSP they

The first recommendation this report presents is an alteration to the existing flow direction in the hydrological zone of Zeeland Refinery. Currently water is expelled into the ''Westerschelde'' this is to be changed with water being redirected through the dike in the direction of the N62. Depending on the volume currently being expelled a significant volume of water can be retained. A precondition is that water quality is maintained and monitored by the waterboard in cooperation with Zeeland Refinery.

Another recommendation is the construction of a series of channels within the north of NSP. This an infrastructure project which should be implemented in close cooperation with the Waterboard Scheldestromen as this network needs to be connected to the existing grid. By implementing such a network, a large quantity of precipitation which falls within NSP can be utilized within Vlissingen and Borsele. An aboveground channel can also aid in increasing percolation and refilling water tables within NSP.

Further expansion of use of the "Evides Industrie Water" network needs to be closely examined. Firstly, water can be used to refill the sub-surface aquifer near the Zalco plant. Secondly Evides in cooperation with the municipality Borsele needs to research the possibility of allowing farmers to tap into the overcapacity of the industrial water grid. A total of $1000m^3$/hour is available for these two strategies. By allowing farmers to utilize this capacity in periods of drought harvests of sensitive crops can be saved.

Finally, a number of follow-up researches are proposed. One significant research which is proposed is the assessment of whether the dock walls found in NSP increase the water retaining capacity of the port. For this a further analysis is to be made of the docks as well as deeper substrates in which these docks are anchored. This would provide valuable information as a confined aquifer would provide considerably improved retention characteristics over and unconfined aquifer. Additionally, by means of dye mapping the rate at which water enters and leaves the substrate can be mapped as to be able to determine realistic water capacity of a port zone. It further allows for the more effective use of active percolation methods as it could provide an estimate of water which can be supplemented.

The final follow-up research proposed is a price preparedness research into what price points for irrigation water are viable for farmers. By determining what price can be paid for a cubic meter of water, water suppliers can determine what sources can be established. This research should make a clear distinction between fruit and crop farmers.

The construction of channels within NSP is to be the recommendation to be implemented first. By applying such a method, a large volume of suitable water can be maintained whilst also improving percolation thereby increasing the storage of water within the substrate.

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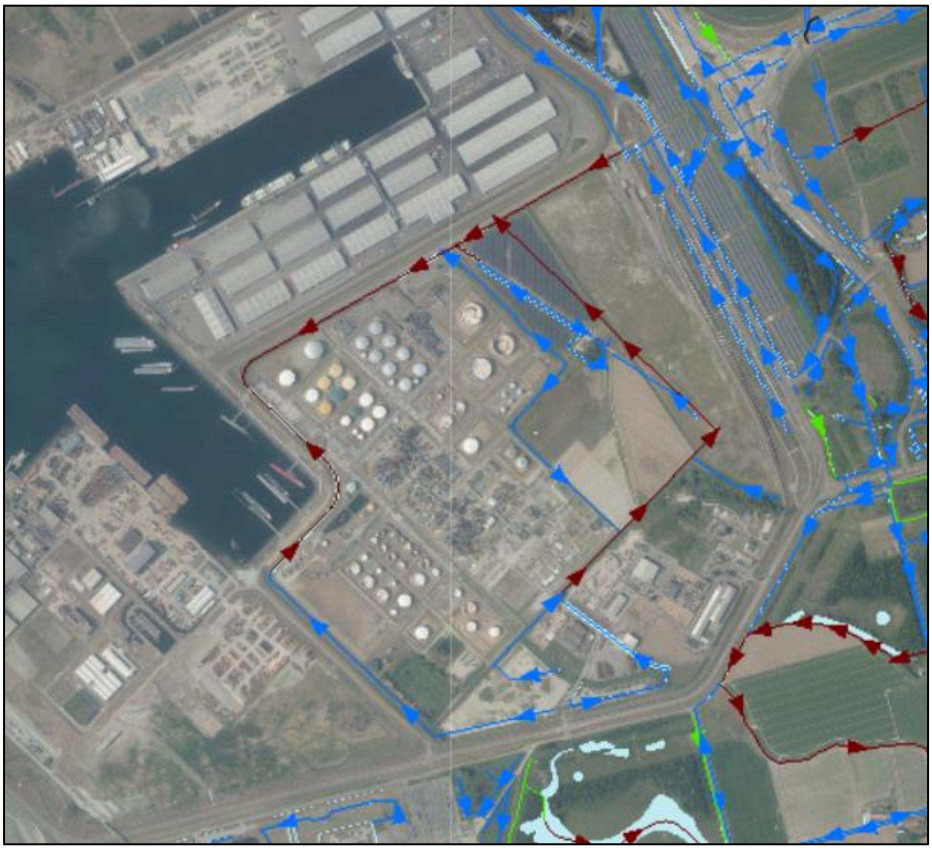
1 Appendix

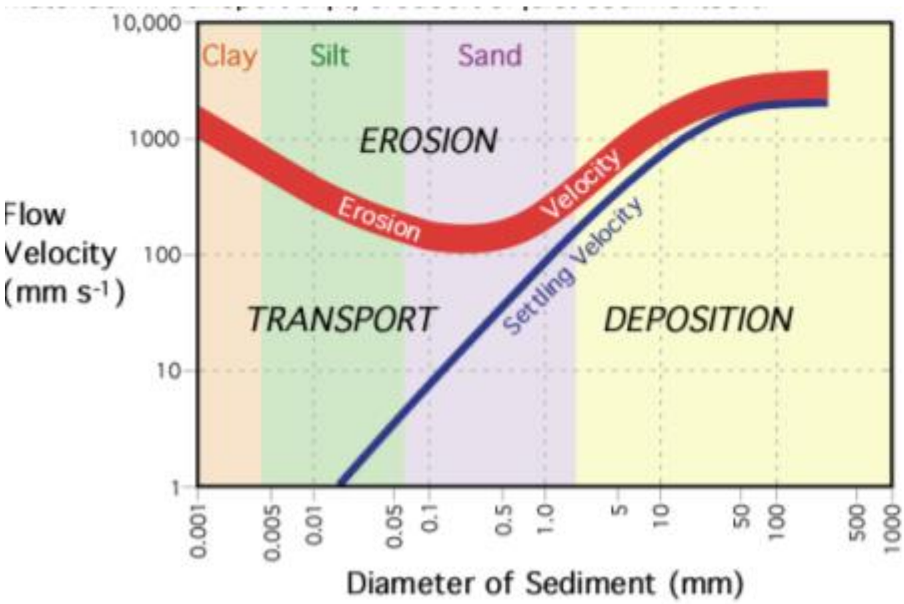
RA Chart Northern Hemisphere

Northern Hemisphere													Southern Hemisphere											
Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Lat**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
3.8	6.1	9.4	12.7	15.8	17.1	16.4	14.1	10.9	7.4	4.5	3.2	50°	17.5	14.7	10.9	7.0	4.2	3.1	35	55	8.9	12.9	16.5	18.2
4.3	6.6	9.8	13.0	15.9	17.2	16.5	14.3	11.2	7.8	5.0	3.7	48	17.6	14.9	11.2	7.5	4.7	3.5	4.0	6.0	9.3	13.2	16.6	18.2
4.9	6.6	9.8	13.0	15.9	17.2	16.5	14.5	11.5	8.3	5.5	4.3	46	17.7	15.1	11.5	7.9	5.2	4.0	4.4	65	9.7	13.4	16.7	18.3
5.3	7.5	10.6	13.7	16.1	17.2	16.6	14.7	11.9	8.7	6.0	4.7	44	17.8	15.5	12.2	8.8	6.1	4.9	5.4	7.4	10.6	14.0	16.8	18.3
5.9	8.1	11.0	14.0	16.2	17.3	16.7	15.0	12.2	9.1	6.5	5.2	42	17.8	1.55	12.2	8.8	6.1	4.9	5.4	7.4	10.6	14.0	16.8	18.3

Channels Managed by Waterboard Scheldestromen



Erosie Grens



Interviews Agricultural Sector (Dutch)

Vragen Agrariers

Naam Ondervraagde:

Telefoon Nummer:

Agrarier/Fruitteler/Vak Expert Water/Loonbedrijf

1. *Wat voor agraries bedrijf betreft het?*

2. *Wat is het totale oppervlak (Hectaren) van u bedrijf?*

3. *In welke periode gebruikt U het meeste water?*

4. *Wanneer u het meest bewatert wat is the bron (Slot of eigen reservoir) als het de slot is vraag of hij weet waar dit vandaan komt?*

5. *Hoeveel dagen geeft U water in de droge periodes (Geduirende een Zomer maand)?*

6. *Wanneer U bewatert hoeveel kubieke meter verbruikt u dan?*

7. *Houdt u rekening waar u water vandaan komt?*

8. *Heeft u last van de concentratie Zout in het water/en of de bodem?*

9. *Besproeit u u akkers ook om vorst schade te voorkomen*