A flood disaster in retrospect

EXAMINING EVACUATION STRATEGIES BY COMPARING THE 1953 DUTCH FLOOD SCENARIO WITH THE PRESENT DAY SITUATION.

BACHELOR THESIS DELTA MANAGEMENT

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DELTA ACADEMY APPLIED RESEARCH CENTER

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[Dutch]

"Landgenoten, die door de ramp getroffen zijt en gij redders en helpers in de ruimste zin, wij staan allen vol ontzag tegenover het grote leed, dat ons gehele volk trof toen een deel daarvan een week geleden werd overvallen door storm en vloed: tegenover de moed, door zovelen betoond in de nood, en tegenover de verschrikking doorstaan door hen, die van ons heengingen, en door hen die bij ons bleven met het zware lot, dat zij thans dragen.

Nederland is niet alleen het kind van de rekening geworden op het punt van de doorbraak van zijn dijken, maar het heeft ook als een kind het hoogste gebod gevolgd van de naastenliefde – ons door Christus gegeven, Die alle leed doorleden heeft en kent. Zelfs onze supe- rieur ontwikkelde techniek was machteloos de ramp op het kritieke moment af te wenden. Zij moest het opgeven tegenover wat ons lot moest zijn, en dus toch nooit met mensenmacht te keren is.

Maar, op het kritieke moment, waar materiële hulp niet kon worden aangewend werd de gééstkracht van de mens opgeroepen. De doorbraak van de dijken riep, daartegen in, een springvloed op van medeleven met elkander. De eendracht uit de oorlogstijd, was plotseling weer paraat. Dit hief ons volk in eens op boven alle afscheidingen en ieder compromis der samenleving uit.

Wij voelen er allen de weldadigheid van, weer samen te werken in het streven voor één grote zaak, en in ons enthousiasme werken we door zonder er op te letten of wij moe worden of schenken weg, zonder te letten op wat wij ons ontzeggen. Als straks de zwaarste stoot is opgevangen, en ook het normale leven weer een groot deel van onze aandacht zal vergen, dan wens ik ons allen toe, dat we met taaie volharding toch het herstel en de wederopbouw in dezelfde geest mogen volbrengen, met onze saamhorigheid in het oog en voor ieder zichtbaar.

Hoe dieper de nood, die zijn offers nam, des te dieper is tevens in de harten het beginpunt gelegd voor een verbroedering der mensheid, wat tot vér over de grenzen van het vaderland zijn weerklank vond. Dit was zo bij hen die zelf getroffen en zelfs zeer zwáár getroffen werden door deze zelfde ramp, die ons echter niet door menselijke verdorvenheid werd aangedaan.

Het raadsel van het waarom is alleen bekend aan Hem, die weet wanneer hij elke van zijn kinderen tot zich roept, en Die weet welke beproeving, welke krachtmeting, wij kunnen verdragen, elk afzonderlijk en allen te samen.
God doet thans een beroep op onze geestelijke veerkracht, en op ons vertrouwen in Hem. Dit lijden voert maar naar één uitkomst, zowel voor de doden als voor de levenden, en dat is: naar de barmhartigheid van God en waar deze werkt in de mens. Overal waar leed is, is zegen nabij".

Her Majesty Queen Juliana of The Netherlands[1]

8 Feb. 1953

[1] *A speech held on February 8 1953, a national day of mourning* (Watersnoodmuseum, 2018).
[2] Front cover photo: *Waves on the North Sea, 1950's postcard (Zeeuwse Bibliotheek, Beeldbank Zeeland)*.

Preface

My thesis research started on the 1st of February, 2018, exactly 65 years after the *big flood* washed away 1836 lives in the Dutch delta. This year marks the 65th memorial year of the disaster, and a National Memorial was held in Ouwerkerk on February 1st to commemorate those who lost their lives as a result of the flood. There was no other way that I could have commenced my research, than to stand with those commemorating, and attend the National Memorial:

We are gathered at the very location where the dikes gave way on that fatal morning and water rushed in to flood the hinterland: There I stand, looking at the Dutch tricolor as it flies half-mast. The rain pours down and the wind lashes my face. I can only imagine how cold those hit by the flood must have been while laying in the water holding on to something buoyant for dear life. I raise my collar while I listen to the man standing next to me: *'I lost my brother during the flood.'* He tells me. And while pointing to the word *'silence'* engraved on the monument:

'Worst was the silence. The terrifying silence that followed the flood waters.'

It were those words that echoed through my mind while I worked on finalising my Bachelor's Programme of Delta Management with this research during the last months.

Before you lies the result of analysing a flood disaster in retrospect.

I would like to thank those working at the Delta Academy Applied Research Center for allowing me to work along side you. A special thanks to my in-company mentor *Jean-Marie Buijs* for your guidance and support.

Thanks to *Stefan Nieuwenhuis* at the WMCN for your time and effort in sharing your expertise in flood risk management with me. A special thanks to *Marcel Matthijsse* at the Safety Region Zeeland for sharing your knowledge. I appreciated your willingness to share from your years of experience of working in the field.

To *Teun Terpstra*, thank you for you valuable insights and encouragement during the start-up phase of the research and later during the interview.

Finally a word of thanks to *Pierre Bleuzé*, tutor at HZ University of Applied Sciences for your trust and capable mentorship in the last four years and especially during the process of this graduation project.

I hope you appreciate the read,

Jurriën St Jago

Vlissingen, 8th of June 2018

Abstract

In the night from January 31st to February 1st 1953 the Netherlands was hit by a flooding disaster with major impacts. This thesis examines the flood diaster in retrospect through examining evacuation strategies by comparing the 1953 Dutch flood scenario with the present day situation. The central question is what the effect would be of a 1953 flood scenario on a current day evacuation of Reimerswaal and the hinterland of Zuid—Beveland and Walcheren. The sub-questions are structured in such a way that first an understanding of the 1953 flood scenario is developed and secondly the current situation in relation to flood consequences is examined. This lead to a structured analysis of the effect of a 1953 flood scenario on a current day evacuation of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren.

In chapter 4 the results of the research are presented. The following three chapters give the structure of the execution of the research: Chapter 4.1 is a historic analysis, examining the 1953 flood scenario for Reimerswaal and the hinterland of Zuid-Beveland and Walcheren. The flood resulted in 17 dike breaches in the primary and regional sea-defence of the Reimerswaal region, Zuid-Beveland. The hydrological situation shows water levels reaching up to 5-6m in some of the flooded polder areas. Various polders were subject to the influx of the semidiurnal tides for months. Preventive evacuation was non-existent and eye-witness accounts testify to vertical evacuation at the moment or directly after the dikes breached in some places.

Chapter 4.2 assesses the current situation, examining a 1953 flood scenario taking place in the present day by looking at flood consequences. Nowadays the peninsula on which Zuid-Beveland and Walcheren is located has over 210,000 inhabitants. Over 22,500 of these live in the municipality of Reimerswaal (dike ring 31). With the ability of the European weather model ECMWF to forecast a 1953 storm scenario 10 days in advance and capacity at the WMCN and KNMI to model this into a definitive hydrological situation with 20% certainty 5 days in advance, and 80% certainty 2 days before impact, the total time frame in which a 1953 storm scenario is anticipated is 10 days, with a gradual increase in certainty leading up to the moment of impact. Dike breaches at the Oost-Inkelen Polder (Kruiningen Veerhaven) and Reigersbersche Polder (near Bath) would flood 90% of the surface area of Reimerswaal with 0.5-5m of water. Consequences affect: *Livability*, due to inundation and failiure of critical infrastructure in the flooded area this is seriously affected. On the other hand, relatively little immediate impact for the non-flooded hinterland is anticipated. Critical infrastructural assest are expected to remain functioning for the hinterland. *Connectivity* to the hinterland will be suffering due to the loss of the railway and A58 high way connection west-east.

Chapter 4.3 consists of the flood scenario translated into a Flexible Evacuation Strategy by examining the implications of a 1953 flood scenario for a current day evacuation of the region. The Flexible Evacuation Strategy makes use of both preventive evacuation and vertical evacuation. The strategy has four evacuation options: *voluntarily leaving, obligatory leaving* (preventive evacuation) and *voluntarily staying, obligatory staying* (vertical evacuation). The effect of a 1953 flood scenario would imply for Reimerswaal the need of *preventive evacuation* for most of the region. In order to execute this strategy and get people moving adequate and timely crisis communication is paramount, accompanied with vigorous evacuation decision making. Chapter 6.2 and 6.3 conclude the research with conclusions and recommendations in which it is noted that the hydrological situation would imply the need for preventive evacuation, dealing with uncertainties regarding available time for evacuation, storm predictability and decision time is the main issue and adequate risk and crisis communication in order to provide timely coping strategies for inhabitants are essential as solutions. Further research is recommended in identifying evacuees (groups), an evacuation timeline, connectivity and relocating/rehousing.

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1. Introduction

1.1 Research context

February 1st 1953, a dark day for the people of The Netherlands. An extraordinary ruthless North-western storm stirs up extreme high waves. Dikes breach at many places over a length of 187km and water rushes in to flood the polders. 1836 people die on this fatal day in a flooding disaster that would mark and scar the Dutch and their delta for years to come.
To prevent such a disaster from happening again the Dutch Delta Plan was executed resulting in the construction of a series of storm surge barriers known as the Delta Works, shortening the Dutch coastline by 700km and increasing the country's water safety (Hage, 2015). These measures where anchored in the Delta Law of 1958 (Deltawet, 1958). Water safety, however, is not something that was fully attained and realised with the completion of the Delta Works, but something that needs constant attention.

The Netherlands is a low-lying and flood prone country. Because of its coastal location the Dutch delta is vulnerable to flooding from the sea due to high tides and storm surges (Wesselink, et al., 2015).

At the same time economic and infrastructural assets, essential to Dutch welfare and survival, are often located at low-lying areas and people have built up their livelihoods within the delta. For this reason the Dutch government wants to ensure that the Netherlands is protected against flooding, and prepare for weather extremes, now and in the future (Delta Programme , 2018). A revision of the 1958 Delta Law resulted in the 2011 Delta Law that called for a yearly Delta Programme (Deltawet waterveiligheid en zoetwatervoorziening, 2011). The Delta Programme is an initiative of the Dutch government to facilitate national protection against floods, both coastal and fluvial (river) floods, with its anticipated increased severity as a result of climate change (MI&M, 2017). Part of the Delta Programme is the Delta Plan on Flood Risk Management. This yearly plan comprises studies, measures and provisions relating to the fields of flood risk management and spatial adaptation in the Netherlands. It also provides details on flood risk management projects that are being undertaken. This shows that flood risk management is embedded in Dutch policy and legal frameworks (MI&M, 2017).

Nonetheless water safety is not something to be taken for granted. According to the IPPC the increasing influence of the changing climate with impacts such as sea level rise, weather extremes and intensified storms will pose coastal risks such as an increased risk of coastal flooding in the years to come (IPCC, 2014).

For this reason the question is asked: *what if…?* What if a storm with the same flood consequences as in 1953 would strike again? What would the implications of such a disastrous flood scenario be in the present time?

1.2 Statement of the research problem

National Water Plan of the Netherlands

In the decades following the 1953 flood technical measures as well as policy measures were installed to increase flood safety.

Nowadays the Dutch National Water Plan directs the national and regional strategic water policies and its related spatial policies. Within the National Water Plan the government provides the framework for the development and implementation of regional specific water plans. The current plan is in effect from 2016-2021 and every six years this plan is revised. The content of the plan consists of guidelines on the national water policy, preferred developments, necessary measures and management plans for fluvial areas and areas at risk of flooding (MI&M, 2015).

Since the implementation of the first Delta Plan following the 1953 flood, the areas at risk of flooding in the Netherlands have become increasingly inhabited. Over time the economic and infrastructural assets in these regions have increased as well raising the stakes for water safety policy. With an increasing complexity of critical infrastructure and society's dependence on these networks the need for an adequate water safety strategy is paramount.

Multi-Layer Safety (MLS)

Within the National Water Plan the water safety of areas at risk is attained through investing in the different layers of Multi-Layer Safety:

1. Reducing flood probability through flood *prevention*: dikes and dams etc.

2. Limiting the flood *consequences* through water robust spatial adaptation

3. Limiting the flood *consequences* through effective disaster management

Hoss et al., (2011) explains it in the following way: *'Multi-layered Safety (MLS) introduces the novelty of integrating different types of measures into Dutch flood management: reducing the probability and the consequences of floods. So far the Netherlands has mainly relied on flood prevention, thus probability-reducing measures. MLS consist of three layers. Prevention is the first layer of MLS. The second and third layers are consequence-reducing measures, namely spatial solutions and crisis management. The first two layers are physical measures, whereas crisis management concentrates on organizational measures.'* (Hoss, Jonkman, & Maaskant, 2011)

This approach is based on both dikes and dams, spatial design and effective disaster management: the three layers of Multi-Layer Safety. With this approach the Dutch take on water safety resulted in a paradigm shift in recent years: from flood prevention through dams and dikes to a *flood risk* based approach (Ellen, 2015). Smart combinations between measures in different layers are made to increase water safety and in specific cases for instance reducing the need for dike reinforcements in layer 1 on the long term. Buuren et al., (2015) however state in their evaluation of the pilot projects on Multi-Layer Safety that smart combinations in layers 2 and 3 have not proven to be sufficient and cost-effective to suffice for basic water safety on the short and middle long term. They concluded that on the short and middle long term only measures in the first layer will adequately provide water safety (Buuren, Ellen, Leeuwen, & Popering-Verkerk, 2015).

Research into flood risk: probability and consequences

Though the probabilities of flooding might be small, the possible consequences have become increasingly severe over the years. Since the possibility of a flooding in the Dutch delta cannot be ruled out it is necessary to conduct research in this field. In recent years research is done into flood risk: consisting of flood *probability* and *flood consequences* in the Netherlands (Projectbureau VNK2, 2012). Additionally research is done into vertical evacuation in the Netherlands as a strategy to cope with flood consequences (layer 3) (Kolen, Vermeulen, Terpstra, & Kerstholt, 2015). Furthermore a Flexible Evacuation Strategy is developed for a specific region (IJssel-Vechtdelta) in the Netherlands (see chapter 2 of the theoretical framework for specifics regarding the Flexible Evacuation Strategy) (Vreugdenhil, Verhoeven, & Kolen, 2015). Research into the use of a Flexible Evacuation Strategy is part of gaining insight into the consequences of a flood.

Lack of knowledge: What is still missing?

What is still needed is additional, area specific research into the possible *flood consequences* in the Netherlands. One of the ongoing researches into a specific area is the RAAK-project initiated by the Delta Academy Applied Research Centre at HZ University of Applied Sciences. Within the project *'Critical Infrastructure in the Resilient Delta'* the research group formed a consortium with the Province of Zeeland, Municipality of Reimerswaal, Safety Region Zeeland, Rijkswaterstaat Zee & Delta, Scheldestromen Water Board and research institute Deltares. The aim of the project is twofold: Firstly to develop knowledge on cascade effects due to failing critical infrastructure as a result of flooding, and secondly to develop measures in prevention, response and the recovery phase of a flood. The goal of this project is to enable professionals working in the field of water safety to increase the resilience of society. The pilot area on which the project focusses is the municipality of Reimerswaal in Zeeland and its surroundings.

The following research is part of this bigger, ongoing research project into flood consequences conducted by the research group. As part of the ongoing research, this research aims to give insight in the consequences of a flood specifically in relation to evacuation.

The local context to which the Flexible Evacuation Strategy will be assessed in this research is the area of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren in the Province of Zeeland. (Dike rings 28, 29, 30 and 31) Reimerswaal is a narrow stretched municipality in the Province of Zeeland lined by water on both sides: the Eastern Scheldt in the north and the Western Scheldt in the south. Providing access for 210.000 people living in the hinterland, and situated in one of the lowest lying areas of the province it is located at a hotspot for critical infrastructure and flood risk (CBS, 2018).

> *This research aims to assess the effect of a 1953 flood scenario on the current day evacuation of this area. Within this assessment the concept of a Flexible Evacuation Strategy is leading and evaluated against the flood scenario that hit the area in the winter of 1953.*

Relevance

The relevance of this research is first of all found in the fact that the increasing influence of the changing climate with impacts such as sea-level rise, weather extremes and intensified storms will increase the risk of flooding in years to come (IPCC, 2014). Secondly there is a lack of knowledge on the cascade effects in critical infrastructure sectors in relation to flood consequences, also regarding evacuation. Thirdly there still is insufficient integration of Multi-Layer Safety in water safety policy (e.g. Flexible Evacuation Strategy applications). Since evacuation affects both the flooded region as well as the surrounding regions into which evacuees are transported, it is relevant to take those surroundings (e.g. hinterland) into account as well when conducting research into evacuation related critical infrastructure and flood consequences.

This leads to the following research question:

1.3. Research question

What would the effect of a 1953 flood scenario be on a current day evacuation of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren?

1.4 Sub-questions

1. ***Examining the 1953 flood scenario:***

1.1 What was the flooding scenario of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren in 1953?

2. ***Examining a 1953 flood scenario taking place in the present day:***

2.1 What would a 1953 flooding scenario of Reimerswaal look like in the present day?

2.2 What would the consequences of a 1953 floodscenario of Reimerswaal be for the hinterland of Zuid-Beveland and Walcheren in the present day?

3. ***Translating the floodscenario into a Flexible Evacuation Strategy:***

3.1 What are the implications of a 1953 flooding scenario for a current day Flexibe Evacuation Strategy of Reimerswaal?

2. Theoretical framework

Flooding Scenario

A flooding scenario is a description of an assumed reality which is based on substantiated assumptions (Kolen, Westera, Kosters, & Nieuwenhuis, 2015). Scenarios describing the course of a flood are flooding models. The consequences of a flooding are modelled in victim models and evacuation models are used to give insight into the opportunities of leaving a certain area.

Flood risk: flood probability and flood consequences

In recent years research is done into the risk of flooding and flood consequences in the Netherlands.

Between 2006 and 2014 the project *Veiligheid Nederland in Kaart* (VNK2) was executed in which the aim was to provide an analysis of the risk of flooding and flood consequences in the Netherlands. The project was commissioned by the Dutch Ministry of Infrastructure and the Environment (IenM), Waterboard Union (Unie van Waterschappen) and Inter Provincial Collaboration Platform (IPO) and executed by Rijkswaterstaat in collaboration with flood defence operators/managers, Provinces, knowledge institutes and engineering firms. This resulted in a cohesive analysis of the risk of flooding and possible consequences for each of the 53 dike rings in the Netherlands (Projectbureau VNK2, 2012). By 2014 the flood risks for: Dike ring 28 Noord-Beveland, Dike ring 29 Walcheren, Dike ring 30 Zuid-Beveland (west), and Dike ring 31 Zuid-Beveland (east) were completed, providing insight in the risk of flooding and possible consequences for this peninsula in the Province of Zeeland.

Besides research into the risk of flooding, research is also conducted into how to act when these risks become reality. Where evacuation is a possible measure to reduce the risk of casualties in case of flooding, HKV Lijn in water and TNO (commissioned by WODC) did specific research in vertical evacuation in the Netherlands as strategy to cope with consequences due to failure of primary flood defences along the Dutch coast, Lake IJssel and the major rivers: Rhine, Meuse and Scheldt (Kolen, Vermeulen, Terpstra, & Kerstholt, 2015).

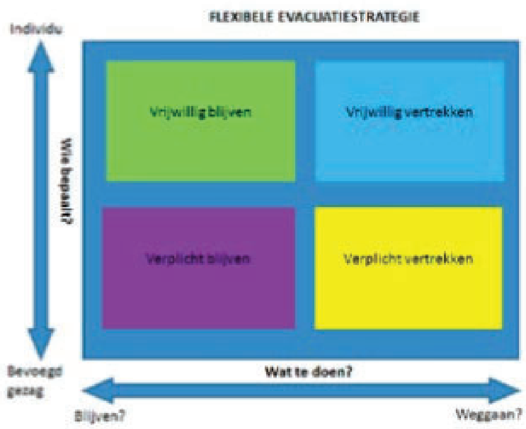
There were two central questions to this research: 1. Under what conditions will vertical evacuation contribute effectively to the safety of people (i.e., focus on revention of casualties)? 2. What measures can (reasonably) be taken by government or private sector (stimulated by government) in order to improve circumstances during survival (i.e., focus on ‘quality’ of survival circumstances)?

This resulted in some conditions and requirements for vertical evacuation in which it is noted that defining conditions and requirements is a decision problem.

Flexible Evacuation Strategy

Within the Dutch IJssel-Vechtdelta (province of Overijssel) it is impossible to know beforehand how much time there is available to evacuate and area with an upcoming flood thread. It is not always possible to safely evacuate all the inhabitants from the area at risk of flooding (Maaskant, Kolen, Jongejan, Jonkman, & Kok, 2009). For this reason the Safety region of IJsselland developed a Flexible Evacuation Strategy. This strategy is based on both preventive and vertical evacuation and can be applied for every flood risk scenario. Within the IJssel-Vechtdelta the Province, municipalities, water board and the Safety Region work together on integrated water safety strategies based on Multi-Layer Safety. With the Flexible Evacuation Strategy the Safety Region contributes to the reduction of the flood risks (Vreugdenhil, Verhoeven, & Kolen, 2015). The Flexible Evacuation Strategy is visualized as follows (see figure 4.25 for an elaborate version in English):

WAT DOE JIJ BIJ EEN OVERSTROMINGSDREIGING?
Vrijwillig vertrekken: je verlaat vrijwillig het bedreigde gebied. Je regelt zelf opvang.
Vrijwillig blijven: je blijft vrijwillig in het bedreigde gebied. Je kent dichtbij een bereikbare, droge en veilige plek.
Verplicht vertrekken: de overheid verplicht je om te vertrekken uit het bedreigde gebied. Je kunt om hulp vragen; er is nog voldoende tijd.
Verplicht blijven: de overheid verplicht je te blijven op een veilige, droge plek in het bedreigde gebied. Evacuatie uit het bedreigde gebied is vanaf dit tijdstip te gevaarlijk.



There are three components to this strategy:

1. *Risk communication* ensures timely preparation for inhabitants to a possible flood risk.
2. *Coping-Strategies* are provided by the Safety Region and Municipality to enable inhabitants to increase their own safety.
3. Based on *recent (up to date) flood thread information* the government will structurally and in an early stage advise the inhabitants on options for staying or leaving the area.

Resulting in four Flexible Evacuation Strategy options:

staying in the area.

1. Voluntarily staying
2. Obligatory staying

leaving the area:

3. Voluntarily leaving
4. Obligatory leaving

One of the recommendations for further studies made by HKV Lijn in water, TNO and WODC is the following: *To consider vertical and preventive evacuation in conjunction*.

This will aid the development of evacuation strategies and their implementation by the safety regions (crisis management and crisis communication focusing on different target groups) and municipalities (spatial planning policy for shelters, risk communication) and by national authorities: a broad, national communication campaign and information provision (Kolen, Vermeulen, Terpstra, & Kerstholt, 2015).

Related terms:

Preventive evacuation:

'People evacuate to a safe location outside the threatened area before failure of flood defences.' (Kolen, Vermeulen, Terpstra, & Kerstholt, 2015)

Vertical evacuation:

'In a vertical evacuation people evacuate to a high, dry place within the threatened area (in the U.S. literature referred to as sheltering in place).' Vertical evacuation is an alternative to preventive evacuation, or can be implemented in combination with preventive evacuation (Kolen, Vermeulen, Terpstra, & Kerstholt, 2015).

Liveability (during a flood event):

Degree to which an area is able to support living.

Self-sustainability:

Being able to maintain oneself by independent effort. (Merriam-Webster, 2015)

"You want to be your help until help arrives," said Derrec Becker, Public Information Officer for the South Carolina Emergency Management Division (Thelisha Eaddy, 2017).

Crisis communications:

"The collection, processing, and dissemination of information required to address a crisis situation." (Coombs & Holladay, 2010)

Risk communication: (Dutch: Risicocommunicatie)

Orientation, communication, (actively) informing the public on risks to which they are exposed, before a disaster takes place (e.g. flood event).

Risk communication reveals the available coping strategies to the public and makes sure that these are seen as realistic options (Vreugdenhil, Verhoeven, & Kolen, 2015).

Coping strategies: (Dutch: handelingsperspectief)

Offering (feasible) options for taking action, opportunities, possibilities:

e.g. provided by the Safety Region and Municipality to enable inhabitants to increase their own safety during a flood risk event.

Stakeholder interaction

The way in which stakeholders such as the government, inhabitants and local businesses interact before, during and after a flood event.

Evacuation fraction

The evacuation fraction is the expected value of the percentage of inhabitants that is able to leave the area at risk of flooding before the dikes breach.

3. Methodology

Project goals and objectives

Aim of the project is to form answers to the main question: *What would the effect of a 1953 flood scenario be on a current day evacuation of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren?*

Answering the research question will be done in three steps:

1. Historic analysis, examining the 1953 flood scenario: *What was the flooding scenario of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren in 1953?*

2. Current situation, examining a 1953 flood scenario taking place in the present day: *What would a 1953 flooding scenario of Reimerswaal look like in the present day? What would the consequences of a 1953 floodscenario of Reimerswaal be for the hinterland of Zuid-Beveland and Walcheren in the present day?*

3. Translating the floodscenario into a Flexible Evacuation Strategy: *What are the implications of a 1953 flooding scenario for a current day Flexibe Evacuation Strategy of Reimerswaal?*

The sub questions are structured in such a way that first and understanding of the 1953 flood scenario is developed and secondly the current situation in relation to flood consequences is examined. This will lead up to a structured analysis of the effect of a 1953 flood scenario on a current day evacuation of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren.

Each step is divided in goals (what will the project accomplish) and objectives (how will the goal be reached):

1. Goal: *The 1953 flood scenario for Reimerswaal and the hinterland of Zuid-Beveland and Walcheren is mapped out.*

- Conduct literature study to make an historic analysis.
- Consult experts at Rijkswaterstaat on the 1953 flood scenario.
- Indentify the hydrological situation.
- Visualise the dike breach locations and flood scenario for Reimerswaal.
- Create a time line for the storm anticipation to give insight in availiable time to evacuate.
- Map out evacuation options for Reimerswaal and the hinterland of Zuid-Beveland and Walcheren.
- Gather information on evacuation fractions.

2. Goal: *The reality of a 1953 flood scenario taking place in the present day is mapped out.*

- Conduct literature research on the time frame in which a 1953 storm scenario would be anticipated in the present day.
- Identify flood consequences of Reimerswaal for the hinterland.
- Create an area analysis for a 1953 flood scenario of Reimerswaal in the present day.

3. Goal: *The implications of a 1953 flooding scenario for a current day Flexibe Evacuation Strategy of Reimerswaal are made visible.*

- Identify the concept of a Flexible Evacuation Strategy according to the available literature (Vreugdenhil, Verhoeven, & Kolen, 2015).
- Design two interviews with experts on water safety and evacuation to get an understanding of flood consequences in relation to evacuation.
- Conduct an interview with Marcel Matthijsse (Safety Region Zeeland) and evaluate the interview outcomes.
- Conduct an interview with Dr. Teun Terpstra (HKV Lijn in Water) and evaluate the interview outcomes.
- Benchmark the experts findings with the Flexible Evacuation Strategy.
- Create an overview of the anticipated evacuation fractions for Reimerswaal, Zuid-Beveland and Walcheren.
- Assesses implications of time frame and evacuation fractions on evacuation and coping strategies.
- Draw conclusions and give recommendations based on the research findings.

Time and scope: chosen research aspects and delimitations

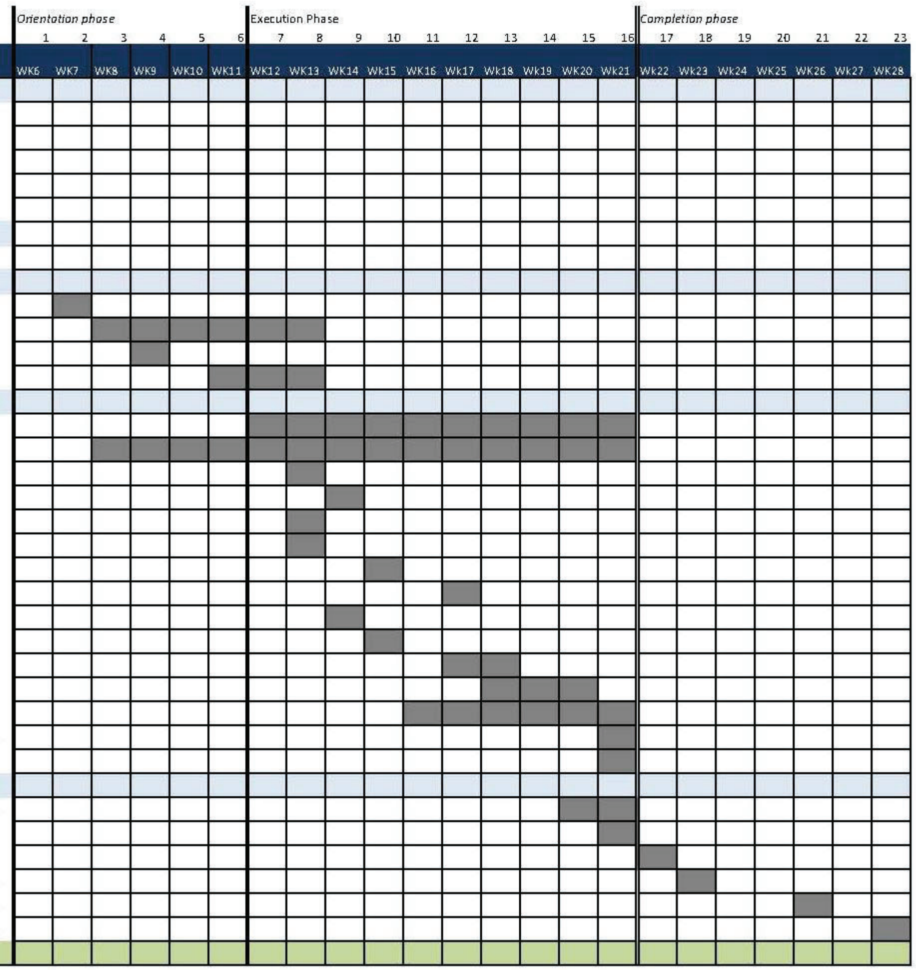
The graduation period in which the research takes place is from February 1st till June 10th 2018 (18 weeks). The research activities of the project were concentrated between March 12th till May 25th (10 weeks). The other weeks were used for orientation, participation in an exchange workshop, different kinds of reporting and related work activities.

Within the research the choice is made not to focus on *flood probability* for the area of Reimerswaal and the hinterland but to focus on *flood consequences*. This is done since research into flood probability requires rigorous technical data processing and analysis and is not feasible within the research scope. Secondly it deflects attention from the aim of the bigger on-going research, namely: research into flood consequences of the pilot area of Reimerswaal. There is relatively little insight into the consequences of flooding for specific regions in The Netherlands. In The Netherlands people know the big flood of 1953, for this reason it is interesting to look at what the consequences would be today with a similar hydrological situation. The same hydrological situation is used as in 1953 so for this reason the focus is first on the historic analysis, secondly on the current situation and thirdly on implications for evacuation of the area itself and on the hinterland. The mile stone planning on the following page quantifies the time and scope of the research project.

Workplan: milestone planning + competence progress

Project Name: Bachelor Thesis Delta Academy Applied Research Center
Student: Jurriën St Jago
Start Date: 1 February 2018
End Date: 30 June 2018

Tasks	Competence	Start	End	Days	Status
Competencies					
1.2 Exploring the area	1			1	In progress
1.3 Exploring the policy strategies	2			1	In progress
2.2 Developing an integral vision	3			1	In progress
3.2 Specifying market needs	4			1	In progress
ing projects. Defining, if needed, a schedule of requi	5			1	In progress
0. Preparaton Phase					
Start Document		22-jan	30-jan	10	Complete
1. Orientation phase					
Hydro-Social Deltas Exchange Workshop		10-feb	17-feb	8	Complete
Research Proposal		19-feb	26-mar	35	Complete
Impact Analyse Dijkring 31 Zuid-Beveland		1-mar	1-mar	1	Complete
Feedback on Research Proposal / Adjusting					Complete
2. Execution phase					
Research Report				1	In progress
Desk research					In progress
Set-up Portfolio		26-mar	29-mar	4	Complete
POP-PAP Goals/Description					In progress
Workshop Vital Infra./Resilient Delta		28-mar	28-mar		Complete
First Assessment: In-company evaluation					Complete
Mid-term day presentations		11-apr	11-apr	1	Complete
Impact Analyse Dijkring 29 Walcheren		24-apr	24-apr	1	Complete
Complete research set-up/planning					Complete
Design interviews		9-apr	13-apr		Complete
Conducting interviews					Complete
Processing interviews					
Portfolio: competency description and proof					
Go/No Go For submitting final report		25-may	25-may	1	Not started
Feedback for completing Final Report					
3. Completion phase					
Discussion				1	Not started
Conclusion and Recommendations					
Finalise report and portfolio					
Submit final report and portfolio		10-jun	10-jun	1	Not started
Final presentations		28-jun	28-jun	1	Not started
Graduation ceremony		13-jul	13-jul	1	Not started



Research design and methods

The research approach has been through qualitative research. Given the time span limitations and scope of the research the choice is made for this research approach. Part of the research focuses on a historic analysis of the 1953 flood. In the decades following this flood a lot of numerical data was generated through quantitative research. This research build on the available data on flood risk and intends to contribute to ongoing research into flood consequences in the Netherlands and specifically in the Reimerswaal region.

The following research strategies are selected to work towards answering the main question:

Conducting desk research and literature study (both professional and academic sourced)

Desk research and literature study formed the basis of this research. Both professional and academic sourced literature was used in the process of answering the research questions.

Consulting libraries / archives / databases

The consultation of libraries (Zeeuwse Bibliotheek), archives (Zeeuws Archief, Archief van de Deltacommissie) and databases was also part of the research methods. A wide range of historical sources was used providing knowledge and data on the big flood and the work field of flood risk management which developed following the flood disaster.

Conducting interviews

An interview is a conversation guided by the researcher according to a specific *structure* and with a specific *aim* (de Lange, Schuman, & Montessori, 2011). The form and the aim of the interviews for this project are interviews on behalf of research. According to Bill Gillham (2000) interviews on behalf of research aim to obtain information and understanding of issues relevant to the general research project or to obtain answers to the specific research questions (Gillham, 2000).

The choice is made to use interviews as a research method and consult experts in the field of water safety, flood risk and crisis and evacuation management in order to find answers to the formulated research questions. For this purpose two open interviews are conducted. The reliability and credibility of the interview outcomes is found in the expertise of the consulted professionals.

Interview I: The first interview is conducted with MSc. Marcel Matthijsse. He is a senior policy advisor and program manager at the Safety Region Zeeland. He is responsible for three programmes of which one is the national WAVE2020 program that focusses among other things on area specific evacuation strategies, and another program under his care is WAVE2, focussing on local areas within the Province of Zeeland in relation to water safety. In the WAVE2 program he is responsible for the Impact Analysis for Zuid-Beveland East and West and Walcheren in which coping strategies regarding flood threads are assessed.

Interview II: The second interview is conducted with dr. ir. Teun Terpstra. He is a long time researcher and senior consultant flood risk at HKV for the department Water and Climate. He is working on innovation development and climate adaptation and an expert on flood risk management.

A Transcript of the interviews can be found in the appendices. (Interview with Marcel Matthijsse in appendix I, interview with Teun Terpstra in appendix II)

Consulting experts in the field

An additional research method was consulting experts in the field. MSc. Stefan Nieuwenhuis is an expert at the Water Management Center Netherlands (WMCN, as part of Rijkswaterstaat). He is an advisor on Hydro Meteo Coastal- and Delta region. Since 2008 he was involved with initiating the National Coordination Commission on Floods. He is also co-author of the 2014 renewed National Action Plan on High Water and Floods. He provided valuable knowledge on the 1953 flood scenario (Chapter 4.1) and historic and current time frame and process of storm weather forecasting (Chapters 4.1.2 and 4.2.2).

4. Results

Introduction

In chapter 4 the results of the research are presented. The following three chapters give the structure of the execution of the research:

Chapter 4.1 is a historic analysis, examining the 1953 flood scenario: *What was the flooding scenario of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren in 1953?*

Chapter 4.2 assesses the current situation, examining a 1953 flood scenario taking place in the present day: *What would a 1953 flooding scenario of Reimerswaal look like in the present day? What would the consequences of a 1953 floodscenario of Reimerswaal be for the hinterland of Zuid-Beveland and Walcheren in the present day?*

Chapter 4.3 consists of the floodscenario translated into a Flexible Evacuation Strategy: *What are the implications of a 1953 flooding scenario for a current day Flexibe Evacuation Strategy of Reimerswaal?*

4.1 Historic analysis: examining the 1953 flood scenario

In the night from January 31st to February 1st 1953 the Netherlands was hit by a flooding disaster with major impacts. An extraordinary ruthless North-Western storm stirs up extreme high waves and dikes breach at many places over a length of 187km. Water rushes in to flood the polders and large parts of the Province of Zeeland, and parts of Zuid-Holland and Noord-Brabant are inundated by the sea water. 1836 people die. 47.000 livestock animals and 140.000 poultry animals drown. 200.000 acres of land floods and 4.500 homes and buildings are destroyed and 400.000 homes damaged (Zeeuws Archief, 2018). In the primary flood defence of Zuid-Beveland the dikes breach at many locations: Everdingenpolder, two breaches. Kruiningen, three breaches. Waarde, seadike. Zimmermanpolder, seadike. Rilland, seadike. Bath, seadike. Zuidvlietpolder, western seadike (Hage, 2015). (See appendix III for a complete map of dike breach locations in Dikering 31 Zuid-Beveland East). In this chapter the hydrological situation and 1953 flood scenario is presented.

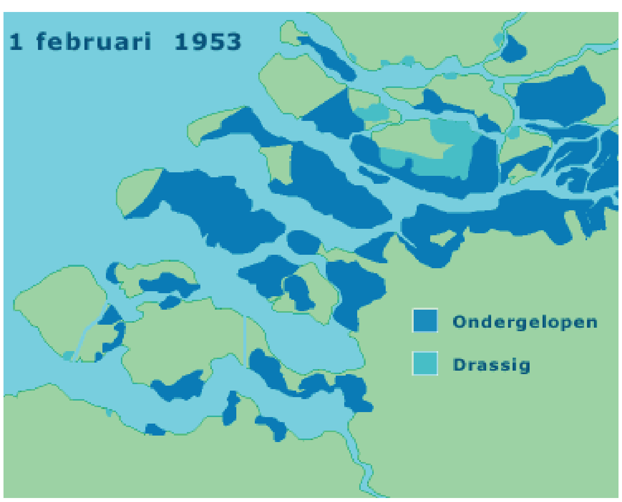


Figure 4.1: Inundated land, February 1, 1953 (Zeeuws Archief, 2018)

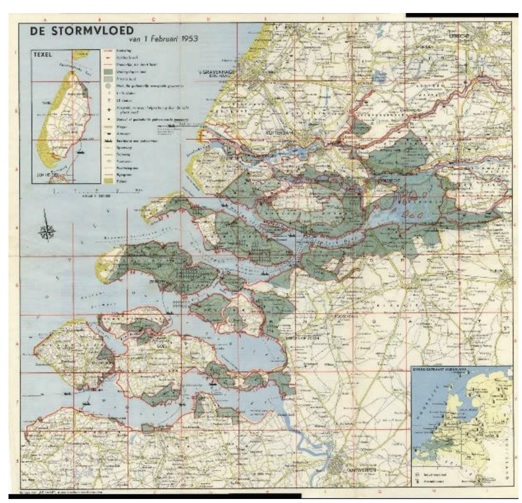


Figure 4.2: Disaster area map 1953 flood (De Ramp, 1953)

Hydrological situation:

In the Netherlands the ‘*grenspijl*’ (extreme water level) is a water level that on average twice a year is met during high tide (Aquo-Lex, 2012). A storm surge happens when the wind and air pressure stir up the water level above the *‘grenspijl’* level. In the Province of Zeeland this level is on average 1.5m above mean high tide (Zeeuws Archief, 2018).

Figure 4.3 shows the storm surge levels on the North Sea leading up to the 1953 flood: the height in meters above the predicted high-tide level. For the Provinces of Zeeland and Zuid-Holland this meant an additional 2.5 meters of water above the astronomic high tide.

Hage (2015) shows that for places such as Bath and Rilland in Zuid-Beveland this caused a total water level of +5,60m NAP. The sea dikes in this area were between +5.50-6.50m high, this meant water was building up till the dike crest.

The water mass was forced with gale force winds down the North Sea against the dikes.

Figure 4.4 shows the surge (Dutch: *opzet*) at 4:00am on February 1st. At this moment the surge in combination with high tide reached peak water levels at the Dutch coast (figure 4.5).

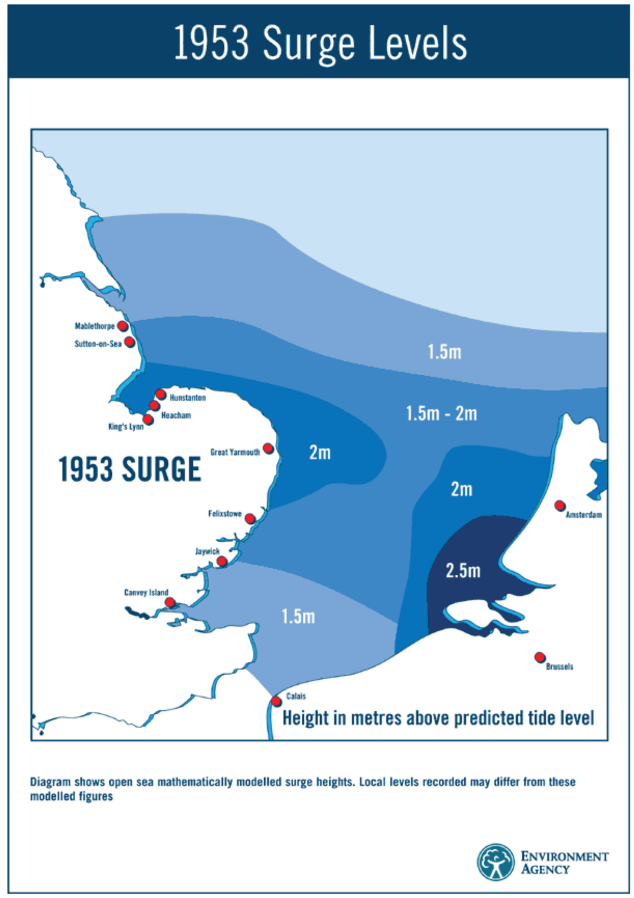


Figure 4.3: 1953 North Sea surge levels (UK Environment Agency, 2018)

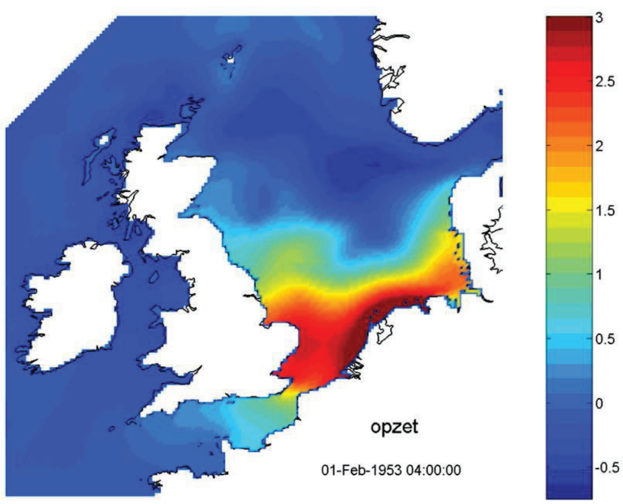
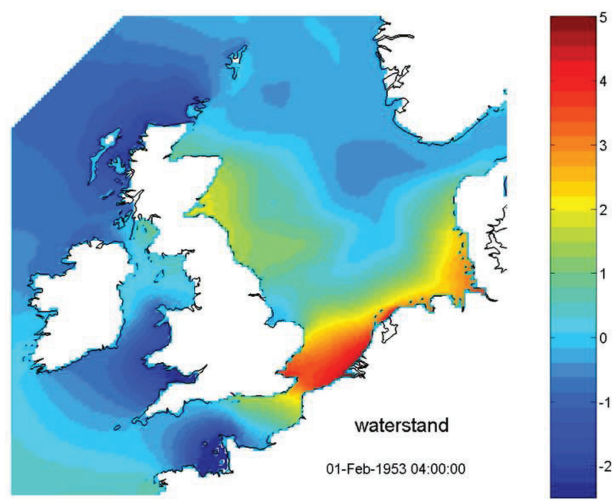


Figure 4.4: Surge water levels at 4:00am 01 Feb (Rijkswaterstaat Directie Zeeland, 2003)



Figuur 4.5: Total water levels at 4:00am 01 Feb (Rijkswaterstaat Directie Zeeland, 2003)

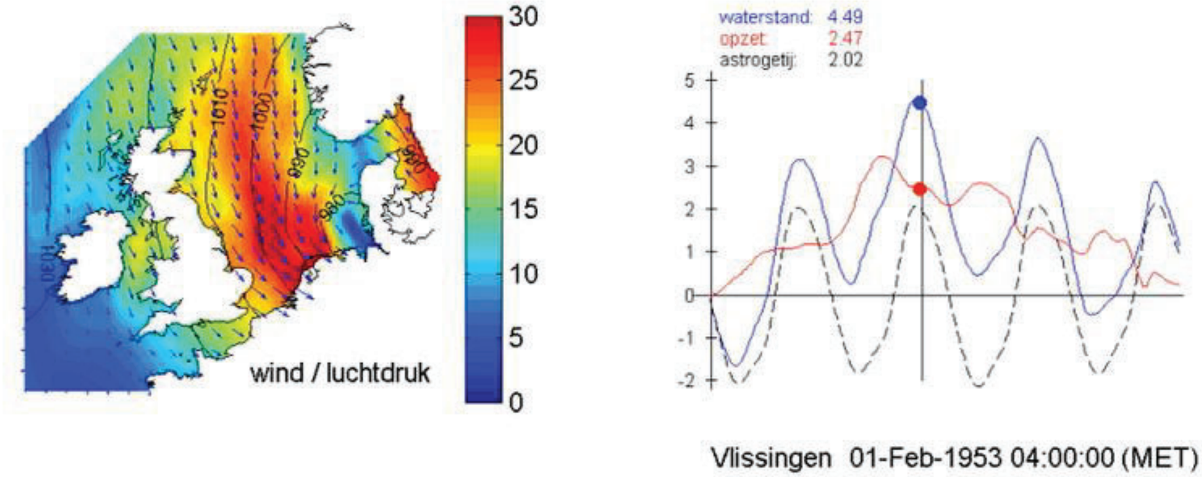


Figure 4.6: Left: Wind direction and air pressure. Right: Total water level (blue) at Vlissingen (Walcheren, Zeeland) Both on February 1st 1953 at 4:00am, when the dikes breached. (Rijkswaterstaat Directie Zeeland, 2003)

The wind direction and air pressure in figure 4.6 give a good image of the combination of inconvenient circumstances. The north-western storm with peak wind speeds at sea of 63 knots (Force 12 on Beaufort scale) coincided with a spring tide at a moment when the peak of the storm hit the coast during high tide.

Human factor

It can be argued that the 1953 flood was not only a natural disaster however. Besides the natural component of the storm which is out of human control, there was a human factor as well (Baalen, 1989).

Baalen (1989) argues that the 1953 flood was a particular blow in the face for the people of the Netherlands. It happened in a time in which the Dutch were just recovering from the (material) damage caused during the German occupation in WWII and were now experiencing the tension of the Cold War. It was a time in which it was likely that a new world war could break out and societies fear was focused on war, and not on other dangers such as the Netherlands oldest enemy: water. The inhabitants of Zeeland, Zuid-Holland and Noord-Brabant felt safe from the water behind their dunes and dikes.

Still, the flood disaster was not unexpected for everyone. At Rijkswaterstaat it was already known for years that the Dutch coastal defence, especially in the Delta region, would be unable to withstand storm surges. Already in 1939 the Dutch minister for waterworks installed a commission to investigate which storm scenarios could be expected in years to come and analyse whether the coastal defences would be able to withstand such scenarios. In 1944 the commission finalized its analysis in a report that was not made public (Baalen, 1989). The commission concluded that: *'On practically all locations downstream [delta region] there are dikes that are not high enough to withstand storm surge situations which could be reasonably expected. In Zeeland and Noord-Brabant there are dike sections that do not offer enough protection during storm situations. In the years to come it is expected that the chances on intensified storms will increase. Firstly due to natural causes such as the rising sea level and secondly due to man-made interventions such as the land reclamation in the Biesbosch which is expected to commence in the near future. The advice is to shorten the Dutch coastline by damming the sea and river arms, close off the Hollandsche IJssel (…) and further more higher the dikes in the Delta region.'* (ARA, 1944)

At the time not the central government but the local Water Boards were responsible for most of the coastal defence. The Water Boards bordering the coastline bore the responsibility for maintaining and reinforcing the coastal defences in their region. Only a small part of the coastline fell under the direct responsibility of the Dutch national government. It was only when a maintenance work was too heavy a financial burden for the local Water Boards that the national government would occasionally share in the costs (Baalen, 1989).

As with every other subject of politics and budgeting, investing in the maintenance and reinforcement of the coastal defences is a political choice. Sadly but understandable however in the years following WWII Dutch budgeting was focused on rebuilding the nation which suffered immensely during war time. This meant that cut backs were made in other areas such as investing in the coastal defences. The human factor in the 1953 flood is consequently the matter of choice and responsibility in a lack of adequately maintaining the level of water safety in the delta.

It was the combination of the natural factor: the intensity of the storm and timing of the hydrological situation, and the human factor: the state of the coastal defences, that lead up to the dike breaches and flooding of the delta region.

4.1.1 What was the flooding scenario of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren in 1953?

Flood area analysis:

Here follows the flood area analysis[3] of Zuid-Beveland (Reimerswaal area) during the 1953 flood.

In examining the flood scenario the choice is made to focus on Zuid-Beveland East (the red-encircled area in figure 4.7). This is the eastern part of the region of Zuid-Beveland which nowadays mostly comprises the Municipality of Reimerswaal.

Figure 4.7: Project area Zuid-Beveland east, red-encircled.

This area is nowadays bordered in the west by the *Kanaal door Zuid-Beveland* waterway and in the east by the *Schelde-Rijnkanaal (Kreekrak)* waterway. The Schelde-Rijnkanaal was constructed in 1975 and hence did not exist at the time of the 1953 flood. During the flood this was agricultural land east of the Reigersbergse Polder (Hage, 2015).

[3] Flood scenario visuals are retrieved from the DELTA53-model and used by permission from Rijkswaterstaat Directie Zeeland, Hydro Meteo Centrum Zeeland, 2003. Dike breach data: *Atlas van de Watersnood 1953* (Hage, 2015).

Kruiningen Polder and Kruiningen Water Board: First dike breaches: Between 3:00-3:30am the dikes in the *Veerhaven* breach. Between the western and eastern harbor dam a breach forms of 150m wide and 8,5m below NAP. Quickly after this breach deepens to 25m with a capacity of 22 million cubic meter.

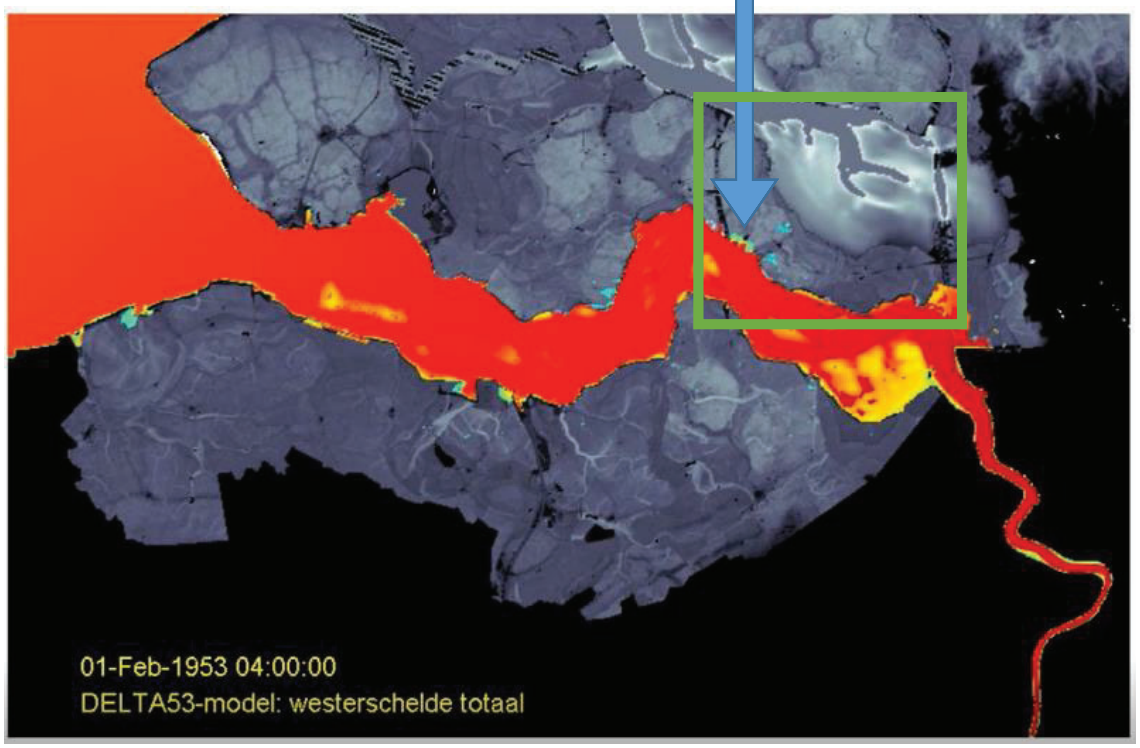


Figure 4.8: Dike breaches in the main coastal defence. First breaches at Kruiningen between 3:30-4:00am 01/02/1953 See figure 4.11 for a detailed map of the flood aftermath in the green-framed area of Reimerswaal.

Figure 4.8 represents the spatial situation at the start of the flood disaster. The first dikes at the Kruiningen Polder and Kruiningen Water Board have been breached and water starts to flow in the polders. National Publication *'De Ramp'* (1953) gives the following account: *"Early on Sunday morning, while the rest of the Netherlands sleeps an inferno hits the isles of Zuid-Holland and Zeeland and the region of West-Brabant. In communities, villages and rural farms, many fight for their lives, miles away from their familiar surroundings, in the dead of night, in a fierce storm, in flooded and disintegrated houses and on dikes flushed away by the force of the water."* (De Ramp, 1953)

At 4:22am the first telex messages arrive in the rest of the Netherlands. The messages originate from: Zwijndrecht, Dordrecht, Maassluis and Hoek van Holland, West-Brabant, Kruiningen and Vlissingen. The true magnitude of the disaster however does not take shape yet till late afternoon the following day. News that adequately describes the situation is scarce, and those outside of the disaster area are unaware of the flood disaster unfolding in the Delta.

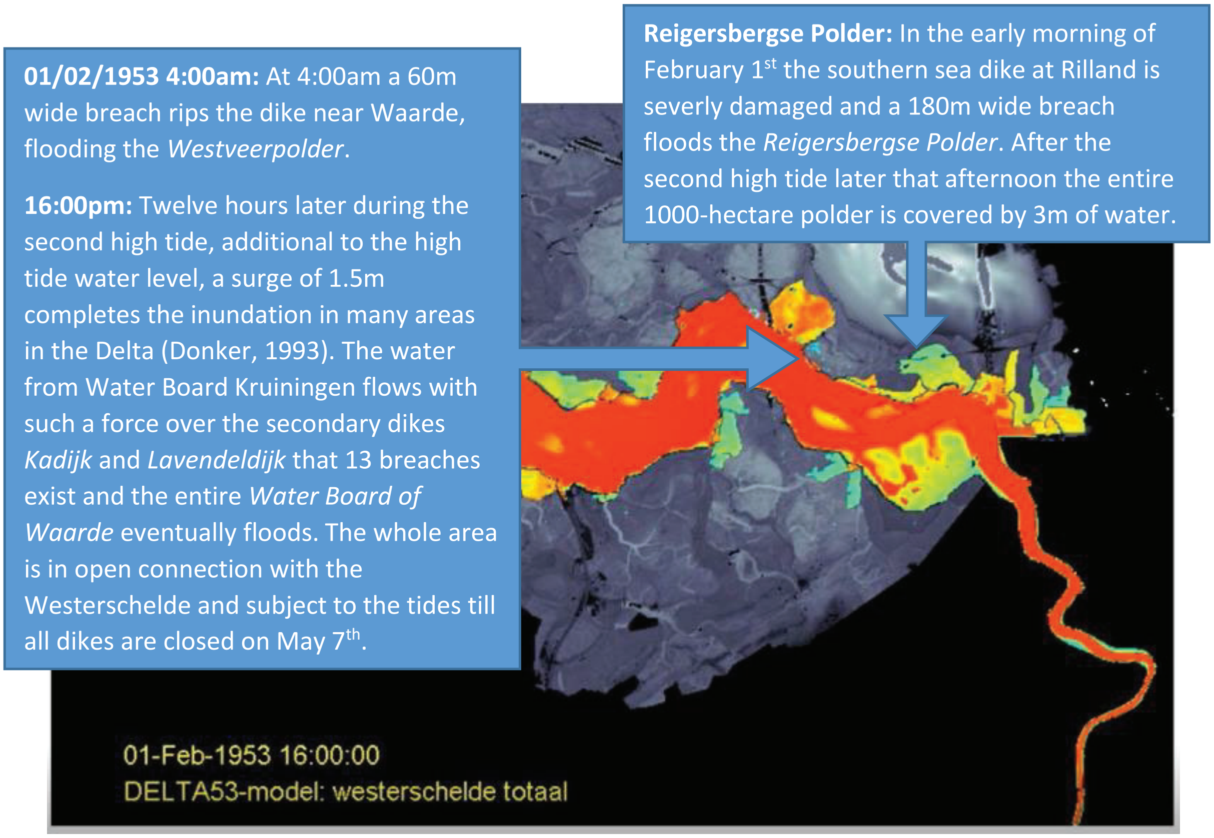


Figure 4.9: Second high tide at 16:00pm February 1st.

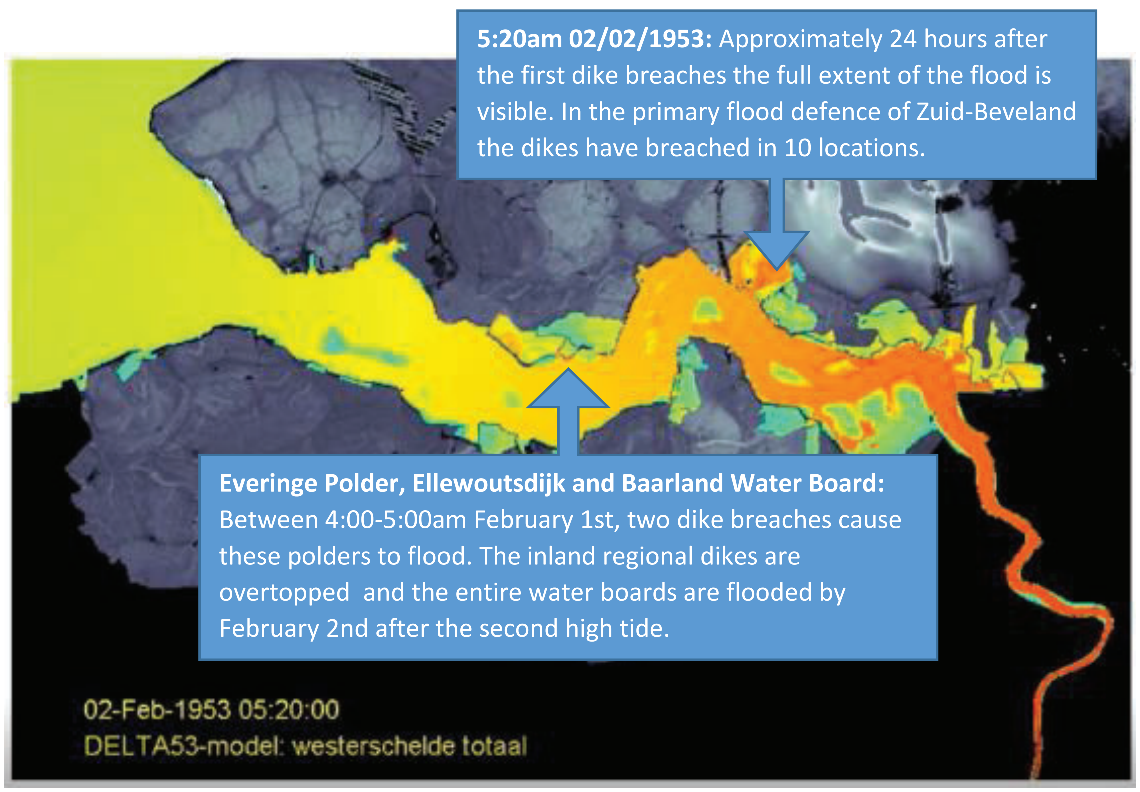


Figure 4.10: Disaster area 24 hours after impact.

Damage control Reigersbergse Polder: The 1000-hectare *Reigersbergse Polder* is covered with three meters of water. The water now reaches the secondary dike at the *Bathpolder*, which is not yet inundated. Tidal movement now erodes the secondary dike and in order to prevent the Westerschelde to break through to the Oosterschelde in the north, directly after the flood a dam is constructed to reinforce the secondary dike. This proves to be effective and a breakthrough from one side to the other side of the peninsula is averted.

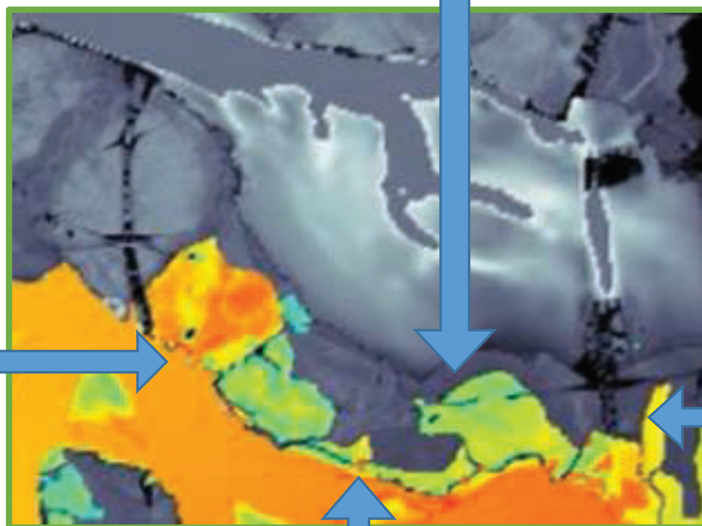


Figure 4.11: Flood aftermath for the area of Reimerswaal.

Oost-Inkelen Polder: Through the two eastern breaches a wall of water floods the polder. It tops the secondary dike and covers the *Oost-Inkelen Polder*: 1,400-hectare of Water Board Kruiningen is flooded.

Polderlands: Various polder lands towards Bergen op Zoom and west Brabant are inundated and prohibit quick access to the disaster area from outside the region.

Zimmermanpolder: A breach of 60m wide and 4m below NAP floods the *Zimmermanpolder*. Though the water stands 5m tall in the polder, the damage is limited since the secondary dikes are strong and high enough to contain the water within the Zimmermanpolder.

The full extent of the flood aftermath is seen in figure 4.11. More than half of the surface area of Reimerswaal (Zuid-Beveland east) is flooded.

Hage (2015) explains that the disaster happened in the complete dark of night. In none of the eye-witness accounts that were recorded following the event people make note of damaged dikes before midnight on the 31st of January. All the reports that came in record dike breaches before 6:00am the following morning. After 6:00am it was getting low tide and water levels were dropping. This means that all the damage done to the primary sea-defences happened in a time span of merely six hours (Hage, 2015). It is remarkable that most of the dike breaches happened at the lee side of the dikes: the southern dike stretches, turned away from the wind (see figure 4.12). KNMI meteorologist Ton Donker (1993) ascribes this to the fact that those dikes were constructed lower in height compared to the wind side dikes, since lee ward dikes are less prone to overtopping waves. Unfortunately due to the high surge water level, waves were still overtopping the dikes which started to erode on the land side slopes, leading up to dike failure, and whole stretches of dike giving way to the force of the water (Donker, 1993). It is a damage that resulted in the loss of lives and livelihoods.

Figure 4.12: The dike breach locations at Kruiningen Veerhaven (left: 150m wide) and Oostgat (right: 200m wide). Aerial photograph taken from a Douglas DC-3 on May 1st 1953 by KLM Aerocarto, commissioned by Rijkswaterstaat. Documented in Zeeuws Archief and published by Koos Hage in his 2015 – 'Atlas van de Watersnood 1953' (Hage, 2015).

In Kruiningen alone already 59 people died as a result of the flood. Casualties in Zuid-Beveland are furthermore in Rilland-Bath (12), Waarde (1), Oostdijk (6), Ellewoutsdijk (3), Oudelande (3) and Hoedekenskerke (1) (De Ramp 1835+1, 2018). In total 97 people lose their lives during the flood and aftermath in Zuid-Beveland.

In Walcheren 1,150 hectare of the 22,000 hectare total surface area is inundated. The damage done here is mostly material damage (HKW, 2003). Except for Vlissingen: large parts of the inner city of Vlissingen (Walcheren) flood and 3 people die as a result of the disaster (De Ramp 1835+1, 2018).

4.1.2 In what time frame was the storm anticipated?

The KNMI (Koninklijk Nederlands Meteorologisch Instituut) is the Dutch national data and knowledge centre for weather forecast, climate and seismology information.

On Saturday night 31st of January 1953, the night of the flood disaster, meteorologists Herman Bijvoet (1918-2000) and Klaas Rienk Postma (1913-2005) were on duty in the KNMI weather information centre. The weather charts of Saturday night were so distressing that Bijvoet and Postma went to great length in order to get the storm warning across to those in danger in the Netherlands (KNMI, 2018). Weather information was primarily spread through radio broadcasts. At that time there were however no broadcasts at night. At midnight all stations closed in order to commence next morning. In their distress Bijvoet and Postma tried to convince the national stations to be on-air after midnight but according to Slager (2009) they were denied this possibility which left them feeling utterly powerless (Slager, 2009).

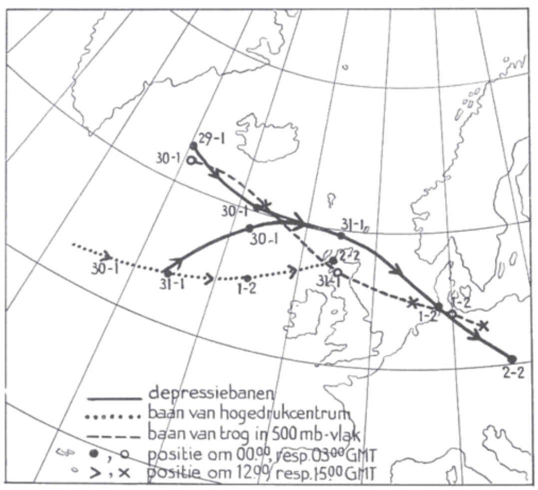


Fig. 1.1.22. Banen der verschillende druksystemen

Figure 4.13: The path of the storm (thick line) coming down the North Atlantic via Scotland down the North-Sea between January 30th and February 2nd 1953 (KNMI-contribution to the Delta commission report).

According to Postma the Netherlands was not completely taken by surprise in regards to the storm. Since Friday night January 30th the storm that had formed earlier that day south of Iceland was monitored. Record wind speeds were reached Saturday when one of the worst hurricanes ever recorded in this region hit the north of Scotland, topping over millions of trees. After Scotland the storm moved down south and wind direction shifted to north-northwest. This meant that a storm field with a 1,000km diameter was funnelled down over the North-Sea heading straight for the Dutch coast. Postma did not foresee the big flood, since he was unaware of the state of the dikes, but a severe storm with wind speeds of 11 Beaufort resulting in a lot of damage, was anticipated (KNMI, 2018).

Storm and weather warnings were back in the day spread by the KNMI via *telex* to the various institutions in need of this information (e.g. radio stations). The flood warning was valid from the moment of broadcasting till the second high tide following the broadcast. On the basis of the development of the storm and the morning weather chart of Saturday 31st of January (7:00am) the following broadcasted flood warnings were given (Donker, 1993):

31 January 9:50am:
'Warning for a west-northwest storm for all regions within the Dutch coastline.'
(Wind and storm warning service)

31 January 11:00am:
'Siginificant high water for the regions Rotterdam, Willemstad, Bergen op Zoom and Gorinchem.'
(Storm surge warning service)

Since the flood warning was valid for the two consecutive high tides, these warning were valid for the Saturday afternoon high tide between 16:00pm and 17:00pm, and the Sunday morning high tide between 4:00am and 5:00am. It was during this second high tide that the dikes would eventually breach, something which was not reckoned with at the moment.

In the course of Saturday afternoon meteorologists got the first signs that the weather situation was developing into a dangerous situation. The path of the storm and the wind intensity above the North-Sea could lead to higher surge water levels on Sunday morning in the Delta region than earlier anticipated. At 13:00pm new surge levels for Sunday morning at the tide stations of Bergen op Zoom and Vlissingen (Zeeland) and Hellevoetsluis (Zuid-Holland) were calculated which could lead to water levels up to 5.0m. These predictions lead to the flood warning level being raised from *significant high water* to *dangerous high water*. Dike watch (surveying/monitoring) was intensified and the following messages were broadcasted via telex:

31 January 17:15pm:
'Warning for a severe west-northwest storm for all regions within the Dutch coastline.'
(Wind and storm warning service)

31 January 17:47pm:
'Dangerous high water for the regions Rotterdam, Willemstad, Bergen op Zoom and Gorinchem.'
(Storm surge warning service)

Shortly after the Saturday afternoon high water moment the PTT-Telex office in Amsterdam notified all relevant institutions concerning the expected storm and hydrological situation for Sunday morning. At 18:00PM Saturday evening and on consecutive hours the following special news broadcast was aired:

"A severe storm rages over the northern and western regions of the North-Sea. The storm system is expanding further over the southern and eastern regions of the North-Sea. It is expected that the storm rage with severe weather will last through the entire night. As a result of the storm the regions of Rotterdam, Willemstad and Bergen op Zoom were warned at 17:30pm earlier this afternoon for dangerous high water levels."

According to Donker (1993) the formal storm and flood warning requirements were met with these messages. The weather charts that came in at 19:00pm that night however, were distressing to such a degree that it was decided to continue a non-stop monitoring of the development of the storm situation from that moment on.

It becomes evident that the time frame in which the storm was anticipated, starting from Friday night till Sunday morning is more than 24 hours. The realisation of the degree of severity of the storm was progressing over the hours leading up to the big flood as new data and weather information became available. Figure 4.14 gives an overview of how the storm anticipation developed over time.

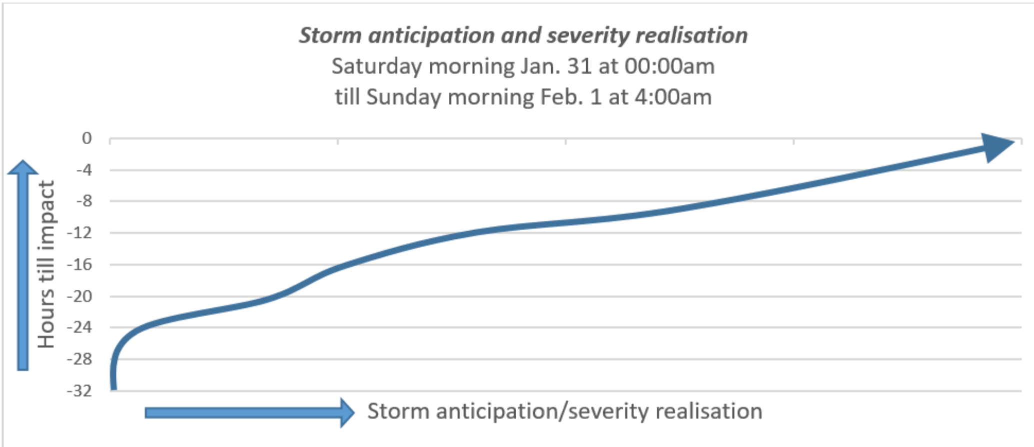


Figure 4.14: This figure shows how the storm anticipation and the realisation of the severity at the KNMI progressed over time, starting at 32 hours before impact (January 31st 00:00am) and ending at the time of the first dike breaches (February 1st 4:00am).

4.1.3 What was the available time to evacuate before the dikes breached?

When addressing evacuation before the impact of a flood disaster you are referring to preventive evacuation. Preventive evacuation assumes that people, livestock or goods are moved or relocated from the area at risk to an area outside of the risk zone before impact. Virtually all eye witness accounts of the big flood such as recorded by Slager (2009) testify to evacuation taking place at the moment, or right after the moment that the dikes breached. Organised, preventive evacuation, following on the flood warnings broadcasted on January 31st was non-existent. Nowadays this might come across as ignorant, naïve or a misinterpretation of the storm system, but it should be taken into account that in 1953 the severity of the storm only became apparent when accurate weather charts came in during the last 24 hours before impact. Secondly, flood and storm warnings were not reckoned as an immediate impulse for evacuation since the people living in the Delta dealt with severe storms before (1913, 1914, 1916, 1920, 1923 and 1938). The storm of September 7, 1944 even reached hurricane force (Beaufort 12) at the Vlissingen data station (Donker, 1993). All these storms did not have the same impact as the 1953 storm would have a few hours later. Hence, the urge for preventive evacuation was not obvious.

Figure 4.15: Kruiningen dike breach and flood pattern at 4:00am, 4:20am and 4:40am February 1 1953.

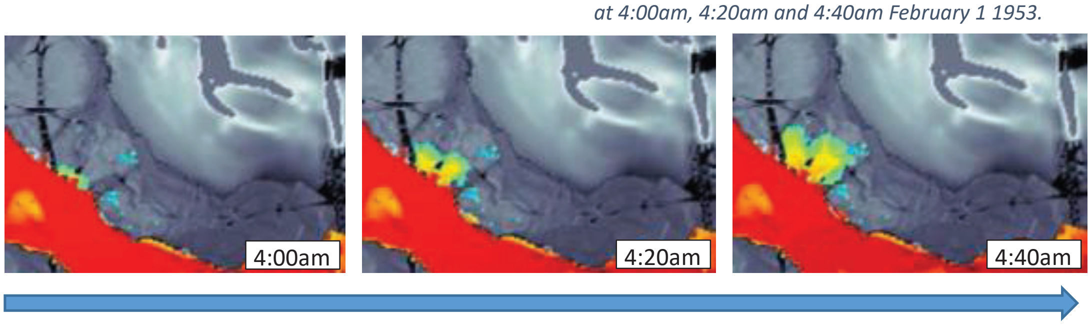


Figure 4.15 shows the dike breach and flood pattern at Kruiningen at 4:00am (left), just minutes after the breach. Twenty minutes later at 4:20am (middle) the village of Kruiningen is already inundated. At 4:40am (right) the entire inhabited area of the Kruiningen polder is flooded.

This simulation shows that there was between 10-40 minutes after the dike breach till the water swept through most of the inhabited area. If an evacuation order was given after the weather charts of Saturday morning 31st of January came in, the evacuation time would have been less than 24 hours. But now, strinking in the dead of night, with no prior evacuation warning or order, the flood took people by surprise leaving no time to evacuate.

4.1.4 What were the evacuation options for Reimerswaal and the hinterland of Zuid-Beveland and Walcheren?

Shelter in place (no evacuation): One of the most deployed evacuation options by the people hit by the big flood was *the 'shelter in place'* option. This measure is not a measure in which people are relocated to another area or building, but an emergency response option in which the occupants stay inside the structure. It is a last resort option used when evacuating people to an external building or location poses the evacuees to more risk than staying in the building. In his research into casualty levels following a big flood, Jonkman shows that 60% of the casualties following the 1953 flood where due to the high speed of the rising water level (Jonkman, 2004). This explains why evacuation to an area outside of the risk zone was not an option for most people. An example of the shelter in place option is recalled in the eye witness account of Adriana Cafra-Wanders, twelve years old during the flood and located at the Maria-Oord boarding school in the municipality of Kruiningen in Zuid-Beveland (De Ramp 1835+1, 2018):

'At 19:30pm we all went to bed. All of a sudden in the middle of the night the door of the dorm swung open and Gertruda, the head teacher, came running in the dorm waking us all up and screaming that we had to grab all our clothes and our blankets and move quickly upstairs. By that she meant the first floor of the villa we were staying at. We were astonished and did not realise that it was only three or four o'clock in the morning. We did what she ordered us to do. Next to the dorms was the entrance hall where our coats hang on the wall. I considered grabbing my coat but decided not to do it. By the time my sister walked through that corridor a few minutes later the water reached already knee-high. Later we got to know that at that moment the water outside was already 1.5m high. All the boys and girls, nearly 100 of them, the head teacher and the pastor who were all sleeping on the ground floor were just moved upstairs when 5 till 10 minutes later the entrance door flew open and the water rushed in the building. One teacher was still in the kitchen. She wanted to grab some bread to take upstairs and tried to reach the stairs, but did not make it. She was dragged through the corridor by the water and could luckily hold on to a railing for dear life. Later she was rescued by my brother and sister who were capable swimmers. They tied a rope of sheets and rescued her. Now we had to wait till what level the water would rise. We were fortunate that the water did not reach the first floor in the end.'

Figure 4.16: Boarding school Maria-Oord located in the municipality of Kruiningen, (Zuid-Beveland) February 1953.

In other areas of Zeeland eye witness accounts tell of the fire department and city council trying to warn the inhabitants and evacuate them by coach in the disaster night, but being stopped in the attempt by water rushing over the dike roads sweeping away the motor-bus in a ditch (Slager, 2009).

Evacuation options before the flood were very limited and for those who were fortunate enough to be warned in time, taking shelter on a higher floor was a last and only resort.

Post-flood evacuation (rescue): Almost 100,000 people had to flee for the water and were evacuated out of the disaster area after the flood. On February 2nd the rescue evacuation of people in the flooded regions started. Many people were relocated out of the area on boats, carts, trucks and all sorts of transport. DUKW-amphibious vehicles were used as well as hydroplanes and helicopters to transport people (Zeeuwse Ankers, 2014). Figure 4.17 and 4.18 show the evacuation of people and livestock out of Zuid-Beveland, loaded onto the back of carts and trucks.

Figure 4.17: Livestock evacuation on February 2 1953, Zuid-Beveland (Kruger, 1953).

Figure 4.18: Evacuation of Beveland (Copyright unknown, 1953).

Adriana Cafra-Wanders recalls being rescued from the first floor of the Maria-Oord boarding school on February 1st late afternoon (De Ramp 1835+1, 2018):

> *'Late afternoon they started with the rescue of the children, teachers and elderly people that the teachers were taking care of. I remember having to climb out of the window, down a sloping rooftop into a rowing-boat. Coaches were located at the dikes ready to evacuate us to the nearby town of Goes. The evacuation venue was a large hall. We got something to eat when we arrived and me sister and I were taken home by some volunteers. I remember it being a family with a daughter a few years older than me. We stayed with them for a week after which our mother was able to pick us up.'*

Adriana's experiences were typical for a lot of people living in the disaster area. The first shelter accommodations were often church and school buildings. Later the refugees were relocated and sheltered with host families who voluntarily offered places to stay. A month after the big flood more than 72,000 people were still residing at temporary evacuation addresses and in October 1953 11,000 people were still not returned to their original places (Zeeuwse Ankers, 2014).

4.1.5 What were the evacuation fractions for Reimerswaal, Zuid-Beveland and Walcheren in 1953?

Preventive evacuation (or horizontal evacuation) means leaving the area that is threatened by a flood. The percentage of people living in the area that is able to leave the area before a dike breach is called the *evacuation fraction* (Rijkswaterstaat, 2018). This percentage is determined by the warning time, population density, the capacity of the infrastructure needed for evacuation and the distance to safe high grounds. Since there was no warning time for evacuation with the big flood and those who were able to flee were notified moments before or at the time of dike breach, it is difficult to speak of evacuation fractions in this case. Following the eye witness accounts it has to concluded that the evacuation fractions for Reimerswaal, Zuid-Beveland and Walcheren were close to zero.

Jonkman (2004) states that in 1953 250,000 people in the south-west delta were hit by the flood and 1836 people died as a result of the big flood. Following these numbers the mortality of the 1953 flood is around 1% (Jonkman, 2004).

Figure 4.19: Evacuation on a country road following the big flood in Zeeland (van Wijk, 1953).

4.2 Current situation: examining a 1953 flood scenario taking place in the present day

Chapter 4.2 describes the current situation by examining a 1953 flood scenario taking place in the present day. First an overview is given of what such a scenario would look like in Reimerswaal. Secondly the time frame in which a 1953 storm scenario would be anticipated is presented. Thirdly the consequences of a flooding of Reimerswaal for the hinterland of Zuid-Beveland and Walcheren is mapped out.

4.2.1 What would a 1953 flooding scenario of Reimerswaal look like in the present day?

Nowadays the peninsula on which Zuid-Beveland and Walcheren is located has over 210,000 inhabitants. Over 22,500 of these live in the municipality of Reimerswaal (dike ring 31). Figures 4.20 and 4.21 represent a flooding scenario in the present day (1/4000) which resembles the 1953 big flood situation. Two major dike breaches are modelled.

Inhabitants per municipality	
Zuid-Beveland region:	
Borsele	22.721
Goes	37.653
Kapelle	12.710
Reimerswaal	22.565
Walcheren region:	
Middelburg	48.303
Veere	21.863
Vlissingen	44.489
Total:	**210.304**
Reference date: January 2018 (CBS, 2018)	

On the left you see the dike breach at the Oost-Inkelen Polder, which is the breach that floods the Kruiningen Polder at the Kruiningen Veerhaven. On the right the breach near Bath floods the Reigersbergsche Polder. These major breaches flood approximately 90% of the surface area of Reimerswaal. If a similar flood scenario would happen today over 22,000 people would be affected in Reimerswaal alone. The figures show that the water level for half of the surface area will be over 2.0m high. In this 50% of the inundated area water levels can reach up to 5.0m (Nelen & Schuurmans, 2018). In the scenario the closure locations (coupures) are closed according to the storm surge monitoring plan and the non-closable culverts are open. It is a six day simulation showing the maximum water depths.

Figure 4.20: Scenario: Dike breach at Oost-Inkelen Polder (Kruiningen Veerhaven) 1/4000. Maximum water depth in meters. (Nelen & Schuurmans, 2018)

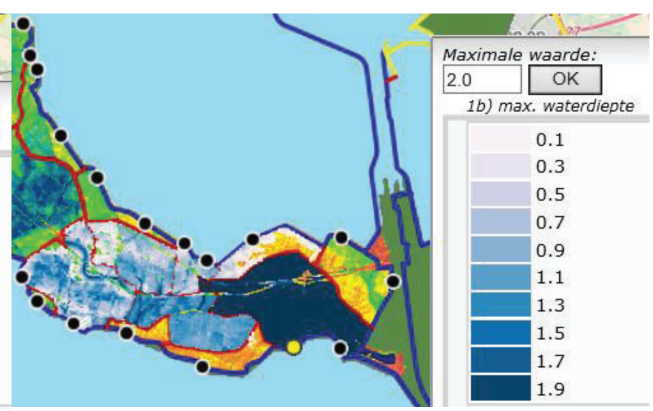


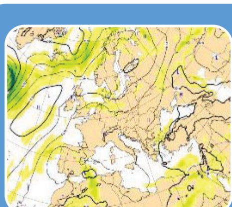
Figure 4.21: Scenario: Dike breach at Reigersbergsche Polder 1/4000. Maximum water depth in meters. (Nelen & Schuurmans, 2018)

4.2.2 In what *time frame* would a 1953 storm scenario be anticipated in the present day?

In the Netherlands water safety is a shared responsibility. Through various organizations and (governmental) institutions adequate water safety is attained. As part of Rijkswaterstaat the *Watermanagement Centrum Nederland* (WMCN, Water Management Center of the Netherlands) plays a central role in this. The WMCN works on water information, crisis advice and sharing knowledge. In this the WMCN works together with the KNMI, Water Boards, Provincial governments, Safety Regions and knowledge institutes.

According to Stefan Nieuwenhuis, expert at WMCN (personal communication, May 18 2018) the WMCN-HMC (Hydro Meteo Center as part of WMCN) models four times a day the Rijkswaterstaat end prognosis for the water levels in the Netherlands in accordance with the KNMI. When a storm surge is expected this frequency is raised to eight times a day. When a possible dangerous situation is approaching the early warning flood thread information is the responsibility of the WMCN. Information provision is coordinated by the WMCN-LCO, National Commission for Flood Thread Coordination (Landelijke Coördinatiecommissie Overstromingsdreiging). The WMCN-LCO has a key role in the national information supply concerning high water levels (Nieuwenhuis et al., 2016). In first place the professional network partners are informed, such as: Rijkswaterstaat, Water Boards, Safety Regions and national crisis organizations.

At a certain moment a press release will be given and the national press will be continuously informed. This takes place in accordance with the national crisis organization. When it concerns national security and ensuring civil safety the administrative column is responsible for evacuation decisions and evacuation advise. The time frame in which a similar storm situation would be anticipated and forecasted in the present day is represented in the following process:

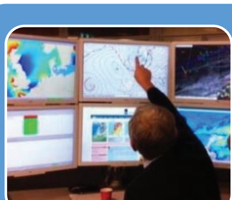


10 days before impact

- Via the European weather model (ECMWF) an ensembled forecast can be created and monitored 10 days in advance. A clear picture of the extend and scope of the storm is known at that point. An uncertainty at that moment is what the path of the storm will be and what the possible impact will be.

5 days before impact

- At five days before impact the WMCN is able to provide a good interpretation and calculate the expected water levels at the coast. Still there will be a big uncertainty (20% certainty) of the coincidence of the peak of the storm with the astronomic high tide. Nonetheless, flood thread warnings will be initiated 5 days before impact.



2 days before impact

- Two days in advance there is an 80% certainty of the precise extend of the impact along the coast. At this stage specific flood thread information and warnings for individual coastal regions will be issued.

In the last two days before impact the coastal division of the WMCN will issue storm surge warnings on the basis of the Rijkswaterstaat end predictions concerning the hydrological situation. These are communicated via telephone to those responsible for maintaining and operating storm surge barriers, dikes and embankments. On the basis of the most recent data planning and decision making is carried out in accordance with the *National Crisisplan for High Water and Floods* (Departementaal Coördinatiecentrum Crisisbeheersing, 2016).

The storm scenario as it developed in 1953 was well predicted according to the abilities back in the day. The amount of data collection methods and abilities nowadays compared to 1953 is enormous. Calculations of the 1953 data set with current computers resulted in a prediction with certainty 3-4 days in advance (KNMI, 2018).

With the ability of the European weather model ECMWF to forecast a 1953 storm scenario 10 days in advance and capacity at the WMCN and KNMI to model this into a definitive hydrological situation with 20% certainty 5 days in advance, and 80% certainty 2 days before impact, the total time frame in which a 1953 storm scenario is anticipated is 10 days, with a gradual increase in certainty leading up to the moment of impact.

4.2.3 What would the consequences of a 1953 floods cenario of Reimerswaal be for the hinterland of Zuid-Beveland and Walcheren in the present day?

According to the United Nations Office for Disaster Risk Reduction, in order to map and delineate an area affected by floodwaters, it is needed to select a *design* event (UNISDR, 2002). The design event can be estimated by various approaches. One of these approaches is by using a historical worst-case scenario that happened in the region, or could possibly happen again. This is called storm transposition. Within this research the design event is the 1953 flood scenario of Reimerswaal.

This chapter looks at the consequences of such a scenario for the hinterland of Zuid-Beveland and Walcheren in the present day. As seen on figure 4.22 (red marked area) Zuid-Beveland and Walcheren form a geographic peninsula in the Province of Zeeland. This has some serious implications on the flood consequences for the region. The North-Sea is located West of the Netherlands. In relation to flood risk the hinterland is therefore generally referred to as the land in the East. Since Reimerswaal forms the bottle neck to the peninsula, the hinterland for this case is towards the East (Noord-Brabant) as well as towards the West: Zuid-Beveland and Walcheren (see blue arrow in figure 4.22).

The consequences for the hinterland are divided in *liveability*, *connectivity* and *evacuation and aftermath*.

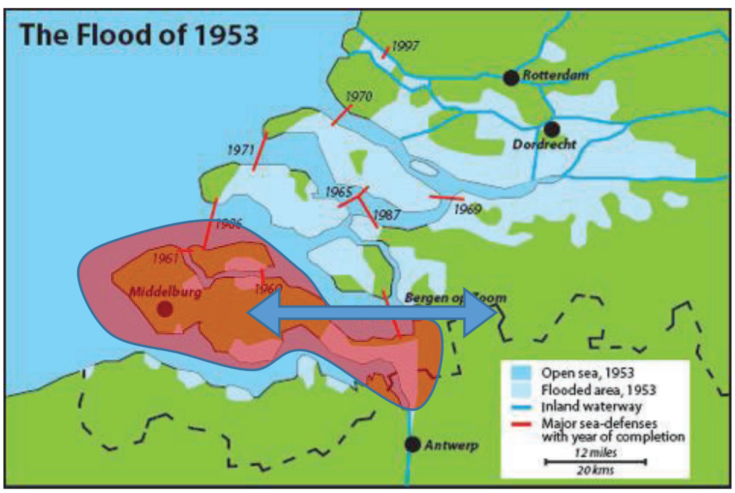


Figure 4.22: The peninsula of Zuid-Beveland and Walcheren with the direction of the hinterland (blue arrow) on both the East and West sides of Reimerswaal.

Liveability

Within the RAAK—project Critical Infrastructure in the Resilient Delta research is done into flood consequences for Reimerswaal (cascade effects). The Impact Analysis for Zuid-Beveland East showed that the impact of a flood for Reimerswaal is severe, with water levels reaching up to 5m and locally even 6m high leaving communities uninhabitable for months.

The implications of such a flood scenario for the hinterland on the other hand are more nuanced. According to Marcel Matthijsse (appendix I) no major problems are expected for the vital infrastructure affecting the hinterland. Expected is that the pipelines, as long as they are located firmly in the ground, will not flush away by a flood scenario of Reimerswaal. Teun Terpstra (appendix II) supports this and explains that following the analysis of the RAAK-project it became apparent that the impact to the hinterland could be only moderate. As long as the electricity (high voltage network) remains functioning, other vital infrastructural networks are expected to stay operational as well.

Acccording to Herrman & Lewis (2014) liveability is determined by a supportive community that is safe and secure, with transportation options and facilitated with essential networks for existence and development. This in relation to (built) environment, health and safety, and housing (Herrman & Lewis, 2017).

The liveability of the flooded area itself is a big problem according to Matthijsse (appendix I). Unlike the hinterland, the flooded area is given up. The factors that determine liveability will not be existent here anymore. In the hinterland these might still be in place but it should be taken into account that services such as healthcare services could not be available, and it will take months to restore these services. One determining factor of liveability is the availability of transportation options. This leads to the following flood consequence category: connectivity.

Connectivity

Connectivity in the wake of a flooding scenario is a major issue. Matthijsse (appendix I) explains that the hinterland will be cut off from the rest of the country via its east-west route. Accessibility is a major issue here. The national highway A58 will be inundated blocking of the most important road for access to the hinterland. Especially the availability of roads and communication means is of importance according to Terpstra (appendix II). When there is more than only a few centimeters of water on the roads the use of these roads is already a risk. This is because you will not be able to see the road or damage done to the road. When there is more than 20cm of water on the roads, cars will not be able to use the road at all anymore. At the places where these water levels occur roads will be out of use and the infrastructural assets will be lost.

Furthermore the railway crossing the flooded region will be inundated and out of use preventing the in- and export of supplies.

Evacuation and aftermath

The Safety Region Zeeland bears the responsibility for the preparation and execution of evacuation and crisis management. This is done in cooperation with various partners (Matthijsse, appendix I). The evacuation and crisis plan for Reimerswaal is a strategic plan focused on the preventive evacuation of people living in the area. This is because the people have to get out *before* the area floods, since a flood from the primary water system would render Reimerswaal uninhabitable and a dangerous place to be in. Not everybody would want to leave, but the aim is to leave as little people as possible behind in the area that will flood. A time frame of 48 hours is needed to evacuate the entire area. However, 24 hours before impact the storm will be intense to such a degree that it will be impossible to evacuate people safely. Uncertainties in this are the eventual strength of the storm and the high water levels that will be reached. The uncertainty is whether the hydrological norm for evacuation will be crossed and an evacuation will be initiated.

One thing is certain, and that is that if the dikes breach, the consequences will be significant. An actual evacuation will be executed as follows:

Safe grounds for people living in Reimerswaal are found in Bergen op Zoom and the surrounding region of Brabantse Wal. These are high enough grounds to provide a safe refuge for people from the low lying areas. Additional safe grounds are further east ward in the direction of the city of Tilburg (Noord-Brabant). During an evacuation of Reimerswaal and the Hinterland of Zuid-Beveland and Walcheren a time frame of 48 hours will be needed. The distance from Domburg (west) till Tilburg (east) is approximately 150km. The strategy is to evacuate the area via the A58 highway in one flow from Domburg till Tilburg. All exits along the highway will be closed off and evacuees drive in one stretch all the way till they reach the area surrounding Tilburg (see figure 4.23).

Figure 4.23: Evacuation route for Reimerswaal and the hinterland of Zuid-Beveland and Walcheren.

In this region the evacuees will be given shelter. Those who can stay and take shelter with relatives living west of Tilburg will then use the local road network to drive back into that direction (see blue arrows in figure 4.23). This is done because the full length of the highway will be needed to accommodate the flow of vehicles leaving the threatened disaster area. A challenge in this is that it takes time to access the highway A58. Secondly the sequence of evacuation is of importance: evacuating from west till east, starting in Walcheren and ending in Reimerswaal. If you would only want to evacuate Reimerswaal it would take half a day (Matthijsse, appendix 1). For the complete evacuation there is a general evacuation plan in place. This is however not worked out in detail but on headlines with the exception that it already is predetermined when the evacuation decision will be made.

The aftermath of a pending flood event will cause the direct need for shelter and accommodation of evacuees in the hinterland. While inundation in Zuid-Beveland West and Walcheren will be limited, the degree of having a supportive community can be determining in the resilience of the hinterland. In 1953 the higher grounds in Goes were used to shelter evacuees directly after the flood (De Ramp 1835+1, 2018). Matthijsse (appendix I) explains that initially the evacuees can be sheltered in sports halls or convention centres following an evacuation. If the dikes eventually hold and do not breach the evacuees can return home after the storm passes. If the dikes do breach, the shelter has to be for the long term. Accommodation could then be organised at bungalow parks and temporary disaster refugee camps.

When addressing the aftermath, Matthijsse stipulates that a missing element in planning is answering the question of relocation / rehousing. Nationwide this is an issues which is relatively unexplored. The question is whether moving people back to the flood region is feasible. Determining the economic value of the flooded land, besides the emotional value, is an important issue here.

Van Staveren et al., (2014) describes the Dutch delta as a socio-technical system suffering from technological lock-in (van Staveren, Warner, van Tatenhove, & Wester, 2014). It is a system that on the one hand comprises of social actors and on the other hand is maintained through various physical and technical measures to address flood management. It is an artificial situation in which expected rising water levels and increasing storm intensity and frequency (IPCC, 2014) cause higher water safety norms for dikes and constant subsequent dike reinforcements and heightening of dikes. On the other hand social persistence in living in those low-lying areas threatened by the water pose inhabitants to risks. With an increasing population the pressure on land use is rising as well. In a country where historically people settled on elevated areas in the landscape such as sand ridges, creek ridges and high grounds (Naturalis, 2018), nowadays technological advancement (e.g. im-poldering) enabled the Dutch to live in those areas which are less strategic in relation to water safety. Reimerswaal is such a low-lying area, surrounded by dikes, which from a water safety point of view is less strategic to inhabit.

Further upstream in the Dutch river delta van Staveren et. al., (2014) explores the option for de-poldering in the Netherlands as a strategy for long-term delta survival. This as a gradual transition from a system causing technological lock-in to a sustainable long-term approach to living in the delta. In the aftermath of a flooding of Reimerswaal, with implication for the hinterland of Zuid-Beveland and Walcheren the question whether it is feasible to move back to the flooded lands is something to consider as Matthijsse (appendix I) points out.

4.3 Translating the flood scenario into a Flexible Evacuation Strategy

This chapter describes the flood scenario as translated into a Flexible Evacuation Strategy. First the focus is on the implications of a 1953 flood scenario on a current day Flexible Evacuation Strategy, looking at the phases of disaster management and the influence of multiple stakeholders. Secondly the evacuation fractions for the region are examinded. The chapter closes wiith the implications of the anticipated time frame and evacuation fractions for the present day evacuation options for the area.

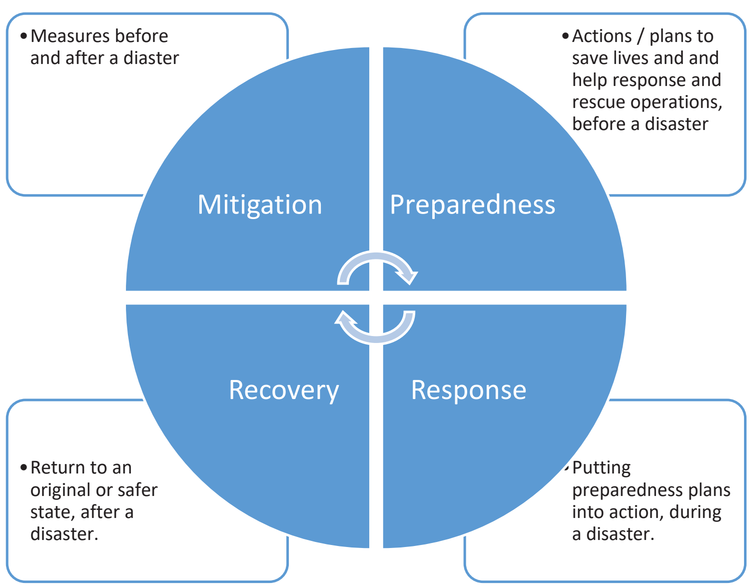
4.3.1 What are the implications of a 1953 flooding scenario for a current day Flexibe Evacuation Strategy of Reimerswaal?

The National Action Plan on High Water and Floods (Landelijk Draaiboek Hoogwater en Overstromingen) prescribes the plan of action in case of flood threads in the Netherlands. The plan describes the responsibilities and information exchange of the crisis partners in the wake of a flood (Klingen, 2016). As mentioned before, the information provision is coordinated by the WMCN-LCO, National Commission for Flood Thread Coordination (Landelijke Coördinatiecommissie Overstromingsdreiging). The WMCN-LCO has a key role in the national information supply concerning high water levels (Nieuwenhuis et al., 2016). In first place the professional network partners are informed, such as Rijkswaterstaat and the Water Boards. They are in charge of taking the appropriate water system measures. The Safety Regions are informed as well and they are responsible for the evacuation of people within their region.

Multi-Phased: Diaster Management Phases

Dealing with a possible flooding event consists of four disaster management phases: 1.Mitigation: preparing for future disasters and minimizing their effects, 2.Preparedness: preparing to handle a disaster, 3.Response: Responding safely and adequately to a disaster, 4.Recovery: Recovering from a disaster. (See figure 4.24)

Figure 4.24: The four phases of diaster management (Wisner & Adams, 2002).



Recent dike reinforcements in dikering 31 (Zuid-Beveland East) is a form of flood mitigation measures (Bart & Bossenbroek, 2011). The National Action Plan on High Water and Floods is how the preparedness phase takes shape. In both these two phases pre-impact capacity building measures and actions take place.

The response phase includes actions such as the Safety Region putting an evacuation plan into action. The recovery phase is marked by answering the questions of relocation to and rehabitation of the disaster area. The latter two phases are focussed on emergency response, restoration and reconstruction.

Multi-Stakeholder

The process of evacuation is also multi-stakeholder. The government, local community, private sector and crisis partners all play a role in this. Literature shows that during a crisis situation situational altruism emerges, which is the intrinsic motivation to do good (Scholtens & Helsloot, 2015). This can be channled into spontaneous networks of people living in eachother vicinity aiding oneanother. According to Scholtens & Helsloot (2015) the emerging of so called *superpromotors* is inevitable. These superpromotors are people who already have a central place in the existing social networks (e.g. leaders of sports clubs, local pastors, school leaders), and can help to facilitiate local disaster management. Matthijsse (appendix I) explains that in the current evacuation and crisis management plans the emerging of superpromotors is not yet taken into account. He acknowledges however that this is something that has to be incorporated in preparedness planning. A difficulty is that it is not always certain beforehand who the individuals will be that display this kind of behaviour during a crisis situation. Something that is already worked on is an idea concerning a local community safety center. This could be a location based for example at a local fire station where such superpromotors with a social network could take a position of leadership during an flood emergency. This could be facilitated by the fact that some people are assigned a position of leadership by the mass during an emergency, rather than the pre-defined (governmental) leaderhip positions in society (Matthijsse, appendix I). In the current evacuation and crisis management plans not enough notion is given to these concepts yet, while they could aid the formation of teams on a local level that would take on their responsibilities during a flood event.

Flexible Evacuation Strategy

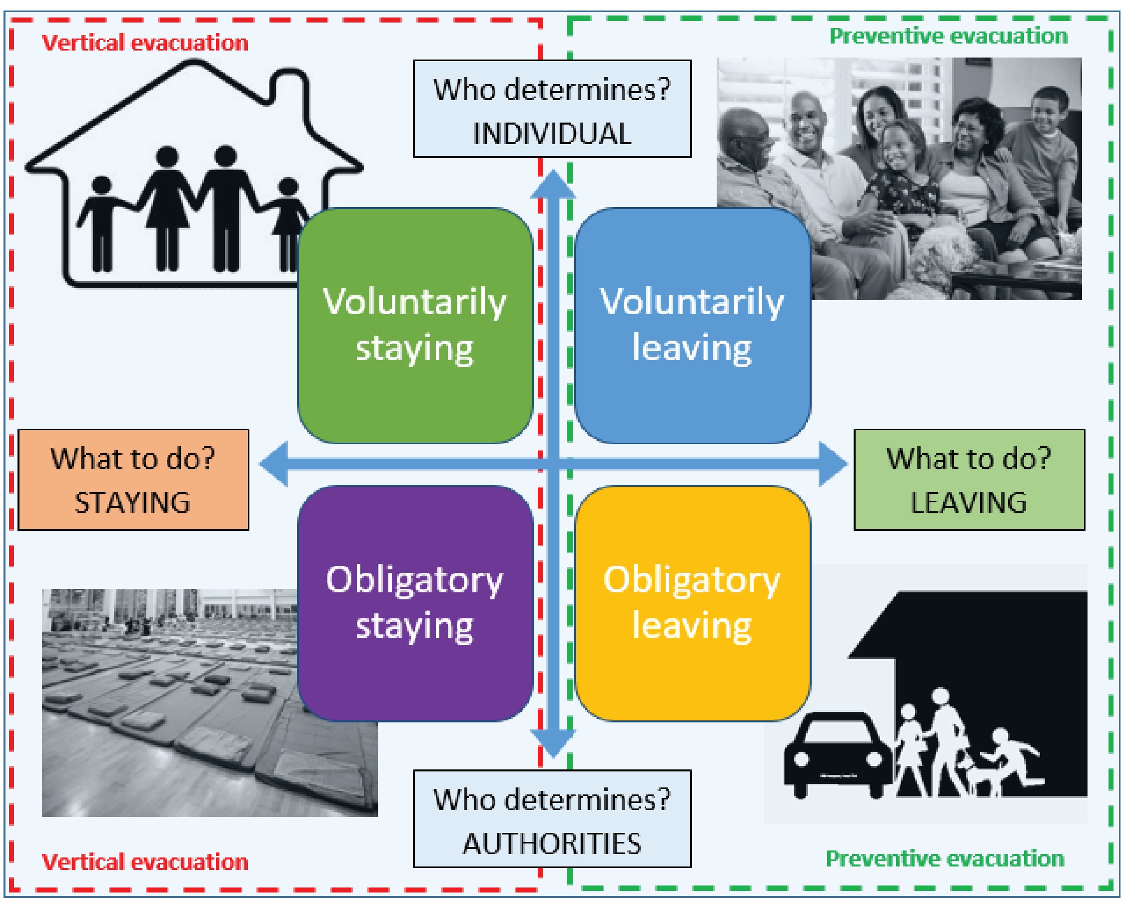
One of the issues in the process of evacuation is dealing with uncertainties. First of all the uncertainty of the intensity and path of the storm and secondly the coincidence of storm impact with the astronomical high tide and surge. Determining which specific regions will be at risk is therefore difficult. An additional uncertainty is if the water defence systems will hold up and if dikes will actually breach. Another complication is the effect on society that an evacuation will have. Matthijsse refers to this as ‘pulling the plug’ from the societal system. Schools, businesses and services close down resulting is massive economic and social impacts. For this reason the decision to set an evacuation in motion is a difficult one. Add to this the essential time needed to efficiate an evacuation against the time frame in which the impact area and consequences reach a degree of certainty and it becomes evident that it is a weighty decision to make for those in charge.

In the IJssel-Vecht delta, an area more upstream in the Dutch river delta, a Flexible Evacuation Strategy is developed. Also in this region in the wake of a pending flood thread it is uncertain how much time there is available to evacuate the area. The strategy is based on both preventive en vertical evacuation and can be applied for every flood threat scenario (Vreugdenhil, Verhoeven, & Kolen, 2015).

Vreugdenhil et. al., (2015) explains that instead of taking an evacuation decision for the whole area in the last moment, the Flexible Evacuation Startegy takes account of the uncertainties that mark a flood thread situation. The base line for this strategy is the early and continuous information supply for inhabitants. The inhabitants are offered one or more options to find a safe place to shelter before a possible flood. Either outside the threathened area (preventive evacuation) or within the flood area on a high floor in a safe building (vertical evacuation). The strategy has three components: 1. Inhabitants are informed on the possible flood thread through risk communication. 2. Inhabitants and businesses work on increasing their own safety through the multiple coping strategies that are offered by the municipality and Safety Region. 3. On the basis of up-to-date flood thread information the government will inform and advise the inhabitants continuously on the actual possibilities to either stay in the area or leave the area. Through this the Safety Region makes use of the self-sufficiency of the people, and less pressure is put on the evacuation decision of the government (Vreugdenhil, Verhoeven, & Kolen, 2015).

Figure 4.25 shows the four option of the Flexible Evacuation Strategy: *Voluntarily Leaving:* in this scenario you voluntarily leave the threathened area (preventive evacuation) and arrange your own shelter accommodation. *Voluntarily staying:* here you stay voluntarily in the threathened area and take shelter in a nearby dry safe location (vertical evacuation). *Obligatory leaving:* the government obliges you to leave the threathened area. You can ask assistance and there is still time to evacuate (preventive ecvacuation). *Obligatory staying:* the government obliges you to stay in a safe dry location within the threathened area (vertical evacuation). From this moment on it is no longer safe to leave the threathened area.

Figure 4.25: Flexible Evacuation Strategy, adapted from Vreugdenhil et al., (2015).

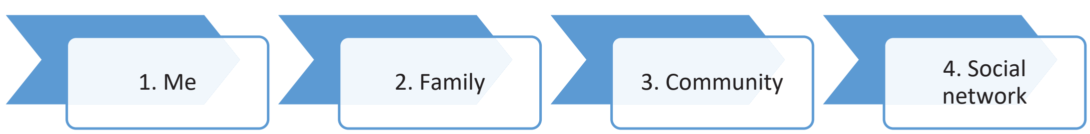


According to Matthijsse (appendix I) the 1953 flood scenario and hydrological situation for Reimerswaal confirms that the people have to be evacuated beforehand (preventive evacuation). The safety norms and standards for dikes are nowadays higher, but nonetheless it is is still a valid scenario. Services in the flood area will fail during a flood. In the decades following the 1953 flood the urbanisation and infrastructure has increased and the number of people affected by the flood will be higher nowadays. For this reason a timely evacuation is essential.

Terpstra (appendix II) explains that timely and adequate risk communication (in the cold phase) and crisis information and communication (in the warm phase) is crucial in relation to evacuation. Matthijsse (appendix I) confirms this and states that the government has the responsibility to inform the people and make them aware of the available coping strategies. In return the people tend to follow up on this information and act according to the instructions. To understand what is needed to successfully execute a Flexible Evacuation Strategy the question is: What is needed to get the people moving and acting?

The authoritative force is not determining in this. For this reason Matthijsse does not fully accord with the principles of the Flexible Evacuation Startegy. Research shows that the majority of people in crisis situations tend to follow the evacuation advise (appendix I). A possible difficulty with the Flexible Evacuation Staretgy is the *obligatory leaving* coping strategy. Realistically it is not feasible to oblige the inhabitants to leave the area. There is not enough manpower (e.g. police, military) to carry out such a decree. Addittionally it is ultimately the decision of the *individual* whether an evacuation advise is followed. Examples in the last decades show that not all people will follow government instructions and some will also choose to 'weather out the storm', against instruction of the authorities, such as happened during the 2005 hurricane Katrina in the region of New Orleans (USA) with catastrophic consequences for many (Shearer, 2010).

For this reason Matthijsse pleads for a evacuation strategy that is always voluntarily: the individual choice of the people will remain. The relation between the individual and the authorities is as follows: Since it is expected that the great majority of the individual decisions will follow the governemental advise, information needs to be available on different levels: What does it mean for:



If there is a sufficient flow of information on the impact on those four levels people will act. The Impact Analyses for Zuid-Beveland executed in 2018 contributes to gaining insight on flood consequences on the local level. Questions to be answered are: What can happen in this area and what is the coping strategy?

In relation to a Flexible Evacuation Strategy for Reimerswaal Matthijsse opts for working towards *deliberately leaving* versus *undeliberately leaving*, instead of *voluntarily leaving* versus *obligatory leaving*. In this case *deliberately leaving* means that the individual made beforehand a carefully weighted and considered decision to leave, which could be translated as conscious competence (Maslow, four stages of competence). This displays a high degree of the individual's self-sufficiency and preparedness. *Undeliberately leaving* on the other hand, means that the individual is taken by surprise wondering what is happening. This could be translated into conscious incompetence in which the individual shows a low degree of self-sufficiency and a high degree of unpreparedness.

4.3.2 What are the anticipated *evacuation fractions* for Reimerswaal, Zuid-Beveland and Walcheren?

Horizontal (preventive) evacuation means leaving the flood threathed area. The evacuation fraction is the expected value of the percentage of inhabitants that is able to leave the area at risk before the dikes breach. Figure 4.26 shows the factors on which the evacuation fraction is depended.

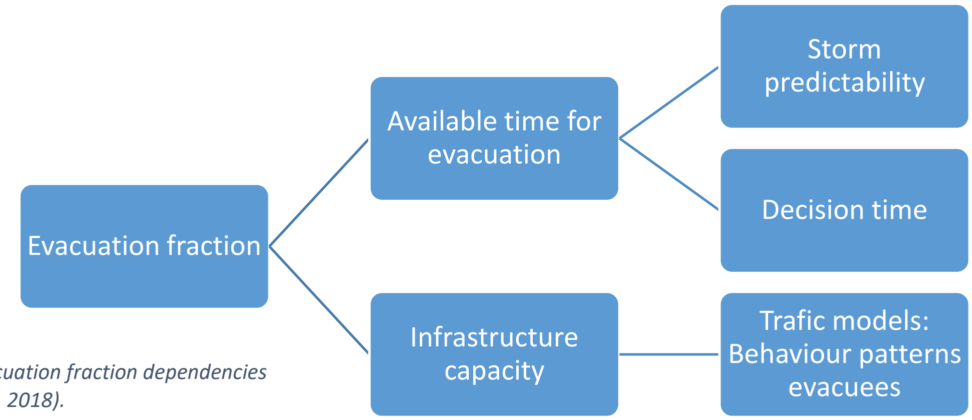


Figure 4.26: Evacuation fraction dependencies (Rijkswaterstaat, 2018).

The evacuation fraction is determined according ot the availiable time for evacuation and the infrastructure capacity. The infrastructure capacity is modelled with traffic models which take into account the behavioural patterns of evacuees as well as the faction of people that will be non-responsive. The available time for evacuation is depended on the storm predictability and the decision time for an evacuation order. As mentioned earlier, the storm predictability and decision time is heavily influenced by uncertainties. Nowadays it should be reckoned with a total time frame of 10 days, with certainty concerning the definitive hydrological situation of 20% 5 days in advance, and 80% certainty 2 days before impact. Since this results in a shorter warning time the evacuation fractions along the coast are lower than further upstream in the delta (Rijkswaterstaat, 2018).

Figure 4.27 displays the evacuation fraction of Reimerswaal, Zuid-Beveland and Walcheren. The region has a total average evacuation fraction of 0.26 (26%). Depending on the available days to evacuate the fraction is higher.

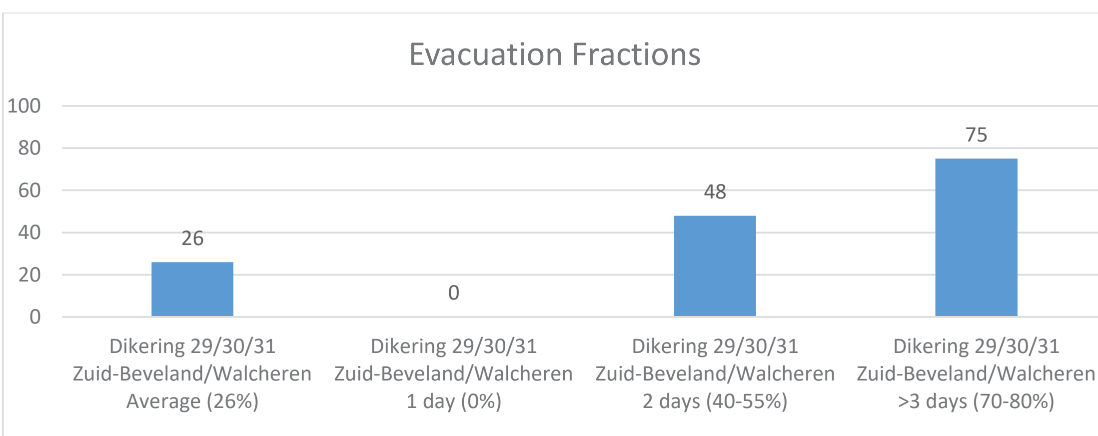


Figure 4.27: Evacuation fractions for Zuid-Beveland and Walcheren categorised according to the amount of available days to evacuate (Bart & Bossenbroek, 2011) (Rijkswaterstaat, 2018).

4.3.3 What would the anticipated *time frame* and *evacuation fractions* imply for the current day *evacuation options* for Reimerswaal and the hinterland of Zuid-Beveland and Walcheren?

The average evacuation fraction (0.26) implies that evacuation options for the region could be limited. Few people will be able to leave the area due to a limited warning time and extreme weather circumstances (Terpstra, appendix II). There is a 40-50% chance that the available evacuation time is up to two days. With two days or more availibale for evacuation, evacuating the region is feasible. According to Terpstra vertical evacuation options will be available depending on the water depth: people will be able to shelter in their own home on a higher floor for a few days (1-3 days).

Besides dealing with uncertainties, there are three challenging factors concerning evacuation options for the region: According to Matthijsse (appendix I) in the days leading up to the flood, first of all the difficulty is to evacuate the region of Walcheren, Zuid-Beveland and Reimerswaal from west till east, and to let people only leave the area when it is their turn (figure 4.28). This is something that has to be reckoned with in the evacuation planning. How do you make sure that people wait for their turn in order to prevent an overload of the infrastructure, in the middle of a crisis situation? Secondly during an evacuation of this area it is needed to utilise the full 24 hours of an day. Unfortualltely a natural tendency of people is not wanting to be evacuated at night and travel in the dark. Thirdly the people have to be convinced during a preventive evacuation to leave their properties behind, while there is no visible immediate thread.

According to both Terpstra (appendix II) and Matthijsse (appendix I) a solution to these three challenges is found in adequate risk and crisis communication. Knowledge, training, awareness and thoroughness are key: Knowledge of coping startegies regarding preventive and vertical evacuation, flood risk awareness of local inhabitants, training for crisis team in relation to evacuation decisions, and thoroughness: valour among those in authority to make argumented evacuation decisions. Only in that way evacuation options leading to the least amount of victims will be available and an evacuation can be realised.

Figure 4.28: (Preventive) evacuation route and direction for Walcheren and Zuid-Beveland: from west till east.

5. Discussion

The historic analysis of the 1953 flood showed that approximately 100 people lost their lives during the big flood in Zuid-Beveland and Walcheren in which the dikes of the southern primary sea defence at the Westerschelde breached in various places. It was a natural disaster (storm surge) with a human component (state of the dikes). It became evident that the time frame in which the storm was anticipated, starting from Friday night (January 30) till Sunday morning (February 1) was more than 24 hours. In this time the storm was sufficiently forecasted and storm warnings were issued according to the standards back in the day. The results show that response to these warnings and realisation of the degree of severity however was insufficient and lacking, resulting in inadequate precautions taken (e.g. non existent preventive evacuation).

A 1953 flood scenario taking place in the present day with dike breaches at the same locations would mean that approximately 90% of the surface of Reimerswaal would be flooded. The hydrological situation (up to 5m high water levels in some places) would cause major impacts on the livablity of the disaster area, with relatively little immediate impact for the non-flooded hinterland. Impact on vital infrastructure of the hinterland is expected to be minimal, while the flooded region will experience major connectivity issues and loss of infrastructural assests such as no access via the west-east route on the state highway and railway services being out of order (e.g. supply, dispatching of goods).

Both the literature and the interviews confirmed that in relation to flood prediction and evacuation decision making, dealing with uncertainties is a major issue. The influence of the time uncertainty on the evacuation options for Reimerswaal are significant. The evacuation fractions are however a number developed in a theoretical environment, while the Impact Analyses of the WAVE2 project focusses on the reality and local implications of such a possible flooding scenario. The practical implications for the area are therefore still in the process of being shaped.

A salient factor in efficiating a Flexible Evacuation Strategy is the importance of adequate risk communication in the cold phase of a flood and crisis communication in the warm phase of a flood, providing timely coping strategies for the inhabitants.

It is anticipated that the majority of people tend to follow the instructions given during crisis communication by the authorities. Adequate communication is therefore essential. A descripancy between theory and practice is that the emerging of superpromotors during a crisis situation as described in the theory is not yet taken into account in crisis planning regarding flood threats. It is however acknowledged that this is important to incorporate.

In executing the methods I learned that following a predefined research methodology was very helpful. The destiction of project goals and objective helped structuring the research of the three sub-question chapters in a logical way. Because every goal was devided in objectives, the complex research became tangible and in this way manageable to execute.

Consulting experts in the field was a good experience since it helped clarifying some of the research concepts. At the same time expert involvement ensured reliability and validity of the research outcomes.

6. Conclusions & Recommendations

6.1 Answering the questions

Main question: *What would the effect of a 1953 flood scenario be on a current day evacuation of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren?*

1. Historic analysis, examining the 1953 flood scenario: *What was the flooding scenario of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren in 1953?*

In the night from February 1st to February 2nd 1953 the Netherlands was hit by a flooding disaster with major impacts, resulting in 17 dike breaches in the primary and regional sea-defence of the Reimerswaal region, Zuid-Beveland (appendix III). The hydrological situation shows water levels reaching up to 5-6m in some of the flooded polder areas. Various polders were subject to the influx of the semidiurnal tides for months. Preventive evacuation was non-existent and eye-witness accounts testify to vertical evacuation at the moment or directly after the dikes breached in some places.

2. Current situation, examining a 1953 flood scenario taking place in the present day: *What would a 1953 flooding scenario of Reimerswaal look like in the present day? What would the consequences of a 1953 floodscenario of Reimerswaal be for the hinterland of Zuid-Beveland and Walcheren in the present day?*

Nowadays the peninsula on which Zuid-Beveland and Walcheren is located has over 210,000 inhabitants. Over 22,500 of these live in the municipality of Reimerswaal (dike ring 31). With the ability of the European weather model ECMWF to forecast a 1953 storm scenario 10 days in advance and capacity at the WMCN and KNMI to model this into a definitive hydrological situation with 20% certainty 5 days in advance, and 80% certainty 2 days before impact, the total time frame in which a 1953 storm scenario is anticipated is 10 days, with a gradual increase in certainty leading up to the moment of impact. Dike breaches at the Oost-Inkelen Polder (Kruiningen Veerhaven) and Reigersbersche Polder (near Bath) would flood 90% of the surface area of Reimerswaal with 0.5-5m of water. Consequences affect: *Livability*, due to inundation and failiure of critical infrastructure in the flooded area this is seriously affected. On the other hand, relatively little immediate impact for the non-flooded hinterland is anticipated. Critical infrastructural assest are expected to remain functioning for the hinterland. *Connectivity* to the hinterland will be suffering due to the loss of the railway and A58 high way connection west-east.

3. Translating the floodscenario into a Flexible Evacuation Strategy: *What are the implications of a 1953 flooding scenario for a current day Flexibe Evacuation Strategy of Reimerswaal?*

The Flexibile Evacuation Strategy makes use of both preventive evacuation and vertical evacuation. The strategy has four evacuation options: *voluntarily leaving, obligatory leaving* (preventive evacuation) and *voluntarily staying, obligatory staying* (vertical evacuation). The effect of a 1953 flood scenario would imply for Reimerswaal the need of *preventive evacuation* for most of the region. In order to execute this strategy and get people moving adequate and timely crisis communication is paramount, accompanied with vigorous evacuation decision making.

6.2 Conclusions

The aim of the research was to examine the implications of a 1953 flood scenario on a current day evacuation of Reimerswaal and the hinterland of Zuid-Beveland and Walcheren. This was done through making a historic analysis, looking at the current situation and examining the Flexible Evacuation Strategy. The research provided insight in the historic hydrological situation. It has also identified the time frame in which a similar storm scenario would be anticipated in the present day. Furthermore it examined the implications that the time frame and evacuation fraction have on the evacuation options of the region. Also the importance of crisis communication in relation to evacuation became evident. Following the research done it can be further concluded that:

- The hydrological situation surrounding a 1953 flood scenario would imply the need for *preventive evacuation* of Reimerswaal.
- The *evacuation fractions* are a number developed in a theoretical environment, while the Impact Analyses of the WAVE2 project focus on the reality and local implications of such a possible flooding scenario. The practical implications for the area are therefore still in the process of being shaped.
- *Dealing with uncertainties* regarding avalible *time for evacuation*, *storm predictability* and *decision time* is one of the major challenges.
- Furthermore, *evacuating from west till east, utilising the full 24 hours of the day* and *convinceing people to leave their properties behind* will hamper evacuation.
- It is anticipated that the majority of people tend to *follow the instructions* given during crisis communication by the authorities.
- Therefore, It is essential to provide adequate *risk communication* in the cold phase of a flood and *crisis communication* in the warm phase of a flood in order to provide timely coping strategies for the inhabitants.

6.3 Recommendations

The following recommendations for research and implementation are based on the study findings:

1. *Identifying evacuees:* Research to identify exactly which people need to be evacuated, and where they are located within the region of Reimerswaal is recommended. This will enable aimed, directed, crisis communication regarding the coping strategies for the people within the region during a flood threat.
2. *Identifying evacuation timeline:* When the evacuee groups are identified and localised an evacuation time line could be developed in order to give insight in the course of an evacuation. This timeline should be adaptive depending on flood scenario's and time availability with room for uncertainties.
3. *Connectivity:* Furthermore it is recommended that research is done into the connectivity during a flood event: whether communities can be reached via routes outside of dike ring 31 and if there is an alternative route available from west till east besides the inundated A58 highway.
4. *Relocating/rehousing:* Finally an interesting suggestion for further research is to explore the possibilities of relocating or rehousing following the aftermath of a flood of Reimerswaal. The question whether moving people back to the flood region is feasible should be investigated to ensure long-term sustainability of living in the Dutch delta.

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