Greening Flood Protection in the Netherlands
A knowledge arrangement approach

Stephanie K.H. Janssen

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Stephanie K.H. Janssen

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Preface

This book completes a unique period in my (working) life where I was given the opportunity to dive into the fascinating worlds of research, Building with Nature, flood protection projects and the knowledge therein. This PhD gave me a whole lot of freedom and the opportunity to learn and gain in-depth knowledge and understanding of these interesting topics. I can only be terribly thankful to those who gave me the opportunity and trust to start this project and to those who helped me along the way. In this preface I take the opportunity to thank some of these people in person.

It was a privilege to work with three very supportive and inspiring persons: my promotors Arthur Mol and Jan van Tatenhove and my co-promotor Henriëtte Otter. Their efforts made this PhD trajectory both an enjoyment and a success. Our meetings were very inspiring and always gave me a lot of energy to get back to work. Moreover they helped writing and co-authored three of the papers that result from this PhD. I am very thankful for this! Some particular contributions I like to mention here. Tuur has provided many sharp critiques and observations, useful suggestions (the term 'science-cum-policy fields' was found by him) and feedback on my English language. Jan has been a most optimistic supervisor, who introduced me to the worlds of marine governance and policy arrangements and gave constructive critiques on my work. With Henriëtte it all started. She saw an opportunity in this project and enabled me to combine it with my Deltares projects. She has been invaluable in her support on how to organise (the process of) my research and work, has always provided me critical as well as constructive critiques and has been a great sparring-partner in all these years.

This study is based upon three Dutch case studies. Without the many informants in these projects, the possibility to attend project meetings and the use of project documentations this would have been impossible. I am very grateful for the opportunities and help I received. In particular I would like to thank Zjef Ambagts, Brigit Janssen-Stelder, Lukas Meursing and Anet Lablans. MSc student Arjen Francke has supported me in the Markermeer dikes case study.

Three papers were submitted in scientific journals, of which two have been published by now. The review processes and the feedback and critiques on the three papers have been

very helpful in structuring my line of thinking, theory development and literature study. I am grateful for the time and efforts the reviewers and editors spend on my work.

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This PhD was initiated and co-funded by Ecoshape. Besides the financial contribution Ecoshape facilitated numerous events which enabled me to interact with and learn from professionals in the field and fellow PhD's, to share my work and to build a network. I am grateful for their efforts.

Without my dear friends and family I could never have completed this project. For the necessary distraction from work my friends Aby, Anita, Birgit, Dorien, Guusje, Imke, Linda, Lonneke, Wieneke and dames 6 were of vital importance. I hope to spend more time with them now this project is completed! My parents, Marion, Bart, Max, Mieke, Maurits, Wieneke, Dion and Jelger, were always supportive and interested over the years. My parents and Marion and Bart have been fantastic in taking care of our two boys whenever I had to work. Another special word is for my parents because they are at the origin of all this. They taught me to make the most out of everything, always broaden my horizon and gave me the confidence that I can make it. Without these lessons I had never achieved this point. This book is devoted to both of them. Last but not least I mention here

my husband Wessel and my two beautiful sons Friso and Piet Hein. These three men are the most important in my life and make me incredibly proud.

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List of abbreviations

BFP	Basic Flood Protection
BKL	Basic coastline position (*Basis Kustlijn*)
BwN	Building with Nature
CEA	Cost Effectiveness Analysis
CPB	Central Planning Agency (*Centraal Planbureau*)
DGW	Directorate General Water
EBM	Ecosystem-based management
EHS	National Ecological Network (*Ecologische Hoofdstructuur*)
EIA	Environmental Impact Assessment
ENW	Expertise Network Water (*Expertise Netwerk Waterveiligheid*)
GFP	Greening Flood Protection
HHNK	Waterboard Hoogheemraadschap Hollands Noorderkwartier
HWBP	High Water Protection Program (*Hoogwaterbeschermingsprogramma*)
I&M	Ministry of Infrastructure and Environment (*Ministerie van Infrastructuur en Milieu*)
KA	Knowledge Arrangement
LNV	Ministry of Agriculture, Nature and Food Safety (*Ministerie van Landbouw, Natuur en Visserij*)
NGO	Non Governmental Organisation
PAA	Policy Arrangement Approach
PDA	Preferred Design Alternative
PZH	Province of South-Holland (*Provincie Zuid-Holland*)
RWS	Rijkswaterstaat
V&W	Ministry of Public Transport, Public Works and Water Management (*Ministerie van Verkeer en Waterstaat*)
VROM	Ministry of Housing, Spatial Planning and the Environment (*Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieu*)
WwN	Working with Nature
WoK	Way of Knowing

1 Introduction

1.1 Flood protection in the Netherlands

1.1.1 An introduction

The Netherlands is a relative small country in the north-western part of Europe. It has a total surface area of about 34.000 km^2 and roughly 17 million inhabitants. Four rivers discharge in the Netherlands: the Rhine, the Meuse and the smaller rivers Scheldt and Ems. The Netherlands is located in the lowest delta in the world (LOLA Landscape Architects, 2014) and approximately 25% of the country lies below sea level. The lowest point is -6,67m in a polder near Rotterdam. Without the extensive system of dikes, dams and dunes, 65% of the country would be vulnerable for floods coming from the sea and the rivers (Figure 1.1). The famous saying “God created the world, and the Dutch created the Netherlands” refers to the many interventions of the Dutch in their landscape. Damming parts of the sea and tidal inlets, canalizing water ways, and reclamation of land made the Netherlands what it is today. The location and design of the country makes flood protection a crucial condition for a safe and healthy living.

Figure 1.1 The vulnerability of the Netherlands for flooding (source: Rijkswaterstaat, DWW)

Flood protection barriers are omnipresent in the Netherlands: over 22.500 km of dikes, dunes and dams form the landscape (LOLA Landscape Architects, 2014). Approximately 3500 km make up the ‘primary’ flood protection barriers and are most important for flood protection. Some 14000 km of dikes are regional structures, forming a second line of protection. In addition, there are many older, historical dikes that are part of the landscape but today have no flood protection function. The maintenance of the flood protection infrastructure requires ever-increasing efforts as the irreversible and on-going land subsidence causes a ‘technological lock-in’ (Wesselink et al., 2007). Drainage of land and lowering the water level causes settling of land and subsidence. Consequently, additional drainage and lowering the water level is needed, the land subsides further and so on. Flood protection measures are needed to protect the sinking land from flooding. Simultaneously, dikes that are built for flood protection inhibit sedimentation processes that would otherwise heighten the land. Instead the sediments stay in the river and elevate the river bed. Besides the on-going physical processes, the use of land and its economic and societal value increase. The impact of a potential flood becomes more and more disastrous. Since the cultivation of land, flood protection has been a central concern of Dutch citizens, administration and politics.

Influenced by economic, societal and technological developments and occurrence of (disastrous) flood events, flood protection strategies evolved over the centuries. By the end of the 13th century a strategy of accommodating, in which people lived on dwelling mounds, was replaced by a strategy of protecting land (Van Koningsveld et al., 2008). The role of technology became more and more important. In the prosperous 17th century, known as the ‘Golden Age’, technological developments spurred and allowed for improved protection standards, uniformity in dike designs, and large reclamations projects. The latter created agricultural land to feed to growing population. Flood events and failure of dikes (for example when pileworms destroyed the ubiquitous wooden dike constructions around 1730) triggered innovations in dike construction such as the use of stone materials and shallow slopes. More recently in the 20th century two major flood incidents marked breakthroughs in flood protection management and formed the occasion for two large scale projects. The storm surge of 14 February 1916 and the food shortage during World War I formed the final occasions to effectuate ‘Plan Lely’[1] to dam the Zuiderzee in the north of the Netherlands. A 32 km dam, the Afsluitdijk, shortened the coastline by 300 km, 120.000 ha fresh water lake was created and some 220.000 ha of land reclaimed (Van Koningsveld et al., 2008). The second significant flood incident happened when in 1953 a north-western storm and spring tide caused a disaster in the south-western part of the Netherlands. Over

[1] Cornelis Lely had developed a plan to dam the Zuiderzee already in 1891

1800 people lost their lives and 200.000 ha of land was flooded. The major Delta works followed and radically changed the land in this part of the Netherlands by closing of large parts of the Rhine-Meuse delta. A range of innovative dams and barriers were constructed to prevent future flood disasters. Scientific knowledge became more and more important in the 20th century to support the complex engineering structures in both projects (Van Koningsveld et al., 2008). One of the novelties was the use of statistical data in the Delta works. Instead of the highest water level experienced, designs of flood infrastructures were now based on the probability of failure (Van Koningsveld et al., 2008; Wesselink et al., 2007).

1.1.2 Recent trends

Flood protection strategies gradually evolve. Two significant developments affect how flood protection is approached today.

First, the understanding of negative environmental and ecological consequences of conventional ‘hard’ flood protection infrastructure such as dikes and dams has increased (Airoldi et al., 2005; Van Wesenbeeck et al., 2014). These ecological effects include losing and changing habitats and species diversity and altering sedimentation patterns (Airoldi et al., 2005). The Delta works in the Netherlands resulted in a range of such ecological problems including eutrophication, habitat loss and stratification as a result of lost connectivity, reduced tidal flow and disrupted sediment balance (Van Wesenbeeck et al., 2013). Authors have begun to criticise traditional hard flood protection structures for being unsustainable, expensive to maintain and even exacerbating flood effects as these remove natural water storage areas and channel estuaries and rivers (Smits et al., 2006; Temmerman et al., 2013). The construction process of the ‘Oosterschelde’ dam, which is one of the Delta works barriers, is indicated as the start of an ecological transformation in flood protection management (Disco, 2002). This barrier was initially designed to close the estuary, but after strong opposition an alternative, semi-open dam was designed and constructed. The 8 km dam is composed of 62 sliding doors between pillars, which are open during normal conditions to allow for tidal fluctuations and closed during storm conditions. The ecological transformation in flood protection is not an isolated development, but can be understood to reflect broader societal change that has been indicated as ‘environmental modernization’ (Mol, 1999). This social theory of environmental reform has addressed the changing role of science and technology, from merely causing environmental problems to becoming part of the solution, and has indicated changing roles and responsibilities of actors, including NGOs, and the state. Korbee et al. (under review) showed how these developments also apply in the most recent Dutch land reclamation project: the 2.000 ha port extension known as the ‘Second Maasvlakte’. In line with the increased environmental awareness and ecological transformation in flood protection management, several authors now advocate environmental friendly flood protection solutions, which are more sustainable, cost-effective and have fewer side effects (Hale et al., 2009; Temmerman et al., 2013; Van Wesenbeeck et al., 2014).

Second, the changing climate poses new challenges to flood protection management and infrastructure. Rising sea levels, the occurrence of extreme storm events, extreme river discharge affect requirements for flood protection management. In the Netherlands for each 50 to 80 cm of sea level rise the probability of flooding increases with a factor 10 (Aerts & Botzen, 2013; Aerts et al., 2008). In response to this 'new reality' the 'second delta committee'[2] was installed to developed plans to secure future living, working and investing in the Netherlands for the coming 200 years (Delta commissie, 2008). They successfully made the Dutch politicians and citizens aware of the threats associated with the changing climate and the need to set up the now running Delta programme (Verduijn et al., 2012). While it is likely that the rates of the rise in sea level and the occurrence of extreme storms will increase, prediction of the exact amounts of increase is impossible (IPCC, 2013). Climate change is associated with uncertainties regarding the magnitude of its impact. In light of these uncertainties authors have recommended no- or low-regret measures (Cheong et al., 2013) and adaptive strategies and flexible designs that can be adjusted to changing circumstances (Aerts & Botzen, 2013; Gersonius et al., 2013). The traditional hard infrastructure is rigid and is designed for long spans of time, but ecosystem-based solutions are typically more flexible and adaptive. Therefore, green solutions have been advocated as a way to deal with climate change (Hale et al., 2009; PIANC, 2011; Spalding et al., 2013).

1.1.3 A new pathway: "Building with Nature"

Environmental awareness and the changing climate enabled experimenting with a new pathway in Dutch flood protection management (Van Koningsveld et al., 2008). This approach is labelled 'Building with Nature' (BwN), in contrast to 'building *in* nature' and 'building *of* nature' (De Vriend & Van Koningsveld, 2012; De Vriend et al., 2014; Van Slobbe et al., 2013). BwN employs and enhances nature and simultaneously contribute to socioeconomic and environmental goals (Vikolainen et al., 2014; Waterman, 2008, 2010). These elements contrast with 'traditional' approaches that are intended to minimise impact on nature or compensate for loss of nature. In the BwN approach, the characteristics of the ecosystem contribute to flood protection, for example by attenuating waves, stabilising shorelines or retaining sediment.

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[2] The first Delta committee was installed after the 1953 flood disaster and developed plans for the Delta works

The idea that underlies BwN was first introduced in the early 1980s by Honzo Svašek (1926-1994), a hydraulic engineer who was born in Czechoslovakia and was educated and worked in the Netherlands[3] (IADC, 2010). Ronald Waterman has further elaborated on the concept (Waterman, 2008, 2010). In the last decade, BwN concepts and the development of relevant knowledge have developed rapidly. In 2007, the two largest global Dutch dredging companies[4] initiated a €30 million public-private innovation programme that is called Building with Nature[5,6]. This extensive programme (2008-2012) was implemented by the Ecoshape consortium and involved private companies, national and local governmental authorities, research institutes and universities (De Vriend & Van Koningsveld, 2012). Scientific research was combined with pilot projects in the Netherlands and in tropical areas. After the programme was completed, Ecoshape initiated a second programme that was even more focused on successful implementation (Ecoshape, 2014b). Ecoshape is not the only initiative in the BwN field. The Dutch Scientific Council (NWO) announced a €4 million subsidy for Building with Nature research in 2012[7]. The NatureCoast[8] programme, which involves research on soft sandy solutions, also began an extensive research effort in 2012.

BwN also gained increasing attention and support at policy and political levels. The Dutch National Waterplan (Ministerie van V&W, 2009) and the current 'Delta program' for flood protection demonstrate that the concept is an innovation that deserves further support (Ministerie van I&M & Ministerie van EZ, 2014). The national Minister who is responsible for flood protection personally advocates the use of natural dynamics and BwN in flood protection measures because they 'make the water system more flexible and robust and better equipped to deal with extreme situations'[9].

1.1.4 Building with Nature solutions

The range of possible BwN solutions is diverse. In the Netherlands, these include oyster reefs, mussel banks, vegetated foreshores, e.g., salt marshes and willow plains, and sand nourishments. Corals, sea grasses and mangroves have been employed in tropical regions in a BwN strategy. The type of BwN solution that is applicable and the potential impact on flood protection strongly depend on local conditions. Ecological, morphological and

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[3] http://www.svasek.com/company/history.html
[4] Van Oord and Royal Boskalis Westminster
[5] See www.ecoshape.nl
[6] This PhD research is co-sponsored by this programme.
[7] http://www.nwo.nl/onderzoek-en-resultaten/programmas/Building+with+Nature
[8] Naturecoast.nl
[9] Letter to the parliament by the Minister of Infrastructure and Environment, mw. drs. M.H. Schultz van Haegen, on water policy, 26 April 2013, IENM/BSK 2013/19920.

hydrodynamic conditions (Borsje et al., 2011) and available space (Bouma et al., 2014) determine the potential and the effectiveness of a BwN strategy. BwN applications are often combined with traditional hard engineering structures for optimal use (Cheong et al., 2013). Four different applications that illustrate the BwN strategy in the Netherlands are described below.

Salt marshes

Coastal salt marshes are located between land and sea, where vegetation and sedimentation processes operate in dynamic interaction (Figure 1.2). Salt marshes contribute to flood protection by dissipating wave energy, counteracting erosion and facilitating sedimentation processes (Gedan et al., 2011; Moller et al., 2014; Wamsley et al., 2010). The degree of wave reduction that a marsh can provide depends on the load on the marsh in terms of size, speed, duration and intensity of waves and the salt marsh characteristics in terms of type and density of vegetation, size of the marsh and the coastal profile (Van Loon-Steensma & Vellinga, 2013; Wamsley et al., 2010). These conditions are not stable. Vegetation in the marsh varies seasonally and climate change causes changes in sea level and wave action. Under favourable conditions, i.e., when sediments are available, marshes can be self-sustaining and can even adapt to sea level rise. Salt marshes are important for biodiversity. They are unique habitats that provide nursery grounds for fish, breeding and feeding grounds for birds and nutrient cycling (Spencer & Harvey, 2012).

Figure 1.2 Salt marsh in the Wadden sea

Salt marshes are a common habitat in the Wadden Sea, which is in the northern part of the Netherlands. The Wadden Sea is a shallow area that is situated between a number of barrier islands and the mainland. Dikes and sandy dunes protect the barrier islands and the mainland against flooding. Due to previous land reclamation, the current salt marshes are the result of ongoing maintenance efforts (De Jonge & De Jong, 2002). In the experimental project ‘Salt marsh development Koehoal’ (Ecoshape, 2014a), a ‘sediment engine’ is employed to facilitate the natural growth of the salt marshes. The sediment engine provides increased sediment supply to the Koehoal area. The sediment is obtained from maintenance dredging in a nearby harbour.

Oyster reefs

Oyster reefs (Figure 1.3) stabilise intertidal flats, reduce erosion and trap sediments, and can be used to replace such traditional flood protection measures as groins and revetments (Borsje et al., 2011; Rijkswaterstaat & Deltares, 2013). In

Figure 1.3 Oyster reef

addition to contributing to flood protection, oyster reefs enhance biodiversity (Scyphers et al., 2011) and improve water clarity by removing sediment from the water column (Coen et al., 2007).

Oyster reef construction experiments have been conducted in the south-western region of the Netherlands (De Vries et al., 2007; Rijkswaterstaat & Deltares, 2013). The Eastern Scheldt is subject to erosion processes, and intertidal flats are gradually disappearing. Intertidal flats are important for birds and seals and also for wave dampening. Experimental oyster reefs were constructed in 2007, 2009 and 2013. Preliminary results show that new oysters attach themselves to the reef and that silt is deposited behind the reefs (Rijkswaterstaat & Deltares, 2013).

Sand nourishments

Sand nourishments are a form of 'soft-engineering' that counteracts erosion of sandy coastlines. Sand nourishment is more resilient, flexible and adaptive than such traditional hard engineering approaches as dikes and dams, (Van Slobbe et al., 2013). Different nourishment strategies, such as dune nourishment, beach nourishment and shore-face nourishment, can be employed. Shore-face nourishment feeds the beach with sand or functions as a barrier to waves. There has recently been a mega-nourishment experiment in the Netherlands that is known as the 'Sand Engine' (Stive et al., 2013). In cases where dunes constitute the hinterland, the transport of Aeolian sand contributes to the formation of natural dunes that form a flood protection barrier.

Figure 1.4 Dune area

Sandy dunes (Figure 1.4) protect 75% of the Dutch coastline, which is about 400 km long (Mulder et al., 2011). A policy of sand nourishments that is known as 'dynamic preservation' has been employed since 1990 to prevent erosion of the coastline (Mulder et al., 2011; Van Koningsveld et al., 2008). Dynamic preservation implies that the coastline is not fixed at a particular position but natural dynamics of sand and sediment transport are optimally used (Van Koningsveld & Mulder, 2004). The objective of this policy is to "to guarantee a sustainable flood protection level and sustainable preservation of values and functions in the dune area" (Ministerie van V&W, 1990). While this implies a multi-functional approach, evaluation of the policy showed that sand nourishments for functions besides flood protection is only partly achieved (Lubbers et al., 2007). In maintaining the coastline at its desired position the policy has been very successful (Giardino et al., 2011; Lubbers et al., 2007).

Willow plains

Figure 1.5 Willow trees being cut

Vegetation contributes to the flood protection function by dissipating wave energy, stabilizing coastline and catching sediments (Gedan et al., 2011). The particular contribution depends on the size of the vegetation plane, the density of the vegetation and biomass production (Shepard *et* al., 2011). Well known types of wave attenuating vegetation are mangroves and salt marshes. In the Dutch environment typical vegetation types, which represent wetlands from salt to fresh water, are: cord grass, grass weed, reed and willow trees (Figure 1.5) (Borsje et al., 2014). The Noordwaard project provides an illustration of the application of willows for flood protection.

The Noordwaard project is a component of the Dutch 'Room for the River' programme. Room for the River supports an integrated approach to river basin management that is intended to enlarge the discharge capacity of Dutch rivers and simultaneously improve spatial quality (Rijke et al., 2012). The flood protection standards for the Noordwaard polder implied a need to construct a dike near historical Fort Steurgat. An alternative dike design that involves a willow flood plain was chosen after citizen protests. The willow trees (*Salix alba*) assume some of the flood protection function and are expected to reduce wave heights, which may be up to 70% under extreme conditions (De Oude et al., 2010). The dike that is behind the willow flood plain was therefore designed with a lower crest height that allowed citizens to preserve their view of the river (Borsje et al., 2011).

1.2 Greening Flood Protection

Building with Nature is typically a Dutch term. It is employed and communicated by Dutch researchers, contractors, policy-makers and politicians both in the Netherlands and abroad. However, the basic concept, which is to introduce natural dynamics and ecosystem improvement to the design of flood protection, is a global phenomenon. Similar concepts are used outside of the Netherlands and in more international contexts. Prevailing concepts include (but are not limited to) ecological engineering, ecosystem-based management and working with nature. Consistent with these concepts, this thesis is about 'Greening Flood Protection'. Before explaining this concept further, I will first provide a brief overview of these prevailing concepts.

Ecological engineering is defined as the design of sustainable ecosystems that integrate human society with the natural environment for the benefit of both (Mitsch, 1993; Mitsch, 2012). It involves the restoration of disturbed ecosystems and the development of new ecosystems that have value for both humans and nature. A fundamental principle in ecological engineering is the 'self-design' of ecosystems (Odum & Odum, 2003), which contrasts with conventional engineering approaches that are intended to control the design and rule out uncertainty (Mitsch, 2014; Mitsch & Jørgensen, 2003). Self-design means that the organisation of an ecosystem itself is included in the ecosystem design.

Ecosystem-based management (EBM) is an integrated management approach that is used widely in the ocean and marine management literature. EBM recognises the complexity of interactions in ecosystems, including interactions with humans, and the multiple functions and services that ecosystems deliver. Ecosystems need to be healthy to deliver services from which humans can profit. EBM departs from the idea of single-issue optimisation of an ecosystem (Barbier et al., 2008; Katsanevakis et al., 2011; McLeod et al., 2005).

The PIANC, which is an influential network that includes professionals in the field of waterborne transport (including the development of ports, waterways and coastal areas) employs the concept 'Working with Nature' (PIANC, 2011). Working with Nature (WwN) is defined as "an integrated process which involves working to identify and exploit win-win solutions which respect nature and are acceptable to both project proponents and environmental stakeholders" (PIANC, 2011, p.1). In its positioning as a 'proactive approach', WwN is closely related to BwN. Opportunities for ecosystem protection, restoration or enhancement should be explored early in the decision-making processes of infrastructure development and should go beyond mitigating or compensating for negative effects.

Some comparable concepts are used in the field of flood protection. Hale et al. (2009) refer to 'ecosystem-based adaptation' of coastal communities in response to climate change. This form of adaptation is intended to preserve and restore ecosystems so that they can provide (cost-effective) protection against such climate-related threats as floods and storms and continue to deliver other ecosystem services. Van Wesenbeeck et al. (2014) use 'nature-based flood defence' to refer to flood protection solutions that make use of (restored) coastal ecosystems, often in combination with (existing) hard coastal infrastructure. Temmerman et al. (2013) similarly use 'ecosystem-based coastal defence' in denoting flood protection designs that make use of the properties of different types of ecosystems to accommodate to storm surges and to accommodate to rises in sea level.

As the central concept in this thesis I use 'Greening Flood Protection' (GFP). GFP reflects the particular orientation of this research, whereas the previous mentioned concepts, including BwN, have a (slightly) different or broader orientation or do not cover particular aspects. The following arguments sustain this choice. GFP denotes a primary focus on flood protection and not on other marine-related developments, for which some of the above concepts have also been used. GFP depicts greening flood protection in the broadest sense. Consistent with some of the above concepts, ecosystem properties are often used in combination with (existing) conventional hard infrastructure designs. Ecosystems in flood protection can therefore have a relative minor role or alternatively take over the entire flood protection function. In this thesis I intend to cover the full range of green flood protection designs, from slightly green to entirely green. Lastly, GFP is intended to include a process perspective instead of a single focus on the final flood protection design. The decision-making process precedes the outcome, which becomes the final flood protection design.

GFP is directly inspired by the concepts that were introduced earlier and has three main characteristics. First, natural dynamics are included in the flood protection design and contribute to its flood protection function. Natural dynamics relate to what Odum and Odum (2003) have called ‘self-design’. The self-organisation of an ecosystem is included in the design of a GFP solution and contributes to its flood protection function. Natural dynamics include biotic processes, such as vegetation processes or shellfish dynamics, and abiotic processes, such as wind and wave dynamics. Second, GFP enhances the (local) ecosystem. This can be in the form of restoration, preservation and improvement of existing ecosystems or the creation of a new ecosystem. Increases in the quality and extent of the ecosystem constitute enhancing the ecosystem. Finally, GFP combines flood protection and nature functions. The combination may be direct, for example when multiple project objectives are explicitly formulated, or indirect. When GFP is applied often more functions are integrated, given the broad range of ecosystem services associated with green solutions (Hale et al., 2009). In this thesis however, the main orientation is on the combination of flood protection and nature functions.

1.3 Problem definition

A central challenge for GFP in the Netherlands is the actual realisation or implementation of a GFP solution in flood protection projects. Flood protection projects are projects that intend to contribute to the flood protection level. A quick scan of scientific and grey literature and policy documents reveals twelve examples of GFP in flood protection projects (Table 1.1). This represents a small minority of Dutch flood protection projects. It indicates how far GFP deviates from standard practise in Dutch flood protection projects. Moreover, five of the twelve projects are pilot projects, and are therefore not part of mainstream flood protection management. The lack of GFP success in flood protection projects is not limited to the Netherlands. Other authors have reported on the challenge of actual implementation of green solutions. Temmerman et al. (2013) concluded from their global inventory on ecosystem-based coastal defences that there is currently a lack of large-scale GFP applications.

Table 1.1 Dutch GFP examples

#	Dutch GFP example	Description	Type and stage of project	GFP solution?
1	Sand Engine (De Vriend et al., 2014; Ministerie van I&M & Ministerie van EZ, 2014; Stive et al., 2013; Temmerman et al., 2013; Van den Hoek et al., 2012; Van den Hoek et al., 2013; Van Slobbe et al., 2013)	A 21,5Mm^3 ('mega') sand nourishment along the coastline in the western part of the Netherlands (case study chapter 3).	Pilot experiment project. Construction completed in 2011.	Yes
2	Prins Hendrik dike (De Vriend et al., 2014; Ministerie van I&M & Ministerie van EZ, 2014; Seijger et al., 2013)	A sandy dike structure that contributes to flood protection and nature development at the barrier Island Texel in the north of the Netherlands.	Flood protection project. The sandy structure is preferred design alternative. Expected start of construction in 2017.	Yes
3	Sophia Beach (De Vriend et al., 2014; Ministerie van I&M & Ministerie van EZ, 2014)	Instead of dike reinforcement, sand (dune) nourishments are conducted in front of the dike structure.	Flood protection project. Completed in 2013.	No particular contribution to ecosystem or use of natural dynamics.
4	Green Dollard Dike (Ministerie van I&M & Ministerie van EZ, 2014)	The Green Dollard dike is a broad clay dike, covered with grass. In front of the dike a salt marsh attenuates waves.	Flood protection project. One of the designs that are being explored.	Yes
5	Noordwaard (Borsje et al., 2011; De Oude et al., 2010; De Vriend et al., 2014; Temmerman et al., 2013; van Staveren et al., 2014)	River dike that is behind a willow forest that contributes to the flood protection function by means of dissipating wave energy (see section 1.1.4).	Flood protection project. Under construction.	Yes
6	Oesterdam (De Vriend et al., 2014; Ministerie van I&M & Ministerie van EZ, 2014; Van den Hoek et al., 2013)	Sand nourishment in front of a dam in the south-western region of the Netherlands. The sand positively affects the redistribution of sand in the Eastern Scheldt basin, dissipates wave energy and provides valuable habitat.	Pilot project. Completed.	Yes

#	Dutch GFP example	Description	Type and stage of project	GFP solution?
7	Hondsbossche sea defence (De Vriend et al., 2014)	A hard sea defence is reinforced with a sand barrier in front of it. Wind, wave and current dynamics redistribute sand and contribute to flood protection northward. Nature area is enlarged and provides new opportunities.	Flood protection project. Under construction.	Yes.
8	Ecological Shore dike (De Vriend et al., 2014; Rijkswaterstaat & Deltares, 2013)	Sand dike in front of the ‘old’ dike that is located in Markermeer lake. The ecological design contributes to flood protection and the ecological quality of the lake (Chapter 5).	Flood protection project. GFP design that was abandoned in decision-making.	Yes
9	Oyster reefs (Borsje et al., 2011; Temmerman et al., 2013)	Oyster reefs stabilise intertidal flats and counteract erosion (see section 1.1.4).	Pilot project. Completed.	Yes
10	Coastline maintenance (Borsje et al., 2011; Van Slobbe et al., 2013)	Use of sand nourishments and Aeolian sand transport for flood protection. Sustaining other functions (see section 1.1.4).	Flood protection operative policy.	Yes, to a limited extent. Nature functions are achieved
11	Reed Marshes (Rijkswaterstaat & Deltares, 2013)	Floating mats that are made of willow roots were placed in front of a hard dike structure to enable the formation of reed marshes. Reed marshes have ecological value, improve water quality, dissipate wave energy and foster sedimentation.	Pilot project. Executed between 2008 and 2010.	Yes
12	Soft Sand Engine (Rijkswaterstaat & Deltares, 2013)	Creation of sandy forelands to dissipate wave energy. The forelands also create breeding grounds for birds and can grow with sea level rise provided there is sufficient sediment supply.	Pilot project. Executed between 2011 and 2012.	Yes

1.3.1 Factors hindering realisation of greening flood protection in flood protection projects

Technical as well as governance-related issues hinder the realisation of GFP in flood protection projects. Temmerman et al. (2013) assert that uncertainties about the long-term effectiveness of GFP solutions are an important knowledge gap (Temmerman et al., 2013). Bouma et al. (2014) highlight knowledge gaps that are related to the protective value of vegetation during storm conditions, the long-term resilience of GFP solutions, and understanding the mechanisms that determine thresholds for ecosystem establishment. De Vries et al. (2013) note deficiencies in the tools and protocols that are needed for the assessment of flood protection barriers.

A broad range of governance factors also affect GFP success in flood protection projects. These include the role of stakeholder involvement, governance arrangements, financial issues, legislation and policies for dealing with uncertainties. In two studies on Building with Nature in Marine Infrastructure, Korbee et al. (2014) and Korbee and Van Tatenhove (2013) concluded that BwN designs are unlikely to emerge under traditional governance arrangements that are commonly used in ‘hard’ infrastructural designs. BwN governance arrangements differ in terms of actors, rules and discourses. Enabling conditions include a widened actor coalition, political will to include ecological improvement and an adaptive management strategy (Korbee et al., 2014). The multifunctional nature of GFP solutions gives rise to a broader actor coalition that involves different stakeholders, public administrations and citizens (Van Slobbe et al., 2013), and that coalitions should be involved from the early stages of project development (De Vriend et al., 2014). The public perception of stakeholders and citizens is a crucial factor and may enable or constrain GFP. Citizen protests created opportunities for GFP in the Noordwaard project (see section 1.1.4), but the public perception that valuable reclaimed land should not be returned to the sea strongly impeded the development of salt marshes in the south-western region of the Netherlands (Temmerman et al., 2013). Cheong et al. (2013) addressed the difficulty of traditional cost-benefit analyses for GFP solutions. Inclusion of the ecological benefits of GFP solutions is one of the main challenges. Vikolainen et al. (2014) studied the implications of European nature conservation legislation for GFP. According to their research, the potential for success can be increased when legislation is handled in a proactive way at the early stages of the GFP decision-making process. Several authors have highlighted the need to deal with the uncertainties of GFP instead of ‘just’ developing more knowledge to compensate for an incomplete knowledge base. Uncertainties in GFP solutions also arise from the dynamics and natural variability of ecosystems, which are inherently unpredictable. Several authors have specifically advocated the need for adaptive management practices to deal with this uncertainty (see Borsje et al., 2011; Van Wesenbeeck et al., 2014). Monitoring and evaluation of operational GFP solutions are an important element of such an approach (Borsje et al., 2011; De Vriend et al., 2014; Katsanevakis et al., 2011). Van den Hoek et al. (2012) have stressed the importance of uncertainties that originate from different 'knowledge frames', which lead to different, but equally valid interpretations of the present knowledge, problem or a situation. Different knowledge frames lead to ambiguity that should be dealt with in new types of approaches.

The natural dynamics and combination of functions in GFP designs require different processes of knowledge production, development and use than commonly applied (Brugnach & Ingram, 2012). This topic however has been addressed only to a limited extend. Some authors did highlight the importance of cooperation among different disciplines and experts (e.g., Bouma et al., 2013; Mitsch, 2014). However, these suggestions were restricted to the 'knowledge' domain and did not directly address the relationship between knowledge and decision-making. Further, it is not discussed what the impact of knowledge in decision-making actually is in terms of enabling or constraining GFP in flood protection projects and how knowledge in decision-making can be improved. In the next section I elaborate on this topic.

1.3.2 Knowledge in greening flood protection decision-making

Knowledge is used for the analysis of problems, finding and designing solutions, completing legal procedures and generating public trust and support (Van Buuren et al., 2010b). The involvement of a wide variety of actors, with different and diverging perceptions, interests and backgrounds, often results in debates on knowledge during decision making (Koppenjan & Klijn, 2004). There is not a single supplier or source of objective (scientific) knowledge that can 'speak truth to power'. In fact many different ways of arriving at knowledge are possible. Different actors hold different kinds of knowledge including, expert, bureaucratic and stakeholder knowledge (Edelenbos et al., 2011). Further, flood protection projects form a complex, technological, matter. The Dutch flood protection constitutes a knowledge-intensive domain. Technology and science have played an important role in structuring Dutch flood protection over the last centuries (Van Koningsveld et al., 2008). Knowledge is thus an essential factor in decision-making in flood protection projects.

Knowledge uncertainties and different views of actors makes knowledge in decision-making a delicate process, in which more knowledge does not lead to a solution but rather fosters 'report wars' and 'dialogues of the deaf' (Koppenjan & Klijn, 2004; Van Eeten, 1999). A knowledge perspective then draws attention to a range of such challenges as different and fragmented forms of knowledge, sensitivities around information and the political site of knowledge (O'Toole & Coffey, 2013). The knowledge that is produced and used should be accepted and relevant for the decision-making process and should at the same time be (scientifically) valid. If too much emphasis is put on the former, 'negotiated nonsense' may be the result, while an emphasis on the latter may cause 'superfluous knowledge' to emerge (De Bruijn & Ten Heuvelhof, 1999; Van de Riet, 2003).

Dealing with these knowledge-related challenges is crucial to foster realisation of GFP in flood protection projects. This type of decision-making, which I label 'GFP decision-making', refers to the process of decision-making in flood protection projects that intend to apply a GFP design solution. Knowledge in GFP decision-making has three particular characteristics. These characteristics form the starting point for this research and the construction of a conceptual framework on knowledge in GFP decision-making in the next chapter.

First, GFP decision-making involves plural policy domains that interact. GFP solutions combine nature and flood protection functions[10], and this implies the involvement of the nature and flood protection policy domains. Combining different domains is typically challenging given the different 'domains-specific systems and styles of planning' (Van Tatenhove et al., 2000, p.208). Differences in policy domains hinder integration, which is needed for realising innovations such as GFP (Leroy et al., 2001). In the Netherlands, which form no exception, the nature and flood protection policy domains are characterised by fragmentation (Van Buuren et al., 2010a). Moreover, the flood protection domain is a particular powerful domain, in terms of the actors, resources and rules involved. Both fragmentation and the difference in power inhibit integration. The focus on more integration and participation in the flood protection domain over the last decades may indicate changes in the position and orientation of the flood protection domain (Van Der Brugge et al., 2005; Wiering & Arts, 2006). Nevertheless, flood protection remains the explicit a primarily focus in the flood protection domain along with a preference for technical measures (Jong & Van den Brink, 2013; Van den Brink et al., 2011). The multiple policy domains involved in GFP decision-making implies that knowledge requires more than 'just' integrating different knowledge disciplines, but overcoming differences and fragmentation of policy domains as well.

Second, the flood protection domain is characterised by nested knowledge and knowledge processes. This means that knowledge and knowledge processes are closely intertwined with the policy domain and directly related to the context of development and use. The

[10] As depicted in section 1.2 more functions are often involved, but in this thesis the primary focus is on the nature and flood protection functions

contextual nature of knowledge has been highlighted by various authors as an important feature of knowledge to meaningfully contribute to decision-making (McNie, 2007; Nowotny et al., 2001). The flood protection domain has traditionally been influenced by technology and science (Van Koningsveld et al., 2008; Van Koningsveld et al., 2003). Governmental and research professionals have always had a dominant role (Lintsen, 2002). Today, experts and bureaucrats still form a close network characterised by 'disciplinary congruence and institutionalised relations' (Edelenbos et al., 2011). The strong institutionalised nature of knowledge, knowledge processes and experts in the Dutch flood protection domain inhibit the introduction of new forms of knowledge, including GFP. The preference for technology and engineering knowledge further complicates the introduction of GFP.

Third, GFP is an innovation that introduces a new form of flood protection in flood protection projects. The distinctive context in which an innovation is introduced impacts the potential success of an innovation (Hartley, 2005). GFP introduces new knowledge, values and principles for flood protection that will not automatically fit the flood protection domain. For example GFP solutions are based on natural dynamics, whereas the traditional flood protection approach is based on controlling and ruling out uncertainties. Therefore, dynamics in the flood protection domain will emerge upon introduction of GFP decision-making. Successful realisation of GFP involves adaptation and change in the flood protection domain as well as in the GFP solution in order to arrive at a 'fit' between the two.

1.4 Research objectives and questions

GFP is an emerging approach in Dutch flood protection projects. GFP solutions involve natural dynamics, a contribution to the ecosystem and a combination of nature and flood protection functions. Realisation of GFP in Dutch flood protection projects is still far from standard practice. Knowledge in GFP decision-making is of central importance for GFP success and has not yet been sufficiently assessed. The objective of this research is therefore formulated as follows:

To improve the understanding of knowledge in GFP decision-making and learn how knowledge in GFP decision-making can be improved to support GFP in flood protection projects.

To reach this this objective, I intend to answer the following three research questions in this thesis:

Research question 1 How to understand knowledge in GFP decision-making?

Research question 2	How does knowledge in GFP decision-making enable or constrain GFP in flood protection projects?
Research question 3	How to improve knowledge in GFP decision-making in order to enable GFP in flood protection projects?

1.5 Research approach

The research methodology, case selection and data collection that were used to answer these three research questions are discussed below.

1.5.1 Methodology: case study research

I used the 'case study' approach as a research methodology in this study. Yin (2009) defines a case study as: "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (p. 18). This approach differs from other research methods, such as histories, surveys and experiments. A case study differs from histories in that it relates to a contemporary and on-going phenomenon. It differs from a survey in taking the real-life context into account and it differs from an experiment in that it involves an uncontrolled phenomenon. I consider the case study as the most appropriate method because GFP decision-making in flood protection projects is a real-life and complex phenomenon. It allows GFP decision-making to be studied while it is on-going and it involves all relevant contextual factors.

The unit of analysis in the case study is the GFP decision-making process that precedes a formal decision in a Dutch[11] flood protection project. A flood protection project is a project that is intended to contribute to Dutch flood protection. Whether GFP is actually achieved in the design solution is determined after a formal decision is made on a project. Three criteria are used for the selection of three case studies (see section 1.2). A multiple case studies approach is preferable over a single case study approach, because the empirical basis for the research is stronger. However, this research is limited to three cases because data gathering and in-depth analysis of case studies is a time-consuming process.

The case studies contribute to answering the research questions (section 1.4). In this research, a conceptual framework is constructed (chapter 2) that is based on theoretical insights and informed by characteristics about knowledge in GFP decision-making in flood protection projects (section 1.3.2). This conceptual framework is applied in the three cases

[11] This research concerns flood protection projects in the Netherlands although this is not always explicitly mentioned.

studies and reflected upon to improve the theory. Therefore, conclusions are based on knowledge in GFP decision-making for each case study. The case studies will then be compared. This cross-case analysis (chapter 6) is used to answer the three research questions. A schematic representation of the research design of this thesis is provided in Figure 1.6.

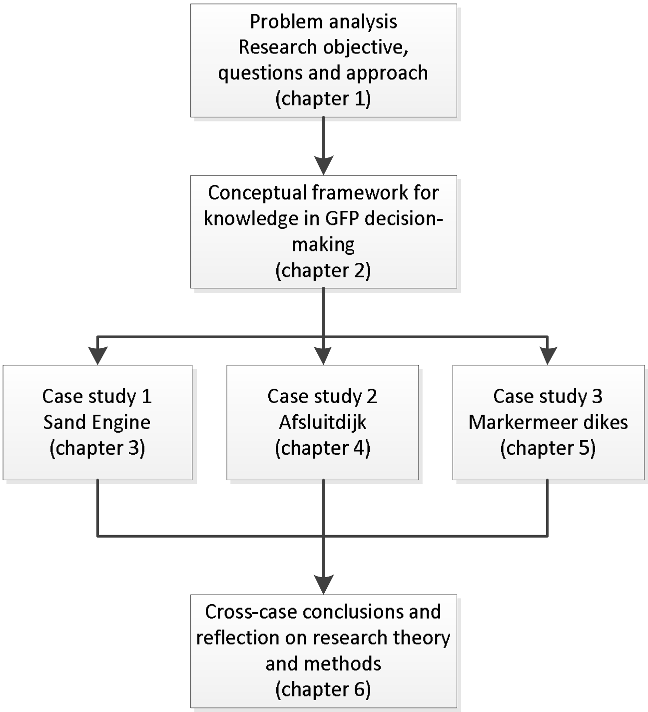

Figure 1.6 Research design of the thesis

An important consideration in case study research is safeguarding the quality of the research to prevent subjective interpretations of the data and generalisability to understand the degree to which case study findings apply to a broader context. A combination of three strategies is employed to prevent subjective interpretation of the case study results. The results of the analyses of the case studies are checked with key informants in the case study. A combination of data sources or ‘data triangulation’ is applied (see section 1.5.3). Last, a conceptual framework, based on theory, is constructed and applied to guide data analysis. Generalisability in case studies implies that “the investigator is striving to generalise a particular set of results to some broader theory” (Yin, 2009, p.43). Such analytical generalisation differs from statistical generalisation (as used in surveys), which is oriented toward generalising to the larger universe. Two strategies are important to safeguard analytical generalisability and allow for theory building (Yin, 2009). First, relationships must be drawn between the case study and the relevant theory. In the present research, a conceptual framework that is based on theoretical insights is constructed and employed in the case studies. Second, relationships must be drawn between the case study and other case studies. In the present research, the same approach is replicated in three case studies. Findings from the case studies are compared in a cross-case analysis.

1.5.2 Case selection

Three criteria were used to select three case studies: the Sand Engine (chapter 3), the Afsluitdijk (chapter 4) and the Markermeer dikes case (chapter 5). These relate to the unit of analysis (GFP decision-making in a flood protection project), representativeness of the case studies (the Dutch flood protection domain and variations therein) and practical considerations (that make it possible to do the research).

The case study should be a Dutch flood protection project that involves GFP decision-making, which means that there is an intention to apply a GFP design solution. The outcome of the case study, the design solution and whether this involves GFP or not, cannot be determined beforehand because the data collection includes real-life observations (section 1.5.3). However, meaningful cases should involve an intention to use GFP in the design solution. This intention was reflected in the objectives of the Sand Engine and Afsluitdijk case studies. The Sand Engine combined four different objectives that included nature and flood protection. The Afsluitdijk project included an intention to use an integral approach and ‘doing more than just flood protection’. The Markermeer dikes case study project itself did not involve an intention to use GFP in the design solution, but the intention was formulated in the national flood protection policy.

The present research concerns flood protection projects in the Netherlands and selected case studies should meet this criterion. However, there are numerous flood protection projects in the Netherlands, and they are very diverse. Projects cover different geographical areas (coastal, lake or river protection), different projects and programmes, and different flood protection functions (with a national or regional orientation). Three case studies can’t represent all these different categories. However, case studies that are limited to one sub-category will not contribute to a more general understanding of knowledge in GFP decision-making in flood protection projects. Covering multiple sub-categories provides a broader understanding of Dutch flood protection projects and their use of knowledge in GFP decision-making. I therefore employed a ‘diverse case’ strategy in case study selection to enhance representativeness of the case studies for Dutch flood protection (Seawright & Gerring, 2008). The primary objective of this strategy is “the achievement of maximum variance along relevant dimensions” (Seawright & Gerring, 2008, p.300). These relevant dimensions are here the type of project or programme within the flood protection domain and the geographical area. Hence, each of the three case studies falls into a different sub-category of Dutch flood protection projects representing a different type of project or programme and geographical area, but have in common that all are part of the flood protection domain and intend to apply a GFP design solution. The Sand Engine is designed to contribute to the maintenance of the coastline, the Afsluitdijk is an infrastructure project, and the Markermeer dikes case study is a project that is within the second High Water Protection Program (HWBP-2). Other sub-categories of flood protection projects are not included. For example, fluvial flood protection projects that fall within the significant Room for the River program are not covered in this research.

The case studies should allow for proper data collection, including observations and document study. These two data collection methods require that the researcher be allowed to study the project closely. The researcher should be allowed to participate as an observer in relevant meetings. The researcher should also be given access to relevant data, including such confidential documents as minutes of meetings, internal notes and e-mail correspondence. In sum, the participants in the case study should support the efforts of the researcher to gather data. I was able to participate closely in each of the selected projects and access was provided to relevant data in each project.

1.5.3 Data gathering and analysis

Direct observation, examination of documents and interviews were used to gather data.

Direct observations are used as a data source in all three case studies. This form of data is important for understanding the context of the case study. Meetings are often recorded in minutes, but information may be lost and information about the atmosphere, such as disagreement, amazement, anger, expectation, inconvenience or confidence, is usually not included. A detailed overview of the observations in the case studies is provided in Appendix I. In the Sand Engine, I attended formal meetings of the project team, public consultation meetings and informal projects gatherings. In the Afsluitdijk project, I attended formal meetings of the project team, project sessions, workshops and informal project gatherings. In the Markermeer dikes project, I attended a formal project meeting, two workshops and a number of informal project meetings. I was given use of a workspace in the Afsluitdijk and Markermeer dikes projects, which allowed me to mingle with the project participants and have many informal conversations. The selection of the occasions for direct observations was pragmatic and was guided by such practical considerations as scheduling and the importance of the meeting as determined by the meeting agenda and the possible participants. I got involved at the end of the decision-making period that was under study[12] in the Sand Engine and the Markermeer dikes projects. I had many more opportunities to use direct observation In the Afsluitdijk project[13].

Documents are a very important data source. Documents record the information of a case study and are therefore a form of ‘hard’ evidence. There is a variety of interesting and relevant documents, including formal (research) reports, contracts, minutes of meetings and (e-mail) correspondence. I had access to much of the project documentation in each case study. I had access to the digital project archives of the Afsluitdijk and the Markermeer dikes projects, which contained many different kinds of documents. Different informants provided documentation in the Sand Engine project.

Interviews are the third main source of data. Interviews allow for asking specific questions and gaining insight into the different perspectives of the people who are involved. The selection of respondents is very important. The respondents should represent different roles and perspectives in the project. An overview of the interviews that were conducted is provided in Appendix I. The interviews were scheduled after a period of orientation in the project that involved observations and document study. Selection of the respondents was based on: 1) the contacts and information that had been gained during the first period of observation and document study, 2) ‘snowballing’, in which the respondents were asked to identify other relevant respondents at the end of each interview and 3) a checklist of the ‘type’ of respondents that had to be covered at a minimum. This included a ‘policy’ and a ‘knowledge’ person in the flood protection and nature domain. All interviews were documented in reports, and respondents were asked to review and approve the interview reports. A deadline was established to acquire indirect approval by the respondent.

Examples of the questionnaires that were used in the case studies are included in Appendix II. The interviews in the Sand Engine were structured in a semi-open manner, and they were guided by a particular set of pre-established questions. In the Afsluitdijk and the Markermeer dikes projects, the interviews were conducted in a more open manner that followed the ‘clean language approach’ (Grove & Panzer, 1989; Lawley & Tompkins, 2000). The clean language approach is intended to minimise unintended influence of the interviewer. The ways in which questions are asked directly impact on the answers that are given by the interviewees, which is a phenomenon that is also known as ‘priming’ (Van

[12] I got involved in the Sand Engine project in October 2009. The formal decision that marked the end of the decision-making period under study was made at the end of December 2010. The first observation In the Markermeer dikes project was in October 2012, and the formal decision that marked the end of the decision-making period was made in February 2013.

[13] The first contact was in June 2010, and the formal decision that marked the end of the decision-making period was made December 2011

Helsdingen & Lawley, 2012). This approach was valuable because I had already developed an understanding of the case prior to doing the interviews. A central feature of the clean language approach are 'ultra-open' questions that contain as few assumptions and metaphors about the respondent as possible (Sullivan & Rees, 2008). The ultra-open questions allow the story of the respondent to be almost totally independent of the ideas and words of the interviewer, and the respondent has maximum freedom to choose the answer that he or she considers to be suitable. The interviewer structures the ideas and opinions of the respondent and encourages the respondent to elaborate (Sullivan & Rees, 2008; Van Helsdingen & Nijburg, 2012). The structure of the interview consists of four main elements: 1) some introduction questions to understand the position of the respondent, 2) one central question that covers the topic of the interview, 3) a set of clarification questions and 4) a checklist that is to be used at the end of the interview to determine if all topics that the interviewer deemed to be relevant were covered.

Besides the formal interviews, informal interviews were also an important source of information. Many informal meetings contributed to the understanding of the case studies in the Afsluitdijk and Markermeer dikes projects.

Data analysis followed the conceptual framework (chapter 2). In this framework the main elements and relations to be studied come to the fore, such as actors and their coalitions, rules and regulations, discourses, resources and knowledge bases that are found in the different policy domains of nature and flood protection. The found data are classified according to the policy domain and dimension within to generate an overview of the respective 'knowledge arrangements' (see chapter 2). Moreover a timeline is included for understanding the dynamics in this setting. Classification of the data was supported by the usage of Excel files. To determine the outcome of GFP decision-making in terms of the design solution and whether or not this reflects GFP, first a formal decision on the design solution is indicated. Second, this formal decision is assessed in terms of the three GFP characteristics, which were formulated in section 1.2.

1.6 Outline of the thesis

A conceptual framework for knowledge in GFP decision-making in flood protection projects is constructed in Chapter 2. This framework is based on theoretical insights and is informed by the three characteristics regarding knowledge in GFP decision-making.

Chapters 3, 4 and 5 present empirical analyses of the three Dutch case studies. These analyses are guided by the conceptual framework of interacting knowledge arrangements. The particular insights and the interesting aspects differ in the different case studies. The chapters on the Sand Engine and Afsluitdijk projects have already been published in scientific journals. The chapter on the Markermeer dikes project is under review for publication in a scientific journal. The particular focus of the journal, specific requests by the reviewers, particularly interesting aspects of the individual case studies and the fact that the case studies were published or submitted during the on-going research process cause the chapters to vary slightly in focus and approach.

Chapter 6 combines the insights from the case studies in a cross-case analysis, which forms the basis for answering the research questions. This chapter includes the conclusions and recommendations of this research. There is also a reflection on the research and an outlook for GFP decision-making in the Netherlands.

2 Interacting knowledge arrangements, a conceptual framework

In chapter 1, an introduction was provided with regard to the scope of the research, the problem under study, the objectives and research questions, and the methodology. In brief, I concluded that although Greening Flood Protection (GFP) is an emerging approach in Dutch flood protection knowledge, policy and politics, GFP in flood protection projects remains scarce. This research addresses knowledge in GFP decision-making in flood protection projects and the way knowledge functions to enable or constrain GFP in flood protection projects.

This chapter addresses the development of a conceptual framework for knowledge in GFP decision-making[14]. In the introduction, I identified three characteristics of knowledge in GFP decision-making in flood protection projects (see section 1.3.2). These three characteristics make up the requirements for the development of a conceptual framework on knowledge in GFP decision-making. I also presented the methodology of the case study research. This methodological choice implies a fourth criterion for the conceptual framework. In sum, the conceptual framework for knowledge in GFP decision-making should fulfil the following criteria:

1. Recognise the plurality of policy domains that interact and are involved in GFP decision-making. GFP decision-making requires the combination of policy domains related to nature and to flood protection.
2. Acknowledge that knowledge and knowledge processes are nested in particular policy domains, or, in other words, that they are 'contextual'. The Dutch flood protection policy domain has a long tradition in which governmental and research professionals as well as technology play a dominant role.
3. Allow for an assessment of dynamics and change. Greening flood protection introduces an innovation in routine flood protection practices. It is not just the

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[14] Although not mentioned explicitly in the remainder of this chapter and thesis, knowledge in GFP decision-making refers to knowledge in GFP decision-making in flood protection projects

knowledge that will change due to such an innovation, the policy domain is expected to change as well to arrive at a fit between the two.

4 Allow for empirical research. Three flood protection project case studies, which intend to arrive at a GFP design, will be analysed. A proper analysis requires a conceptual framework that is sufficiently operationalised to be applied in empirical case study research.

The approach to the development of a conceptual framework is as follows. As a starting point, I take the literature on knowledge in decision-making and identify three conceptually different models. These models are evaluated on the above-mentioned four criteria for a conceptual framework. The models provide a good overview and starting point, but none of them meets all four criteria. To complement the models on knowledge in decision-making, I introduce the policy arrangement approach (Arts & Leroy, 2006; Van Tatenhove et al., 2000). The policy arrangement approach was developed to study dynamics in the environmental policy domain. Combining insights from the literature fields, in section 2.3, I define a conceptual framework of interacting knowledge arrangements to study knowledge in GFP decision-making in three case studies.

2.1 Models on knowledge in decision-making

Knowledge in decision-making is understood in different ways. Based on the literature, I identify three models: the linear model, the co-production model and the Ways of Knowing (WoK) model. In each model, the relation between knowledge and decision-making is understood in a different way. This section ends with an evaluation of the three models using the four criteria for a conceptual framework.

2.1.1 Linear model

The linear model (Röling, 1992) represents a conventional understanding of the relation between science and policy based on a 'two-communities' perspective (Caplan, 1979). The two communities represent the worlds of science and of policy. In the concept of two communities, science and policy are separate worlds that are characterised by different languages, values, reward systems, rationalities, and logics. Science can be distinguished from other activities by means of universal criteria (Merton, 1973). This model assumes a 'science-based fix for all societal problems' (Röling, 1992, p. 46). Consequently, a central problem is the non-utilisation of science by policy-makers. Solutions to this 'gap' between science and policy are found by improving the quality and quantity of communication from science to policy (Caplan, 1979) to transfer and translate scientific output (Van Kerkhoff & Lebel, 2006).

The linear model has been criticised for a number of its basic assumptions, and there is currently broad consensus that the model is inadequate for understanding the complex relation between science and policy. The following three points summarise the most important criticism. First, the context of science production is ignored in the linear model. This context includes, for example, the research funds and time available, the location of the work and the background of the researcher (Van Kerkhoff & Lebel, 2006). These ‘personal and practical dimensions of science’ affect the production and output of science. Second, the idea of universal criteria is problematic. Gieryn (1983, 1995) has shown that the boundaries between science and non-science are not natural and fixed but can be changed and contested. Third, the particular perspective a researcher holds in knowledge production is not included in the linear model. Science is the result of a particular interpretation of the researcher; consequently, multiple, different and conflicting interpretations of science are possible. The linear model ignores the contribution of other knowledge providers and sources (Röling, 1992). These three arguments support the claim that science is hardly as autonomous, certain and accepted as suggested in the linear model (Van Kerkhoff & Lebel, 2006).

In sum, the unrealistic nature of the linear model is now widely acknowledged. Likewise, the linear model is not applicable as a conceptual framework for knowledge in GFP decision-making. Such a model should acknowledge that science is not the only source of knowledge and that context influences knowledge creation (criteria 2). In the next section, I will introduce the co-production model, which addresses a number of the flaws in the linear model.

2.1.2 Co-production model

In the co-production model, the worlds of science and policy collectively produce knowledge (Turnhout & Leroy, 2004). This contrasts with the linear model, where knowledge is the exclusive domain of science. The main argument underpinning the co-production model is that science is ‘socially constructed’ and not a natural authority. Science is a constructed ‘fact’ resulting from prevailing values and perspectives about the status of science. As such, the authority and domain of science is changeable and will change when its context alters. The status of science and the criteria that distinguish science from non-science are then the result of ‘boundary work’ (Gieryn, 1983, 1995; Jasanoff, 1990). Gieryn (1983) summarises: ‘[S]cience is no single thing: its boundaries are drawn and redrawn, in flexible, historically changing and sometimes ambiguous ways’. Whereas in the linear model, the relation between science and policy is static (i.e., the boundaries do not change and the different responsibilities are clear), in the co-production model, the ‘science-policy interface’ becomes a blurred arena where science and policy overlap without clear boundaries (Turnhout et al., 2007).

The boundary work concept has generated ample attention in the literature. Different boundary arrangements are introduced to describe how boundaries can be shaped to efficiently connect. Two distinct examples are the boundary object and the boundary organisation. Star and Griesemer (1989) introduced the boundary object to address science as a heterogeneous activity, claiming that most scientific work is conducted by diverse groups of people. The boundary object is used for ‘translating between viewpoints’ or ‘social worlds’ and is defined as ‘an analytic concept of those scientific objects which both inhabit several intersecting social worlds [. . .] and satisfy the informational requirements of each of them [. . .]. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognisable, a means of translation’ (Star & Griesemer, 1989, p.393; Turnhout, 2009). Boundary objects can be maps, models, pictures, prototypes or other objects. Turnhout (2009) concludes that the ambiguity and flexibility of the boundary object determine its effectiveness. Lejano and Ingram (2009) explain the effectiveness of boundary objects through their ability to facilitate network interactions and the co-production of meaning. The ‘boundary organisation’ was introduced by Guston (1999, 2001) as a stabilising boundary arrangement that can address the dynamics of boundary work. Dynamics are perceived as a risk that may lead to confusion and instability. The boundary organisation involves representatives from science and policy and serves as a frontier for both. Boundary organisations have distinct lines of accountability to science and policy.

Science has no exclusive status in the co-production model. Therefore, this model allows multiple different forms of knowledge. In addition to scientific or expert knowledge, practical or lay knowledge can inform policy developments (Eshuis & Stuiver, 2005; Hommes, 2008; Rinaudo & Garin, 2005). Lay knowledge is held by stakeholders, grounded in their experiences and bound to particular locations. Another form of knowledge is ‘bureaucratic knowledge’ (Edelenbos et al., 2011). This type of knowledge is located in administrative and governmental practices and concerns the processes and contexts that are relevant here, including, for example, the knowledge of decision-making or legal processes and (relations among) relevant stakeholders (Hunt & Shackley, 1999).

The knowledge that is required or relevant in a particular policy setting is a central concern in the co-production model. The challenge is to produce knowledge that is credible, salient and legitimate (Cash et al., 2003). Credibility means the knowledge is scientifically valid, saliency means the knowledge is sufficiently attuned to the needs of decision-makers, and legitimacy relates to the knowledge production process, which should be unbiased and fair. To achieve such knowledge, new forms of knowledge production are developed that involve practices of participation, integration, learning and negotiation between scientists and policy makers (Van Kerkhoff & Lebel, 2006). A risk of collectively determining and developing knowledge is an excessive focus on discussion at the expense of knowledge content, resulting in 'negotiated nonsense' or excessive focus on content at the expense of relevance for the decision-making context, resulting in 'superfluous knowledge' (Van de Riet, 2003).

In sum, in the co-production model, science is just one of the possible types of knowledge. The relation between knowledge and policy is dynamic and subject to boundary work. The boundaries between knowledge and policy are continuously negotiated and changed in a fuzzy area where knowledge and policy worlds overlap. The co-production model recognises that knowledge is inherently related to the context (criteria 2) and allows for the assessment of dynamics and change (criteria 3). However, it does not involve the plurality of policy domains that interact in GFP decision-making (criteria 1), and the main focus remains on interactions between the worlds of knowledge and policy.

2.1.3 Ways of Knowing model

The WoK model is reflected in a small but growing body of literature in which discussions on knowledge are not found at the boundary between knowledge and policy fields but at the boundary between multiple science-cum-policy fields. These science-cum-policy fields are conceptualised as 'Ways of Knowing' (Feldman et al., 2006; Schneider & Ingram, 2007; Van Buuren, 2009), knowledge coalitions (Van Buuren & Edelenbos, 2004), knowledge frames and networks (Dewulf et al., 2013) or knowledge systems (Coffey & O'Toole, 2012).

WoKs were first introduced in a paper by Feldman et al. (2006) as a way to 'understand the structuring of knowledge that is associated with policy issues' (p.89). Since this first introduction, the concept has been applied by a number of scholars to explain how knowledge is developed and results from different WoKs (Lejano & Ingram, 2009); how policy entrepreneurs can manage and influence policy processes by altering or integrating different WoKs (Feldman et al., 2006); how the fluidity of knowing enables change and transitions (Ingram & Lejano, 2009); and how knowledge inclusion can be organised among multiple bodies of conflicting knowledge (Van Buuren, 2009).

Feldman et al. (2006) defined WoKs as 'dynamic networks of heterogeneous objects' (p. 90). The WoK network consists of human and nonhuman elements, including actors, knowledge, techniques, events and others, and is tightened by associations that need continuous renewal to remain stable. As such, the network is fluid and dynamic, and there is a potential for change in the continuous enactment and re-enactment of relations. Change can be established by introducing new objects to the network, changing associations or combining different WoKs. In an extensive conference paper, Schneider and Ingram (2007) addressed the meaning and implications of WoKs in detail. They defined the WoK as 'how one interprets the elements in a policy space and makes sense of the relationship among them. It is a narrative or story that holds all of the pieces together in a relatively coherent way. The elements include people, objects, ideas and relationships among them' (Schneider & Ingram, 2007, p.2). These two definitions show inconsistency in specifying what a WoK actually is, with Feldman et al. (2006) defining WoKs as a network and Schneider and Ingram (2007) defining them as a narrative or story.

A WoK gives rise to particular types of knowledge, knowledge production, involvements of knowledge actors and knowledge sources. Depending on the WoK, the role and type of knowledge that is accepted can vary significantly (in terms of the co-production model, boundaries between knowledge and policy in different WoKs are drawn in different ways). Whereas in one WoK, understanding an issue may be informed by scientific research, in another WoK, lay knowledge may serve as the main source of information. The structure of a WoK determines the valid forms of knowledge production and what type of knowledge is credible, salient and legitimate (Lejano & Ingram, 2009). Conflicts over knowledge therefore occur mostly *between* WoKs and not *within* WoKs because differences can be found between WoKs. As WoKs are inherently dynamic, so is knowledge in WoKs. 'Knowing' as opposed to knowledge is emphasised in the WoK model: 'a [WoK] can be distinguished from knowledge in that it emphasises the *active* dimension of knowing a problem' (Schneider & Ingram, 2007, p.4, emphasis added). A focus on only knowledge would divert attention from the importance of action (Feldman et al., 2009). Knowing implies a focus on the process rather than on static outcomes and includes knowledge *processes,* such as knowledge production and gathering data, as well as making meaning of knowledge. As Van Buuren (2009) summarises, 'a WOK comprises different knowledge processes [….] linked with the three essential processes of knowing *what, why* and *how*' (p.211). This focus on the processes of knowing 'allows [us] to understand how to engage people in entertaining new and different ways of knowing' (Feldman et al., 2009, p.125).

Multiple WoKs are often present around policy issues (see Box 2.1 for two examples). Different interests, beliefs, disciplinary orientations, education, and experiences give rise to different WoKs and thus to the presence of multiple WoKs. This multiplicity may be a source of conflict or fragmentation in policy strategies and plans and may inhibit collective decision-making (Van Buuren, 2009). At the same time, it can provide an opportunity. The dynamic and fluid nature of WoKs makes confrontation among WoKs a factor of change. This factor may change relations within WoK networks or introduce new elements, which can be opportunities for new and inclusive understandings.

Box 2.1: Examples of multiple WoKs

Feldman et al. (2006) provide an example of multiple ways of knowing around agriculture production. One way of knowing agriculture production is the uniform and cheap production of crops for consumers. The network consists of farmers, consumers, manufacturers and chemical companies that provide fertilizers and pesticides. Another way of knowing agriculture production is the production of safe and healthy food for consumers by means of environmentally friendly production methods. This way of knowing network does not involve fertilizers or pesticides but includes certification procedures and labels to inform consumers about the healthy characteristics of the products.

In a similar way, multiple ways of knowing can be identified around the development and maintenance of flood protection barriers, such as dams. Dams provide protection against floods, may save the lives of those living and working in the hinterland, and allow for economic development in the region. The network may consist of the flood protection agency, the constructers of the barriers and institutes that calculate and establish methods to assess flood protection levels. Another way of knowing dams could be as ecological barriers. Dams serve as barriers by inhibiting natural processes such as fish migration, interaction between fresh and salt water and sedimentation. This network is made up of environmental NGOs, fisheries, ecologists and knowledge about the development of species, habits and ecosystem processes. The parallel existence of the two ‘dam’ WoKs may feed conflict when the construction or reinforcement of a dam is on the agenda. NGOs may put great effort into preventing dam building and ecological damage, while flood protection agencies aim to provide the required flood protection levels and a plan for timely construction.

The operationalisation of WoKs constitutes the weak part of the body of literature. There is no uniform understanding of what a WoK is. WoKs seem to include any element that affects ways of knowing without providing a form of ordering among these elements or setting a boundary for what is inside and what is outside the WoK. As a result, a systematic analysis to operationalise WoKs for empirical research becomes seriously complex. In a special issue on WoKs, Feldman and Ingram (2009) confirm this observation, stating, ‘[W]e have found the concept of ways of knowing attractive and elusive, and we come to this writing with only a rough idea of what a way of knowing is and what it is not’ (Feldman et al., 2009, p. 124). Explicating the WoK model thus requires additional effort. Other authors have used different concepts for a similar understanding of knowledge and knowledge processes in decision-making. Three of these approaches may inform the explication of the WoK model: the knowledge coalitions by Van Buuren and Edelenbos (2004), the knowledge frames and networks by Dewulf et al. (2013) and the knowledge systems by Coffey and O'Toole (2012).

Examining the origin of knowledge conflicts, Van Buuren and Edelenbos (2004) revisited the problem of knowledge production and argued that ‘the main problem in the production and transfer of knowledge lies not so much in the division between a scientific world and a policy world as traditionally is argued, but more in a departmentalisation of different knowledge coalitions that consists of both knowledge providers (scientists, advisors and so on) and users (such as policy-makers)’ (Van Buuren & Edelenbos, 2004: 290). In a case study, these authors show how knowledge is developed in isolated groups of closely interacting knowledge and policy stakeholders who represent similar perspectives on the issue at hand. The actors in the knowledge coalition have a certain relationship, operate according to particular rules of the game and understand knowledge in a particular way.

Dewulf et al. (2013) explored theories of knowledge to arrive at a ‘dynamic view on knowledge frames and networks’ that they apply to the issue of climate change. In line with the above, they argue that ‘the crucial barrier in science-policy relations is not always at the border between policy makers and researchers in a particular policy domain but between policy makers and researchers from different policy domains (Van Buuren & Edelenbos, 2004), or in other words: between different knowledge frames and networks’ (Dewulf et al., 2013, p.243). A knowledge frame entails a particular perspective on knowledge: what knowledge is relevant, how one should arrive at knowledge, how one should use it and the like. Dewulf et al. (2009) apply an ‘interactional approach to framing’ that implies that frames and perspectives are created in networks of interacting actors. Networks – informed by configuration theory (Termeer & Kessener, 2007) – are understood as places where people interact, develop shared meaning and produce knowledge informed by a particular perspective. This knowledge, in turn, informs and structures the network. These networks and the ideas within them tend to stagnate due to frequent interactions among similar actors, whereas dynamics arise from confrontation among networks with different perspectives. In their approach, Dewulf et al. (2013) stress that a cognitive approach to framing and knowledge – a frame as a ‘representation stored in memory’ – is less appropriate because it ignores the relational aspect of framing, in which perspectives and knowledge result from interactions among actors.

Coffey and O'Toole (2012) study knowledge dynamics in coastal management processes and introduced an analytical framework of ‘knowledge systems’. They understand coastal knowledge systems as ‘a dynamic intersecting network of multiple separate knowledge systems, each of which represents diverse values and world views, and which are advocated to varying degrees by different organisations and individuals’ (p.324). In line with Dewulf et al. (2013), they argue for a framework that combines ‘ideational’ aspects, including perspectives and discourses, and ‘networks’, in which actors and institutions are central. They explicitly acknowledge that analysing the multiplicity of knowledge systems is necessary to understand knowledge dynamics. For the empirical analysis of these knowledge systems, a 'mixed-methods' approach is introduced that combines insights from stakeholder analysis, network analysis, institutional analysis and discourse analysis.

In sum, the WoK model (comprising insights from four concepts with similar ideas: WoKs, knowledge coalitions, knowledge frames and networks and knowledge systems) understands knowledge and policy as a coherent and dynamic whole and therefore meets criteria 2 and 3 for a conceptual model of knowledge in GFP decision-making. A plurality of WoKs (criteria 1) is fundamental in the model as the central boundary is between and not within knowledge-cum-policy fields. Operationalisations of WoKs are not yet fully crystallised (criteria 4). The examination of conceptualisations draws attention to networks of interacting actors and perspectives on policy issues and knowledge. In networks, actors interact while developing shared meaning and interaction rules. Consequently, a shared perspective is developed on policy and knowledge. Knowledge results from the interactions in the network and the perspectives on knowledge. In turn, knowledge informs and structures the network. A 'relational' understanding of knowledge informs this model, meaning that knowledge is built and understood in interaction among actors. A schematisation is presented in Figure 2.1.

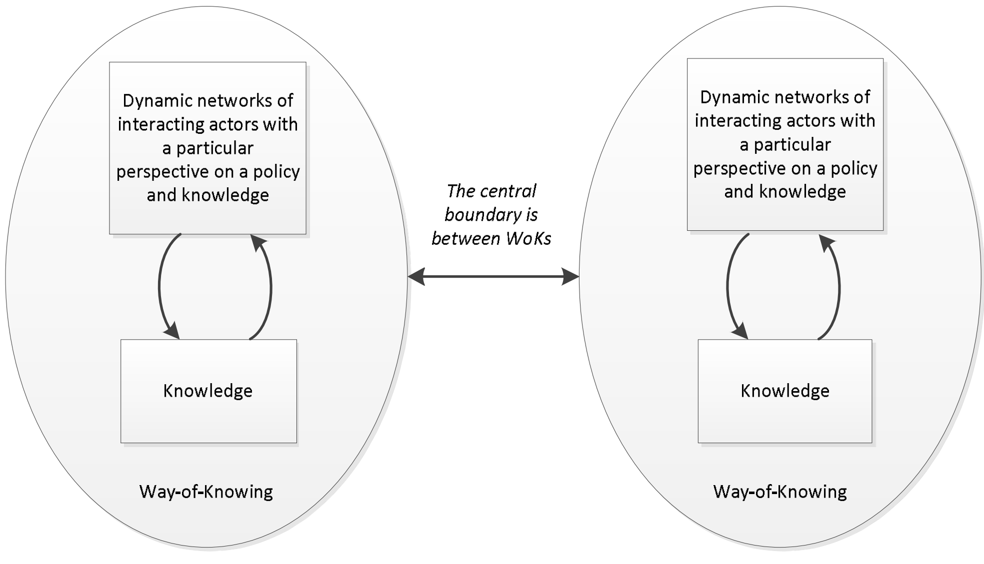

Figure 2.1 Schematisation of the WoK model

2.1.4 Evaluating models on knowledge in decision-making

I identify three different models that represent different understandings and conceptualisations of knowledge in decision-making: the linear model, the co-production model and the WoK model. The first two models prioritise the boundary between knowledge fields and policy fields, whereas the latter prioritises the central boundary of knowledge-cum-policy fields, treating knowledge and policy as a coherent whole (Figure 2.2).

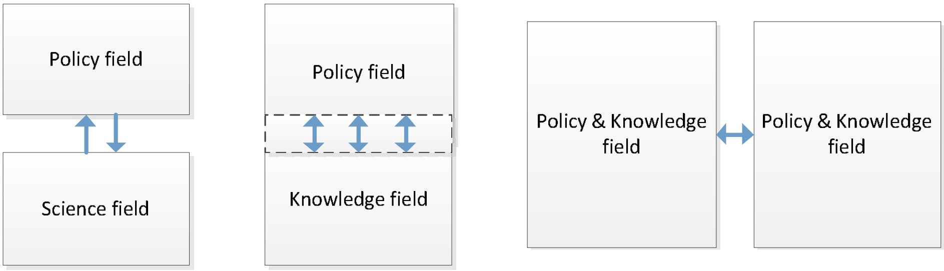

Figure 2.2 Three models representing different understandings of knowledge in decision-making

In the introduction of this chapter, I formulated four requirements a conceptual framework should meet to enable analysis of knowledge in GFP decision-making in the empirical research. I evaluated three models of knowledge in decision-making (summary in Table 2.1). The linear model is not applicable because it only meets the requirement that the framework should allow for case study analysis. The co-production model acknowledges the nested nature of knowledge in policy domains but lacks a focus on the interactions between domains. Moreover, although it recognises the nested nature of knowledge and knowledge processes, it also problematises this relation. The WoK model meets three criteria for the plurality of policy domains, the nested nature of knowledge and knowledge processes, and dynamics and change. However, the drawback of this model is its conceptual vagueness. It is still in the process of development and is not yet fully crystallised. Therefore, the WoK model is not applicable as a conceptual framework for case study analysis. For that, further operationalisation is required.

Table 2.1 Evaluation of three models on knowledge in decision-making

Model: / Requirement:	Linear model	Co-production model	Ways of Knowing model
1. Plurality of policy domains	No – focus on science-policy interactions	No – focus on knowledge-policy interactions	Yes – focus on WoK-WoK interactions
2. Knowledge and knowledge processes are nested in policy domains	No – science and policy boundaries are independent of policy domains	Yes – knowledge is contextual and thus nested in a particular policy domain	Yes – knowledge and policy form a coherent whole
3. Assessment of dynamics and change	No – this model assumes fixed boundaries	Yes – this model assumes negotiable and dynamic boundaries	Yes – this model assumes continues dynamics
4. Allow for empirical research	Yes – empirical analysis has a focus on knowledge transfer and translation to enable science utilisation	Yes – empirical analysis has a focus on processes of boundary work to establish credible, salient and legitimate knowledge	No – this model is not yet fully crystallised

Because none of the presented models on knowledge in decision-making meet all four criteria for a conceptual framework, additional theory is needed to construct a conceptual framework for knowledge in GFP decision-making. In the next section, I introduce the policy arrangement approach (Arts & Leroy, 2006; Van Tatenhove et al., 2000). I use this theory to complement the WoK model on the fourth criterion and allow for a more systematic operationalisation of it. The policy arrangement approach has been very effective in analysing stability and changes in policy domains. Although it does not explicitly involve knowledge (processes), there are three reasons that make it an attractive approach. First, the policy arrangement approach has a significant track record in empirical applications in a broad range of fields. The use of four different dimensions in the policy arrangement allows for operationalisation in case studies. Second, the policy arrangement approach was developed to analyse policy domains. In this research, a plurality of policy domains is a key characteristic of GFP decision-making (criterion 1 for a conceptual framework). The WoK model does not explicitly recognise multiple policy domains but merely focuses on different perspectives. Last, four interrelated dimensions are central to the policy arrangement approach: actors and coalitions, rules and regulations, resources, and discourses. The policy arrangement approach thus covers the idea of networks of interacting actors with particular perspectives used in the WoK model and can be regarded as complementary to the WoK model.

2.2 Policy Arrangement Approach

The policy arrangement approach (Arts & Leroy, 2006; Van Tatenhove et al., 2000) was initially developed to analyse and explain change and stability in environmental policy processes. The authors aimed for an approach that recognised the 'plurality and dynamics of the institutionalisation of environmental politics and policies' (Van Tatenhove et al., 2000: 30). In their argument, stability and change in the environmental domain are the result of two dualities: the duality of structure and the substantive-organisation duality. The authors situate the policy arrangement approach in the middle of these two dualities by aiming for a 'practical "meso level theory" or approach' (Leroy & Arts, 2006: 5). This approach functions as a 'bridging concept' (Van der Zouwen, 2006) that connects different ideas in social science theory.

The duality of structure is rooted in the work of Giddens (1984, 1990) and brings to the fore the duality between strategic and structural change. Strategic change relates to the interactions among actors and innovations in day-to-day policy processes. Structural change relates to structural processes in society, understood as 'political modernisation'. Structural processes include, for example, globalisation, the rise of ICT and Internet usage, Europeanisation or individualisation. These developments reflect changing relations between the state, market and civil society and imply new and changed forms of governance, such as multi-level, multi-actor and multi-sector governance (Wiering & Crabbe, 2006). The authors of the policy arrangements approach explain policy change by both strategic and structural change. The focus in this research on knowledge in GFP decision-making in projects aligns with the day-to-day policy processes in the policy arrangement approach rather than the structural processes. These day-to-day processes are reflected in the concept of policy arrangements, where the substantive-organisation duality is found.

2.2.1 The concept of policy arrangements

The concept of policy arrangements is designed to analyse change in daily policy processes. The policy arrangement reflects the second duality: the substantive-organisation duality. This duality reflects a debate in the social sciences where change is explained either by focusing on framing, cognitions, and other substantive factors or by material and organisational factors, such as rules, resources and relations. The concept of policy arrangements comprises both explanations because they consist of four dimensions (Table 2.2): one substantive dimension of 'discourse' and three organisational dimensions, 'actors and coalitions', 'resources' and 'rules and regulations' (Arts & Leroy, 2006; Van Tatenhove et al., 2000). A policy arrangement is defined as the 'temporary stabilisation of content and organisation of a particular policy domain at a certain policy level or over several policy levels' (Van Tatenhove et al., 2000: 54). The four dimensions are inherently interrelated, meaning that a change in one of the dimensions is likely to imply changes in other dimensions (Liefferink, 2006). Consequently, the policy arrangement is a dynamic concept. To illustrate this interrelatedness, policy arrangement scholars have schematised policy arrangement as a tetrahedron (Figure 2.3) (Leroy et al., 2001). The 'policy domain' as used in the definition of policy arrangements is described rather broadly: 'all policy practices with regard to an issue, such as climate change, nature conservation, acid rain and the like' (Van Tatenhove et al., 2000: 54). The delineation of the policy domain can be accomplished by either focusing on institutional boundaries, such as formal legislation, the responsibilities of particular government authorities (e.g., ministries), and policy documents or by the actions of actors that challenge existing boundaries, such as proposals to change responsibilities.

Table 2.2 The four dimensions of the policy arrangement

Dimension	Explanation
Discourse	The discourse dimension captures the views and narratives of the actors involved. It reflects the storylines that are told in a particular policy arrangement and provide meaning to a particular policy domain (Van Tatenhove et al., 2000). Discourses include notifications about what is conceived as a problem and what is not, possible solutions and how these should be achieved. It represents ideas and views about who relevant stakeholders are and what type of knowledge or science is relevant. Moreover, discourse can be characterised by the use of particular concepts such as 'sustainability', 'cost-efficiency', or 'eco-products'. The discourse dimension in the policy arrangement is inspired by the work of Hajer (1995) and Dryzek (1997) on discourse theory.
Actors and coalitions	The actors and coalitions dimension refers to the actors involved in the policy arrangement and how these relate to one another. Actor coalitions reflect groups of actors that are related to each other, share goals and engage in collective action. This relation can be based on (resource) dependency, shared beliefs, or a shared interest in a particular solution (Meijerink & Huitema, 2010).
Rules and regulations	Rules and regulations refer to the formal and informal rules that structure the actions of actors. Formal rules include, for example, legislations, official agreements or contracts, whereas informal rules relate to unwritten agreements and culture that structure the behaviour of actors and affects what type of action is accepted and what is not. Rules structure the procedures, interaction processes and boundaries of the policy arrangement and thereby enable and constrain the actions of actors.
Resources	The resource dimension relates to the (division of) resources and related power. It concerns the actual resources available, such as money or knowledge, as well as the ability of actors to employ specific resources related to power. Power is determined by the scarcity of a resource as well as by its importance in a particular domain.

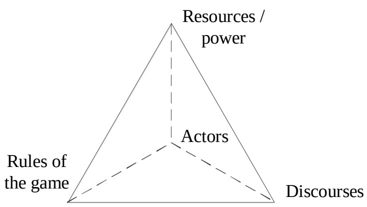

Figure 2.3 Schematisation of the policy arrangement (Leroy et al., 2001; Liefferink, 2006)

2.2.2 Evaluating the policy arrangement

The policy arrangement approach is introduced to complement the WoK model. It is an analytical framework that allows for the analysis of stability and change in a policy domain. For this research, the concept of a policy arrangement itself, as a framework for analysing day-to-day interactions, is of central concern.

The policy arrangement is compatible with the WoK model and provides added value. Compatibility is found on three aspects. First, both the policy arrangement and the Wok model combine ideas of networks and perspectives. In the policy arrangement, networks of actors and the related interactions of rules and resources are found in the three organisational dimensions, and the particular perspective is reflected in the substantive 'discourse' dimension. Second, both approaches emphasise dynamics and change. Third, both recognise a multiplicity of policy domains or ways of knowing and the impact of their interaction. The main advantage of the policy arrangement vis-à-vis the WoK model is its suitability for empirical research; the policy arrangement approach has been applied by many scholars in various policy fields. Applications can be found in water management, spatial planning, nature conservation, marine infrastructure, and road infrastructure (Buizer, 2008; Hegger et al., 2012a; Korbee et al., 2014; Seijger et al., 2013; Van der Zouwen, 2006; Wiering & Arts, 2006; Wiering & Immink, 2006). Moreover, the policy arrangement is explicitly oriented towards policy domains, in contrast to the WoK model. In this research, the plurality of the policy domains of nature and flood protection is assumed as a particular characteristic of knowledge in GFP decision-making.

Knowledge and knowledge processes are only addressed to a very limited extent in the policy arrangement. Knowledge is identified as a resource and may constitute part of the discourse, but it has no central role. An understanding of knowledge and knowledge processes, including producing, using and sharing knowledge, is not conceptualised or emphasised in the framework. By focusing on knowledge as a resource that is possessed by actors and affects power distribution, emphasis is placed on a 'cognitive' understanding of knowledge. In such an understanding, knowledge is regarded as "a thing that can be transferred from one container or mind to another container or mind" (Bouwen & Taillieu, 2004: 146). The relational understanding of knowledge that is central to the WoK model, in which knowledge and meaning occur in interaction and processes of knowledge production, sharing and using come to the fore, is largely neglected.

2.3 Conceptual framework: interacting knowledge arrangements

In this section, I introduce the conceptual framework for analysing knowledge in GFP decision-making in flood protection projects. The construction of this conceptual framework is informed by characteristics of knowledge in GFP decision-making in flood protection projects (section 1.3.2) and the theories explored in this chapter. The conceptual framework is titled, ‘interacting knowledge arrangements’. In section 2.3.1, I first describe the conceptual framework. In section 2.3.2, I introduce four different modes of interaction that may exist between knowledge arrangements. Lastly, I reflect on the meaning and usage of the conceptual model.

2.3.1 Interacting knowledge arrangements

The WoK model and the concept of a policy arrangement form the basis of the conceptual framework (Figure 2.4 provides a schematisation of the conceptual framework). The conceptual framework is designed along the lines of the WoK model and operationalised by means of the four dimensions of the policy arrangement. The following ideas of the Wok model are employed: knowledge and policy fields make up a coherent and dynamic whole; multiple WoKs are present around a policy issue; the central boundary is between and not within WoKs; and knowledge is both a practice and content.

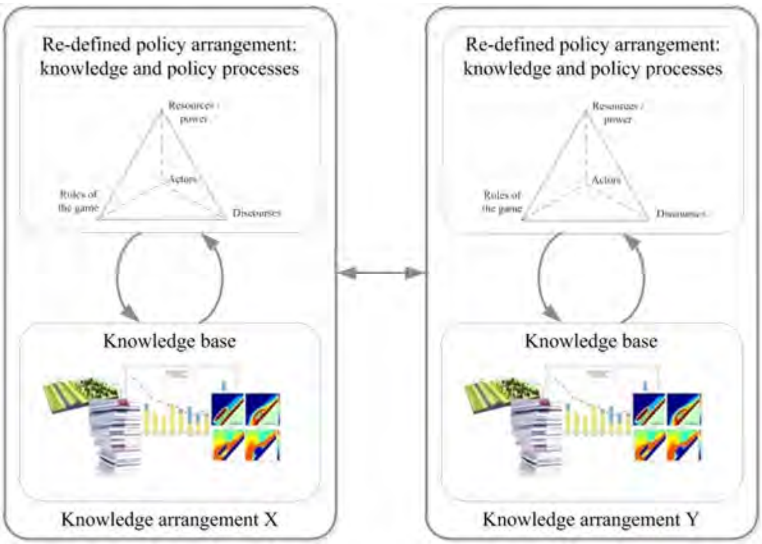

Figure 2.4 Conceptual framework of interacting knowledge arrangements

The conceptual framework involves two knowledge arrangements that interact. I define a knowledge arrangement as the dynamic interdependent constellation of a (redefined) policy arrangement (involving knowledge and policy processes) and a knowledge base within a policy domain. Following Van Tatenhove et al. (2000), a policy domain is interpreted broadly as all policy practices with regard to an issue such as nature or flood protection. For GFP decision-making, the policy domains concern the nature and flood protection policy domains (criterion 1 for a conceptual framework). Knowledge and policy processes and the knowledge base within one policy domain form a dynamic and coherent whole (criteria 2 and 3 for a conceptual framework). Within a particular domain, knowledge and policy processes and knowledge bases are attuned, and the so-called 'knowledge-policy gap' is non-existent. Knowledge and policy processes have a substantive and organisational side defined by the four dimensions of the policy arrangement. Because the dimensions in the policy arrangement do not account for knowledge processes, these are redefined to include knowledge actors and coalitions, knowledge rules, knowledge resources and knowledge discourses (Table 2.3). Knowledge and policy processes result in and are informed by a particular consolidated content: the knowledge base. Following Hommes (Hommes, 2008; Hommes et al., 2009), the knowledge base is defined as a collection of knowledge sources (e.g., research reports, models, data, and practical experiences) that is made explicit and relates to a specific constellation of discourses, actors, rules and resources.

Table 2.3 Redefined policy arrangement dimensions

Dimension	Redefined policy arrangement dimensions to include knowledge and knowledge processes
Discourse	The discourse dimension captures the views and narratives of the actors involved regarding a certain issue and the required and appropriate knowledge, including knowledge sources, methodologies, and actors, among others.
Actors and coalitions	The actors and coalitions dimension refers to the actors involved in the policy arrangement and how these relate to one another. Actors can have a variety of roles in the policy arrangement ranging from decision-maker to stakeholder or expert.
Rules and regulations	Rules and regulations refer to the formal and informal rules that structure the action of actors and the development, interpretation and use of knowledge.
Resources	The resource dimension relates to the (division of) resources and related power. Resources include financial resources, data sources, tools for knowledge development, and political and decision-making power.

Knowledge processes in the knowledge arrangement reflect the 'active dimension of knowing a problem' (Schneider & Ingram, 2007). They involve the process of defining what knowledge is relevant and appropriate (e.g., employing a discourse on science or local knowledge (Nursey-Bray et al., 2014)), what resources should be employed (e.g., data and tools to establish the knowledge), what actors are involved (e.g., who is able to obtain and produce knowledge and who may assess it) and what rules to obey (in terms of methodology or possible participation).

2.3.2 Modes of interaction between knowledge arrangements

In GFP decision-making, the nature and flood protection policy domains interact. This is reflected in the *interaction* between knowledge arrangements in the conceptual framework. In this section, I will introduce a typology to indicate possible interaction modes between knowledge arrangements. However, I first address some relevant literature on boundary work and other existing typologies.

The interaction between knowledge arrangements can be understood as boundary work, although not in its traditional meaning (see section 2.1.2). Conventional studies on boundary work have a bias towards the dominance of science (Metze, 2010) and discuss boundary work as an activity at the 'science-policy interface' (Turnhout et al., 2007). However, the concept has also found its way into knowledge in decision-making in terms of the WoK model. In these studies, the concept is employed to conceptualise the boundaries and boundary work between WoKs. Boundary work between WoKs can have two purposes: bridging boundaries and thereby connecting WoKs or, alternatively, blurring boundaries and creating a new WoK (Dewulf et al., 2013; Van Buuren & Edelenbos, 2004). Feldman et al. (2006) and Dewulf et al. (2013) specifically considered boundary organisations, boundary objects and boundary experiences (i.e., joint activities such as field visits, workshop participation or joint problem solving) as useful tools in managing the boundaries between WoKs.

Work by other authors on typologies inspires the development of a typology for the modes of interaction between knowledge arrangements. Hunt and Shackley (1999) develop a typology that described different types of relations between knowledge arenas (producing fiduciary, academic and bureaucratic knowledge). They distinguished among 'interaction', 'integration' and 'hybridisation'. Interaction refers to 'loose coupling', where knowledge is exchanged but arenas are independent and are not reshaped by the relation. Integration refers to a 'close fit', where the relation affects and reshapes the knowledge arenas. Some sharing of tacit knowledge occurs, and integrated practices start to emerge. Hybridisation implies dissolving boundaries. Instead of transferring or translating knowledge, knowledge is negotiated and mutually constructed. Janssens and Van Tatenhove (2000) discuss integration between policy arrangements and identified four different stages: differentiation, coordination, cooperation and integration. They state that 'in the differentiation stage there is no coherence and the sectors are fully independent. During coordination procedures and administrative instruments achieve coherence, while the sectors remain largely independent. Cooperation is “coordination plus”: sectors are working together to formulate a partly mutual policy. In the final stage a new unity is created. No distinction can be made between the different sectors, which have merged’ (Janssens & Van Tatenhove, 2000: 155). In addition to these stages, the authors discuss the ‘direction’ of integration and ‘aspects’ of integration. Directions can be horizontal, vertical, internal or external. Internal integration occurs within domains, whereas external integration occurs between domains. Horizontal or vertical integration refers to the administrative levels involved. Aspects of integration imply that policy domains can be divided into parts that constitute organisational elements, policy documents, (legal) tools or other aspects. Although some aspects may be part of the integration, others are not. By discussing the aspects and directions of integration, attention is drawn to the locality of integration activities. Integration does not necessarily cover the entire domain; on the contrary, it often covers parts of domains, such as certain aspects or administrative levels. This also holds for GFP decision-making: projects are temporary and local institutional occurrences.

In this research, I identify four different interaction modes between knowledge arrangements: separation, cooperation, integration and unification (Figure 2.5). Table 2.4 provides a detailed description of the four interaction modes. The result of interactions among knowledge arrangements can differ greatly; knowledge arrangements may be brought together or driven further apart (Lejano & Ingram, 2009). Therefore, the typology of interaction modes between knowledge arrangements covers the full range of possible interactions, from the separation of boundaries to a complete blurring of boundaries. The typology of interaction modes includes the awareness of ‘locality’. The cooperation and integration interaction modes are occurrences at particular locations. First, these interaction modes are temporal. Second, they apply only to a particular project. Unification, however, is ‘universal’ in that it is permanent and applicable beyond the situation of a single project. Unification thus implies the disappearance of the ‘initial’ knowledge arrangements (i.e., the originally interacting knowledge arrangements). Because unification is an interaction mode beyond a single project and this research involves the scope of projects, this interaction mode is not expected to be found in this research. The four interaction modes suggest clearly distinguishable modes of interaction between knowledge arrangements, but hybrid modes of interaction are also possible. Hybrid modes of interaction cover characteristics of multiple interaction modes. A knowledge arrangement comprises five elements (‘aspects’, in the words of Janssens and Van Tatenhove (2000)): actors and coalitions, rules, resources, discourse and knowledge base. In a hybrid interaction form, these elements cannot all be understood by the same interaction mode. For example, the knowledge base is an integrated instance, but financial resources are separate.

Table 2.4 Description of four interaction modes between knowledge arrangements

Interaction mode	Description
Separation	Separation among knowledge arrangements relates to a lack of connection between the boundaries of the knowledge arrangements. This implies that no communication occurs among arrangements and that arrangements operate independently and in isolation from the other arrangements. If knowledge arrangements are separated, actors act and are independent and rules and regulations among domains are separate, as are resources and discourses. Furthermore, the knowledge bases are independent. In GFP, a project's entire separation is unlikely because GFP is an approach that involves two policy domains: nature and flood protection.
Cooperation	Cooperation among knowledge arrangements relates to a connection between boundaries. When cooperation is found among knowledge arrangements, communication and awareness among the knowledge arrangements are established. The different knowledge arrangements remain in place, but the boundaries may shift somewhat as a consequence of alignment. Actors communicate and know each other; they may participate in deliberative bodies and agree on some matters. Different discourses exist, but these may include reference to discourses in other knowledge arrangements. Rules and regulations may become attuned, for example, by establishing agreements. Resources are separate, but mobilisation may be communicated or even negotiated. Knowledge bases are developed in separate locations, but knowledge transfer and translation occur. One knowledge base can serve as an input for another knowledge base.
Integration	Integration among knowledge arrangements relates to a time-space-specific blurring of the boundaries of the initial knowledge arrangements. The initial arrangements locally merge into a new knowledge arrangement that combines elements from the initial arrangements. The merger implies more than just putting the two arrangements together because "integration indicates bringing disparate elements into a whole" (Van Kerkhoff, 2005: 458). Integration is a local and temporary instance because the initial knowledge arrangements co-exist, but not at that specific place and time. A new, integrated knowledge arrangement consists of an actor coalition that comprises actors from both initial arrangements. A particular set of rules and regulations applies to this arrangement. Resources are pooled, and a new collective discourse is formed. Knowledge development is a collective exercise resulting in a collective knowledge base.
Unification	Unification relates to the permanent blurring or dissolving of boundaries between the initial knowledge arrangements. The initial knowledge arrangements are entirely replaced by a new and integrated knowledge arrangement. Unification differs from integration in being permanent and not bound to a location, such as a project setting. Unification is therefore not feasible within the boundaries of a project (the scope of this research). It is the result of a process that exceeds a single project because it requires multiple projects, policies and societal developments over a longer period of time.

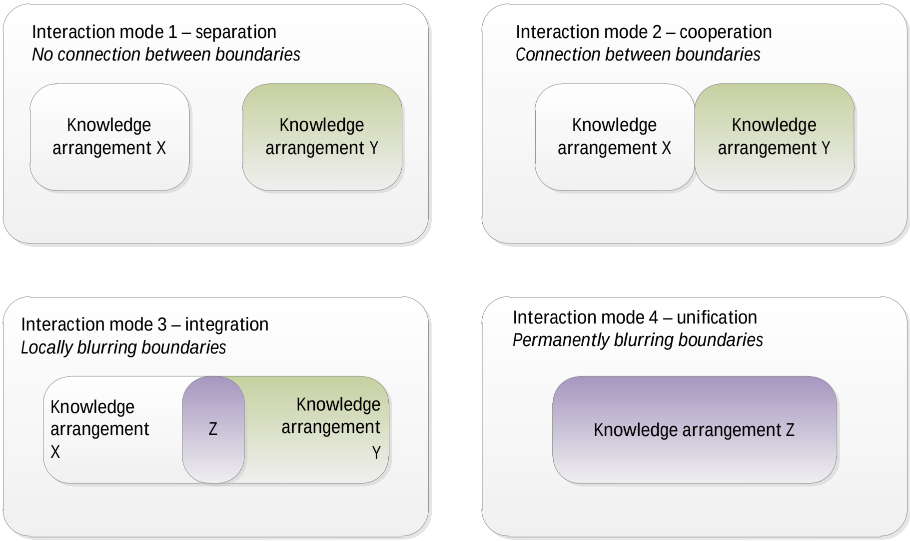

Figure 2.5 Schematisation of the four interaction modes between knowledge arrangements

2.3.3 Meaning and usage of the conceptual model of interacting knowledge arrangements

A conceptual framework 'explains […] the main things to be studied – the key factors, constructs or variables – and the presumed relationships among them' (Miles & Huberman, 1994, p.18). The conceptual framework of interacting knowledge arrangements indicates how knowledge in GFP decision-making functions and can be analysed. It is constructed based on the four criteria for a conceptual framework presented and insights from relevant theory (sections 2.1 and 2.2, this chapter).

In this research, the conceptual framework has two functions. First, it contributes to understanding knowledge in GFP decision-making (research question 1). As such, it functions as a 'tentative theory' (Maxwell, 2013) of knowledge in GFP decision-making. Second, it guides the case study research. It describes the concepts and their relations that are studied and analysed in the three case studies and provides the 'analytical lens'. Based on the application of the conceptual framework in the case studies, the conceptual framework can be improved (contributing to the conceptual framework as a theory and answering research question 1). Furthermore, this application can contribute to answering research questions 2 and 3 on how knowledge enables and constrains GFP in flood protection projects and how knowledge can be improved. Data collection and analysis in the case studies follows the conceptual framework. In the case studies, I first identify the knowledge arrangements in the project. These knowledge arrangements are described by the five dimensions of the knowledge arrangement: the actors, rules, resources, discourse

(Table 2.3) and the knowledge base. Secondly, for each dimension of the knowledge arrangement, I have identified the interaction mode (Figure 2.5, Table 2.4).

3 Greening Flood Protection—An interactive knowledge arrangement perspective[15]

Abstract

In flood protection, the dominant paradigm of ‘building hard structures’ is being challenged by approaches that integrate ecosystem dynamics and are ‘nature-based’. Knowledge development and policy ambitions on greening flood protection (GFP) are rapidly growing, but a deficit remains in actual full-scale implementation. Knowledge is a key barrier for implementation. To analyse conditions for the implementation of GFP, a knowledge-arrangement perspective is developed. The knowledge-arrangement perspective is applied on a case study of successful implementation of GFP in the Netherlands, the pilot Sand Engine Delfland, a large-scale (21.5 Mm3) sand nourishment project. This project confirms that an integrated knowledge arrangement enables GFP as it allows for multifunctionality. Effectiveness of the integrated arrangement in this project is explained by its ‘flexible’ nature providing ample design space. This was possible because core values in flood protection and nature were not part of the integrated arrangement. More generally the case study demonstrates the difficulties of implementing GFP in existing mainstream flood protection routines. These are not (yet) geared to incorporate uncertainty, dynamics and multifunctionality, characteristics associated with GFP. The Sand Engine project can be regarded as a ‘field laboratory’ of physical and institutional learning and an innovation for mainstream flood protection.

3.1 Introduction

Traditional ‘hard’ infrastructure for coastal protection against flooding is more and more criticized for being unsustainable and expensive. Damming estuaries and building dikes

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[15] This chapter has been published as: Janssen, S. K. H., van Tatenhove, J. P. M., Otter, H. S., & Mol, A. P. J. (2014). Greening Flood Protection—An Interactive Knowledge Arrangement Perspective. Journal of Environmental Policy & Planning, 1-23. doi: ♦10.1080/1523908X.2014.947921

have unforeseen degrading effects on coastal ecosystem environments (Van Wesenbeeck et al., 2014). The construction costs of artificial structures are high and are accompanied by significant maintenance expenditures (Smits et al., 2006). Meanwhile, sedimentation processes change and negatively influence adjacent areas which then also need expensive engineering infrastructure (Airoldi et al., 2005). A promising alternative for conventional coastal protection practices is greening flood protection (GFP).[16] Such forms of protection, for example, by means of mangroves forests, wetlands or sand nourishments, use natural characteristic and dynamics to mitigate wave energy, stabilize coastlines and serve as flood protection barriers (Gedan et al., 2011; Van Wesenbeeck et al., 2014). In addition, GFP expands and improves ecosystem environments and can provide substantial coastal ecosystem services, such as fisheries production or carbon sequestration (Hale et al., 2009). GFP is inherently multifunctional, as it combines environmental and social objectives (Barbier et al., 2008; Van Slobbe et al., 2013; Vikolainen et al., 2013). Although it is proposed as a sustainable and cost-effective solution in coastal zones prone to changing (climatic) conditions and flooding (Cheong et al., 2013; Hale et al., 2009; Spalding et al., 2013; Temmerman et al., 2013), GFP is not a universal solution as its effectiveness greatly differs among locations and works often well in combination with conventional hard infrastructure (Cheong et al., 2013; Temmerman et al., 2013). Nevertheless it is important in providing low-regret, sustainable and cost-effective solutions for current coastal protection challenges.

GFP significantly differs from conventional flood protection practices. Generally speaking, the latter are static, mono-functional and hard-designed structures aimed at minimizing uncertainty and controlling flood risk, while the former are dynamic, multifunctional and soft measures allowing some uncertainty related to natural variability and dynamics of ecosystems (Naylor et al., 2012; Van den Hoek et al., 2012). While conventional constructions are fixed and finished after implementation, GFP solutions continue to develop as a form of 'self-design'[17] (De Vriend et al., 2014; Mitsch, 2012; Odum & Odum, 2003). Actual implementation of GFP has proved to be a significant challenge. In fact, up until now implementation remained largely in the form of (small-scale) pilots (De Vriend et al., 2014), while large-scale applications are still absent (Temmerman et al., 2013).

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[16] A variety of terms have been used to more or less the same ideas of more green forms of protection against flooding. For example, we found: ecosystem-based management (Barbier et al., 2008) or adaptation (Hale et al., 2009), ecological engineering (Cheong et al., 2013; Mitsch, 2012), building with nature (De Vriend et al., 2014; Van Slobbe et al., 2013), ecological enhancement (Naylor et al., 2012) or nature-based flood defence (Van Wesenbeeck et al., 2014).

[17] Defined by Mitsch and Jørgensen (2003, p.369) as 'the property of systems in general to reorganize themselves given an environment that is inherently unstable and non-homogeneous'.

Whereas pilots form an important tool in exploring or evaluating innovations and can form the first step towards actual implementation, they also show that GFP has not yet found its way into mainstream flood protection management (Vreugdenhil et al., 2010). As knowledge development on GFP is still rapidly progressing (Mitsch, 2012) and policy and politicians continue to express support (Naylor et al., 2012), the most pressing challenge for GFP remains related to the question how to proceed full-scale implementation?

To understand the advancement of GFP, we focus in this paper on the role of knowledge. The multifunctional nature, ecosystem dynamics and unpredictability (uncertainty) in GFP designs require different processes of knowledge production, development and use than commonly applied (Brugnach & Ingram, 2012; Giebels et al., 2013). Knowledge should reflect social and ecological complexity (Giebels et al., 2013) and bridge and integrate ecological and flood protection expertise.

The aim of this paper is to understand decision-making on GFP from a knowledge perspective through answering the following question: How can knowledge processes enable or constrain GFP decision-making? To answer this question we gathered empirical data from a GFP project in the Netherlands: the Pilot Sand Engine Delfland. This project is a 21.5Mm^3 sand nourishment project along the coast integrating ambitions for nature, recreation, flood protection and innovation (PZH & RWS, 2014). The paper is structured as follows. First, we introduce the analytical framework of knowledge arrangement, used for the case study analysis. In Section 3.3, the applied research approach is discussed, followed by a description of the Sand Engine case study in Section 3.4. In Section 3.5, the results of the case study are discussed and we finish the paper by concluding upon our findings in Section 3.6.

3.2 Theory: a knowledge-arrangement perspective

3.2.1 Knowledge literature

The literature on theories covering the role of knowledge in decision-making is extensive. We categorize the literature on knowledge into two fields: one investigating ‘science–policy’ interactions and the other investigating interactions among different ‘ways of knowing’. This categorization is based on our aim to understand the dynamics of knowledge for GFP.

Science–policy interactions research. The mainstream field of knowledge research is directed to investigate the ‘science–policy interface’ (Bremer & Glavovic, 2013; Turnhout et al., 2007). In this field we broadly discern two models that are fundamentally different. The first model is known as the linear model (Röling, 1992). This model represents a conventional understanding of the relation between science and policy building on the ‘two-communities’ perspective (Caplan, 1979). Science and policy are understood as separate worlds having different languages, values, rewards systems and the like and can be distinguished by means of universally applicable criteria. Moreover, this model assumes a ‘science-based fix for all societal problems’ (Röling, 1992, p.46). In this understanding, challenges in the science–policy interface relate to the lack of science-use in policy-making. Solutions are found in improving communication and translation of science to policy. This model is nowadays considered rather outdated and is criticized for being an oversimplification of reality. However, it is still vivid in some fields (McNie, 2007).

The second model is known as the co-production model (Jasanoff, 2004; Wiering et al., 2001). From this perspective, science is considered contextual and the boundaries between science and policy are socially constructed rather than universally applicable (Gieryn, 1983). What counts as scientific knowledge is different for different locations and situations and locally co-produced between science and society in participatory processes (Bremer & Glavovic, 2013). Besides science, it allows for other forms of knowledge, such as expert, bureaucratic and stakeholder knowledge (Edelenbos et al., 2011). While in the linear model the process of asking research questions and producing and validating knowledge is considered the domain of ‘science’—and thus not relevant for science–policy interactions—in the co-production model this becomes a central matter of concern in such interactions. Risks relate to the development of ‘negotiated nonsense’ or ‘superfluous knowledge’ (Van de Riet, 2003) and research is guided by the challenge to produce knowledge that is credible, salient and legitimate (Cash et al., 2003). Solutions are found in new forms of knowledge production, including practices of participation, integration, learning and negotiation between scientists and policy-makers (Van Kerkhoff & Lebel, 2006).

In summary, whether the boundaries of science and policy are considered universal and fixed (as in the linear model) or negotiated and contextual (as in the second model) the common denominator in both models is a focus on the relation between science and policy. The multiplicity of knowledge in the co-production model aligns with the knowledge challenge in GFP (Bremer & Glavovic, 2013; Coffey & O'Toole, 2012; O'Toole & Coffey, 2013). The co-production model, however, does not deal with the interactions and potential conflict between different science–policy arrangements, while we consider this a main concern in GFP. For that, we turn to the literature on ‘ways of knowing’.

Ways of knowing research. In an upcoming field of research the focus on science–policy interaction has shifted towards the idea of multiple ‘ways of knowing’ (WoKs) (Feldman et al., 2006; Van Buuren, 2009) or knowledge coalitions (Van Buuren & Edelenbos, 2004). The WoK perspective puts the interactions among different WoKs central, as these are considered more important for (competing) knowledge claims and use than the interactions between science and policy (Van Buuren & Edelenbos, 2004). Coffey and O'Toole (2012) show how such an understanding is particularly warranted in assessing coastal dynamics given their complexity, conflict and multiple knowledge forms. Frequent and ongoing interactions within a WoK (Dewulf et al., 2013) and disciplinary congruence among scientists and policy-makers institutionalize relations in a single domain (such as flood protection) (Edelenbos et al., 2011). As a result, science–policy interactions within that domain are not perceived as problematic because forms of knowledge to define problems and solutions are framed in similar ways in science as in policy. Rather, knowledge conflicts occur at the boundary of different WoKs. Hence, the simultaneous existence and interaction of multiple WoKs is explicitly recognized. The interaction processes among WoKs are an incentive for processes of meaning-making, where meanings converge or reinforce each other (Lejano & Ingram, 2009). WoKs are very dynamic and in continuous flux (Lejano & Ingram, 2009). As WoKs are inherently dynamic so is knowledge in WoKs. ‘Knowing’ as opposed to knowledge is emphasized: ‘a [WoK] can be distinguished from knowledge in that it emphasizes the *active* dimension of knowing a problem’ (Schneider & Ingram, 2007, p.4, emphasis added). Knowing implies a focus on the process rather than on static outcomes and includes processes of knowledge production and gathering as well as meaning-making of knowledge. The main research questions then cover the understanding of the dynamics within WoKs, interactions between WoKs and the crossing of boundaries among WoKs. Boundary management is often introduced as a solution (cf. Dewulf et al., 2013; Lejano & Ingram, 2009; Muñoz-Erickson, 2013; Van Buuren & Edelenbos, 2004) but is applied in a different way from boundary management between science and policy, as introduced by Gieryn (1983).

In the literature different concepts are used for similar ideas—WoKs, knowledge coalitions, knowledge–actions systems—emphasizing different research traditions and operationalizations. In defining WoKs, Schneider and Ingram (2007) considered meaning-making the result of interactions among objects, including artefacts, reports, stakeholders and more. In contrast, knowledge coalitions, as introduced by Van Buuren and Edelenbos (2004), are primarily defined from an actor perspective. Dewulf et al. (2013) include a structural perspective by linking networks and frames in explaining the role of knowledge. A drawback of the WoK research is that the concept is not yet fully crystallized.[18]

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[18] The authors of the Ways of Knowing concept are fully aware of this: ‘we come to this writing with only a rough idea of what a way of knowing is and what it is not’ (Feldman & Ingram, 2009, p.124). (Muñoz-Erickson, 2013) did empirical research into ‘knowledge action systems’. She based her analysis on a network analysis, which provides evidence of the existence of these systems, but does not include the dynamics inherent in ways of knowing.

3.2.2 Analytical framework for understanding knowledge for GFP

The multifunctional nature of GFP explicitly draws attention to the integration of knowledge from different domains. Domains are often strongly institutionalized and characterized by frequent internal interactions. This is especially true for the Dutch flood protection domain, building upon a long tradition of protection against flooding and close interactions between flood protection science and coastal management (Van Koningsveld & Mulder, 2004). Moreover, the coastal zone is characterized by fragmentation among policy domains (Van Buuren et al., 2010a). The main knowledge challenge of GFP is thus not expected to lie between science and policy within domains, but rather with interactions among domains. We therefore build upon insights of the WoK research. As concepts used in this field lack operationalization, preciseness and thus potential as analytical framework for case study analysis, we introduce a new approach allowing for a more structured and systematic analysis of interaction among WoKs.

Building upon the policy arrangement approach towards knowledge arrangements. To construct our model of knowledge arrangements we employ the policy arrangements as developed by Van Tatenhove et al. (2000). This analytical framework is especially useful to unpack the policy side of what we will label a knowledge arrangement. The policy arrangement framework has mainly been applied to analyse stability and change in the environmental policy domain. A policy arrangement is defined as 'the temporary stabilization of the organization and substance of a policy domain at specific level of policy making' (Van Tatenhove et al., 2000, p.54) and makes up four dimensions: (1) actors and coalitions, (2) rules and regulations, (3) discourses and (4) resources. The dimensions are interrelated and dynamics result from this as 'a change in one of the dimensions is likely to lead to changes also in one or more of the other dimensions' (Liefferink, 2006, p.66).

The policy arrangement framework has demonstrated its applicability in a broad array of research domains (including water management, spatial planning, nature conservation, marine infrastructure, road infrastructure). Yet this framework has not been designed to analyse ways of knowing. Understanding processes of knowing—including producing, interpreting and using knowledge—is not conceptualized nor emphasized in the policy arrangement framework. Therefore we (1) re-interpret and redefine the dimensions of the policy arrangement as to allow for understanding processes underlying knowing (Table 3.1) and (2) relate this redefined policy arrangement to the knowledge base that is continuously being developed and used. Following Hommes (2008) and Hommes et al. (2009) we define a knowledge base as a collection of knowledge sources (i.e. research reports, models, data, practical experiences, etc.) that have been made explicit and are related to a specific policy arrangement. The (redefined) policy arrangement and its interactions with the knowledge base together make up what we refer to as the knowledge arrangement (Figure 3.1). A knowledge arrangement is then defined as the dynamic interdependent constellation of a knowledge base and the (redefined) policy arrangement within a specific domain.

Table 3.1 Re-interpretation of the dimensions of the policy arrangement to allow for understanding processes of knowing

Dimension	Interpretation of the dimension for the understanding processes of knowing
Discourse	The discourse dimension captures the views and narratives of the actors involved regarding a certain issue and the required and appropriate knowledge sources, methodologies, knowledge actors, etc.
Actors and coalitions	The actors and coalition dimension refers to the actors involved in the policy arrangement and how these relate to one another. These include actors involved in knowledge processes
Rules and regulations	Rules and regulations refer to the formal and informal rules that structure action of actors and the development, interpretation and use of knowledge
Resources	The resources dimension relates to the (division of) resources and related power. Resources are, for example, finances, knowledge sources, knowledge development capabilities or political and decision-making power

Interacting knowledge arrangements. Following our theoretical approach and empirical notions on GFP in the coastal zone, GFP becomes a matter of interacting knowledge arrangements (Figure 3.1). Interaction can have multiple outcomes: separation, cooperation, integration and unification (Janssen et al., 2014a). Our presupposition is that an effective implementation of GFP requires integration among sectoral/domain-specific knowledge arrangements. Authors have argued for comprehensive governance approaches as opposed to sectoral governance (Halpern et al., 2008; Katsanevakis et al., 2011), have demonstrated the impeding nature of multiple discourses on knowledge for GFP decision-making (Nursey-Bray et al., 2014) and have argued for interdisciplinary knowledge research and design for nature-based coastal management (Naylor et al., 2012; Van Wesenbeeck et al., 2013).

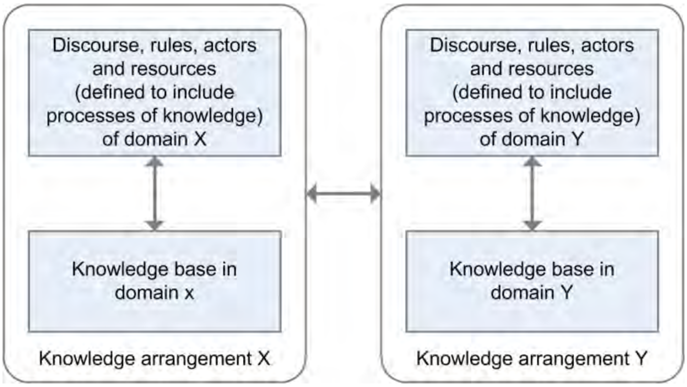

Figure 3.1 Schematic overview of interaction among knowledge arrangements. A knowledge arrangement is build-up of the re-interpretation of the policy arrangement (i.e. explicitly recognizing knowledge processes) the knowledge base.

In the literature, integration is defined in multiple and varying ways (Derkzen et al., 2009; Van Kerkhoff, 2005). We build upon the general notion by Van Kerkhoff (2005, p.458): 'integration indicates bringing disparate elements into a whole'. Applied to knowledge arrangements, integration refers to the emergence of a new (temporary) knowledge arrangement for a particular issue on a particular place. Such an integrated knowledge arrangement includes an actor coalition involving actors from the original arrangements, a collective set of agreements, a collective discourse in the actor coalition, resources originating in both original knowledge arrangements and collective developing, interpreting and using knowledge. Integration is often location and time specific and not a permanent state. Integration can take place at the project level while leaving sectoral knowledge arrangements at the national level unaffected. Moreover, the integration can disappear when the project ends. Integration differs from cooperation, as cooperation does not involve collective discourses, rules, knowledge development, resources or actor coalition. With cooperation these dimensions remain founded in separate knowledge arrangements, while communication and mutual informing is employed. Integration differs from unification in that the original knowledge arrangements continue to exist beyond the time- and location-specific boundaries of the integration.

3.3 Research approach

In order to study interacting knowledge arrangements and its outcome in the context of GFP projects we analysed the project Pilot Sand Engine Delfland (hereafter Sand Engine). This single case study approach enabled in-depth analysis of knowledge arrangement interactions. We selected the project halfway 2009 based on three criteria. First, the objectives of the project integrated multiple functions, including flood protection and nature. Second, GFP principles were used in the designs of the Sand Engine which are the use of natural dynamics, such as wind and waves for sand transport, and natural dune growth. Third, we gained full access to the project in terms of meetings, interviews and project documents.

For data collection we used participatory observations, interviews (12x see appendix), and studied project documentation, including all minutes of meetings of the project team and the steering committee, internal notes and knowledge documents. The interviews were semi-structured and informed by a list of about 10 questions that guided the interviews. The interviewees were selected based on their position in the project and their home-institutions. Some interviewees were suggested by earlier interviewees. Two well-informed project participants were consulted on earlier versions of this paper: one provincial respondent and one Deltares respondent. The latter had a history in Rijkswaterstaat (RWS) and had been working on Sand Engine ideas since 2005.

The data were structured by means of the theoretical framework of interacting knowledge arrangements using the five dimensions of the knowledge arrangement. We focused on the interaction between the flood protection and nature domains[19] (the 'foundational' domains) and the outcome of this interaction in the Sand Engine project. Addressing the sectoral domains is crucial for understanding possible integration (Derkzen et al., 2009). We start our analysis from the foundational knowledge arrangements after which we continue with the Sand Engine knowledge arrangement. We address each dimension separately, zooming into the discourses applied, the actors in the project, their relations, resources, the rules and regulations determining the process and the knowledge base resulting from this. In the analysis of the dimensions in the sand engine we analyse how these are related to the foundational arrangements. Our analysis starts from the beginning of the project until the decision for the preferred design in February 2010. The emphasis is on the planning phase (April 2008–February 2010), as in this period the main knowledge development and decision-making developed.

3.4 Case study: pilot Sand Engine Delfland

Two parties, RWS and the province of Zuid-Holland (PZH), joined forces in 2007 to work on the realization of the 'Sand Engine'. RWS had been working on ideas for large-scale nourishments as part of their responsibility for coastline maintenance. PZH, dealing with

[19] Recreation was also one of the objectives, for which a knowledge arrangement could have been identified. Given our focus on GFP, we restricted the analysis to the interactions among the nature and flood protection knowledge arrangements.

increasing spatial pressure and a significant lack of green recreational areas, had an interest in expanding their land-area seawards. The implementation process of the Sand Engine can be regarded as quite successful: after signing an 'ambition' agreement among nine interested stakeholders in April 2008 in which the goals and ambitions of the project were agreed upon, it took about 3.5 years, without significant delays, until the Sand Engine was fully realized (Figure 3.2).

Figure 3.2 Aerial view of the Sand Engine just after completion (9 August 2011 Zandmotor).

The Sand Engine is a multifunctional and large-scale sand nourishment project. It was constructed as a hook-shaped peninsula piling up 21.5 Mm3 of sand. It has an above water area of 75 ha, and is attached to the South-Holland coastline over a length of 2 km. The bulk of sand is expected to disperse along the coastline and dunes in a natural manner and disappear over a period of about 20 years (Stive et al., 2013). This approach serves multiple functions: it contributes to flood protection by compensating for sand losses from erosion processes along the coastline; it creates temporary recreational and natural areas; and it contributes to natural dune formation. The project was set up as a 'pilot'—or put in different words: an experiment—and contributes to knowledge development and learning. The Sand Engine 'experiment' is being monitored intensively and first observation show that the nourishment is indeed feeding the adjacent coasts (Stive et al., 2013).

In the following sections we describe the knowledge arrangements of flood protection, nature and the Sand Engine project by elaborating on the actors, discourses, rules, resources and knowledge base (a summary is provided in Section 3.4.4, Table 3.2). Such an elaboration allows us to understand how flood protection and nature were combined in this project and what conditions allowed for implementation of GFP decision-making.

3.4.1 Flood protection knowledge arrangement

Part of the Dutch flood protection policy consists of the maintenance of the coastline.[20] Coastline maintenance is organized to counteract structural coastal erosion by means of sand nourishments. It involves close monitoring of the coastline and nourishing sand at those locations where erosion occurs. Yearly, 12 Mm3 is nourished along the coastline divided over multiple smaller nourishments. The Sand Engine directly affects coastline maintenance: a large amount of sand is added to the coast and extends the coastline. It is a new and innovative strategy, mostly for the scale used.

The objective of coastline maintenance is: 'the sustainable preservation of safety against flooding and of values and functions in the dune area' (Ministerie van V&W, 1990). The position of the coastline in 1990—defined as 'Basic Coastline' (BKL) – governs the execution of sand nourishments. Nourishments for other functions than flood protection (e.g. recreation) are more expensive and poorly articulated, caused by fragmented policy fields (Lubbers et al., 2007; Mulder et al., 2011; Van Buuren et al., 2010a).

Three *actors* prevail in coastline maintenance: RWS, the Directorate General Water (DGW) and Deltares. Both RWS and DGW are part of the Ministry of Transport, Public Works and Water Management (V&W). RWS has a central position being responsible to execute the coastline maintenance policy. DGW is responsible for water policy, including coastline maintenance. Deltares is a research institute working among others in the field of coastal morphology and having a leading position in Dutch coastal research programmes. Deltares is preferred knowledge supplier for the ministry. Other stakeholders are informed about coastline maintenance policy and works, but there is only limited decision-making involvement of local governmental actors, such as provinces and municipalities, non-governmental organisations (NGOs), other research institutes and users of the coast in designing and executing the coastline maintenance policy.[21]

The *discourse* in coastline maintenance is dominated by the principle that flood protection and maintaining functions in the coastal area requires keeping the coastline at BKL position. Structural loss of land to the North Sea, either resulting from erosion or sea-level rise, should be prevented. Hence, the discourse is focused on 'preservation' of the coastline,

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[20] Flood protection strategy comprises the maintenance of the coastline and the water defence (dunes or hard structures). These two are separate entities and organizationally split.
[21] Involvement differs among regions. For an overview, see Donkers and Jacobs (2005).

rather than 'development'. Coastline maintenance, in particular the use of BKL and sand nourishments, is generally regarded a success and goes largely uncontested (Lubbers et al., 2007; Van Koningsveld & Mulder, 2004). Climate change and associated sea-level rise have raised discussions on the nourishment budget and the need for further coastline extension beyond BKL. These discussions also drew attention to the use of larger and innovative types of nourishments other than the beach and foreshore nourishment that are currently common (Giardino et al., 2011) such as the Sand Engine (interview DGW representative, 10 February 2010).

Rules and regulations in coastline maintenance show stable patterns with only gradual changes since 1990 (Van Koningsveld & Mulder, 2004). A focus on long-term coastline maintenance (Ministerie van V&W, 2000) resulted in increasing the nourishment budget from 6 to 12Mm^3 yearly. In 2007, water policy addressed the need for innovation in coastline maintenance, with an explicit reference to the Sand Engine (Ministerie van V&W, 2007).

Administrative and financial *resources* lie within the Ministry of V&W. DGW provides RWS an assignment and financial resources to execute coastline maintenance policy. RWS and Deltares have key roles in knowledge development, while DGW trusts upon the expertise of RWS.

The *knowledge base* can be split into two categories. First, there is generic knowledge on coastal, mainly morphological, processes with a focus on understanding system behaviour. Field monitoring, data analysis and numerical modelling are important research methods. Second, there is context-specific knowledge. Exact predictions of morphological processes are difficult and therefore experiences gained over the last 20 years on the local behaviour of the coastline and nourishments are of crucial importance. Both knowledge are intended to contribute to the (cost-) effectiveness of nourishments. The debate on innovative and large-scale nourishments resulted in some exploratory exercises, among others a report exploring the possibilities for and introducing the concept 'Sand Engine' (RWS, 2005).

3.4.2 Nature knowledge arrangement

Nature policy works in two ways. First, nature is found in protected sites. Devolution of nature policy resulted in a central role for regional *actors*: provinces are responsible for management of sites and local actors and environmental NGOs are involved in the execution and monitoring of site management plans (Gerritsen et al., 2009). National government and the European Union define the terms. The *discourse* is dominated by a focus on protection and preservation of the nature sites, which is often specified in terms of species or habitats. These are embedded in strong legislative frameworks of ‘Natura2000’[22] and the National Ecological Network (EHS), which constitute the *rules* for protected sites. Provinces hold decision-making power and financial *resources* when it comes to execution of this nature policy. Traditionally, the nature policy field builds upon scientific insights from ecology and ecologists (Bogaert & Gersie, 2006). Besides ecologists, managers possess site-specific knowledge of nature protection sites. Inspired by the legislative framework, the *knowledge base* is directed towards species, habitats and ecological processes, and related enabling and constraining conditions. The Sand Engine is bordering the Natura2000 site Solleveld and Kapittelduinen. The nature objective of the project however was not related to this site, it served as a boundary condition though.[23]

In a second understanding of nature policy, nature is part of the living environment and spatial planning policy. In contrast to nature site protection, spatial planning is inherently a multi-actor and multi-interest affair as it concerns the allocation of multiple functions. Nonetheless the province is also a central *actor* in spatial planning. The *discourse* on nature in spatial planning and outside protected sites is merely oriented towards supporting recreational functions or improving general attractiveness of an area without concern for particular species or habitats. The representation of nature interests in this battle of competing interests is often poor, originating from a lack of financial *resources* and *regulative* support outside protected areas. A governmental authority as ‘owner’ of nature interests outside the protected sites is often lacking (Van Buuren et al., 2010a), while NGOs have limited power in decision-making and are frequently forced into an opposing role. The Sand Engine nature objective should be understood as part of the spatial planning ambitions of PZH to increase ‘recreational green’ in the coastal zone and to develop this area. A *knowledge base* supported this ambition. Research reported a shortage of 6000 ha for recreation in the coastal zone (Abma & Berkers, 2006). Moreover the possibilities for integral coastal development and extension had been explored suggesting that integral coastal development is important for environmental quality of the area (Adviescommissie voor de Zuid-Hollandse kust, 2006). This advice led PZH to install a committee on coastal development to further explore these possibilities. The committee represented a broad range of stakeholders, including ministries, municipalities and the waterboard (a regional

[22] A European network of nature protected areas under the Birds and Habitats directives.
[23] The Sand Engine could possibly affect the Natura2000 site Solleveld and Kapittelduinen and the protected natural reserve Solleveld. In such cases law prescribes an ‘appropriate assessment’. If the assessment outcome indicates significant negative impacts, mitigation, considering alternatives or compensation is required. For the Sand Engine, the appropriate assessment showed possible impact on Solleveld, which could be mitigated by means of management measures.

water quality and quantity management agency). This committee forms the origin of the Sand Engine project organization.

3.4.3 Sand Engine knowledge arrangement

In the beginning of 2008, a platform supporting innovation and led by the Dutch prime minister asked PZH to develop a plan for the 'Sand Engine'. Moreover, the ministry of V&W made a budget available for the project. The ambition agreement signed in April 2008 among nine stakeholders marked the start of the planning phase. This phase of the Sand Engine constitutes a period of developing design alternatives and a period of selecting, optimizing and deciding upon the preferred design. Four design alternatives were developed: an underwater nourishment, an island, hook-south and hook-north (PZH, 2010). From these designs hook-north was selected as the preferred design. The underwater nourishment was not a visible solution and did not yield any recreational options (both important criteria for PZH). The island was considered too risky for recreation. Hook-south could have negative impact on existing recreation and interfered with a local pumping station. And thus Hook-north was most desirable: it did not disturb any ongoing activities; yielded some (and not too much as this would lead to infrastructural problems) recreational facilities; and was both visible and accessible (Figure 3.3).

Actors and their interests were broadly represented in the Sand Engine project. In the organization of the project up to 15 different actors were involved. The parties that signed the ambition agreement formed the core: the Ministries of V&W (representing both DGW and RWS), Housing, Spatial Planning and the Environment (VROM) and Agriculture, Nature and Food Safety (LNV), PZH, three municipalities, the waterboard and an environmental NGO. PZH and RWS were initiators of the project. PZH was leading the planning phase, initiated design workshops and commissioned (research) reports to consultants. RWS was leading during project execution (2010–2011), while in the planning phase their role was much less prominent. Knowledge parties were also part of the project organization: Delft University of Technology, Deltares, innovation programme Ecoshape and consultancy firms. During the course of the project, new actors entered and left the project organization. For example, drinking water company DUNEA was included in the project team when effects of the Sand Engine on groundwater appeared important.

For PZH, the development of recreational green and the visibility of the Sand Engine were most important. Among others, this led to the hook-north as the preferred design. The interest of RWS for the Sand Engine was threefold: knowledge development for long-term coastline maintenance, as executor of the project and as manager of the coastline (interview RWS representatives, 11 March 2010). During the planning phase RWS was reticent and critical towards the preferred design. From an RWS perspective, hook-north was relatively expensive (an under-water nourishment would be cheaper), unpredictable and inefficient. DGW was less critical and emphasized the innovation potential and also the cost-effectiveness of placing 21.5Mm^3 at once (this approach, in combination with the tender strategy led to a very low sand price). The three involved municipalities and the waterboard mainly aimed to prevent negative effects of the Sand Engine, for example on local recreation, shipping or groundwater levels. Nature interests were poorly represented in the project organization, despite enthusiasm of organizations such as the World Wildlife Fund and the Ministry of LNV.

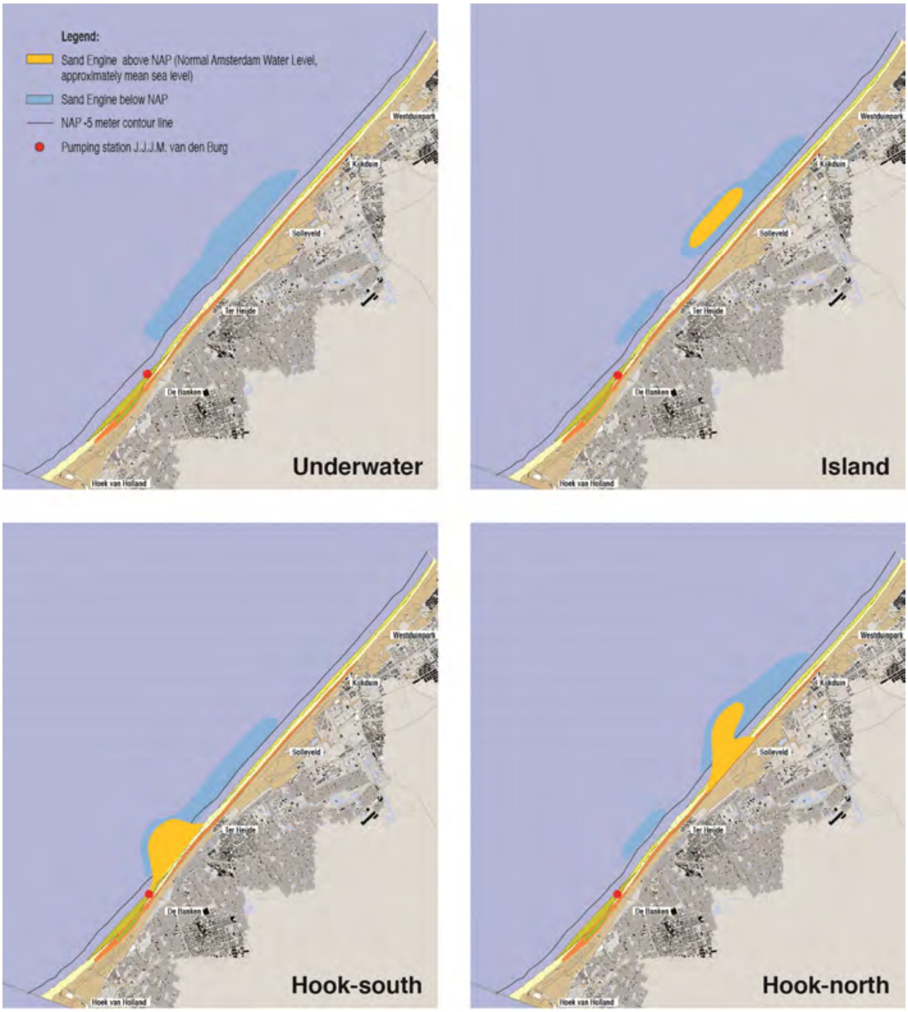

Figure 3.3 Overview of four design alternatives. Clockwise, starting upper left corner: underwater, island, hook-south and hook-north (PZH, 2010)

The Sand Engine is considered an innovative, natural and multifunctional concept, set up as an experimental pilot. Innovation relates in particular to the scale of the nourishment and the multifunctional approach. It meets the need for new and innovative concepts to handle the future challenges for coastal development (this need is expressed in a number of policy documents and advises, for example, the Watervisie (Ministerie van V&W, 2007) and report of the Deltacommittee (Delta commissie, 2008)). The Sand Engine is, in particular in external communication (nationally but also internationally the sand engine is presented as 'building with nature' solution, for example at the World Expo in Zaragoza Spain 2008 and the World Water Forum 2009 in Istanbul), presented as a 'building with nature' solution to coastal development combining flood protection with nature and recreational development. Its mechanisms are natural, as the sand is dispersed along the coastline by means of wind and waves. The announcement for a public meeting provides a good summary of the employed *discourse* (PZH, 2009):

> The Sand Engine is a large amount of sand that will be located in front of the Delfland Coastline. This part of the coast will grow naturally. As a result, more space for nature and recreation is created as well as a contribution to long-term flood protection. The Sand Engine is an innovative pilot, from which knowledge is gained for coastal development, building with nature, and innovative means for coastal reinforcement needed for climate change.

Rules and regulations guiding the decision-making process consist of project objectives, legislation and policy objectives. The project objectives are among others laid down in the ambition agreement and express the intention to combine flood protection, nature, recreation and innovation. These are however described in a general way and are not prioritized. For example, the meaning of 'nature' was not specified in terms of the type, size or location aspired and also 'flood protection' objectives were not specified. The implicit assumption was that any dune growth would contribute to safety and also to nature. Prevailing legislation and policy objectives for both flood protection and nature did not further specify the design, but functioned as boundary conditions: coastline (BKL) erosion and negative impact on the Natura2000 site were to be prevented. The environmental impact assessment (EIA) procedure formed the basis for acquiring necessary permits.

The most prominent *resources* in the project were decision-making power, budget and knowledge. Budget and knowledge were shared. The Sand Engine was financed by the Ministry of V&W for 83.3% and by province PZH for 16.7%, providing these actors preferential positions in the project. The ministerial budget for the Sand Engine was not taken from the coastline maintenance budget. Rather an 'innovation' fund was made available for the Sand Engine. Knowledge was a collective resource throughout the process. Knowledge products—whether workshops, designs, research reports or EIA documents—

were prepared, discussed and assessed collectively in the project team. The central position of PZH as leading in the planning phase provided this actor decision-making power.

The development of the *knowledge base* differed between the designing period (i.e. developing the four design alternatives) and the decision-making and design optimization period (i.e. selection and optimization of the preferred alternative). In designing the four alternatives for the Sand Engine, knowledge development was very interdisciplinary. A multi-disciplinary team of ecologists, morphologists and engineering experts executed a preliminary design study. In workshops, a broad representation of actors and experts jointly developed designs for the Sand Engine. The resulting four designs met the multiple objectives of the project. Also in this phase, morphological developments of the designs were estimated based on computer modelling, including a new software tool integrating ecological parameters. In working towards a decision for the preferred design and in optimizing this design, the focus shifted to the singular effects of the Sand Engine: on ecology, on flood protection, on recreation or other. Knowledge development, informed by the EIA procedure to assess separate effects of the design, continued in a more mono-disciplinary manner. Workshops were organized per discipline for example among morphological experts or ecological experts and reports were developed per discipline. Hence optimizations that synchronized objectives as was done in designing the Sand Engine alternatives did not take place. However, an important exception is the assessment of knowledge. This happened in the multi-stakeholder project team throughout the project. As a consequence, all documents were assessed from multiple perspectives and disciplines.

3.4.4 An integrated knowledge arrangement

The knowledge arrangement on nature and the knowledge arrangement on flood protection became connected around the topic of large-scale sand nourishment. This shared interest led to a knowledge arrangement that integrated the two foundational knowledge arrangements: the Sand Engine knowledge arrangement. This knowledge arrangement is a temporary and location-specific construction. Integration can be found in all five dimensions of the knowledge arrangement: an actor coalition emerged representing actors from both arrangements; there is a collective discourse identifiable connecting the four objectives of the project; a collective set of rules guiding the process and content of the project is agreed upon by actors (a.o. laid down in the ambition agreement); an integrated knowledge base is developed and assessed in an integrated way by means of an interdisciplinary project team, and financial resources from both foundational knowledge arrangements substantiated the project. Some aspects however in optimization and selection of the preferred design show features that we do not regard as integrated. Informed by the EIA procedure, assessment and optimization of the designs was dealt with by looking at separate aspects and knowledge development on these separated aspects. The knowledge arrangements are summarized in Table 3.2.

Table 3.2 Summary of three knowledge arrangements: flood protection, nature and Sand Engine

	Flood protection	Nature	Sand Engine (designing, decision-making and optimization)
Actor	RWS, DGW, Deltares	PZH as the central actor Other (regional) actors such as municipalities, e-NGOs and ministries	Broad coalition of actors in project organization: PZH, RWS, municipalities, NGO's Consultants, Deltares, Universities. Easy entry and exit of actors during the project
Discourse	Coastline maintenance, preservation of BKL, cost-effectiveness, innovation	Protection of species and habitats within protected sites Need for recreational green in integral coastal zone development	Natural Multifunctional Building with nature Pilot
Rules and regulations	Stable processes of decision-making and legislation over last 20 years Policy documents supporting Sand Engine like ideas	Nature sites Spatial planning policy	Project objectives in ambition agreement, not specified or Prioritized BKL and Natura2000 as boundary conditions For decision-making: EIA report and formal procedures
Resources	Coastal maintenance responsibility and budget by RWS Policy development by DGW	PZH responsible and resources for nature policy execution PZH decision-making power in chairing committee for coastal development	Decision-making power with PZH Budget shared among V&W and PZH Knowledge shared throughout the process
Knowledge base	Site-specific and generic coastal morphological knowledge, technical focus Exploration of large-scale and innovative nourishments	For nature sites (ecological), knowledge on species, habitats and enabling processes and conditions Reports on recreational green and integral coastal zone development and extension	Multi-disciplinary workshops and reports Four design alternatives Modelling of designs integrated beach dune model development, knowledge assessment in project team For decision-making and optimization: reports and workshops on singular effects, EIA report

3.5 Understanding integration of knowledge arrangements

Based on the knowledge arrangements in the Sand Engine, we analyse factors that enabled integration of knowledge arrangements (in Section 3.5.1) and that enabled GFP (in Section 3.5.2).

3.5.1 Enabling integration among nature and flood protection knowledge arrangements

Factors enabling integration among knowledge arrangements are found in the developments that preceded integration and the type of integration.

Developments preceding integration. In preparatory developments for the Sand Engine we find two grounds for integration (Huitema & Meijerink, 2010). First, there is a shared interest in the Sand Engine as a solution. In both foundational knowledge arrangements, ideas for multifunctional, large-scale sand nourishments popped up, albeit for different reasons. For coastline maintenance, climate change and sea-level rise induced a debate on long-term coastal protection. A need emerged for increasing nourishment volumes, extending the coastline and development of innovative methods. In the nature knowledge arrangements, an extension of the coastline was considered as a solution for the shortage of recreational green in the coastal zone of the province of South-Holland. The Sand Engine is a solution for different problems, and thus a shared interest. Second, there is resource interdependency among the two arrangements. Actors from both arrangements recognize the value of the resources of the other arrangement representatives, providing a potential for collaborative solutions to emerge (Gray, 2004). PZH was in charge of decision-making by chairing the steering committee and acquiring the assignment of the Prime Minister for developing a plan. The ministry of V&W had budget available for the project.

Flexible integration. Integration was established between flood protection and nature knowledge arrangements. However integration was flexible and moreover core values of the foundational knowledge arrangements were excluded. Both characteristics of integration were central to the success of this integrated knowledge arrangement.

Integration is typified as flexible in particular because the project objectives allowed for various interpretations and the actor coalition was adaptive. The objectives were defined rather generally (in contrast to BKL, species or habitats as used in the foundational knowledge arrangements), making specific assessment impossible. This strategy made finding synergies among functions quite easy and provided ample design space for the Sand Engine. The actor coalition changed—actors left and entered the coalition—depending on the matters on the agenda and their interests. In addition, core values were excluded from the integration. Core values are those elements of knowledge arrangements that are deemed essential, such as the BKL in the flood protection arrangements or the protected species in the Natura2000 site. The design of the Sand Engine and even more its location illustrate this, in particular for the flood protection core values. The Sand Engine was located where it 'can harm the least' (interview Deltares representative, 19 April 2010). The dunes at the location of hook-north had just been reinforced, which made additional flood protection somewhat redundant. Hook-north was complemented with additional nourishment to prevent possible erosion of the BKL in northward direction. These measures assured that any negative impact on ongoing coastline maintenance was prevented. Moreover, the annual budget for coastline maintenance was not used for the Sand Engine as 'effects for maintenance of the coastline are unknown' (interview DGW representative, 10 February 2010).

Flexible integration and the exclusion of core values strongly contributed to the success of the Sand Engine: nothing essential was at stake, not within the project (the objectives are too vague to critically assess) nor outside the project (as core values are protected). This construction prevented possible conflicts or discussion about trade-offs that could possibly have impeded swift implementation. On top of this, the project was a pilot. Everything not accounted for in the project or uncertain could later on be explained by the argument that the project was an experiment.

3.5.2 Enabling greening flood protection: space for design

The integrated Sand Engine arrangement enabled GFP by allowing for natural dynamics and its unpredictability and multifunctionality in the design and generating support for it in decision-making. These conditions directly contribute to implementation of GFP. The multifunctional character of the project required combining multiple perspectives and values that should be reflected in an inclusive process of knowledge production (Brugnach & Ingram, 2012). Such inclusive processes are different from more traditional processes of knowledge production in terms of knowledge type and involvement of stakeholders (Brugnach & Ingram, 2012). Here we consider the relation between the creation of the knowledge base and policy arrangement in the Sand Engine knowledge arrangement and extract factors that enabled integral GFP knowledge development and support.

The entire *actor* coalition was involved in the developments of Sand Engine designs by means of workshops. Besides, all knowledge documents were discussed and assessed in the project team. This approach makes the knowledge base inherently relational (Brugnach & Ingram, 2012). It allowed for including different types of knowledge and different values, representing the different views on the Sand Engine. In addition, face-to-face interaction that happened in both the workshops and the project meetings are important for the transfer and building of tacit project knowledge (Koskinen et al., 2003) as are intensive interactions (Vinke-De Kruijf et al., 2013).

The *discourse* of the Sand Engine represents the various values in the project and at the same time is open for multiple interpretations. In addition, it allowed for uncertainties that are inherent in GFP designs by explicitly presenting the Sand Engine as an innovation and as a pilot. By this, the uncertain aspects of the GFP designs were lightly accepted (later on in the process, management and monitoring plans were developed handle uncertainties).

The *rules* in the project directly affected the development of the knowledge base. The jointly agreed upon project objectives guided the design development. The unspecified formulation provided ample design space for developing the Sand Engine design. It also prevented conflicts (and delays) or the need for trade-offs among goals. In design optimization and selection, the development of knowledge was influenced by boundary conditions and EIA effect assessment. This entailed, for example, investigating the effects on the bordering Natura2000 site and on morphological developments to predict coastline development. The formal rules steered knowledge development towards a more mono-disciplinary mode.

Overcoming disparities in power is one of the main challenges towards creating inclusive and integral knowledge (Brugnach & Ingram, 2012). In the Netherlands, the flood protection domain and related knowledge is deeply institutionalized and provided with ample resources, in contrast to a less well-resourced and organized nature domain (Van Buuren et al., 2010a). In the Sand Engine project, however, the differences in power were less extreme. PZH controlled decision-making in chairing the project, while the role of RWS was downsized and levelled with other project participants. This downsized the dominance of flood protection knowledge and provided room to include other types of knowledge contributing to the multifunctional design.

3.6 Conclusions

GFP is a new and promising approach in flood protection management. Yet it seems that critical issues, such as the role of knowledge in decision-making and implementation, are overlooked. GFP is inherently uncertain, introduces dynamics and unpredictability, and is multifunctional. This will affect processes of knowledge production. Our study focused on understanding the role of knowledge processes in developing and decision-making GFP, by applying an analytical framework of ‘interacting knowledge arrangements’. The analytical concept of knowledge arrangements is a way to analyse ‘WoKs’ by emphasizing interactions between science and policy domains as opposed to focusing on general science and policy interactions.

As a presupposition we argued that an integrated knowledge arrangement was needed to enable GFP. The case study Pilot Sand Engine Delfland confirmed this presupposition and provided detailed insights on the nature of such integration and impact on GFP decision-making. The merit of the integrated knowledge arrangement was in the development of integrated designs that were supported by a wide actor coalition. Important in this respect were the multiple project objectives, the broad actor coalition and power levelling mechanisms. Flexibility of the integrated knowledge arrangement was central to the effectiveness of the integration. Flexibility was found in the interpretation of objectives and actor coalitions providing ample space for designing. Together with the exclusion of core values from the foundational arrangements in the integrated knowledge arrangement, conflicts and discussion were prevented and decision-making could proceed in a fluent manner. The project had become a low-risk exercise with little at stake. The case study provided insights in the factors enabling integration and the consequences for GFP decision-making. However, it did not yet yield insights in the interaction processes among domains. Application to other cases—with more interaction processes visible—is therefore recommended.

A more general insight from the case study points to the difficulties of implementing GFP in everyday flood protection institutions and routines, at least for the Dutch context. It appears that GFP is only possible when positioned outside the daily routines. Both the multifunctionality and the uncertainty related to GFP are difficult to combine in the current construction of the flood protection knowledge arrangement, which is traditionally focused on effective coastline maintenance. However, this pilot project provides an important experience with realizing GFP as trust and confidence was built with an innovative approach. Moreover, it should not be regarded as only a physical experiment as it serves in a similar way as a 'field laboratory' for institutional innovation (Renting & Van Der Ploeg, 2001). The know-how and trust gained might affect future developments in (Dutch) flood protection projects in a positive way. Given the temporary nature of the Sand Engine, the challenge of knowledge transfer to more permanent governance structures becomes a matter of interest (Sjöblom, 2009). Another advantage is that the project attracts visitors from all over the world and serves as an international eye-catcher of innovative Dutch flood protection (and its industry).

This case study provides an example of how boundary integration was enabled by excluding some elements. The annual budget for coastline maintenance and the BKL objective (core values), for instance, were not part of the integration. Literature on boundary work has a focus on linkages across boundaries by, among others, boundary organizations, objects, experiences or other boundary design elements (Dewulf et al., 2013; Guston, 2001; Leith et al., 2014). We suggest that explorations of boundary management should include a focus on the exclusion of certain linkages, as it may provide a key to establishing an effective boundary.

4 The role of knowledge in greening flood protection. Lessons from the Dutch case study future Afsluitdijk[24]

Abstract

Greening flood protection (GFP) is an upcoming approach in coastal protection knowledge and policy. The central notion of this multifunctional concept is that natural processes, nature development and the dynamics of ecosystems are taken into account in realising flood protection. In practice, implementation of GFP is faced with multiple barriers, of which some are strongly related to knowledge. In this paper we aim to further our understanding of the realisation of GFP in projects by focussing on the role of knowledge and specifically looking at the interaction between knowledge related to different policy fields. We analyse under what conditions knowledge can enable GFP in projects. We apply a conceptual framework of knowledge arrangements (KAs) – drawing attention to the policy fields and the knowledge base – on the Dutch flood protection project Future Afsluitdijk. While the project aimed at more than just flood protection, this was not achieved. The case serves as an illustrative example of the struggle to organise knowledge processes for an integrated, greening flood protection design. We identify four main lessons on the role of knowledge: (1) knowledge development should take place at close distance to the policy process and include intensive interaction, (2) multiple design iterations are needed, (3) integration at policy level requires structural embedding to endure, and (4) tools are required that allow for an integrated assessment. Interestingly, the failure of integration between KAs within the project led to the development and re-organisation of the nature domain. As a result nature actors managed to pursue their goals, but in a different arena.

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4.1 Introduction

All over the world deltas and coastal zones have to deal with increasing spatial pressures to accommodate multiple functions. Recreation, economic activities, housing, flood protection, nature conservation, agriculture and infrastructure all battle for space, while the available space in deltas is decreasing (Van Tatenhove & Hajer, 2001). Parallel to this, environmental awareness and interests are increasing in society. Economic and development processes are "increasingly analysed and judged, as well as designed and organised from both an economic and an ecological point of view" (Mol, 2002, p.94). In the field of flood protection and coastal management such an 'ecologically induced transformation' (Mol, 2002) has resulted in practices and discourses of so-called greening flood protection (GFP). GFP as a new upcoming approach stresses that natural processes, nature development and the dynamics of ecosystems are taken into account in realising flood protection. Examples where this new flood protection discourse is put into practice are the use of vegetation for wave attenuation (Borsje et al., 2011; Gedan et al., 2011), (large) sand nourishments for coastline maintenance (Janssen et al., 2014b; Stive et al., 2013; Van den Hoek et al., 2012) and oyster beds for protection against erosion and stabilizing sediment (De Vries et al., 2007; Piazza et al., 2005). Conventional flood protection, for example in the form of traditional dams, dikes, storm-surge barriers, breakwaters and the like, differ from measures that facilitate GFP. The latter have a pro-active stance towards the ecosystem rather than a defensive approach by minimizing potential negative effects on the environment. GFP aims to (pro)actively involve and include nature and environment in optimising flood protection. The GFP discourse has led to a variety of concepts in literature and practice, such as building with nature (De Vriend & Wesselink, 2009; Van den Hoek et al., 2012; Van Slobbe et al., 2013), ecological engineering (Borsje et al., 2011; Mitsch & Jørgensen, 2003), working with nature (PIANC, 2011), ecological enhancement (Naylor et al., 2012) and ecosystem-based management (Katsanevakis et al., 2011; Knol, 2013). But all these approaches work with more or less the same principles and ideas, and intensively exchange these ideas.

In the last decade GFP has gained increasing attention. The common knowledge base on possible alternatives for greening flood design is built for a variety of physical settings (Borsje et al., 2011; Naylor et al., 2012), and GFP is increasingly present in national and international policy documents and in the objectives of individual flood protection projects. Yet, the implementation and realisation seems to move forward less swiftly (Borsje et al., 2011). Combining nature protection or development with flood safety objectives in flood protection projects requires an integrated and multifunctional approach, but in practice numerous barriers complicate the realisation of such multifunctional infrastructures (Katsanevakis et al., 2011; Mulder et al., 2011; Van Broekhoven & Vernay, 2011).

Central to the implementation of GFP is the role of knowledge. Besides functioning as an important resource it structures the involvement of actors and their specific views (Mol, 2008; Toonen & Van Tatenhove, 2013). Knowledge is thus an important factor enabling or constraining decision-making. GFP requires cooperation among a diverse range of disciplines, - including engineering, ecology, (geo-)morphology, climate science, physics, economics and others (O'Toole & Coffey, 2013) - and the development of innovative and integrated perspectives on flood management practices. A substantive body of literature exists on knowledge in decision making with a focus on the transfer of science/knowledge to policy (e.g. Holmes & Clark, 2008; McNie, 2007; Turnhout et al., 2007) and combining different types or disciplinary knowledges (e.g. Rinaudo & Garin, 2005). The multidisciplinary nature of GFP however, draws our attention to the inherent relation between knowledge and policy fields (Edelenbos et al., 2011; Van Buuren & Edelenbos, 2004) and to the interaction between these knowledge-policy fields. In particular the latter is a topic only incidentally addressed. The prevailing policy discourse, the dominant actors with more or less resources, and the relevant rules and regulations of a policy field structure the role and type of knowledge in that particular policy field. GFP projects are characterised by different policy fields meeting each other and subject to changing governance settings (Korbee & Van Tatenhove, 2013). Therefore, the integration of knowledge disciplines in designing measures goes beyond 'simple' overcoming epistemological barriers. In fact, as central in our conceptual framework (section 4.2), it is a matter of double integration: of knowledge and of the policy contexts.

In this paper we aim to further our understanding of the realisation of GFP in projects by focussing on the role of knowledge and specifically looking at the interaction between knowledge related to different policy field. The main question this paper seeks to address is: how and in what ways does knowledge enable GFP in projects? In order to answer this question, we apply a qualitative case study approach (section 4.3) and analyse the Dutch flood protection project Future Afsluitdijk[25] by means of our conceptual framework of knowledge arrangements (KAs) (section 4.2). This project aimed to accomplish "more than just safety"[26] (Ministerie van V&W, 2007) and a range of attempts were undertaken to include nature development in the flood protection design.

The paper is structured as follows. In the next section we introduce our conceptual framework and explain the underlying theoretical foundations. In section 4.3 we discuss our case study design. In the result section (section 4.4) we discuss the interaction among

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[25] In Dutch: Toekomst Afsluitdijk.

[26] Safety refers to matters of safety against flooding. In this paper we will use the term flood protection.

KAs as happened in our case study. These results are then discussed in section 4.5 and we finish the paper by drawing conclusions upon the role of knowledge for GFP (section 4.6).

4.2 Conceptual framework: knowledge arrangements

Knowledge is a crucial asset in the decision-making process of developing infrastructure for flood protection. In analysing problems, finding and designing solutions, following legal procedures and generating public support knowledge is indispensable (Van Buuren et al., 2010b). The involvement of a wide variety of actors, with different and diverging interests and backgrounds, often results in debates on knowledge during decision-making processes (Koppenjan & Klijn, 2004). This is in particular relevant for coastal management. The complexity of coastal environments together with diverse uses and presence of multiple stakeholders makes bringing together of different knowledges a considerable challenge which has often turned out ineffective (Clarke et al., 2013). Understanding coastal development from a knowledge perspective draws attention to particular challenges such as the presence of different and fragmented forms of knowledge, sensitivities around information, the political site of knowledge and uncertainties in understanding (O'Toole & Coffey, 2013). Also such a perspective improves the understanding of knowledge as dynamic and non-linear as opposed to linear 'research and application' (Coffey & O'Toole, 2012; Van Kerkhoff & Lebel, 2006). To overcome knowledge conflicts and to provide 'useful' information or knowledge to policy makers, a large body of research is devoted to closing the gap between science and policy and to overcome epistemological barriers either from a science technology studies or sociology of science perspective (Holmes & Clark, 2008; McNie, 2007; Turnhout et al., 2007) or by proposing actual frameworks to connect scientists and decision-makers (De Jonge et al., 2012). In this paper on the role of knowledge in GFP, attention is on the embeddedness of knowledge in particular policy fields and the related interactions between knowledge and policy.

Within a single policy domain, interactions between knowledge agents and policy makers are frequent and both have often similar orientations and backgrounds (Edelenbos et al., 2011). In addition, frequent interaction allows for sharing of tacit knowledge with more effective knowledge as a result (Hunt & Shackley, 1999). This phenomenon is noticed in literature and captured for example by concepts as 'knowledge coalitions' (Van Buuren & Edelenbos, 2004), 'knowledge arenas', 'ways of knowing' (Lejano & Ingram, 2009), or 'knowledge systems' (Roling & Jiggins, 1998). A systematic analysis however of interaction among these knowledge-policy fields, is lacking or does not include the policy context of knowledge (e.g. Hunt & Shackley, 1999). Here lies the contribution of this paper.

We capture the interaction between knowledge realms and policy fields within a specific domain by the concept knowledge arrangements (KAs). In GFP, KAs related to nature and to flood protection interact and clash with each other. We will analyse these interacting KAs.

4.2.1 Knowledge arrangement

Knowledge and policy are not isolated fields, but they interact and overlap in a 'fuzzy boundary area' (Turnhout et al., 2007). Knowledge development in policy processes is a two level game where knowledge influences policy processes and outcomes and policy making influences knowledge generation and articulation (Koppenjan & Klijn, 2004). In other words, knowledge development and articulation is embedded in its (policy and other) contexts (Nowotny et al., 2001) and thus will differ in both content and orientation among locations of development (Eshuis & Stuiver, 2005). The concept of KAs is based on this recognition that knowledge and policy are interrelated and specific for a particular domain.

The concept of KAs builds upon the idea of policy arrangements as developed by Van Tatenhove et al. (2000). This approach builds on the 'duality of structure' developed by Giddens (1984) and balances structural and discursive elements of policy processes (Wiering & Immink, 2006). A policy arrangement is a "temporary stabilisation of content and organisation of a particular policy domain at a certain policy level or over several policy levels" (Van Tatenhove et al., 2000, p.54). It is identified and analysed by four interrelated dimensions: (1) actors and coalitions involved in policies, (2) discourses that capture views and narratives of these actors, (3) resources applied by actors (e.g. money, knowledge, authority, facilities), and (4) (formal and informal) rules of the policy game (Liefferink, 2006). While knowledge in the policy arrangement approach is recognised as a power resource in a policy domain, the way the knowledge base is created, interpreted and used is not explicitly dealt with. We define a knowledge arrangement as the dynamic interdependent constellation of a knowledge base and the policy arrangement within a specific domain. Following Hommes (2008) and Hommes et al. (2009) we define a knowledge base as a collection of knowledge sources (i.e. research reports, models, data, practical experiences, etc.) that have been made explicit and are related to a specific policy arrangement.

4.2.2 Multifunctional infrastructure development: interacting knowledge arrangements

In greening flood protection, different KAs interact with each other (Figure 4.1). The type of interaction between KAs determines the possibilities for an integrated design. Four types of interaction among KAs can be distinguished: separation, cooperation, integration and unification. Separation reflects no interaction between KAs. Knowledge base and policy development happen within different isolated domains without any sharing or communication back and forth. Cooperation is a form of interaction in which KAs do communicate and are mutually aware of (policy and knowledge base) developments in the other domain. Developments in designing and decision-making may be attuned and mutual influencing and a common agreement or ‘position’ with respect to GFP is conceivable. When KAs cooperate they do not merge into one new KA. The third form of interaction is integration in which KAs do merge, but will not dissolve. Integration means that a new arrangement emerges as a combination of elements of the two former arrangements. Actors cooperate in one team or organisation, and resources and approaches are shared and collective, while the home-institutions remain in place. The initial KAs disappear and are replaced by a new KA when interaction leads to unification. Within the boundaries of a single project, integration is the most far-reaching form of interaction achievable. Unification is the result of a process that exceeds a single project as it requires multiple projects, policies and societal developments over a longer time.

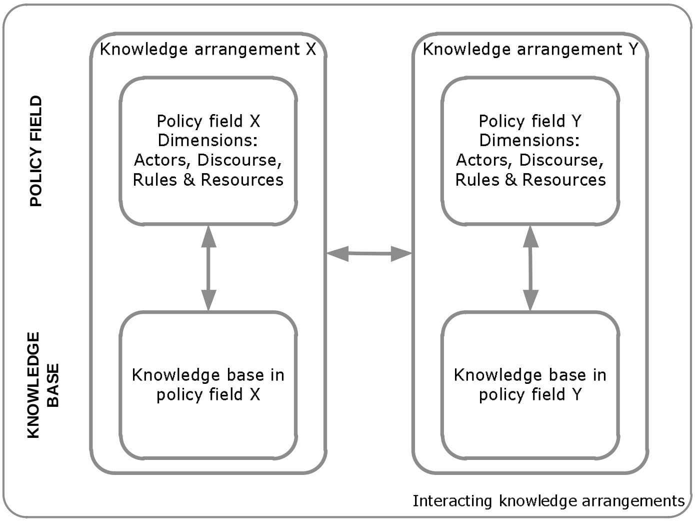

Figure 4.1 Interacting knowledge arrangements.

KAs are inherently dynamic as changes in one dimension are likely to result in changes in another (Liefferink, 2006). The introduction of new reports, actors, scientific insights, legislation, or resources will evoke change in the arrangements to a smaller or greater extent. The confrontation between KAs is also an incentive for change (Lejano & Ingram, 2009; Wiering & Immink, 2006) and can be either constraining or enabling greening flood protection (Koenig-Archibugi, 2002).

Because GFP requires collaborative action of distinct domains, knowledge from different domains should be integrated or become ‘inclusive’: “[inclusive knowledge] paves the way by delivering a joint knowledge base and a shared frame of reference" (Van Buuren, 2009, p.230). Sectoral approaches are less appropriate to lead to GFP (Katsanevakis et al., 2011) and hence an integrated form of KAs is required.

4.3 Case study design: selection and method

In this section we discuss the selection of the project Future Afsluitdijk as our case study and the methods we applied.

4.3.1 Case study area

The ambition of the project Future Afsluitdijk was "to do more than just safety" (Ministerie van V&W, 2007). In fact, the project was to serve as an 'icon' and show the advantages of a synergy approach (Instituut SMO, 2008; Ministerie van V&W, 2007). One explicit goal relates to combining flood protection with nature development, often labelled 'building with nature'. The objective of the project and the integral approach applied makes the case an interesting example for studying the implementation of GFP.

The Afsluitdijk is a dam situated between the Wadden Sea and Lake IJsselmeer and counts as one of the main icons of Dutch coastal engineering (Figure 4.2). Following the big flood in 1916 this dam was constructed to improve flood protection and create agricultural land. It had big consequences for the geographic development of the northern part of the Netherlands (De Jonge, 2009). The dam closed off the Zuider Sea and created Lake IJsselmeer in the north of the Netherlands. Lake IJsselmeer is the largest fresh water body in the Netherlands (1200 km^2) and an important (buffer) for fresh water supply. Furthermore, it facilitates shipping, sand mining, and fisheries. The important natural value of the lake is under stress and central to improvement is the recovery of the transition between the fresh water in Lake IJsselmeer and the salt water in the Wadden Sea (Ministerie van V&W, 2009). Such a salt-fresh water transition is also essential for the natural value of the Wadden Sea (Raad voor de Wadden, 2008). The Wadden Sea is a nature site of global importance and designated as World Heritage Site for its unique natural value (Kabat et al., 2012). It is indicated as a Natura 2000 site in order to maintain and improve biodiversity in the area. The main policy objective for the Wadden Sea is defined as: "the sustainable protection and development of the Wadden Sea as nature area and maintenance of the unique open landscape" (Ministerie van VROM, 2007, p.9). Since the 1960s the ecological value and human impact in the area – e.g. fisheries, gas mining, tourism – have been of growing concern (Kabat et al., 2012). Of particular importance in this process was the Mazure committee who advised negatively on reclaiming the Wadden Sea (Waddenzeecommissie, 1974).

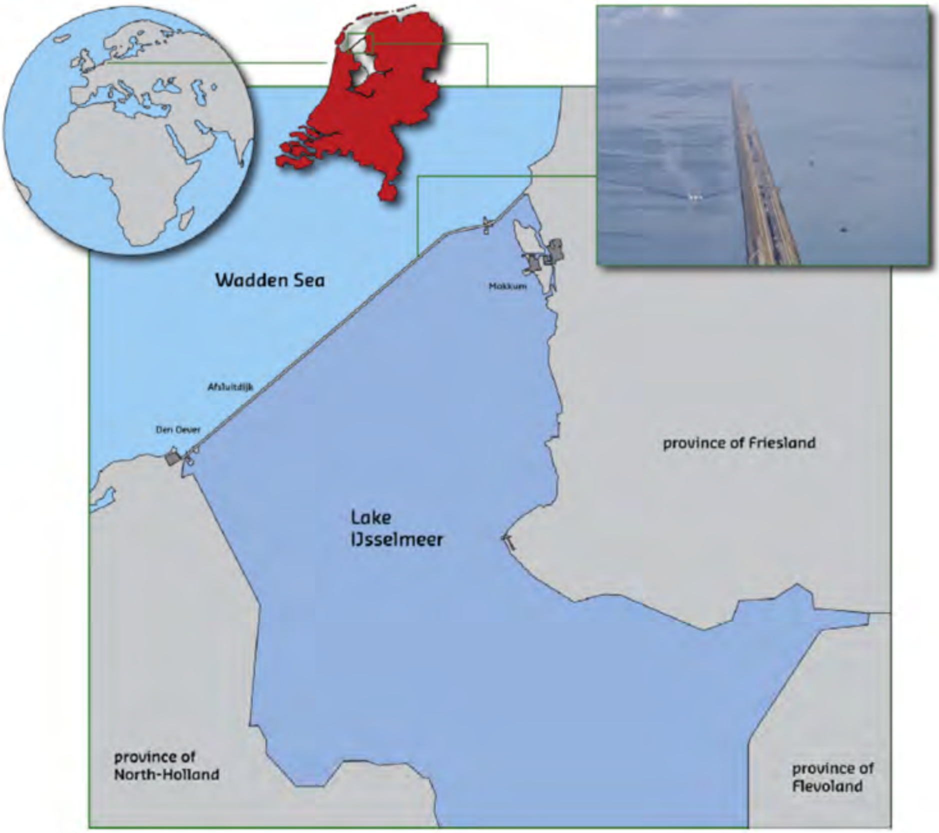

Figure 4.2 Overview of the Afsluitdijk. The Afsluitdijk is located in the north of the Netherlands and closes of the salt Wadden Sea from the fresh water Lake IJsselmeer. At the north-east side the dam is connected to the province of Friesland, at the south-west to the province of North-Holland. At the north-east side of the dam the Lorentz sluices (locks and drainage sluices) are located, in the south-west the Stevin sluices (locks and drainage sluices). The dam contains a road and a bicycle track and accommodates some recreational functions.

Today, the 32 km long Afsluitdijk still counts as a mastery example of Dutch coastal engineering skills. After doing its duty for over 80 years, in 2006 the “grand old lady” of Dutch coastal engineering no longer meets the flood protection standard (withstanding a 1/10.000 year storm). The project ‘Future Afsluitdijk’ (in Dutch Toekomst Afsluitdijk) started in 2007 in order to reinforce the dam.

4.3.2 Methods

To study the project Future Afsluitdijk we used a qualitative case study approach based on data triangulation using five different methods for data gathering. As sources of data we used: seven in depth formal interviews, multiple informal interviews with a broad range of stakeholders, (participatory) observation through attending public and project meetings, and extensive analysis of project documentation. In addition, we discussed the results of the case study analysis and earlier versions of the paper with project participants from the province and the ministry in order to validate observations and interpretations made.

The principal researcher was involved in the project from June 2010 onwards, when the outcome of the project was still unknown. Our real-time data collection (when the project unfolded) yielded insight into the daily practice of the project and specific circumstances that could perhaps not all have been recaptured in interviews or formal documentation afterwards. The participating researcher was provided access to all project documentation, including internal writings, minutes of meetings, e-mail correspondence, (formal) reports etc. Formal interviews were held with two ministerial representatives, one provincial representative, two representatives of nature organisations, one consultant hired by the ministry and one respondent of a market party. Five of the interviews were held in November 2011 (just before the formal decision on the preferred design alternative) and two were held one year later. The formal interviews had a semi-open character and were based on the clean language approach. This approach is rooted in psychology and now applied in many fields including education, health, business and research. Clean language is about gathering information by means of asking ‘ultra-open’ questions that contain as few assumptions and metaphors of the respondent as possible (Sullivan & Rees, 2008). The story of the respondent is therefore minimally mingled with the ideas and words of the interviewer, and the respondent has the maximum freedom to choose the answer he considers suitable. The interviewer structures ideas and opinions of the respondent and encourages the person to elaborate (Sullivan & Rees, 2008; Van Helsdingen & Nijburg, 2012). This interview approach aims to minimise bias by ruling out the assumptions and intentions of the interviewer, which is highly relevant for this particular situation where the researcher is intensively involved in the project.

Data analysis was informed by our conceptual framework of KAs, which was leading in categorizing and organising the extensive data set. This was an iterative process where we combined the diverse and multiple sources of information available. Based on this we extracted the discourses applied, the leading rules and regulations, the actors that played a role and their interactions, the resources that were available and the knowledge base that was constructed.

Our analysis of the case study stops after the selection of the preferred design alternative. Plan and project development however continued after that and currently the minister intends to decide on these in 2015. The project expects to start realisation in 2017, with an anticipated end date of 2021.[27]

4.4 Results

In this section we describe the interaction that occurred among knowledge arrangements (KAs) in the case study Future Afsluitdijk. As the interest is in greening flood protection the focus is on interaction between the two KAs related to flood protection and nature. However, the project Future Afsluitdijk was not directed at combining flood protection and nature alone or specifically. Rather, the project aimed to combine a broad range of functions (including energy, recreation, agriculture and nature).

The case study Future Afsluitdijk can be divided into three successive phases: design, assessment, and decision-making (Figure 4.3).

[27] Source: http://www.rijkswaterstaat.nl/water/plannen_en_projecten/vaarwegen/ijsselmeer/project_afsluitdijk/index.aspx, accessed on 13 December 2013.

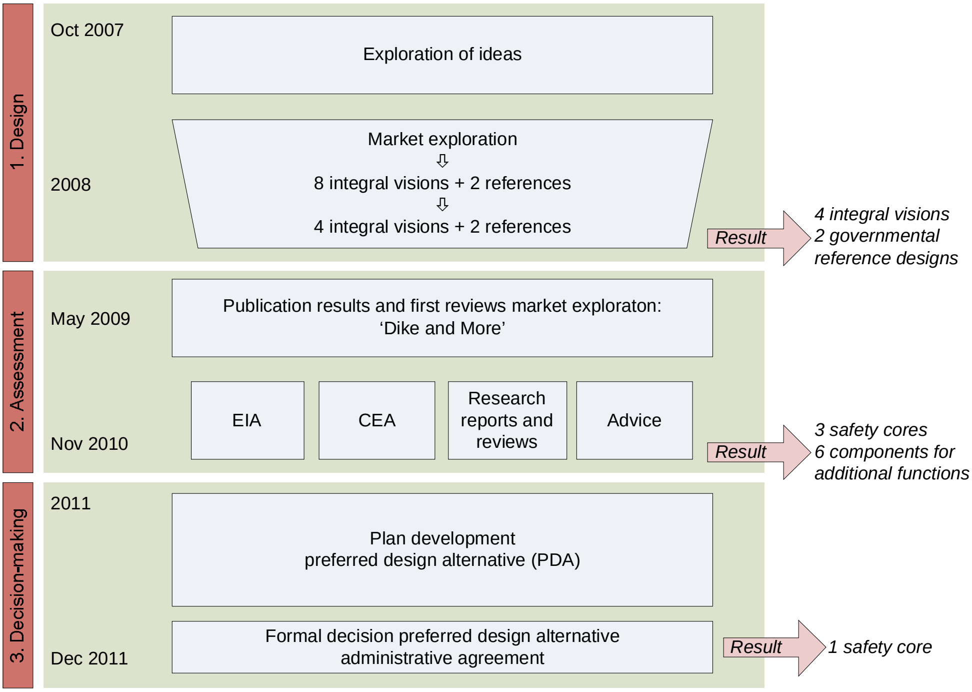

Figure 4.3 Overview of process Future Afsluitdijk towards a preferred design alternative. The project documents underlying this Figure are listed in Appendix IV.

The design phase started with a broad exploration of possible ideas for the future dam. The main question was how the Afsluitdijk could fulfil multiple functions. Over 200 people participated in workshops that led to a wide range of new and innovative ideas and functions, including large iconic structures, aqua-culture, a road surface with integrated solar power, wetlands in the Wadden Sea, and even reopening the Afsluitdijk in order to allow for tidal dynamics (Instituut SMO, 2008). These ideas served as input and inspiration for a so-called 'market exploration'. Market parties were asked to develop visions for the Afsluitdijk, resulting in four very diverse integral visions (Appendix III). In parallel to the design activities of market parties, the ministry of V&W[28] (ministry of Transport, Public Works and Water Management) developed two 'governmental reference designs': an

[28] In October 2010 the Ministry of V&W and the Ministry of Housing, Spatial planning and the Environment (VROM) merged into a new ministry of Infrastructure and Environment (I&M). In this paper we refer to 'the ministry of V&W' or simply to 'the ministry'. Within the ministry of V&W two different departments (directorate generals, DG's) are involved in the project: DG Rijkswaterstaat and DG Water. In this paper we will not discuss the division of roles, responsibilities and tasks among the DG's but directly refer to the ministry of V&W.

overflow-resistant dam and a robust traditional dam (see Appendix III). These designs focused primarily on flood protection.

The ‘assessment’ phase was structured by formal procedures, such as environmental impact assessment (EIA) reporting, cost effectiveness analysis (CEA), and the assessment framework. In order to compare the ideas of market parties, the integral visions were split into a ‘core’ relating to flood protection and several ‘components’ relating to additional functions (e.g. nature protection or creation, sustainable energy, spatial quality). This resulted in four different cores – a conventional dam, an overflow-resistant dam, a storm shield and sand nourishment – and a large range of components, among others silt agriculture, a sustainability centre, naviducts, tidal and flow power stations, bridges, fresh-salt water transitions and wetlands. In a period of almost two years,[29] these cores and components were assessed on their feasibility. This approach resulted in three conclusions: none of the integral visions was feasible as a whole, the elimination of the sand nourishment core, and the selection of a number of components requiring further study.

In the ‘decision-making’ phase the selection of a ‘preferred design alternative’ (PDA) was central. To be included in the PDA each core and component should be sufficiently ‘substantial’, which meant including a plan, a responsible party and an indication of the financial consequences. The limited available financial resources of the ministry and the urgency to improve the dam led to a change in organisation. The ministry emphasised to be responsible for flood protection only and expected other parties to further develop the components. The components lagged significantly behind in terms of organisation, plan development and allocating budget. In addition, the ministry stated that flood protection will not be delayed by the components. As a consequence, the PDA entailed a flood protection core only: the overflow-resistant dam. Disappointment with the course of the project resulted in a period of minimal interaction between the flood protection trajectory (led by the ministry) and the trajectory of developing components (led by other parties). Relationships improved only when an administrative agreement was signed, through which the ministry and governmental parties representing components agreed upon conditions for possible future combination of the core and various components.

[29] The assessment phase was relatively long. In particular the results of the CEA were time-consuming, and delayed by the fall of the Dutch government in February 2010. The CEA is developed by the Central Planning Agency (CPB): an independent research institute working among others at the government’s request. Due to the (unanticipated) elections, the CPB was occupied by calculating effects of the election programs and unavailable for their work on the Afsluitdijk.

In the following sections the interaction among a flood protection KA and a nature KA will be elaborated upon.

4.4.1 Phase 1: design

The design phase was set up in an integrated way, involving a broad range of actors. The project team consisted of representatives of the ministry as well as two provincial representatives. Over 200 people participated in workshops to make an inventory of possible ideas for the Afsluitdijk. Market parties were invited to develop visions as that was believed to result in the most innovative designs. The ministry formulated the assignment to do more than flood protection alone, while the provinces were interested in an integral approach which combined multiple functions. This phase was characterised by a stimulating creativity in the development of ideas. The ministry made financial reservations for the realisation of the Future Afsluitdijk.

The project had an integral character, but the embedding of this integration was weak. In particular, ‘other functions’ (not flood protection) were only marginally organised. For instance, there was no formal agreement between the province and the ministry in the project team. There was no further detailing as to what ‘more than flood protection alone’ or the nature function entailed (as opposed to the detailed description of the flood protection objectives), nor was there a prioritisation of additional functions. Nature and other functions were open for discussion and left to the creativity of the market parties. Moreover, the follow-up process – after the completion of the visions – was undefined and remained vague until the spring of 2009. Integration was also not reflected by the available resources, only the ministry had resources allocated for the project.

Two different knowledge bases were developed in the design phase. First, market parties developed integral visions, inspired by the workshop outcomes. The visions were developed under a strict time schedule imposed by the project team. As a result an entire design cycle was not possible and the visions lacked in-depth discussions and a thorough knowledge base underpinning the designs. The relative open assignment led to major diversity of visions (see Appendix III). As the market exploration had characteristics of a competition setting,[30] the market parties strived for a distinctive eye-catching design, rather than the most sensible plan.[31] A second knowledge base was developed by the ministry. Two ‘governmental reference designs’ were designed to be compared with the integral designs.

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[30] In the perception of market parties, the design assignment was a competition, although it was explicitly stated by the project team that this was not the case.
[31] Interview respondent market party.

In the design phase, there was no full nature KA, but there was one germinating. Actors in the nature domain were incidentally involved in the project: they participated in idea development workshops and provided reflections on integral visions. But nature protection actors were not organised and had no clear ideas for the future of the Afsluitdijk.

An overview of the interacting KAs in this design phase is provided in Figure 4.4.

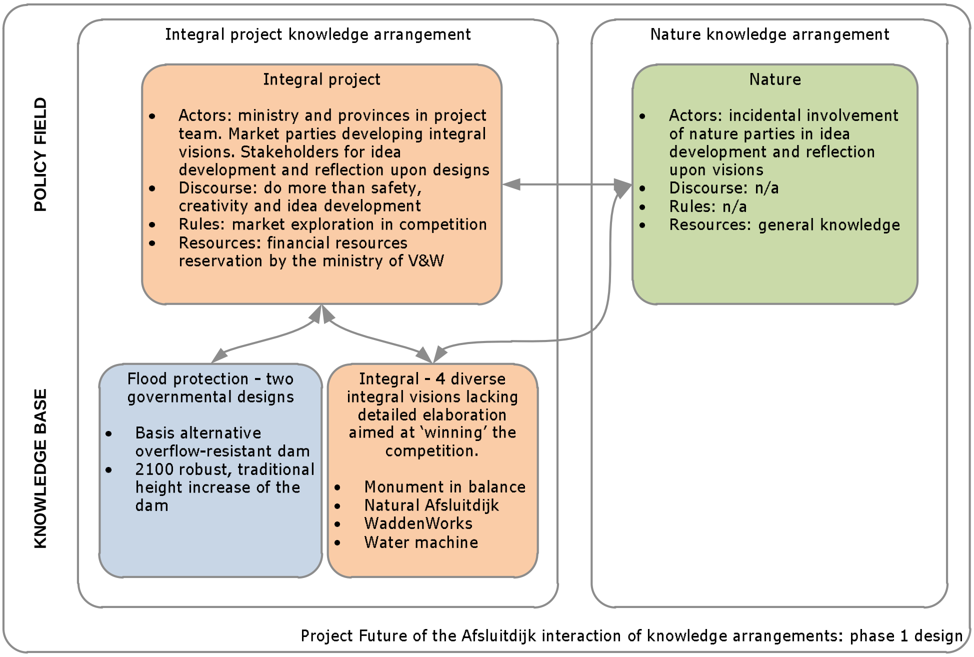

Figure 4.4 Overview of interacting knowledge arrangements in the design phase of the Future Afsluitdijk project.

4.4.2 Phase 2: assessment

The integral set-up of the project, formed at the start of the project, was still in place during the assessment phase: the ministry and provinces were in one project team and there was a shared discourse and shared ideas about the rules of the game. However, after preparing the visions, the market parties played no role anymore. Instead of 'idea development' the discourse changed to a focus on 'the feasibility of cores and components'. Each core and component was assessed on financial, technical and maintenance feasibility. Also in this phase the ministry secured financial reservations, although the availability of the budget became more uncertain due to the economic crisis and the political crisis of the coalition government. The rules of the game included an environmental impact assessment (EIA), a cost effectiveness analysis (CEA) and an assessment framework for supporting final decision-making. This all directly related to the development of knowledge.

The assessment of cores and components led to an extensive knowledge base over a period of about two years (Appendix IV). The knowledge base related to separate cores, components or aspects. This approach resulted in the fragmented development of knowledge as knowledge was produced in separate reviews, research reports and expert sessions. Reviews and assessment were provided on flood protection, nature protection and ecology, spatial quality, sustainable energy and maintenance; expert sessions were held on nature protection and sustainability; and research reports were produced on morphology of sand nourishment, on feasibility of the storm shield, and on legal feasibility of the designs. Depending on the topic, different scientific institutes, different experts, different governmental agencies and/or different interest groups were involved.

The nature KA strengthened in this phase through involvement of nature protection organisations in stakeholder meetings and the expert session on nature. In general, though, nature protection organisations were dissatisfied and disappointed by the course of the project. According to a nature protection respondent: “nature protection organisations were disappointed because at the end of 2010 the project ambition on nature turned out to be of little substance”. Furthermore, concern existed regarding the negative attitude of the national government towards nature and the limited availability of financial resources for the project. Nature protection organisations organised and set up a design exercise themselves in order to collect possible ideas related to nature protection or development and an integral approach. Their effort resulted in the publication Afsluitdijk Naturally Safe[32] (Stichting VBIJ & Waddenvereniging, 2010). The financial resources in the nature KA were minimal. The Future Afsluitdijk project team was hardly aware of the activities in the nature KA.

An overview of the interacting KAs in this assessment phase is provided in Figure 4.5.

[32] In Dutch: Afsluitdijk Natuurlijk Veilig.

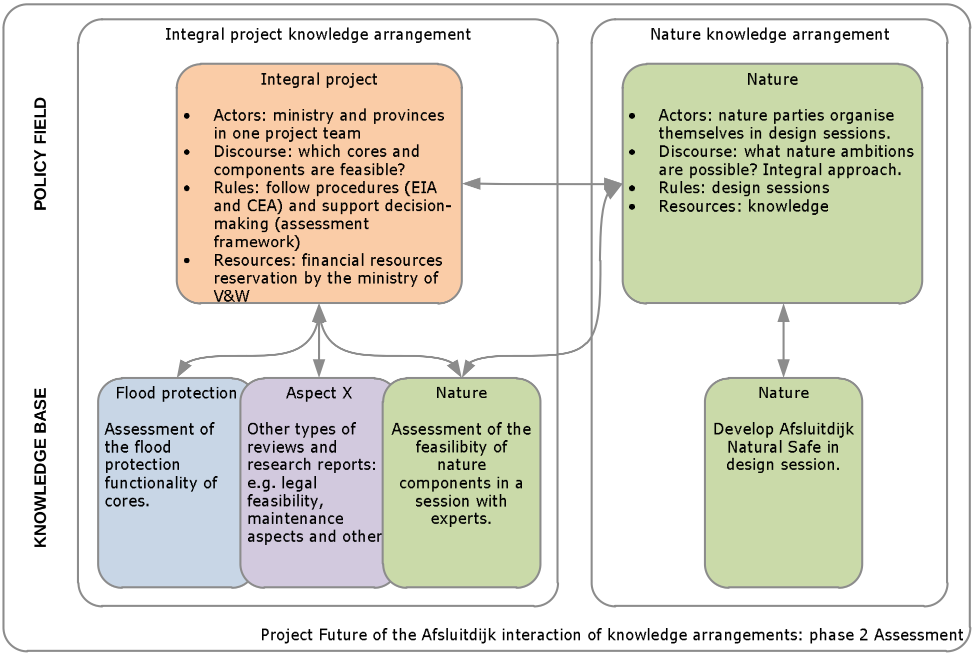

Figure 4.5 Overview of interacting knowledge arrangements in the assessment phase of the Future Afsluitdijk project.

4.4.3 Phase 3: decision-making

When the feasible cores and components were determined, three cores remained (a traditional height increase, the overflow-resistant dam and the storm shield) and six components (pilots for sustainable energy, a sustainability centre, pilots for silt agriculture, fresh-salt transition, small-scale recreation and naviducts). These cores and components were considered for further decision-making in order to establish a preferred design alternative (PDA). The project KA changed significantly at this point, by turning from an ‘integral’ to a ‘flood protection’ KA. The collective project team, consisting of the ministry and provinces, was replaced by another platform, excluding the provinces. The ministry changed their discourse into one emphasizing primary responsibility for flood protection, and no prior responsibility for nature protection or development. Financial resources were attributed to flood protection. The development of the PDA directly affected the development of knowledge. It required selection among the three cores and development of plans for components.

In the assessment phase the nature parties organised themselves, but only in this decision-making phase they were explicitly challenged by the project team to develop a substantial plan for nature: the fresh-salt transition in the Afsluitdijk. This plan however could not be included in the PDA, as it was not sufficiently complete. But the joint responsibility for its development further strengthened the nature KA, in terms of organisation building (a nature coalition was formed guided by the program 'Towards a rich Wadden Sea'[33] and in the Afsluitdijk Ambition Agenda coordinated by the provinces) and in terms of developing a plan for fresh-salt water transition. Building upon Afsluitdijk Naturally Safe (Stichting VBIJ & Waddenvereniging, 2010), the ideas for a fresh-salt transition matured into the idea of a 'fish migration river'. After 2011, some first financial resources were made available for developing the fish migration river.

The administrative agreement was signed in December 2011 and formulated conditions and requirements for future involvement of the components, among others the nature plan, into the flood protection project.

An overview of the interacting KAs in this decision-making phase is provided in Figure 4.6.

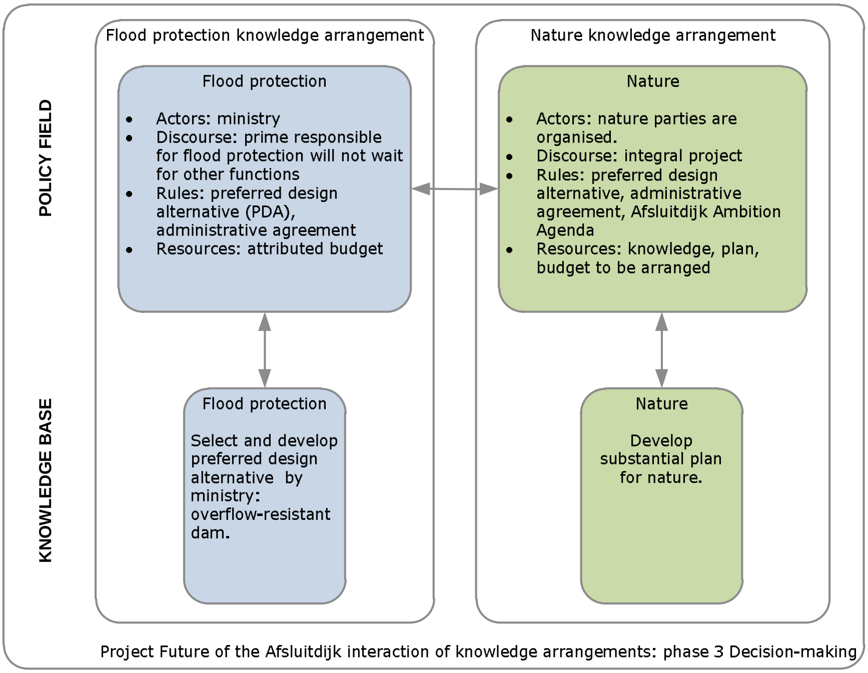

Figure 4.6 Interacting knowledge arrangements in the decision-making phase of the Future Afsluitdijk project.

[33] In Dutch: Programma Naar een Rijke Waddenzee.

4.5 Discussion

As hypothesised in section 4.2, greening flood protection depends on the integration of KAs. What has the case study on Future Afsluitdijk taught us in this respect?

In the project Future Afsluitdijk the type and degree of interaction between KAs changed over time. In chronological order, the process touched upon three ideal types of interaction (section 4.2.2): integration, separation and cooperation. Figure 4.7 schematically relates the three interaction forms to the different phases in the project.

4.5.1 Failure of the integrated knowledge arrangement

In the design phase and the assessment phase an integrated project KA could be identified in which the domains of nature and flood protection were integrated. In particular in the design phase, the integrated arrangement covered both functions. Yet, this integrated KA failed towards the end of the assessment phase when nature interest groups started to organise themselves along separate lines and processes. The project proved not as integrated as it had seemed at first sight.

The integrated KA was not sufficiently institutionalised in the project. Three factors can explain this lack of institutionalisation: (1) the integration at the level of policy fields, (2) the large distance between the project and the development of the integral visions by market parties, and (3) the abandonment of integration in assessing alternatives.

Looking at the four dimensions of policy fields, integration at policy field level lacked structural embedding. Cooperation among policy actors from different fields remained without further obligations. Financial resources for the project were not shared, but were reserved by the ministry only. The discourse seemed of an integrated nature and was shared among the different participants, but was uneven in content: the flood protection function was defined in detail, while the nature function remained rather unspecified, open for discussion and left to the creativity of the market parties. The general formulation of nature or ecological objectives for GFP is more often noticed (Janssen et al., 2014b; Knol, 2013). The design phase witnessed shared rules of the game, however the process to proceed after the design was undefined and unknown. In retrospect and despite ambitions of the project, the integration of the policy fields of nature and flood protection in the design phase was built upon quicksand. It either required reinforcement or, as happened, was bound to fall apart.

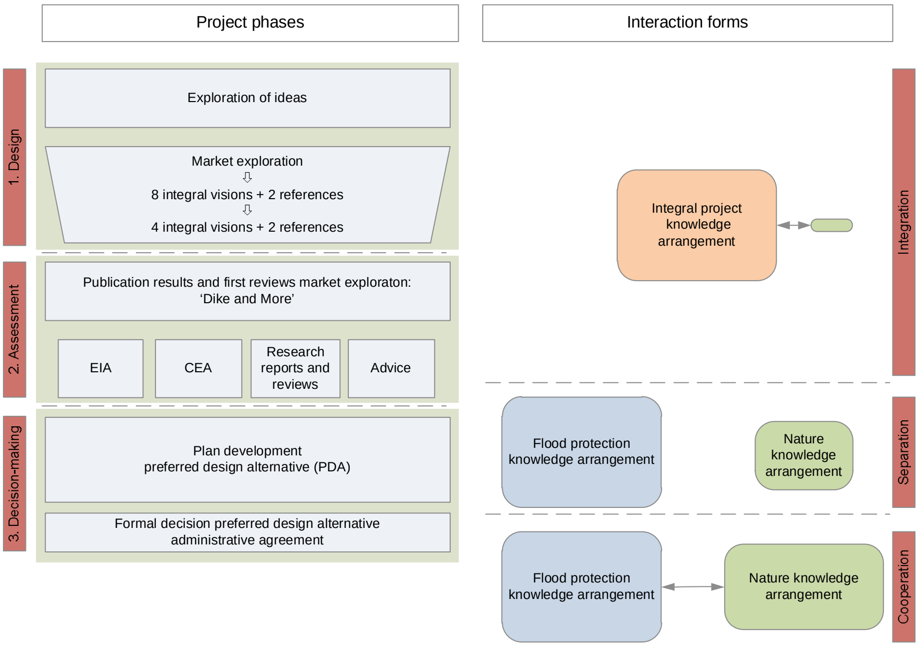

Figure 4.7 Three forms of interaction among knowledge arrangements in the project Future Afsluitdijk: integration, separation and cooperation.

Lack of institutionalisation of the integrated KA is also due to the large ’distance’ between the integral project policy field and the development of the integral visions by the market parties. The ’distance’ between the integral project organisation and the governmental reference designs was notably smaller. Three factors explain the difference in ’distance’. First, ministerial representatives (who were part of the project team) developed the governmental reference designs, while the integral visions were developed by external market parties. The project team deliberately remained at distance from the integral visions of the market parties in order to be able to judge more objectively. When actors are involved in knowledge development they are more likely to accept the outcome (Eshuis & Stuiver, 2005; Hommes et al., 2009). Second, the knowledge base in the development of the integral visions did not match the knowledge base within the policy field. The WaddenWorks integral vision (see Appendix III) was illustrative for this mismatch. This vision was based on ‘soft’, building-with-nature type of physical processes of sand and sediment transport, but applications of and experiences with these types of physical processes are limited in this region. A respondent of the market parties reflected on the knowledge background within the ministry: “There is a technical idiom, which they are very good at. The physical processes relevant for dunes and the functioning of dunes in flood protection are not their expertise.” Hard constructions for flood protection prevail in this area. Based on the known practices and their epistemologies actors interpret and value different knowledge in different ways (Hommes et al., 2009). Third, the transfer of knowledge to the policy actors and fields has been limited. Integral visions of the market parties – captured in reports – were send to the project team with only limited verbal explanation. According to a respondent of one of the market parties, transfer of the underlying ideas of each of the visions “never really happened”. Transfer of knowledge is not only about objective information, but includes subjective views and values. In a situation where experts have diverging background this can be very challenging (Vinke-De Kruijf et al., 2013). Face-to-face communication is highly relevant in order to transfer this tacit knowledge (Koskinen et al., 2003) as well as intensive interaction (Vinke-De Kruijf et al., 2013). Interpreters or knowledge brokers can play a critical role in translating the integral designs into a policy field (Holmes & Clark, 2008; Naylor et al., 2012). Due to the large distance and hence poor embedding of the integral visions in the policy field, ownership of the designs by policy actors failed, in contrast to ownership of the governmental reference designs. The lack of knowledge uptake suggests a re-organisation of the relation between knowledge developers and decision-makers towards an intensified cooperation and exchange of ideas (De Jonge, 2007).

The last explanation of a lack of institutionalisation of the integrated KA relates to the assessment process. During the assessment phase the policy field was still to a significant extent integrated, but the knowledge base lacked integration: the integrated visions were split up and cores and components were judged independently. Also separate aspects were reviewed rather than the multiplicity of functions. According to one of the project members: “the project team did not manage to find an appropriate method that brings about synergy and leads to an integrated assessment”. Splitting the integrated visions into cores and components was not self-evident: fierce project discussions preceded this decision. On the one hand ‘cherry-picking’ was considered unfair, but on the other hand the highly diverse visions were considered incomparable. The developers of the cost effectiveness analysis were decisive with their request to split the visions to enable a ‘sound comparison’. Integrated designs require an assessment approach that equally values the interdisciplinary nature. But while this is acknowledged, methods to do so remain largely sectoral oriented (De Jonge et al., 2012). The development of integrated approaches is highly challenging given the complex and nonlinear social, ecological and economic relations, while for decision making straightforward answers are desired (De Jonge et al., 2012). Moreover, information and data is constrained by spatial and temporal boundaries (Knol, 2013).

In the case study, assessing separate aspects rather than integrated visions was not without consequences. It led to the conclusion that cores and components were independent and lacked synergy. Moreover integrated assessment is important for optimisation of multiple functions in concert, rather than separate functions. But optimisations and design improvements were off the agenda in the assessment phase. The integral visions were treated as fully developed design alternatives while according to a market party representative: “the designs got the status of solutions, while these were developed in a very short period”. When a change in design was proposed a ministerial representative stated that: “it does not fit the process to change the [...] design”.

4.5.2 A period of separation and self-organisation

An interaction form of ‘separation’ emerged in November 2010 when nature parties organised themselves and the flood protection domain raised access barriers by formulating strict access-criteria: plans should be sufficiently substantial in terms of organisation, content and finances. A number of developments in the project preceded this new situation. Nature parties were dissatisfied with the poor representation of nature in the project, the ministerial financial resources turned out to be minimal and flood protection was given prominence and priority. The ministry focused on its core task of safeguarding flood protection and explicitly allocated responsibility for nature to the program ‘Towards a rich Wadden Sea’. Moreover, the ministry made realising the flood protection standard independent from the development of nature plans. As a consequence, two separate KAs emerged: a flood protection KA and a nature KA. Mutual disappointment, different perspectives and discourses, and an inward focus on developing plans within domains severely reduced the interaction between the two arrangements. The difference between the two arrangements is illustrated by a discussion on the criteria for substantial plans. A provincial respondent indicated: “for the ministry something is not substantial when no money is reserved. For the province substantiality is about development trajectories, pilots and experiments, and the big money will come later”. In contrast, a ministerial respondent argued: “substantial plans and financing are required. The region [i.e. parties concerned with other functionalities such as nature] remains too vague”. Interaction became problematic in this phase, as a ministerial respondent noted: “it is difficult to have contact with the province.” During this period of separation, developments were mainly taking place within domains and not across domains.

Separation between KAs and an internal focus within each domain characterised this phase. The resulting strengthening of the nature domain is interesting. While at the start of the project the nature domain was almost non-existent – nature parties were not organised, only incidentally involved and had neither resources nor specific plans for the Afsluitdijk – the explicit criteria raised by the flood protection domain caused the nature domain to organise themselves in terms of actor coalition, discourse and knowledge.

4.5.3 Cooperation as second best

The period of separation was followed by a period in which cooperation arose between the domains. Tuning developments in each of the domains was established. Important in this respect was the ambition agreement that was signed by the ministry and regional governmental authorities representing functions such as nature. In this agreement, requirements for nature functions to become part of flood protection were specified. These requirements were: sufficient financial resources, technical or procedural dependency with the flood protection project, and no delay for the flood protection project. In that sense, flood protection remained the dominant domain, and determined the conditions. But these conditions became aligned with and agreed upon by the nature domain. Cooperation was established between the domains, yet integration vanished out of sight. Separate trajectories do not foster integrated or collective developments, as acknowledged by one of the project participants: “if you don’t work together towards a solution, coherence diminishes” (ministerial respondent). GFP is not established, yet realisation of two separate functions is.

4.6 Conclusions

In this paper we aimed to understand the role of knowledge in greening flood protection (GFP) projects by specifically looking at the interaction between knowledge-policy fields, defined as knowledge arrangements (KA).

Knowledge for GFP is essentially different from sectoral or mono-disciplinary knowledge development as it requires overcoming differences across domains. The Afsluitdijk project is an illustrative example of the struggle to organise a knowledge process towards an integrated, GFP design. When we consider the ambition of the project – an innovative, creative and integral design –the result can be considered disappointingly poor as it did not lead to a multifunctional design. Could this have been different? A reflection of one of the project members is appropriate here:

> “a question that continues to rankle is whether we looked enough for synergy. The integral visions were to some extend comprehensive, but these were only ‘ideas’, without involvement of stakeholders. You cannot prove that synergy would have come about when this was headed for from the beginning. I also don’t know”.

The break between the two domains did not have one single cause. Of course the financial resources turned out minimal and available for flood protection only, but at that point the nature organisations were already dissatisfied and had started separate plan development. The separate assessment of cores and components did not have an integral focus and led to the conclusion that there was no synergy. Moreover, the ministry stated that flood protection would be developed independent from other plans. The strict terms for the nature plans proved to be a blessing. It forced the nature domain to further organise itself in terms of content, actor coalitions and resources.

Based on the analyses lessons can be drawn on the implementation of GFP and the role of knowledge herein. Lessons learned from this project are important for any future project aiming at a multidisciplinary approach and are relevant for those with the ambition to implement GFP in practice, whether that are decision-makers, stakeholders or knowledge developers. GFP requires integration among knowledge arrangements, which is improved by:

- Organizing knowledge at close distance to the policy process: include a broad range of stakeholders in knowledge development with intensive interaction. This improves ownership and uptake of the knowledge developed.
- Including multiple design iterations in the knowledge process as it allows for optimising designs.
- Structurally embedding integration at the policy level: by agreements among stakeholders and detailing ambitions for other functions. Commitment in terms of financial resources may help.
- Tools to assess integrated designs in an integrated way, instead of a focus on separate aspects.

In the scientific literature the role of knowledge in projects has been subject to extensive studies (McNie, 2007; Seijger et al., 2013). We add to this body of knowledge a focus on interaction among different ‘knowledge arrangements’, emphasizing the context related character of knowledge and the idea that multiple policy fields are around. From this we learn that integration at the level of policy fields is an important factor for the uptake and development of knowledge.

5 The challenge of realizing greening flood protection – pathways towards an adaptive and flexible flood protection infrastructure in response to climate change[34]

Abstract

Greening Flood Protection (GFP) is increasingly recognized as an adaptive and flexible approach well-suited to deal with uncertain futures associated with climate change. In the last decade GFP knowledge and policy has rapidly developed, but implementation is less successful and runs into numerous barriers. In this paper we address the challenge of realizing GFP by specifically looking into the role of knowledge in decision-making on a Dutch flood protection project in Lake Markermeer. In this project, an ecological knowledge arrangement and a 'traditional' flood protection knowledge arrangement are confronted and interact. The outcomes provide insights in where the difficulties of implementing GFP actually are and identify some directions towards realisation of GFP. The main challenge is twofold: firstly a self-reinforcing cycle of knowledge production and decision making inhibits the introduction of innovative and multifunctional approaches such as GFP; secondly the distribution of power is severely imbalanced among ecology and flood protection, favouring the latter. Implementation of GFP requires structural change and integration among knowledge arrangements. Such integration can be based upon a shared interest (for different reasons) or mutual dependencies. Crucial success factors for integration are dual accountability and joint knowledge production. The case

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[34] This chapter was submitted as manuscript to Regional Environmental Change as: Janssen S.K.H., Van Tatenhove J.P.M, Mol A.P.J., Otter H.S. The challenge of realizing greening flood protection – pathways towards an adaptive and flexible flood protection infrastructure in response to climate change. After review, the journal has suggested a number of revisions. A revised version of the manuscript will be prepared and resubmitted in the near future.

study and the insights from it show that GFP is far from mainstream practice and implementation requires serious effort and courage as it breaks with historically build practices.

5.1 Introduction

Climate change effects of sea level rise and more extreme storm events directly impact the need for flood protection. In the Netherlands for example, the probability of flooding increases with a factor 10, for each 50 to 80 cm of sea level rise (Aerts & Botzen, 2013; Aerts et al., 2008). Besides an increased probability of flooding, of central concern in dealing with climate change is the associated uncertain future. Flood protection measures are likely to be implemented for time-spans of 50 to 100 years in which climate change can have more or less impact. This has caused many authors to plea for no-regret measures (Cheong et al., 2013), adaptive strategies and flexible designs that can adjust to changing circumstances (Aerts & Botzen, 2013; Gersonius et al., 2013). In particular, greening flood protection (GFP) - through for instance ecological engineering, ecosystem-based adaptation and working with nature - is advocated for dealing with climate change in coastal areas (Hale et al., 2009; PIANC, 2011; Spalding et al., 2013). GFP includes nature and environmental interests in the development of coastal infrastructure and as such contributes to ecosystems quality while achieving flood protection objectives (Janssen et al., 2014a). Protection against flooding is provided by natural elements such as mangroves, salt marshes, or oyster reefs, to attenuate waves, stabilize shorelines or directly serve as a barrier (Gedan et al., 2011; Van Wesenbeeck et al., 2014) or by the natural distribution of sand and sediments. GFP has been valued as more sustainable, cost-effective and ecologically sound than conventional flood protection (Temmerman et al., 2013) and as improving the overall resilience of the coastline by providing a range of ecosystem services (Hale et al., 2009).

While scientist stress the urgency of adapting timely to climate change, implementation requires continuing attention and improved understanding (Kabat et al., 2005; Runhaar et al., 2012). Implementation of GFP advances slowly and up till now large scale application remains scarce (Temmerman et al., 2013). Decision-making on and realisation of these multifunctional approaches remains a challenge (Mulder et al., 2011; Van Broekhoven & Vernay, 2011). GFP governance arrangements and knowledge are different from conventional flood protection governance and knowledge (Janssen et al., 2014a; Korbee & Van Tatenhove, 2013). This paper focuses on the role of knowledge in decision-making on greening flood protection.

The role of knowledge for greening flood protection is challenging for at least three reasons. Firstly, GFP is an innovative practice in flood protection, requiring the development of new knowledge on not yet proven technologies and approaches. Secondly, GFP knowledge is different from conventional flood protection knowledge. While the latter aims at reducing uncertainties by designing systems that can be controlled and predicted, the former welcomes uncertainties by building upon the natural variability of the ecosystem (Van den Hoek et al., 2013). Thirdly, GFP requires the integration of multiple knowledge disciplines, such as ecology, engineering and morphology (Mitsch & Jørgensen, 2003). These characteristics imply a different approach towards knowledge development and use than commonly applied (Brugnach & Ingram, 2012; Giebels et al., 2013). The aim of this paper is therefore to improve our understanding of the role of knowledge and enabling factors for implementation of GFP. Our research is based on the analysis of a case study in the Netherlands: the reinforcement of the dikes along Lake Markermeer.

This paper starts by introducing the concept of knowledge arrangements (section 5.2). This concept is introduced to analytically understand knowledge for GFP. Next, the research material and methods are discussed (section 5.3). Subsequently an in-depth case study is introduced: the Markermeer dike reinforcement project (section 5.4). The results of the case study are in section 5.5, while section 5.6 elaborates on factors enabling greening flood protection. The final section 5.7 represents the conclusions.

5.2 Policy-knowledge interactions: knowledge arrangements

In addressing the role of knowledge in decision-making we can broadly distinguish three research lines[35]. An important line of research covers the interactions between science (or knowledge) and policy in a 'science – policy interface' (Turnhout et al., 2007). In stimulating the development of 'useful' knowledge this body of research is devoted to closing the 'gap' between science and policy (McNie, 2007; Van de Riet, 2003) and to understanding knowledge production processes (Hegger et al., 2012b; Seijger et al., 2014). A second line of research is directed to understanding and combining different types (e.g. multiple disciplines) or sources of knowledge (e.g. lay and expert knowledge) (Eshuis & Stuiver, 2005; Hunt & Shackley, 1999; Petts & Brooks, 2006; Rinaudo & Garin, 2005). A third line of research recognizes that within a policy domain or on specific policy issues, knowledge and policy have similar orientations and backgrounds (Edelenbos et al., 2011) and highlights the conflicts between such knowledge-policy fields (Muñoz-Erickson, 2013; Van Buuren & Edelenbos, 2004). While this research line has grown over the last decade, conflicts between different knowledge-policy field often remain poorly understood and unaddressed, for instance regarding interactions and boundary work among knowledge-

[35] Off course these three topics are not isolated and more often than not these are addressed simultaneously.

policy fields (Muñoz-Erickson, 2013). This paper contributes to an improved understanding of interactions between knowledge-policy fields and the factors determining this interaction.

5.2.1 Interacting knowledge arrangements

We apply the conceptual framework of interacting knowledge arrangements as introduced in a recent paper by Janssen et al. (2014a). This framework allows for a structured analysis of interactions among knowledge-policy fields, highlights the interrelatedness of knowledge and context, and focuses on stability and change of knowledge arrangements. Knowledge arrangements are inspired by the idea of ways of knowing (Feldman et al., 2006; Lejano & Ingram, 2009; Van Buuren, 2009) and based on the policy arrangement approach (Van Tatenhove et al., 2000). A knowledge arrangement is defined as "the dynamic interdependent constellation of a knowledge base and the policy arrangement within a specific domain" and has two main elements: the policy arrangement and the knowledge base (Janssen et al., 2014a).

A policy arrangement is a temporary stabilization of content and organization of a policy domain (Van Tatenhove et al., 2000, p. 54). It is identified and analysed using four interrelated dimensions:

1. Actors and coalitions involved in policies
2. Discourses that capture views and narratives of these actors
3. Resources applied by actors (e.g. money, knowledge, authority, facilities)
4. Formal and informal rules of the policy game

Although in the policy arrangement approach knowledge is recognized as a resource contributing to power in a policy domain, the (creation of a) knowledge base is not given central stage in decision-making processes. Following Hommes (Hommes, 2008; Hommes et al., 2009) a knowledge base is defined as a collection of knowledge sources (i.e. research reports, models, data, practical experiences, etc.) that have been made explicit and are related to a specific policy arrangement.

As a multifunctional approach, greening flood protection combines different knowledge bases and policy fields, or different knowledge arrangements. Therefore interaction among multiple knowledge arrangements is key to GFP (Figure 5.1). Interaction among knowledge arrangements can be classified along four types (Janssen et al., 2014a): separation, cooperation, integration or unification (Table 5.1)

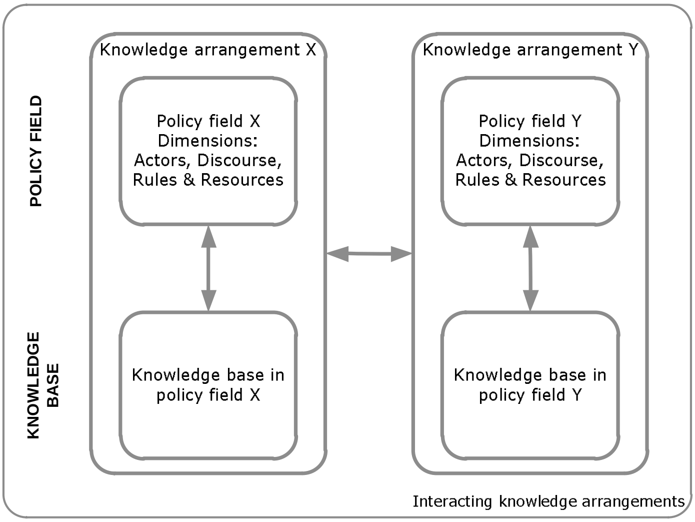

Figure 5.1 Interacting knowledge arrangements (Janssen et al., 2014a)

Table 5.1 Indicators of the four interaction types

Interaction type	Indicators
Separation	Knowledge arrangements operate isolated from each other. No interaction among actors; unrelated rules and regulations; unrelated discourses; no pooling of resources; and different and unrelated knowledge bases.
Cooperation	Communication among actors, mutual awareness and some coordination among activities. Related rules and regulations; partially overlapping discourses; sharing of information (but no shared development); different, but related, knowledge bases.
Integration	A new (temporary) knowledge arrangement coexists with the initial knowledge arrangements. Structural change in terms of actor coalitions; similar rules and regulations apply; shared discourse, objectives and resources; and one knowledge base, integrating the two fields/domains.
Unification	A new, permanent, knowledge arrangement replaces the initial arrangements that cease to exist.

5.3 Material and methods

In order to understand the role of knowledge in GFP a qualitative case study analysis is performed. The Markermeer dike reinforcement project in the Netherlands was selected as a single case for in-depth analysis. Data collection was performed between October 2012 and July 2013. Our analysis ranges from 2009, the introduction of the shore dike solution, until February 2013, the selection of preferred designs.

Data was collected between October 2012 and November 2013 through formal interviews (9x), informal interviews with project participants (i.e. without an approved interview report, 8x), attending public and project meetings (5x), and analysis of project documentation (see Appendix I). We had full access to all project documentation, including internal writings, minutes of meetings, e-mail correspondence, (formal) reports. In addition, preliminary results were discussed with a representative of project. The formal interviews had a semi-open character and were based on the 'clean language' approach, which aims at minimizing (unintentional) influence of the interviewer and ruling out bias (Sullivan & Rees, 2008; Van Helsdingen & Lawley, 2012).

The research followed three successive steps. First, the presence and construction of knowledge arrangements in the case study were identified (section 5.5.1). Second, interactions among these arrangements were analysed (section 5.5.2). Third, factors enabling integration were distilled (section 5.6). Step one and two are based on empirical data and informed by our conceptual framework. Step 3 combines empirical findings with wider literature.

5.4 Case study: the Markermeer dike reinforcement project

The Markermeer dikes are located in the north of the Netherlands (Figure 5.2) and provide protection against flooding from Lake Markermeer. Lake Markermeer is an artificial fresh water-body, man-made by the creation of the Afsluitdijk in 1932, the Houtribdijk in 1976 and several land reclamation projects. These interventions provided safety against flooding, fresh water availability and agricultural land (Lammens et al., 2008). Lake Markermeer was initially planned for land reclamation, but this plan was formally rejected in 2002. Subsequently, attention shifted to the condition of the dikes and the ecological quality of the lake. The weak soil in this part of the Netherlands and the continuous water pressure from Lake Markermeer (as opposed to tidal fluctuations before 1932) had weakened the Markermeer dikes.

An assessment of the condition of the dikes in 2006 resulted in the rejection of about 33 km (24 sections) of the dike trajectory between Amsterdam and Hoorn (Figure 5.2). Waterboard Hoogheemraadschap Hollands Noorderkwartier (HHNK) was commissioned to execute the dike reinforcement project, so that by 2016 the protection level of the dikes should meet the legally required level: to meet a storm with a probability of 1/10.000 years.

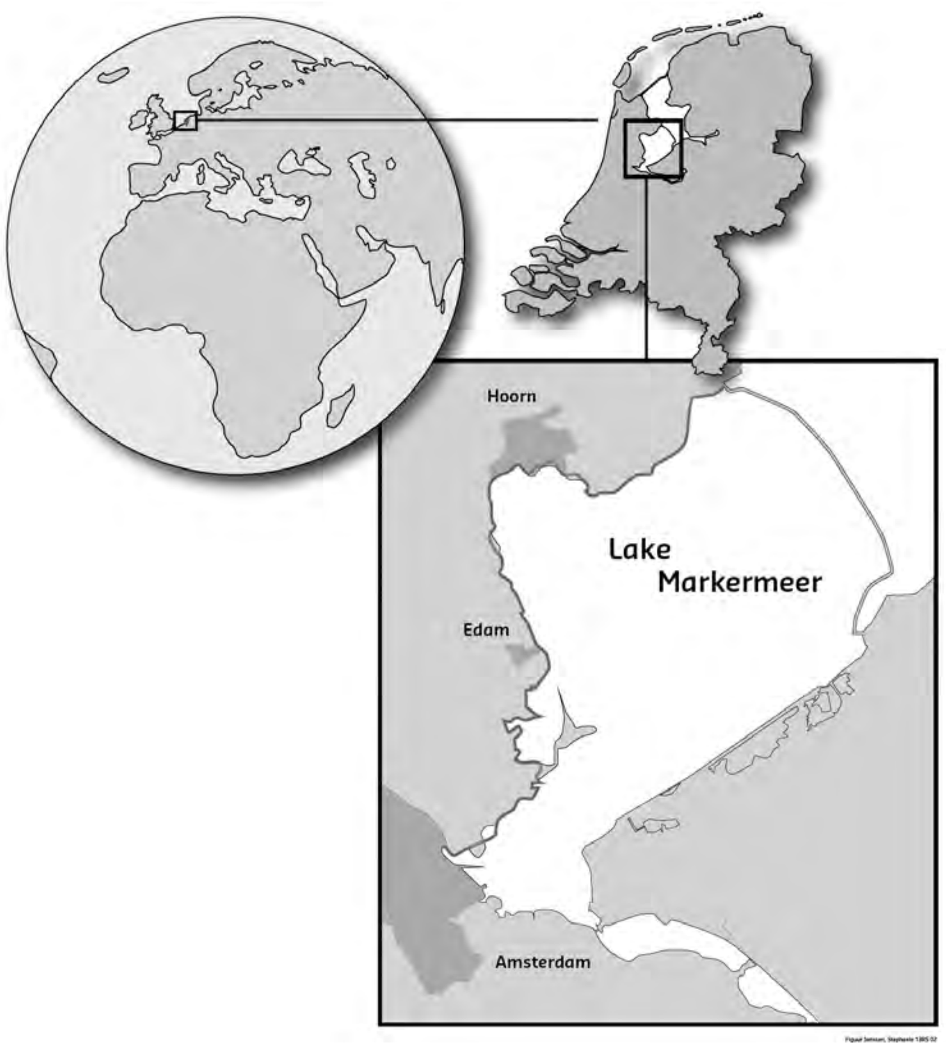

Figure 5.2 Lake Markermeer dikes (the dikes are located at the west side of the lake, marked by the thick line).

The ministerial ambition for synergy between ecology and flood protection at the Markermeer dikes project (Ministerie van V&W, 2008, p. 160) led in 2008 to a project called 'synergy flood protection and ecology'[36]. In 2009, an innovative soft design, the 'shore dike', was introduced in the dike reinforcement project. The 'soft' character of this solution made it an interesting alternative from an ecological perspective (Figure 5.3). Despite the ambition of the Ministry, the possibilities of the shore dike for ecology, and a large knowledge base devoted to it, in February 2013 HHNK continued with a bare or basic shore dike not comprising any green elements. This 'Basic Flood Protection' (BFP) shore dike (Figure 5.4) was selected as the preferred design for almost one-third of the length of the dike reinforcement trajectory.

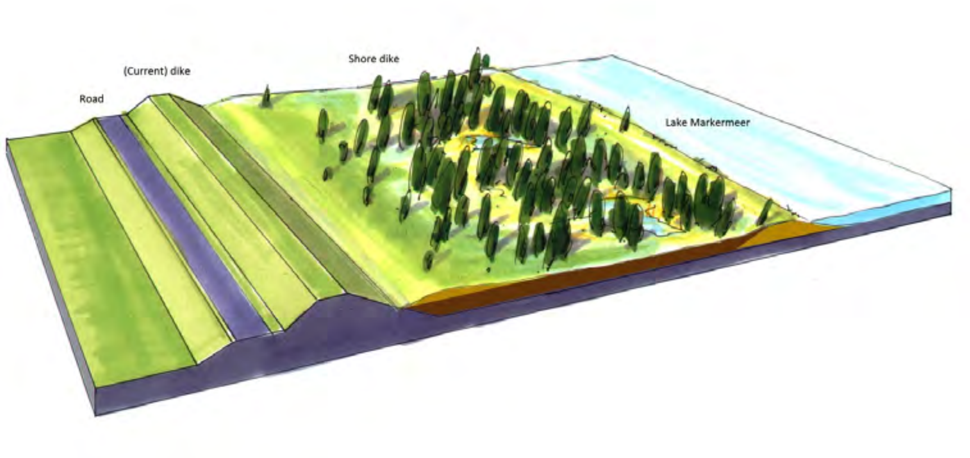

Figure 5.3 Artist impression of an ecological shore dike with a 'swamp forest (Stroming, 2012)

Figure 5.4 Cross-section of a Basic Flood Protection shore dike (Van der Linde et al., 2012)

[36] Execution of the project was with Rijkswaterstaat, an executive directorate general of the former Ministry of V&W. The Ministry of V&W changed in 2010 to the Ministry of Infrastructure and Environment. In this paper we will refer to the Ministry or the Ministry of I&M.

5.5 Case study results

In the Markermeer dike reinforcement project opportunities for GFP were not fully utilized. We analyse the process of decision-making concerning the shore dike from its introduction until the decision for the preferred design.

5.5.1 Two knowledge arrangements

In the development and decision process concerning the reinforcement of the Markermeer dikes, two different knowledge arrangements can be discerned: a flood protection knowledge arrangement and an ecology knowledge arrangement.

Knowledge arrangement: 'Flood protection shore dike'

Flood protection in the Netherlands is rooted in an age-long tradition of fighting against water (Wiering & Arts, 2006). This tradition is characterized by 'hard' constructions such as dikes, dams, levees and storm surge barriers (Van den Hoek et al., 2012) in which technical approaches and engineers dominate (Van Koningsveld et al., 2003). Up until today, flood protection is a powerful policy field in the Netherlands (Van Buuren et al., 2010a). While changes in this hegemonic position are noticed and more integrated approaches are pursued (Van Der Brugge et al., 2005; Woltjer & Al, 2007), today's flood protection seems largely independent of other domains such as spatial planning or nature conservation and remains strongly embedded in powerful sectoral institutions (Van Buuren et al., 2010a; Wiering & Arts, 2006).

In the Markermeer dike reinforcement project HHNK is by law the responsible authority to guarantee flood protection. Flood protection norms are laid down in the national Water Act. HWBP-2[37] is the national program to provide subsidy for reinforcement of dikes that did not meet these norms in 2006 (in total 88 projects and 370 km of dikes). Three criteria are operated for awarding subsidy: soberness (cost-efficiency), robustness (time of lasting: at least 50 years) and appropriateness (for flood protection only). In addition, HWBP-2 poses a strict time-schedule upon HHNK.

HHNK met serious challenges in this dike reinforcement project. In 2008, the calculated design alternatives proved far too expensive and physically too large. A workshop in 2009 resulted in the introduction of a novel shore dike design. While the principle of a shore dike was in essence not new (a body of sand for flood protection is a well-known method in coastal areas), this design was never applied in a stable fresh water lake such as Lake Markermeer. No knowledge was available on such a construction. As a consequence, an

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[37] High Water Protection Program under the Ministry of I&M

extensive knowledge base was built by consultancy firms[38] and the highly respected 'Expertise Network Water' (ENW) was consulted regarding the shore dike. Between early 2010 and the end of 2012, four reports were developed: (1) an exploration study on the idea and possible costs and benefits of the shore dike (Nieuwaal et al., 2010); (2) a feasibility study, assessing three different alternatives of the shore dike on a number of effects (Haarman et al., 2010); (3) a definition study, further defining the shore dike in order to make it a full Environmental Impact Assessment (EIA) alternative (Steetzel, 2012); and (4) an assessment report, comparing design alternatives for each dike section (Van der Linde et al., 2012). Each report built upon the previous and was directly linked to decision-making in the project. The feasibility study led HHNK to include the shore dike in the EIA trajectory and to start a definition study. The definition study prescribed the design that is assessed in the assessment report. Based upon the assessment report HHNK selected the preferred design alternatives for the different dike sections in February 2013.

Knowledge arrangement: 'ecological shore dike'

The ministerial project 'synergy flood protection and ecology' aimed at 'alternative designs for dike reinforcement projects in which flood protection and ecology are combined'[39]. Combining flood protection and ecology is an innovative approach. Ideas emerged in the early 1980s, but came only to full swing during the last decade. Concepts such as 'ecosystem-based' management (Barbier et al., 2008; Katsanevakis et al., 2011; Temmerman et al., 2013), ecological engineering (Borsje et al., 2011; Mitsch & Jørgensen, 2003), building with nature (Van Slobbe et al., 2013), working with nature (PIANC, 2011), are manifestations of including ecosystem dynamics and nature conservation in designing infrastructure. Despite some (small-scale) pilot projects, applications of such approaches are still limited (Borsje et al., 2011). At policy and political levels, however, combining flood protection and ecology is gaining prominence. Besides ambitions in national water policy, the Dutch Minister of I&M recently expressed strong support for 'building with nature'[40]. Although the knowledge base on building with nature is rapidly growing (Mitsch, 2012; Naylor et al., 2012), there remain critical knowledge gaps, for example on the long-term development of nature-based flood defence (De Vries et al., 2013).

When the shore dike was introduced in 2009, it became the prime focus of the 'synergy flood protection and ecology' project, covering two components: (1) the development of an

[38] Royal Haskoning, Royal Haskoning/DHV, DHV and Arcadis were involved.
[39] Interview with representative of the Ministry of Infrastructure and Environment, 13 June 2013
[40] Letter of the Minister of Infrastructure and Environment to the Second Chamber of the Dutch Parliament, 26 April 2013

ecological design of the shore dike, and (2) an exploration of possible connections with other projects in Lake Markermeer. The latter concentrated on ‘shelter measures Hoornse Hop’ project[41]. The idea was that if the shore dike is situated in a sheltered zone, its design could be optimized and hence be cheaper. But research refuted this assumption by concluding that this combination would not result in cost reductions (Smale et al., 2012). Relations with the EU nature conservation objectives (as laid down in ‘Natura 2000’) of the lake and the ecological improvement plan were only explored and not further elaborated upon; such relations would not yield cost reductions for dike reinforcement. The ecological design component was built upon expert sessions, workshops and existing knowledge about the ecosystem in Lake Markermeer. A number of design ideas were explored, but despite ambitions the contribution to flood protection of the ecological designs remained untouched.

The synergy project yielded four reports regarding the shore dike, all developed by Deltares[42]: (1) a quick scan of the ecological added value of the shore dike (Van Meurs et al., 2010); (2) a report comprising a broad exploration of ecological possibilities and possibilities to connect with shelter measures (Wichman et al., 2011); (3) a report on the added value of shelter measures for the shore dike (Smale et al., 2012); and (4) a report describing ecological designs for the shore dike (Noordhuis & Wichman, 2012).

While the ministerial project aimed at synergy, the focus was on ecology. It tried, but did not succeed, to connect with other ongoing projects. The actor coalition of this knowledge arrangement was dominated by the Ministry of I&M and Deltares (developing all four reports), while nature protection organizations were invited and contributed in workshops.

Comparing knowledge arrangements

In our analysis we found two clearly demarcated and contrasting knowledge arrangements (Table 5.2): a dominant and powerful flood protection knowledge arrangement and a rather weak ecology knowledge arrangement. The flood protection knowledge arrangement had ample financial resources and decision-making power, while resources and decision-making power in the ecology knowledge arrangement were meagre. The different historical trajectories were reflected in the knowledge bases: a strong and powerful knowledge base in flood protection versus an exploratory ecological knowledge base containing significant knowledge gaps. In addition, flood protection was strongly

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[41] The shelter measures project is part of the ecological improvement plan for Lake Markermeer. This project aims to create sheltered areas in the lake (i.e. without significant wave activity) hereby improving conditions for water plants, mussels and sparlings and food supply for birds.
[42] Deltares is a research institute.

embedded in institutions by means of the Water Act, while ecology built upon a single and poorly articulated and institutionalized policy ambition.

Table 5.2 Comparing knowledge arrangements on flood protection and ecology

	Flood protection knowledge arrangement	Ecology knowledge arrangement
Actors	HWBP, HHNK, consultancy firms, ENW	Ministry I&M, Deltares
Rules and regulations	Flood protection norms in Water Act HWBP criteria for subsidy	Policy document: National Waterplan Ecological improvement plan Lake Markermeer Natura 2000 site Lake Markermeer
Discourse	Flood protection, meeting criteria of time, budget and soberness, robustness and feasibility.	Ecological design, with opportunities for synergy between flood protection and ecology
Resources	Subsidy by HWBP for dike reinforcement Authoritative resources on decision-making	Research budget Ministry Potential cost reduction by combining with other projects. Little authority on decision-making
Knowledge base	Extensive knowledge base exploring, studying and developing the shore dike from a flood protection perspective. Directly linked to decision-making.	Exploratory knowledge base on development of an ecological shore dike design. Impact on decision making nil.

5.5.2 Interactions between knowledge arrangements

In this section we analyse the interactions among the knowledge arrangements along the lines of the four dimensions of the policy arrangements and the knowledge base.

Interactions found between policy arrangements

Among the *actors* in the respective knowledge arrangements there was full awareness of each other's positions and activities. In 2008, the Ministry proposed HHNK to give the dike reinforcement project a 'double objective' (flood protection ánd ecology). HHNK rejected this proposal, claiming it would lead to delay in the strict time schedule. Instead, HHNK and the Ministry agreed to cooperate on the topic[43]. In practice this meant that parties informed each other about ongoing activities, such as meetings and knowledge

[43] Official letter by HHNK dike grave Luc Kohsiek to the Ministry, 13 February, 2009

development. Representatives of the Ministry attended the dike reinforcement project meetings. While this cooperation was established, formal lines of responsibility remained separate. HHNK depended on and reported to HWBP-2 and hired various consultants for their knowledge base. The Ministry had an internal reporting structure and hired Deltares for their knowledge base.

For the two knowledge arrangements ecology and flood protection specific *rules and regulations* apply which show no overlap. The flood protection knowledge arrangement was guided by flood protection norms as laid down in the Water Act and the criteria for subsidy formulated by HWBP-2. The policy ambition regarding synergy in the national water policy was relevant for the ecology knowledge arrangement. After that – in searching for combining projects – ecological improvement plans in Lake Markermeer (in particular the shelter measures) and its Natura 2000 status were relevant.

Both knowledge arrangements had a typical *discourse* (Table 5.2). However, elements of these discourses were borrowed back and forth. Within the flood protection knowledge arrangement (implicit) references were made to a combination with ecology[44] and the shore dike as a ‘natural’ type of solution[45]. The ministerial synergy project aimed at combining ecology and flood protection and addressed the cost aspect of the shore dike. Despite these overlaps, differences remained and dominated. The flood protection functionality of the ecological design was not articulated in the ecology knowledge base, nor were the three crucial criteria for dike reinforcement (soberness, robustness and appropriateness). In the flood protection discourse, ecology is only handled implicitly.

Resources remained separate. The financial and authoritative resources in the flood protection knowledge arrangement remained exclusively for flood protection. The ‘soberness’ criterion determines that other functions (e.g. nature or recreation) are not paid for through HWBP-2. The limited resources in the ecology knowledge arrangement were devoted to knowledge development. Research for ecology and research for flood protection were strictly separated: “everything done by Deltares is for ecology, and HHNK will not pay for that”[46]. Attempts were undertaken to organize additional resources that could contribute to an ecological shore dike. However, the main attempt – to connect with the shelter measures – did not succeed and no other resources were found.

[44] Press release HHNK, 9 December 2010
[45] Assessment document (Van der Linde et al., 2012, p.23)
[46] Interview with Deltares representative, 2 July 2013

Interactions in creating the knowledge base

Significant knowledge bases were developed in both knowledge arrangements (Table 5.2). These knowledge bases were developed by different parties: the flood protection knowledge base by consultancy firms hired by HHNK, and the ecology knowledge base by Deltares, hired by the Ministry.

When the shore dike was introduced in 2009, the two knowledge bases were separate. The flood protection exploration study states: “this exploration is independent of the exploration for possibilities for synergy between ecology and flood protection […] commissioned by the Ministry” (Nieuwaal et al., 2010). The Ministry was not involved in the workshop that led to the introduction of the shore dike, nor was the Ministry informed about the subsequent exploration study[47]. Successive flood protection reports applied a broader focus. The feasibility study by Haarman et al. (2010) and the definition study by Steetzel (2012) included an ecological alternative that was explicitly considered next to the BFP shore dike. In addition, Deltares employees contributed to and co-authored these studies with respect to the ecological aspects of the shore dike. Ecological reports (Noordhuis & Wichman, 2012; Smale et al., 2012) were annexes in the Steetzel (2012) study.

While the two knowledge bases were combined, there was no integration. The knowledge on ecology and the knowledge on flood protection were treated as two different knowledge bases articulated and developed by different actors. Deltares was explicitly introduced “for ecological possibilities and nature legislation” (Haarman et al., 2010, p.1), and in the definition study the ‘ecological design’ consisted of the BFP profile added with an ecological element. At one point in the process we find a form of integration: a workshop co-organized by HHNK and the Ministry. This event was broadly attended by representatives of both knowledge arrangements and led to the shared conclusion that: “among experts broad support exists for the designs of an E and T [shore dike] alternative” (Deltares, 2012, p.4).

Neither cooperation nor integration among knowledge bases was taken up in the crucial phase of decision making: the selection of the preferred designs. The assessment report by Van der Linde et al. (2012) is an exclusive flood protection product. It was developed by two consultancy firms[48], without input by Deltares or the ecology knowledge base.

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[47] Interview with representative of the Ministry, 13 June 2013
[48] Royal HaskoningDHV and Arcadis

Assessing interactions

Integration did not come about between the flood protection arrangement and the ecology knowledge arrangement (Table 5.3). However, on some aspects the flood protection arrangement was indeed sensitive for input from the ecology field, and boundaries prove semi-permeable. For example, ecological knowledge was included in flood protection reports, and discourses were partially shared. Moreover, actors from the ecology knowledge arrangement were invited and informed on activities from the flood protection knowledge arrangement. But on crucial moments (such as the decision for the preferred design) or when structural changes were envisaged (the double project objective) ecological influences were kept out. HHNK played the role of boundary keeper in rejecting the double objective, dividing research topics (ecology as something 'the Ministry pays for'), and holding 'nature' outside the discourse by focusing on a BFP alternative of the shore dike. This form of boundary management – which inhibited integration – can be understood from the independent position of HHNK in relation to the ecological domain and its highly dependent position related to the HWBP. HHNK saw no need to include ecology in the project (including ecology would not provide added value in terms of the design, financial resources, coalition or other); conversely it might risk potential delays in the strict HWBP time-schedule. The boundary work in this flood protection knowledge arrangement was aimed at keeping the current boundary in place, but as long as no structural changes were foreseen, communication, sharing of information and other border crossing was allowed.

Unlike the flood protection knowledge arrangements, in the ecology knowledge arrangement we distinguish initiatives aimed at structural changing the boundaries and position of the arrangement. This was done by the Ministry in proposing a double objective and considering linkages with other projects (e.g. the shelter measures). If successful, both interventions would have improved the position of the ecology domain.

Table 5.3 Forms of interaction among knowledge arrangements

Dimensions	Interaction among knowledge arrangements
Actors	Cooperation among stakeholders
Rules and regulations	Separated rules and regulations
Discourse	Cooperation among discourse
Resources	Separated budgets and decision-making power
Knowledge base	Cooperation is found in the feasibility and definition study. In the crucial assessment report, ecology knowledge is excluded and separated.

5.6 Discussion on enabling greening flood protection

In an unsuccessful GFP case study, we found two different knowledge arrangements that did not integrate. In the discussion below we deepen our understanding of the underlying mechanisms as well as potential strategies towards GFP.

5.6.1 Challenge: self-reinforcing knowledge arrangements

Knowledge development and policy development strongly interact and make up a knowledge arrangement. In the case study we found that two relations reinforced the knowledge arrangement. The first relation is the impact of the policy field on knowledge development. Policy fields structure the process of knowledge production and the content of the developed knowledge. It affects who is involved in knowledge development and the design principles that are used. Moreover the 'state of the art' in the specific domain is leading and applied. This relation is clearly illustrated in our case study. The policy arrangement enables a knowledge base that fits the design space provided in the policy arrangement. This design space includes the design criteria (such as soberness, robustness and feasibility of the design), the central stakeholders (such as HWBP, ENW, HHNK and consultants) and also accepted methodologies for knowledge development. As the shore dike is an innovation within the flood protection domain the boundaries of the design space are explored and sometimes redefined such as in discussing design methods between HHNK and ENW. The design space offers limited room or few incentives for GFP knowledge development because: (1) GFP is multifunctional and does not meet the 'soberness' criterion, (2) it includes different and new design principles compared to those commonly used/applied (using other materials including vegetation), requiring different research methodologies, and (3) the uncertainties inherent in GFP innovation negatively affect the 'robustness' criterion. The second relation is the impact of the knowledge base on the policy arrangement. The knowledge base determines the decision space. The knowledge base provides a particular set of options (i.e. design alternatives) to be decided upon. In the Markermeer dikes case study the design alternatives did not include a GFP option. Consequently, the decision space is limited to flood protection options.

The two relations form a vicious cycle (Figure 5.5). The self-reinforcing feedbacks (Abel et al., 2011) sustain and even reinforce the knowledge arrangement. This inhibits integration among knowledge arrangements, while it supports fragmentation. Self-reinforcing feedbacks lead to increased interconnectedness and less flexibility (Walker et al., 2006). In addition, path dependency preserves the chosen strategy. Knowledge-policy interactions in the flood protection domain were formed over the last centuries (Van Koningsveld & Mulder, 2004) and led to the recognition of certain actors for knowledge development and research methodologies that are captured in handbooks and manuals or even further institutionalized. These aspects provide trust and allow for decision making on particular knowledge bases. However it also implies a form of ‘entrapment’ towards a particular technology reducing adaptability in infrastructural developments (Walker, 2000). A paradigm shift, such as GFP, involves not just a change in design but involves a change in the policy arrangement alike. Adoption of new technological approaches is not feasible without commitment of involved actors, legislation and resources (Berkhout, 2002; Walker, 2000).

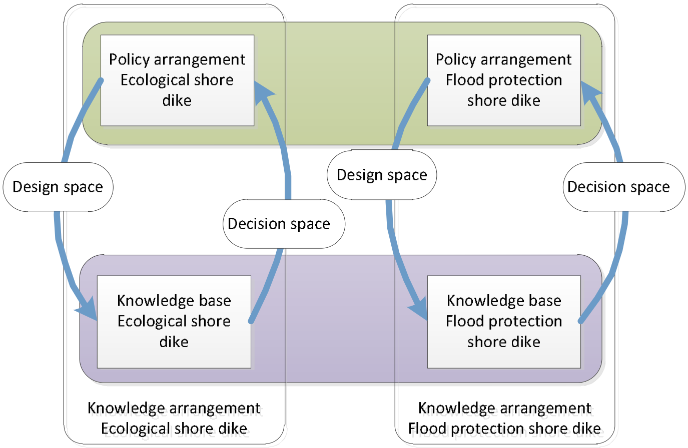

Figure 5.5 Reinforcement of knowledge arrangements

5.6.2 Enabling greening flood protection

Below we explore ways of dealing with fragmentation between knowledge arrangements through handling power imbalance and through handling knowledge development. Both may force a break-through in the vicious cycle (see Figure 5.5) and enable GFP.

Handling fragmentation and power imbalance

Fragmentation and power imbalances are central challenges to comprehensive decision-making (Huitema et al., 2009) and in particular to GFP as the case demonstrated. While fragmentation allows for diversity and accommodation of different interests, it also leads to conflicting or inconsistent policies (Doremus, 2009; Imperial, 2005; Porzecanski et al., 2012). In addition, unequal distribution of power among different institutions and domains hampers integration between institutions (Imperial, 2005; Wondolleck & Yaffee, 2000). Literature on fragmentation points to strategies of improving coordination and cooperation or institutional restructuring for overcoming fragmentation (Huitema et al., 2009; Porzecanski et al., 2012). While the former is about increasing the number interactions, the latter relates to altering interactions.

In an earlier paper on interacting knowledge arrangements we assumed that cooperation is insufficient to enable GFP (Janssen et al., 2014b). The case study confirms this idea. At actor levels, among knowledge bases and at discourse levels we identified cooperation (section 5.5.2), yet this cooperation did not enable GFP. It did not create a collective and combined policy field that allowed for a multifunctional GFP design development. However, it maintained existing accountability structures and prevailing knowledge development methods. Our conclusion is that a form of structural change is needed for integrating existing knowledge arrangements to allow for GFP. Enabling GFP is a matter of institutional re-structuring rather than improving cooperation. This conclusion aligns with the findings of Lejano and Ingram (2009) who explain effectiveness of policy instruments by their ability to create linkages and forge relationships that allow for new ways of knowing. Cash et al. (2003) highlight the crucial role of dual accountability – i.e. to both knowledge arrangements – in order to create linkages for effective knowledge development.

One strategy towards institutional restructuring is coalition building. Meijerink and Huitema (2010) discerned three grounds for building or achieving coalitions. Firstly, coalitions can be based on shared beliefs and ideas of actors. Actors share a similar disciplinary background or hold similar ideological viewpoints. For our case we must conclude that this type of coalition is not very feasible. A second form of coalitions is based on similarity in interests. While beliefs are different, interest in realizing GFP may run parallel. These types of coalitions are based on so-called 'synergy' or 'win-win' solutions. For GFP, finding such synergy seems plausible as scholars have emphasized the multifunctional nature of this type of solutions (cf. Borsje et al., 2011; Van Slobbe et al., 2013). A third form of coalitions is based on mutual dependency. Sharing (financial) resources could enforce cooperation among actors. In the Markermeer dikes case study, however, power imbalance between the knowledge arrangements prevented such a mutually dependent coalition. Hence, the most feasible GFP coalition is one based on shared interests or – when power is more equally distributed –mutual dependencies.

Handling knowledge processes

The presence of an ecological knowledge base in proximity of the flood protection knowledge base did not affect the design of the shore dike. And an integrated knowledge base that included ecological and flood protection knowledge was not developed. As discussed above this follows from internal knowledge arrangement dynamics: the ecological knowledge base does not fit the flood protection design space and is thus not included in the decision-space. The presence of multiple knowledge bases in a project is suboptimal or undesirable when knowledge remains unused or forms the basis for a struggle over different knowledge sources (Deelstra et al., 2003). Moreover, it confirms that often decision-making does not, or only to a limited extent, reflect the diversity of ideas (Brugnach & Ingram, 2012; Feldman & Ingram, 2009).

Integrating multiple knowledges requires a different approach towards processes of knowledge development, affecting: (1) the type of knowledge used, (2) the way knowledge is created, and (3) how different parties are involved in knowledge production (Brugnach & Ingram, 2012). Knowledge production processes should be collaborative activities in which stakeholders equally contribute, to allow for integration of different types of knowledge (Brugnach & Ingram, 2012). Such participatory processes of knowledge development allow for combining multiple knowledge bases and for cognitive and strategic learning among involved parties (Hommes et al., 2009). Multiple knowledge sources can be beneficial in stimulating processes of learning (Eshuis & Stuiver, 2005). Mutual learning processes allow for sharing of expertise, acquiring new information and building creative solutions by sharing perspectives (Wondolleck & Yaffee, 2000). Also, learning allows for developing a context-specific knowledge base. This is in particular relevant for approaches of GFP as these designs depend highly upon site-specific characteristics of the ecosystem (Bergen et al., 2001; Vikolainen et al., 2012). Moreover, the acceptance and relevance of knowledge is more likely when parties are jointly involved in the development of it (Cash et al., 2003; Eshuis & Stuiver, 2005; Hommes et al., 2009).

5.7 Conclusion

Governments are increasingly challenged to consider the (uncertain) impact of climate change on flood protection management. Greening Flood Protection (GFP) is an upcoming approach that in particular meets the requirement of no-regret, adaptive and flexible designs (Cheong et al., 2013). And it is advocated as a promising approach in dealing with climate change (Hale et al., 2009; Spalding et al., 2013). While knowledge and policy on GFP have developed rapidly over the last decade, implementation of GFP advances less swiftly. This paper contributed to understanding the challenges of realising GFP in practice by studying the Markermeer dike reinforcement project. This case study showed that the implementation of GFP, at least for the Dutch situation, is far from self-evident and requires structural changes in the organisation of the flood protection domain.

By employing a knowledge arrangement perspective we found a self-reinforcing cycle: a specific design space follows from the policy field and a specific decision-space follows from the knowledge base. In the flood protection knowledge arrangements, a flood protection knowledge base is created (matching the design space); consequently decision-making is based on this flood protection knowledge base. Historically developed interactions and path dependencies preserve chosen approaches. Such a cycle complicates the introduction of new and innovative approaches and thus inhibits multifunctionality.

Besides the fragmentation that follows from the self-reinforcing cycle, power is unequally distributed which further inhibits a GFP approach: the flood protection field is very powerful in terms of resources, knowledge, legislation etc., while the ecological field is rather weak.

Enabling GFP requires integration among knowledge arrangements and thus a break-through of the self-reinforcing cycle. Increasing interactions or cooperation among knowledge arrangements is considered insufficient to achieve this break-through. Only structural changes in the nature of the interaction will allow development and acceptance of new GFP knowledge and designs. It will alter the design space and open up and provide commitment for integrated GFP knowledge development. Potentially rewarding routes towards integration are the exploration of shared interests in GFP (for different reasons) or creating a mutual dependency among knowledge arrangements. Moreover, the inclusion of accountability to both knowledge arrangements and joint knowledge production is believed to be a crucial success factor.

The case study shows that GFP is far from mainstream practice and implementation requires serious effort and courage, as it breaks with historically build practices is needed. However, as the limits of traditional flood protection are becoming more and more visible (also in this case study) and the climate challenge more urgent, the demand for GFP approaches will increase.

6 Conclusions and reflection

In the introduction chapter of this thesis, I discussed Greening Flood Protection (GFP) as an emerging approach in Dutch flood protection projects. GFP is perceived as a promising and more sustainable alternative to conventional hard flood protection solutions. Realisation of GFP, however, is far from standard practise. To date, knowledge in GFP decision-making has been underexposed and has remained a central challenge. This thesis aims to make a contribution to understanding and improving knowledge in GFP decision-making.

The objective of the study was to improve the understanding of knowledge in GFP decision-making and learn how knowledge in GFP decision-making can be improved to support GFP in flood protection projects. Three research questions were formulated:

1. How to understand knowledge in GFP decision-making?
2. How does knowledge in GFP decision-making enable or constrain GFP in flood protection projects?
3. How to improve knowledge in GFP decision-making in order to enable GFP in flood protection projects?

In the following three sections (sections 6.1, 6.2 and 6.3), I will successively answer these questions. Then, I will reflect on the theory and methodologies used and discuss the particular contributions made in this study. Finally, I provide an outlook for GFP decision-making in flood protection projects.

This conclusion and reflection chapter is based on the research that was presented in the previous chapters. A conceptual framework of interacting knowledge arrangements was constructed (chapter 2) and applied in three empirical flood protection case studies that intend to apply a GFP design solution (chapters 3, 4 and 5). This chapter joins the results in a cross-case analysis. The first case study examines the Sand Engine, a large-scale sand-nourishment project designed and implemented based on GFP principles. The second case study examines the Afsluitdijk, a dam-reinforcement project that had the ambition to provide more than just safety and ultimately employed a mono-functional approach. The third case study examines the Markermeer dikes project, where, despite an innovative dike design with GFP potential and GFP ambition by the ministry, a traditional approach was employed.

6.1 Knowledge in Greening Flood Protection decision-making

The first research question addresses how to understand knowledge in GFP decision-making.

To answer this question, I conceptualise knowledge in GFP decision-making by means of the conceptual framework of *interacting knowledge arrangements.* The conceptual framework is applied in all three case studies. A comparative analysis of the three cases informs the answer to this question and the conclusions on knowledge in GFP decision-making.

6.1.1 A conceptual framework for knowledge in GFP decision-making

A conceptual framework was constructed to understand knowledge in GFP decision-making: the conceptual framework of interacting knowledge arrangements (Figure 6.1). Four criteria for the framework were used to guide its construction: three characteristics of knowledge in GFP decision-making (section 1.3.2) and the need to apply it in three case studies. Existing models for knowledge in decision-making – the linear model, the co-production model and the Ways of Knowing (WoK) model – were evaluated based on the four criteria. None of these models met the four criteria. As a complementary theory, the policy arrangement approach was employed. The conceptual framework for knowledge in GFP decision-making builds upon the WoK model (Feldman et al., 2006; Lejano & Ingram, 2009; Schneider & Ingram, 2007; Van Buuren, 2009) and the Policy Arrangement Approach (Arts & Leroy, 2006; Van Tatenhove et al., 2000).

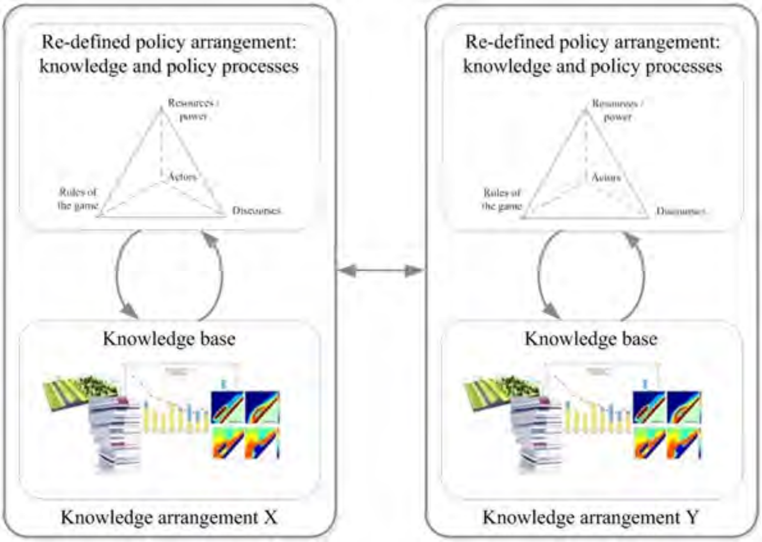

Figure 6.1 The conceptual framework of interacting knowledge arrangements

A knowledge arrangement is defined as: the dynamic interdependent constellation of a (redefined) policy arrangement (involving knowledge and policy processes) and a knowledge base within a policy domain. It consists of two main elements: the redefined policy arrangement and the resulting knowledge base, which, in turn, affects and informs the policy domain. Including knowledge processes in the policy arrangement required redefining the definitions of the four dimensions (actors, resources, rules and discourse) to include knowledge actors, knowledge rules, knowledge discourses and knowledge resources. The knowledge base is a collection of explicit knowledge sources, including reports, (computer) models, and designs, among others (Hommes, 2008; Hommes et al., 2009). The knowledge arrangement forms a coherent and dynamic whole, where a change in (one of the) dimensions, external events or interactions with other domains may serve as an incentive to change orientations and processes.

GFP decision-making involves knowledge arrangements that are related to the nature and flood protection policy domains. Interactions between knowledge arrangements affect the initial knowledge arrangements in different ways. To understand knowledge in GFP decision-making, I developed a typology of four possible modes of interaction (Figure 6.2). I discern between interactions without a connection between the boundaries of the knowledge arrangements (‘separation’), connecting the boundaries (‘cooperation’), blurring the boundaries temporarily (‘integration’) or blurring the boundaries permanently (‘unification’). Hybrid forms, or combinations of the four ideal modes, are possible.

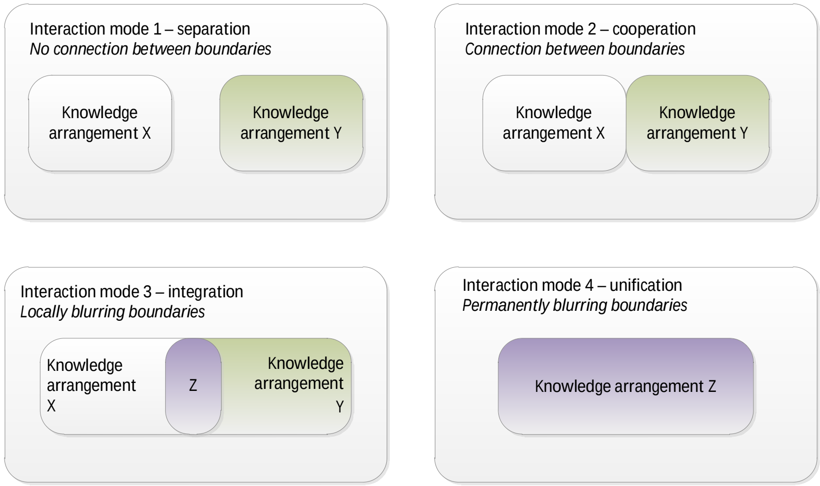

Figure 6.2 Interaction modes between knowledge arrangements

6.1.2 Knowledge in GFP decision-making in three case studies

Knowledge in GFP decision-making is analysed in three case studies by means of the conceptual framework of interacting knowledge arrangements. For each case study, I discuss (1) the knowledge arrangements involved, (2) the mode of interactions between knowledge arrangements and (3) the knowledge processes and the knowledge base in the interaction modes. A summary is provided in Table 6.1.

Sand Engine

In the Sand Engine case study, the interacting knowledge arrangements were related to flood protection and nature. These knowledge arrangements merged into an integrated Sand Engine knowledge arrangement. The flood protection knowledge arrangement concerned the maintenance of the coastline by means of sand nourishments. The knowledge processes and the knowledge base were oriented towards the optimisation of nourishments for coastline maintenance. The nature knowledge arrangement concerned the spatial planning domain. In this domain, nature is one of the functions to be allocated along with other functions in spatial planning, such as recreation, housing, and infrastructure. Nature in the Sand Engine project was employed for recreational purposes and was referred to as ‘recreational green’.

The interaction mode was ‘*integration*’. The integrated Sand Engine knowledge arrangement involved a broad and adaptive actor coalition. The coalition included actors from both initial domains, and depending on the topic, actors entered and left the coalition. There was a collective discourse around the Sand Engine as an innovation and experiment, an example of building with nature and the combining of objectives. Financial resources and decision-making resources from both initial domains were combined in the integrated arrangement. A formal agreement among actors defined the project rules. The integration between knowledge arrangements was '*flexible*'. The flexible nature of the integration between knowledge arrangements was related to the actors in the coalition, who entered and left during the decision-making process depending on the issues at hand and the interests of the actors. The Sand Engine project objectives, which were formulated in an unspecific and open manner, were also flexible. Moreover, flexibility in integration followed from excluding some crucial components or 'core values' of the initial knowledge arrangements. For example, the main indicator for coastline position (the BKL) and the financial budget for coastline maintenance in the flood protection domain were not part of the integrated knowledge arrangement. The exclusion of core values made the project a low-risk exercise and provided ample design space.

A number of knowledge processes can be identified in the integrated Sand Engine knowledge arrangement. First, *knowledge development* was a collective endeavour of multiple actors and multiple disciplines. Second, the *assessment of knowledge* documents was a collective undertaking that was discussed and decided upon by the project team, which was comprised of actors and knowledge parties. In the project team, the processes of knowledge development and knowledge use were discussed, and a decision was made on the preferred Sand Engine design. The assessment of the different Sand Engine designs was of a less-integrated nature. Informed by the Environmental Impact Assessment (EIA) report and procedure, the designs were assessed in terms of separate aspects, such as nature, recreation, and flood protection. This resulted in reports on delineated topics including nature, morphology, air quality, sound quality and sediment dispersal. The *optimisation* of the preferred Sand Engine design (the hook-north) was assessed in terms of separate aspects. In workshops that were organised by discipline, optimisations and assessments were discussed based on factors such as nature and morphology. The knowledge base was then comprised of integral Sand Engine design alternatives and assessment reports on singular aspects that were combined in the EIA report.

Afsluitdijk

In the Afsluitdijk case study, the interaction between the nature and flood protection knowledge arrangements was analysed. Over the course of the project, three different interaction modes between these knowledge arrangements were found, which also affected the nature and flood protection knowledge arrangements. At the start of the project, *integration* between the knowledge arrangements was found. A multi-actor Afsluitdijk project team was formed to organise the flood protection project with a shared discourse, an aim to achieve more than just flood protection, and collective process rules. However, the integrated arrangement failed, and *separation* between the flood protection and nature knowledge arrangement emerged. Flood protection came to the fore as a powerful and strongly institutionalised domain with ample resources, acting independently of the nature domain. The nature knowledge arrangement was initially almost non-existent: Incidentally, (unorganised) nature actors were involved, but they did not have resources or a shared discourse. Over the course of the project, the nature knowledge arrangement germinated, developing into an ambitious field, producing a distinct vision on the Afsluitdijk and initiating a separate nature project. The development of the nature knowledge arrangement enabled *cooperation* between knowledge arrangements, implying attunement and agreement on developments in the two knowledge arrangements.

The three interaction modes – integration, separation and cooperation – involved different knowledge processes and knowledge bases as a result. *Design development* in the 'integration' interaction mode was partly integrated and partly a flood protection exercise. Four integral design visions were developed by multi-disciplinary teams. In parallel, two designs with a sole focus on flood protection were developed by flood protection actors. Second, the *assessment of knowledge* was not integrated but focused on separate aspects of the designs. The integrated designs were split up into separate elements related to flood protection, nature and other functions. Consequently, an assessment was performed on separate aspects, and the integral design visions were no longer treated as a whole. The knowledge arrangements continued in the 'separation' interaction form. In the flood protection knowledge arrangements, the *optimisation* of the flood protection designs preceded the *selection* of the preferred flood protection design. This preferred design was then outlined in a formal document, the Afsluitdijk Master Plan (*in Dutch:* Structuurvisie). The *development of nature knowledge* occurred entirely in the nature knowledge arrangement and led to the development of new ideas for nature alongside the Afsluitdijk. Along with ideas for other functions (e.g., nature and recreation), these ideas were collected in the 'Afsluitdijk ambition agenda'. A disagreement on the knowledge base and knowledge processes in the distinct knowledge arrangements was apparent in the period of 'separation'. For example, a conflict emerged on what counted as a 'substantial design'. A 'cooperation' form of interaction followed the period of separation. The main cornerstone of the cooperation was an 'ambition agreement' among the domains. In this document, developments and process rules were attuned, criteria for cooperation were formulated and the knowledge processes and criteria for the knowledge base were outlined.

Markermeer dikes

In the Markermeer dikes case study, nature[49] and flood protection knowledge arrangements were identified. In both domains, a shore dike design was developed, but from different perspectives. In the flood protection knowledge arrangement the shore dike was considered a cheaper and more efficient alternative in order to achieve a 'sober, robust, and effective' dike reinforcement. In the nature knowledge arrangement – which was oriented toward nature, although it formally advocated synergy between flood protection and nature – the shore dike was primarily recognised as a nature opportunity, and its nature potential was actively considered.

In this project, a hybrid interaction mode between the nature and flood protection knowledge arrangements was found, combining elements of cooperation and separation. Cooperation was found at the level of actors and discourses. Actors were aware of each other, and they communicated and aligned (some) activities; in the discourse, reference was made to the other domain. Furthermore, cooperation was found at the knowledge base level: Reports were shared and referenced. However, rules and regulations were separate. There were separate accountability structures and criteria. Furthermore, resources were not shared between the knowledge arrangements.

The hybrid interaction mode led to knowledge processes on different locations and different knowledge bases. In the flood protection knowledge arrangement, knowledge processes were related to the development of the shore dike design. The idea of the shore dike, which originated in a flood protection workshop, was oriented towards finding cheaper and slimmer alternative dike designs. It was further explored by a flood protection team and assessed in terms of its feasibility in a consultant study. After that, the shore dike became an official design alternative and was further developed in a design study. The resulting shore dike design was compared with other dike designs and consequently selected on 1/3 of the dike trajectory. In the nature knowledge arrangement, knowledge processes evolved in parallel and were largely exploratory in nature, which came in contrast to the flood protection knowledge processes, which had a clear orientation and goal. Three different studies reported the possible nature designs and layouts of the shore dike: a quick scan of nature-added value, an exploratory study on nature possibilities and possible connections with other projects, and a report that illustrated possible nature

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[49] In the description of the Markermeer dikes case studies in chapter 5, I referred to an 'ecological' knowledge arrangement instead of a 'nature' knowledge arrangement. In the description of the case, I decided to maintain the discourse in the project and thus use 'ecological' knowledge arrangements. However, 'nature' similarly captures this overtone.

designs. A fourth report discussed a combination with a nature project in the adjacent Lake Markermeer. Although the knowledge processes occurred at different locations and led to different knowledge bases, these were not ‘separate’ but ‘cooperative’ because across the knowledge processes, knowledge was shared and used. Nonetheless, different ideas existed about knowledge and knowledge processes. A flood protection expert considered the nature plans irrelevant in terms of flood protection contributions, whereas a nature expert considered flood protection knowledge processes ‘conservative’, holding onto ‘traditional flood protection philosophy’.

6.1.3 Conclusions

In this section, I answer the first research question: how to understand knowledge in GFP decision-making.

Knowledge in GFP decision-making is understood as the *interaction mode* between *knowledge arrangements*, revealing particular knowledge processes and knowledge bases. A knowledge arrangement is the dynamic interdependent constellation of a redefined policy arrangement (including policy and knowledge processes) and the knowledge base within a policy domain. Four interaction modes are discerned: separation, cooperation, integration and unification.

Three characteristics of knowledge in GFP decision-making informed the construction of the conceptual framework of interacting knowledge arrangements: the plurality of the policy domains that interact, the nested nature of knowledge and knowledge processes in particular policy domains, and the dynamics of and change in GFP decision-making. In the three case studies these three characteristics of knowledge in GFP decision-making are recognized. Knowledge arrangements for flood protection and nature were found in all three cases, which were characterised by different and particular knowledge processes and knowledge bases. Within the knowledge arrangements, I did not find prevailing knowledge conflicts among the ‘knowledge world’ and the ‘policy world’. Rather, experts had a close relationship with actors, and the knowledge of experts was readily accepted within domains. In the case studies where I found ‘separation’ or ‘cooperation’, the differences in knowledge processes and knowledge bases were evident and were sometimes a source of conflict. Besides unification, which was unlikely to occur in these projects, given their temporary nature, all interaction modes were identified in the case studies. The knowledge arrangements and the interaction between knowledge arrangements were dynamic. In particular, in the Afsluitdijk case study, alterations to the interaction mode were found along with changes in the knowledge arrangements.

Table 6.1 Overview of modes of interaction, knowledge processes and the knowledge base in each case study

Case study	Interaction mode between knowledge arrangements	Knowledge in GFP decision-making: knowledge processes	Knowledge in GFP decision-making: knowledge base
Sand Engine	Flexible integration between flood protection and nature knowledge arrangements	Multidisciplinary and multi-actor design development Collective knowledge assessment in a project team and design assessment on separate aspects Design optimisation in separate aspects Ample design space in all knowledge processes	One knowledge base that is partly integral (Sand Engine designs) and partly based on separate aspects (assessment reports, EIA report incl. appendices)
Afsluitdijk	Failed integration between flood protection and nature knowledge arrangements	Multidisciplinary design development of integral designs and parallel design development of flood protection designs Assessment of separate aspects after splitting the designs into separate parts	One knowledge base that is partly integral (four integral designs), partly flood protection (two flood protection designs) and partly based on separate aspects and design elements (assessment reports, split of designs)
Afsluitdijk	Separation between flood protection and nature knowledge arrangements	Design development in nature knowledge arrangement Design assessment and optimisation and resulting selection among flood protection designs in flood protection arrangement Disagreement on knowledge processes and knowledge base among knowledge arrangements	Two knowledge bases, one flood protection (the Afsluitdijk Master plan) and one for nature and other functions (Afsluitdijk Ambition agenda).
Afsluitdijk	Cooperation between flood protection and nature knowledge arrangements	Agreement on knowledge processes and knowledge base between the two knowledge arrangements	Two knowledge bases (flood protection and nature) that are attuned (in Ambition Agreement)
Markermeer dikes	A hybrid interaction mode between the nature and flood protection knowledge arrangements combining elements of cooperation and separation	Design development on different locations for flood protection and nature Design assessment and resulting selection in flood protection knowledge arrangement Cross-fertilisation of the knowledge processes, but different ideas in the knowledge arrangements.	Two knowledge bases for nature (four reports of an exploratory nature) and flood protection (four goal-oriented reports with a direct decision-making effect)

Based on the three case studies, I can inductively refine the conceptual framework based on two aspects. First, from the knowledge processes that I found in the case studies, I can discern three different types: design development, design assessment and design optimisation. The knowledge processes and the knowledge base had a focus on the design that was to be selected in the project. This is a particular feature of flood protection projects. Second, based on the different interaction modes in the case studies, I can relate particular types of knowledge processes and knowledge bases to the different interaction modes (Table 6.2). The integration between knowledge arrangements involved a single knowledge base in the project and designs that integrated nature and flood protection functions. When cooperation emerged between knowledge arrangements, multiple knowledge bases were found. These knowledge bases were different but agreed upon and attuned in knowledge processes. When knowledge arrangements were separate, multiple knowledge bases were also are identified; however, in this situation, disagreement about knowledge processes and the knowledge base dominated the discussion.

Despite two occurrences of an integration interaction mode between knowledge arrangements in the case studies (in the Sand Engine and the Afsluitdijk case studies), I did not find examples of entirely integrated approaches in design assessment and design optimisation. In the Afsluitdijk, integral designs were split up and assessed in terms of separated aspects. In the Sand Engine assessment, reports on separate aspects were developed, and the optimisation of the integral design was based on separate functions. This indicates a difficulty in organising knowledge assessment and optimisation in an integral manner. The EIA procedure underlies the assessment and optimisation processes. Although this procedure aspires to combine several effects of design alternatives in a multi-criteria table, the effect is that separate aspects receive close attention, and separate research or knowledge trajectories are started. An important challenge for GFP decision-making lies in maintaining an integrated approach despite the obligation to study separate effects in detail. The Sand Engine can be instructive here. Despite the focus on separate aspects and functions in design optimisation and assessment, integration was maintained to a certain extent, as all knowledge processes and bases were discussed in the project team in which the broad range of actors was represented.

Table 6.2 Knowledge processes and knowledge base per interaction mode

Interaction mode	Knowledge in GFP decision-making: knowledge processes and knowledge base
Integration	One knowledge base Integral design development Sectoral and attuned design assessment and optimisation
Cooperation	Two knowledge bases Sectoral and attuned design development, assessment and optimisation
Separation	Two knowledge bases Sectoral and discordant design development, assessment and optimisation

6.2 Greening Flood Protection in flood protection projects

The second research question addresses how knowledge in GFP decision-making enables or constrains GFP in flood protection projects.

To answer this question, I first assess the (preliminary) outcomes – i.e., a formal project decision – of the case studies in terms of GFP. The case studies were selected because they had an intention to apply a GFP design solution. This outcome was not known beforehand for any of the three projects. In the introduction chapter, three GFP characteristics were defined. First, natural dynamics are included in the design and contribute to the flood protection function. Natural dynamics may cover both biotic and abiotic processes and involve, among others, the use of wave energy, sedimentation processes, vegetation and shellfish dynamics. Second, GFP designs enhance ecosystem quality or quantity. Lastly, GFP is a multifunctional solution that combines flood protection and nature functions.

In all three case studies, a formal decision was identified as the (preliminary) project outcome: a preferred design alternative. Each case study continued after the formal decision, potentially or actually creating new opportunities for GFP decision-making; however, these new developments are not included in the analysis.

After determining the outcome of the project, I relate it to the knowledge processes and knowledge base (as defined in section 6.1) and conclude with a discussion of the way knowledge in decision-making enables and constrains GFP in flood protection projects.

6.2.1 Greening Flood Protection in three flood protection projects case studies

Below, I will assess the outcome of the three case studies on the three characteristics of GFP and relate it to the particular knowledge processes and knowledge base.

Sand Engine

In the Sand Engine project, the formal decision on the preferred design was made in the steering group on 17 December 2009. The selected design was the optimised ‘hook-north’ design (Figure 6.3). The hook-north is a 21.5 Mm^3 sand nourishment that is shaped like a hook and attached to the South-Holland coastline.

Figure 6.3 Sand Engine preferred design: Hook North

The hook-north is evaluated positively in terms of the three GFP characteristics. First, natural dynamics form the foundation of the design. Wind and waves facilitate the natural dispersal of the nourished sand in northward and southward directions along the coastline and into the dune areas. This mechanism differs from the routine sand nourishments, where sand is located where sand is desired. Second, the Sand Engine enhances the ecosystem quality in at least two different ways. The Sand Engine creates a new and temporary nature area where nature can naturally evolve. Directly after the construction of the Sand Engine, this resulted in the manifestation of a very rare species: the frosted orache (*atriplex laciniata*). Furthermore, the Sand Engine contributes to the natural formation of dunes (when sand is blown onto the dune area). This is believed to contribute to a more natural dune ecosystem compared to manually constructed dunes. In addition, the Sand Engine is argued to be more environmentally friendly because compared to routine nourishment, it causes less disturbance of seabed life. Whereas the regular sand nourishment strategy involves nourishing roughly every five years, the Sand Engine is designed for a 20-year period. Third, the Sand Engine is also a multi-functional solution. It aims to achieve four different goals that combine flood protection and nature functions along with recreation and innovation.

Integration between the knowledge arrangement in the Sand Engine and the related multidisciplinary and multi-actor knowledge processes were important for all three GFP characteristics. Multiple perspectives aligned, and a shared perspective on the project and design evolved. Ecologists and nature actors were included, and thus, the ecosystem became a central part of the decision-making and design processes. The ample design space available allowed for the acceptance of the uncertainties and unpredictability inherent in natural dynamics. It also facilitated the combination of flood protection and nature because difficult trade-offs were avoided. Design assessment and optimisation were based on separate aspects; therefore, these knowledge processes did not contribute to the combination of flood protection and nature. However, it did result in some design adjustments from which the ecosystem profited. An overview is provided in Table 6.3.

Table 6.3 Effect of knowledge on GFP decision-making in the Sand Engine case study

Knowledge in GFP decision-making: knowledge processes and knowledge bases		GFP: Natural dynamics	GFP: Enhance ecosystem	GFP: Combine flood protection and nature
Knowledge processes	Multidisciplinary and multi-actor design development	X*	X	X
	Collective knowledge assessment in project team	X	X	X
	Design assessment based on separate aspects	X	X	-
	Design optimisation based on separate aspects	X	X	-
	Ample design space in all knowledge processes	X	X	X
Knowledge bases	One knowledge base	-**	X	X
	Integral designs	X	X	X
	Assessment reports on separate aspects	X	X	-

* 'X' indicates that the particular knowledge process or knowledge base supports the GFP characteristic
** '-' indicates that the particular knowledge process or knowledge base does not support the GFP characteristic

Afsluitdijk

In the Afsluitdijk project, the decision on the preferred design was made in December 2011 and outlined in the Afsluitdijk Master Plan. The selected design was an overflow-resistant dam, a construction that allows seawater to flow over the dam in exceptional situations (Figure 6.4). In addition, the master plan stated it would explore a bicycle track as part of the design and give the dam a 'green look'. Moreover, in December 2011, parties from both knowledge arrangements signed an ambition agreement on future knowledge processes and the criteria for combining developments in the two domains.

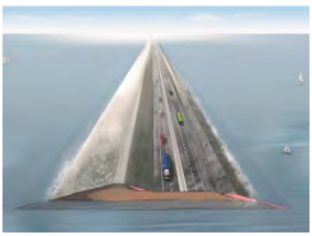

Figure 6.4 Afsluitdijk overflow- resistant dam design

The overflow-resistant dam was not assessed as an example of GFP. First, the dam design did not involve natural dynamics. Although the design was described as an innovative solution for flood protection – allowing for overflow – the construction was a hard design. Second, the design did not improve ecosystem quality. A ‘green look’ was included in the design after it had been criticised as the ‘asphalt dam’ (in Dutch: ‘*Asfaltdijk’*, a corruption of ‘*Afsluitdijk’*); however, it did not enhance particular ecosystems in terms of quality or quantity. Third, the design did not combine flood protection and nature because it was designed only for flood protection. The project objectives were clear, stating that the flood protection level should be improved to withstand a 1/10.000 year storm. The ambition agreement that was signed created the potential to combine flood protection and nature in the future; however, these future developments are not part of the analysis.

In the Afsluitdijk, three different interaction modes were found with corresponding knowledge processes and knowledge bases. The integral design development resulted in GFP designs (the integral visions), involving natural dynamics, contributions to the ecosystem and a combination of flood protection and nature. The developments in the flood protection knowledge arrangement, however, were entirely focused on flood protection without considering enhancement of the ecosystem or natural dynamics. When, in a parallel process, nature designs were developed, these involved a contribution to the ecosystem and natural dynamics. However, no combination with flood protection was facilitated. An overview is provided in Table 6.4.

Markermeer dikes

In the Markermeer dikes project, the daily board of the Waterboard HHNK decided upon the preferred designs for the 33 km dike trajectory on 12 February 2013. For 11 km of the trajectory, the shore dike was the preferred design (Figure 6.5). The shore dike in this decision was the ‘Basic Flood Protection’ (BFP) shore dike, which clearly distinguished it from the nature variant. The BFP shore dike is a sandy dike in front of the existing dike.

The BFP shore dike is not assessed as an example of GFP. First, natural dynamics are not included in the design of the BFP shore dike. The sandy material is designed to remain stable and unaffected by erosion or sedimentation processes. As such, the designers ruled out (natural) dynamics. The designers promoted the shore dike as a ‘natural alternative’ (Van der Linde et al., 2012), which may relate to the soft, sandy nature of the design that differs from the ‘hard’ dikes currently in use. Second, the shore dike does not enhance the ecosystem. In fact, it destructs part of the existing ecosystem environment: a legally protected Natura 2000 site under Dutch law. Not accounted for in the shore dike design is that on the surface of the shore dike, flora and fauna will emerge. Third, the shore dike does not combine flood protection and nature functions. Although the design respects the existing functionalities in its environment, the project and its design are primarily for flood protection.

Table 6.4 Effect of knowledge on GFP decision-making in the Afsluitdijk case study

Knowledge in GFP decision-making: knowledge processes and knowledge bases		GFP: Natural dynamics	GFP: Enhance ecosystem	GFP: Combine flood protection and nature
Knowledge processes	Multidisciplinary design development of integral designs (I)***	X*	X	X
	Design development flood protection designs (I)	-**	-	-
	Assessment based on separate aspects (I)	X	X	-
	Design development nature in nature knowledge arrangement (S)	X	X	-
	Design assessment and optimisation and resulting selection between flood protection designs in flood protection arrangements (S)	-	-	-
	Agreement on knowledge processes and knowledge base between the two knowledge arrangements (C)[50]			
Knowledge bases	Four integral designs (I)	X	X	X
	Two flood protection designs (I)	-	-	-
	Assessment reports, split of designs (I)	-	-	-
	Afsluitdijk Master plan (S)	-	-	-
	Afsluitdijk Ambition agenda (on functions other than flood protection) (S)	X	X	-

* ‘X’ indicates that the particular knowledge process or knowledge base supports the GFP characteristic
** ‘-’ indicates that the particular knowledge process or knowledge base does not support the GFP characteristic
*** In the descriptions, knowledge processes and knowledge bases are related to the particular interaction mode: I = integration, C = cooperation and S = separation

[50] The effect of the cooperation interaction mode on the preferred design cannot be assessed. Because in December 2011 agreements were made to attune the developments, there was not an effect on the design that was decided upon in December 2011.

Figure 6.5 Preferred shore dike design (copied from: Van der Linde et al., 2012)

The interaction mode in the Markermeer dikes project was hybrid, combining elements from the cooperation and separation modes. As a result, all knowledge processes and the knowledge bases were split into two distinct knowledge arrangements. As such, the nature knowledge arrangement designs enhanced to the ecosystem and involved natural dynamics. In the flood protection knowledge arrangements, natural dynamics and contributions to the ecosystem were ruled out. Nowhere were flood protection and nature functions combined.

Table 6.5 Effect of knowledge on GFP decision-making in the Markermeer dikes case study

Knowledge in GFP decision-making: knowledge processes and knowledge bases		GFP: Natural dynamics	GFP: Enhance ecosystem	GFP: Combine flood protection and nature
Knowledge processes	Design development based on different locations for flood protection and nature	-**	-	-
	Design assessment and resulting selection in flood protection knowledge arrangement	-	-	-
Knowledge bases	Knowledge base for nature	X*	X	-
	Knowledge base for flood protection	-	-	-

* 'X' indicates that the particular knowledge process or knowledge base supports the GFP characteristic
** '-' indicates that the particular knowledge process or knowledge base does not support the GFP characteristic

6.2.2 Conclusions

In this section, I answer the second research question: how knowledge in GFP decision-making enables or constrains GFP in flood protection projects.

GFP in flood protection projects implies that the formal decision for a preferred design meets three GFP characteristics: natural dynamics are included in the design and contribute to flood protection, the ecosystem is enhanced, and flood protection and nature functions are combined. Only including natural dynamics and enhancing the ecosystem without combining flood protection and nature functions does not fall into this category. Such a project is more likely to be a nature project, omitting a contribution to flood protection. Combining flood protection and nature functions and contributing to the ecosystem without including natural dynamics could result in the development of a dike with a nature reserve on top of it. However, this is not a GFP project because nature is not related to flood protection, as is the case when natural dynamics are involved. Therefore, all three characteristics need to be met for a design solution to become categorised as GFP.

In only one of the case studies did I find a formal decision that met the three GFP characteristics: the Sand Engine. In the Afsluitdijk and the Markermeer dikes projects, none of the three characteristics was met: There were no natural dynamics, contribution to the ecosystem, or combination of functions. The integral designs, as an intermediary result of the Afsluitdijk project, met the three GFP criteria. These designs were, however, not included in a formal decision.

In total, four knowledge processes were identified in the projects that contribute to all three GFP characteristics: three in the Sand Engine project – multidisciplinary and multi-actor design development, collective knowledge assessment in a project team, and ample design space in all knowledge processes – and one in the Afsluitdijk project – multidisciplinary design development. In the Afsluitdijk case study (chapter 4), it was concluded that the lack of actor involvement in design development inhibited the uptake of the integral designs. Thus, I conclude that multidisciplinary and multi-actor design development enables GFP in flood protection projects. Such an approach enables the alignment of different perspectives, knowledge and methodologies and allows for uptake in decision-making. Likewise, a collective – i.e., multidisciplinary and multi-actor – assessment of knowledge, as was performed in the Sand Engine, also enables GFP in flood protection projects. The ample design space provided in the Sand Engine knowledge processes enabled GFP in flood protection projects by tolerating uncertainties inherent to natural dynamics and by preventing difficult trade-offs between flood protection and nature functions[51].

Knowledge processes that are organised from a single perspective and policy domain constrain GFP in flood protection projects, as happened in the Afsluitdijk en Markermeer dikes case studies. Resulting knowledge bases represent a single function and therefore do

[51] An example of such a trade-off is the location of the Sand Engine. Whereas for flood protection, the Sand Engine was preferably outside the coastline and underwater, allowing for more predictability and effective nourishing, for nature recreation, attachment to the coastline was crucial. The flood protection stakeholders could agree with this because the nourishment was not crucial for coastline maintenance.

not contribute to a multi-functional GFP design. Flood protection designs do not normally include an enhancement of ecosystems or natural dynamics. Nature designs do enhance the ecosystem and also include natural dynamics but do not contribute to flood protection. Moreover, two knowledge bases are created, leaving one knowledge base potentially unused and unrecognised and being a potential source of conflict. For example, in the Afsluitdijk dikes case study actors from different knowledge arrangements disagreed on the requirements for the knowledge base and what counted as a 'substantial' design. Conflict is a risk when different ideas and disagreements on knowledge exist (as in the separation interaction mode). Furthermore, when knowledge is developed in different locations, GFP will not emerge.

Multidisciplinary and multi-actor design development and assessment and integral designs enable GFP in flood protection projects. These are typical characteristics of knowledge processes and knowledge bases in the 'integration' interaction mode between knowledge arrangements (Table 6.2). Thus, I conclude that integration between knowledge arrangements is needed to enable GFP in flood protection projects. The cooperation and separation interaction modes – when knowledge processes are organised in separate locations and lead to multiple knowledge bases – constrain GFP in flood protection projects.

6.3 Improving knowledge in Greening Flood Protection decision-making

The third research question addresses how to improve knowledge in GFP decision-making in order to enable GFP in flood protection projects.

The previous two sections showed that the integration of knowledge arrangements enables GFP in flood protection projects. Integration allows for multidisciplinary and multi-actor knowledge processes and integral GFP designs. Moreover, flexibility in integration – reflected in the ample design space – enables GFP in flood protection projects. Including integration in design assessment and optimisation is not self-evident, given the need for in-depth assessment of separate aspects. GFP in flood protection projects may benefit from approaches that allow for more integration in the design assessment and optimisation processes. Cooperation or separation between knowledge arrangements is insufficient to result in GFP in flood protection projects, given the development of multiple knowledge bases and knowledge processes from different perspectives and in different locations. Nevertheless, cooperation can enable parallel development, whereas for separation, it is more problematic given the lack of attuning (knowledge) developments.

With these insights, the third research question on how to improve knowledge in GFP decision-making can now be formulated more specifically into the following four sub-questions:

- How to enable integration between knowledge arrangements?
- How to include flexibility in the integration of knowledge arrangements?
- How to organise integral design development?
- How to allow for integration in design assessment and optimisation processes?

To answer these questions, I looked into the case studies to see what caused or failed particular interaction modes, how flexibility was included, how integral design development was organised (if achieved) and how the design assessment and optimisation were addressed. Based on the lessons from the case studies, I will draw conclusions (section 6.3.2) and formulate recommendations (section 6.3.3) to improve knowledge and enable GFP in flood protection projects.

6.3.1 Lessons from case studies

Below, I reflect on the four sub-questions for each case study.

Sand Engine

A number of factors enabled integration between knowledge arrangements. Dependency between the two domains of nature and flood protection enabled integration. Financial resources from both arrangements supported the project, and both were needed to fund the project. Furthermore, decision-making power was more equally shared. The Dutch Prime Minister had appointed the province of South Holland – the primary actor in the nature knowledge arrangement – as the party to take the first lead in the project. Rijkswaterstaat – the primary actor in the flood protection domain, which was normally responsible for guiding such a project – was now in the back seat. In addition to becoming dependent, the two arrangements became more balanced; no arrangement could dominate the other. A shared interest in the idea for a sand engine, albeit for different reasons, also enabled integration. In the flood protection domain, the Sand Engine was an innovative approach to coastal maintenance, whereas in the nature domain, it was a way to extend the natural area. Lastly, integration between knowledge arrangements was sufficiently institutionalised to maintain integration during the decision-making process. An ambition agreement was signed at the start of the planning phase in which actors agreed to cooperate.

Flexibility was an important feature of integration in the Sand Engine. Four factors in this project led to this flexibility. First, open or unspecific objectives provided ample design space. Second, some important core values were excluded from the project. These core values were part of the initial knowledge arrangements. Third, the project was positioned as an experiment, meaning that the outcome could hardly fail; this contrasts with normal flood protection projects, where failure is not an option because it would endanger citizens prone to flooding. Lastly, the actor coalition was flexible, meaning that when new topics appeared important, new actors were involved in the project.

Particular tools were employed to facilitate integral design development. The main characteristic is the involvement of multiple actors and multiple disciplines, which allows for the combination of different perspectives in the design. Multi-actor and multidisciplinary workshops were organised, involving all relevant parties and people. An exploratory report suggesting a range of possible designs preceded the workshop. This report was developed by a multidisciplinary team of experts. The results of the design development were discussed by the multi-actor and multidisciplinary project team.

Design assessment and optimisation was partly integral and partly sectoral: it was integral because knowledge processes and all knowledge documents were assessed by the multi-actor and multidisciplinary project team and sectoral because the integral designs were evaluated based on separate aspects, such as nature and morphology. This approach resulted from the requirements in the EIA procedure, which demands the in-depth study and understanding of singular effects.

Afsluitdijk

The Afsluitdijk project is a crucial case study to indicate the factors that influence interaction modes. This project went through three different forms of interaction. First, integration between the knowledge arrangements failed. One factor that explains this failure was the imbalance between the initial knowledge arrangements: Only from the flood protection knowledge arrangement were financial resources provided; the objectives for flood protection were specific, whereas nature objectives were generally formulated; the flood protection domain was strongly organised in terms of institutions and legislation, whereas the nature domain was hardly organised at the start of the project. Integration between knowledge arrangements in the Afsluitdijk was insufficiently institutionalised. There was no formal agreement to keep the objectives or actors together when circumstances became challenging. Before the actual separation of knowledge arrangements, there was dissatisfaction within the nature knowledge arrangement; it was foreseen that nature goals would not be met. When actors in the flood protection domain clearly stated that flood protection was independent of nature and that for nature to become part of the project, some requirements had to be met, separation was a fact. The independent and dominant position of the flood protection domain enabled this approach. Although it led to separation, the tough stand from the flood protection domain also made responsibilities clearer. Any ambition in the nature domain had to be organised within the nature domain, in contrast to the earlier stage of the process, when the flood protection domain had given the impression that they stood for an integral project. This situation caused an internal focus in both domains and enabled the nature knowledge arrangement to mature. When the nature knowledge arrangement matured – in terms of idea and knowledge development, actor coalition, resources, and discourse – the two knowledge arrangements became more balanced, allowing for cooperation as an interaction mode. In sum, the imbalance and related independence and dominance of the flood protection knowledge arrangement led to a failure of integration and caused separation. When the knowledge arrangements became more balanced, cooperation was enabled.

Whereas the Sand Engine included flexibility in the project and interaction mode, this feature was absent in the Afsluitdijk project. In particular, from the flood protection knowledge arrangement, flexibility was impeded on at least three levels: the requirements for dike reinforcement, the planning and the budgets were strict. Over the course of the project, these strict requirements became increasingly more apparent. Rijkswaterstaat stated that it would operate independently of other developments and not await other ideas. Moreover, strict terms were opposed to the nature knowledge arrangement by means of the defining minimal conditions for plans to align with the Afsluitdijk project.

Integral design development occurred in the first year of the project when multidisciplinary teams elaborated integral designs for the Afsluitdijk. Although the result included GFP designs, the large distance from decision-making, limited involvement of actors and the minimal transfer of ideas to actors impeded the uptake of the integral designs in decision-making.

The design assessment and optimisation processes in the Afsluitdijk project were organised in sectoral ways, and integral designs were split up into parts. In addition to the EIA requirements that played a role in steering towards a singular effect assessment, two other factors played a role. First, the need for a ‘sound comparison’ of the available designs led to a division in separate parts. Second, the Afsluitdijk was a large project of national interest. Thus, renowned experts on the many different topics had to be consulted. Experts are by definition not integral but sectoral-oriented; they are specialists in a particular field, with sectoral knowledge as a result.

Markermeer dikes

In the Markermeer dikes case study, a hybrid interaction mode was identified, combining elements of cooperation and separation. As in the Afsluitdijk case study, the two knowledge arrangements were imbalanced and consequently independent. While the flood protection knowledge arrangement had ample resources and strong institutions, was embedded in legislation and had decision-making power, the nature knowledge arrangement was rather weak, with only resources for studies and a policy objective as support. There was no further legal framework to build upon. In addition, the ecological knowledge was exploratory in nature, whereas the flood protection knowledge base was goal-oriented and further developed. The strict division of tasks also inhibited integration: Nature (research) belonged to the nature domain and flood protection (research) to the flood protection domain. From the nature knowledge arrangements, attempts were made over the course of the project to overcome the imbalance and establish some dependency. A proposal for a double project objective was rejected, and combinations with another nature project[52] that implied dependency were explored but not established. The lack of incentive to include nature in the flood protection knowledge arrangement is apparent in this case study. There was no evident added value of such an inclusion. Moreover, involving nature in the design or project would imply additional risks in terms of, e.g., planning and procedures.

Flexibility was inhibited by the strict terms of the flood protection knowledge arrangements. There was a tight project schedule, a fixed budget and strict design assessment criteria (sober, robust and feasible). These conditions left minimal flexibility in designing the project.

Integral design development was inhibited by the fact that knowledge was developed in different locations: nature knowledge in the nature domain and flood protection knowledge in the flood protection domain. Moreover, the lack of integration in project organisation inhibited the development of integral knowledge requests. In the flood protection knowledge arrangement, flood protection knowledge questions were formulated, whereas in the nature knowledge arrangements, nature questions were formulated. Nowhere was the need for an integral approach directly recognised.

Except for the assessment of different types of flood protection designs, design assessment and optimisation processes did not play a significant role in this project. In the assessment of the flood protection designs, no nature designs were involved. These had been abandoned earlier after being evaluated by flood protection criteria.

6.3.2 Conclusions

In this section, I answer the third research question: how to improve knowledge in GFP decision-making in order to enable GFP in flood protection projects. This research question was refined into four sub-questions. Below, I discuss these questions one by one.

[52] The shelter measures ‘Hoornse Hop’.

How to enable integration of knowledge arrangements?

Three factors enabled the integration of knowledge arrangements.

First, dependency between knowledge arrangements enables integration between knowledge arrangements, whereas in contrast, the independency and dominance of one knowledge arrangement over the other inhibits integration. To achieve dependency and prevent independency, knowledge arrangements should be somewhat balanced in terms of actors, resources, rules and regulations, discourse and knowledge. Strong and stable actor coalitions, embeddedness in national legislation and policy, available financial resources, decision-making responsibilities and agreed-upon and institutionalised knowledge and knowledge processes characterise the three flood protection knowledge arrangements in the case studies. This contrasts with the nature knowledge arrangements that were found. Particularly in the Afsluitdijk and Markermeer dikes case studies, there was no legal obligation to realise nature, actor coalitions had to be organised, financial resources were insufficient or had to be arranged, there was hardly decision-making power, and knowledge development was in an early stage. The Sand Engine case study was different in this respect; the nature knowledge arrangement had both financial and decision-making resources, and the flood protection knowledge arrangement had insufficient financial resources and minimised decision-making power.

Second, to achieve GFP in flood protection projects, a GFP solution with added value for both domains is required. Such a solution may be available at the start of the project (as in the Sand Engine project) and thus may be an incentive for integration between knowledge arrangements or otherwise be the outcome of integration. A true challenge for GFP decision-making is that when no GFP solution is available beforehand, the added value of an integrated approach may be unclear and inhibit integration. In the Afsluitdijk and Markermeer dikes case studies, insight into the added value of integration was lacking. In the Markermeer dikes case study, it was not apparent why the integration of nature in the flood protection project would be beneficial. Therefore, the risks associated with involving nature or a GFP design, were not taken.

Third, interaction processes between the two knowledge arrangements affect the development of individual knowledge arrangements. In the Afsluitdijk project, the nature knowledge arrangements matured as a result of knowledge arrangement interaction. This created more balance between the knowledge arrangements and allowed for cooperation.

How to include flexibility in the integration of knowledge arrangements?

A central challenge for including flexibility in integration of knowledge arrangement is the strict organisation of the flood protection domain, which leaves limited room for flexibility, whereas flexibility can play an important role in combining flood protection and nature functions and including natural dynamics in the design. In the flood protection domain, objectives and criteria for designs are defined in a very precise manner. Examples are the required failure probability for dikes or dams (Afsluitdijk), the coastline in terms of BKL (Sand Engine) and the criteria for design assessment: 'sober', 'robust' and 'feasible' (Markermeer dikes). Often, budgets are restricted, and a strict time schedule is imposed on flood protection projects. The inclusion of flexibility in the Sand Engine project by means of unspecific objectives, excluding core values, organising the project as an experiment, and having a dynamic actor coalition provides a valuable lesson.

How to organise integral design development?

Integral design development should be a multi-actor and multidisciplinary exercise. Focusing on only the multidisciplinary characteristic may inhibit the uptake of the integral designs by actors (as occurred in the Afsluitdijk project). The Sand Engine showed how such an approach can be organised in practise by means of workshops and expert studies.

How to allow for integration in design assessment and optimisation processes?

Involving integral approaches in design assessment and optimisation proved difficult in all three case studies. An integral assessment of integral designs is at odds with the EIA requirements to understand and study particular project effects in detail and the desire to include specialists on a particular topic. Sectoral approaches can be disastrous for the uptake of integral designs in decision-making (as in the Afsluitdijk). The tension between integral assessment and the need for detailed knowledge on effects was handled elegantly in the Sand Engine project. The integral nature of the designs was secured by the multi-actor and multidisciplinary assessment of all knowledge documents in the project team.

6.3.3 Recommendations

Following the conclusions in section 6.3.2, five recommendations are formulated to improve knowledge in GFP decision-making and enable GFP in flood protection projects.

1. Be aware of and try to balance the relative strength of knowledge arrangements. This process may lead to dependency between knowledge arrangements and improve the potential for integration between knowledge arrangements.

- The strength of (nature) knowledge arrangements may be improved by organising: an actor coalition, resources, knowledge, rules and regulations and a discourse.
- The dependency between knowledge arrangements can be arranged by: a double project objective, a design alternative with added value for both knowledge arrangements and coupling of nature and flood protection projects (if applicable).

- The balance between knowledge arrangements may result from interaction between knowledge arrangements.

2. Organise value in designs for both knowledge arrangements. A shared interest in the solution may result in and serve as an incentive for integration between knowledge arrangements.

- Include flood protection criteria in the 'nature' design process (when the onus of proof lies with the nature knowledge arrangement, having a dependent position).
- Organise integral design development. This is feasible with integration between knowledge arrangements.

3. Allow for flexibility in GFP decision-making. This can be achieved by:

- Having open and unspecific project objectives,
- Excluding core values of the initial knowledge arrangements from the integrated arrangement,
- Organising the project as a pilot or experiment, and
- Organising an adaptive actor coalition that allows for the inclusion of new actors when required.

4. Organise the design development in a multi-actor and multidisciplinary manner.

5. Integral approaches to design assessment and optimisation proved difficult. Secure an integral approach with the close involvement of a multi-actor and multidisciplinary project team in the knowledge processes.

6.4 Reflection on research

In the previous sections, I discussed conclusions on the three research questions and formulated five recommendations for flood protection projects. Here, I will reflect on the theory and methods employed in this research. The first implies a necessary reflection on the used and developed theory and an illustration of the main theoretical contributions. The second involves a reflection on the used methods and an indication of the value of the results.

6.4.1 Reflection on theory

The theoretical approach in this research builds upon the WoK model (Feldman et al., 2006; Schneider & Ingram, 2007; Van Buuren, 2009) and the Policy Arrangement Approach (Arts & Leroy, 2006; Van Tatenhove et al., 2000).

The WoK model employs an understanding of the relationship between knowledge and policy that is conceptually different from the more established linear and co-production models. The most important distinctive feature is that it does not differ between a policy and a knowledge world, and it finds the critical interactions between knowledge-cum-policy fields rather than within them. This insight is relatively new and constitutes a promising route in understanding contemporary knowledge disputes and processes. The contribution of this thesis to this emerging field of literature is twofold: conceptual and empirical.

In chapter 2, I concluded that the weak part of the WoK model is in its operationalisation. The Wok model suffers from conceptual vagueness that complicates its empirical application. This thesis contributes conceptually to the WoK model by providing a conceptual framework that allows for empirical research. The policy arrangement approach was used to complement the WoK model. The four dimensions of the policy arrangement provide a manageable approach to explicating the WoK model. Moreover, I deliberately discerned among the knowledge processes that unfold in the dynamic constellation of actors, rules, resources and discourse and the knowledge base that results from these processes and in turn affects them. This distinction is emphasised in the WoK literature: ‘Knowing’ highlights the active dimension of knowledge (Schneider & Ingram, 2007). A second conceptual contribution lies in the elaboration of the interaction modes. Interaction between WoKs in the WoK model was identified as a crucial process in determining the dynamics within WoKs. The four interaction modes developed and used in this research – i.e., separation, cooperation, integration and unification – provide a tool to indicate the mode of interaction. Moreover, in this study, I also reflected on the consequences of the particular interaction modes for the case of GFP.

This research has employed the policy arrangement as a main element of the policy arrangement approach (Arts & Leroy, 2006; Van Tatenhove et al., 2000) to complement the WoK model. The original concept of policy arrangements addresses knowledge and knowledge processes only to a limited extent. Knowledge is included as a resource and may be part of the discourse, but it has no central role. The contribution of this study is the inclusion of knowledge and knowledge processes in the policy arrangement by redefining the four dimensions (Table 2.3) and including them in the conceptual framework of interacting knowledge arrangements. Other authors have also noted the exclusion of knowledge in the policy arrangement approach (Hegger et al., 2012a; Seijger et al., 2013; Wiering et al., 2001) and have determined different alternatives to including knowledge and knowledge processes. The strength of the approach employed here is in 1) the explicit redefinition of the four dimensions of the policy arrangements and 2) the explicit distillation from those knowledge processes and the knowledge base.

This study has provided empirical support for the understanding of knowledge in decision-making in the WoK model. In particular, the Afsluitdijk and the Markermeer dikes case studies illustrate how knowledge disagreements emerged not within policy domains but between them. These two case studies showed no integration among different knowledge arrangements (except for the first period in the Afsluitdijk case), and thus, it could clearly be observed how actors, rules, resources, discourse, knowledge processes and the knowledge base were closely related. The focus in this study on flood protection projects in the Netherlands provides a particular perspective. The Dutch flood protection domain has a long tradition and is strongly organised in terms of institutions, knowledge, discourse, resources and rules and regulations. Moreover, there is a strong focus on the prevention of floods. This focus is, for example, different in the UK situation regarding flood protection, where managing the risks of floods by spatial planning is much more common (van den Hurk et al., 2014). The way interaction is shaped between knowledge arrangements in other domains or other countries may differ.

6.4.2 Applicability of the conceptual framework in other fields

Interaction between policy domains is not just a phenomenon that can be found in GFP decision-making. Flood protection happens to interact with other policy domains as well, and ‘greening’ is a phenomenon that is not restricted to flood protection alone. Below, some accounts are described.

In both the Afsluitdijk and the Sand Engine projects, other policy domains in addition to nature and flood protection were involved. In the Sand Engine project, recreation was one of the project objectives. In the Afsluitdijk project, a number of other combinations with flood protection were explored and established, including different forms of energy (tidal hydropower, solar power and salinity gradient power[53]), recreation, and fisheries. In the literature, the ecosystem function and services of green solutions are highlighted (Costanza et al., 1997). Ecosystem services represent ‘the benefits human population derive, directly or indirectly, from ecosystem functions’ (Costanza et al., 1997, p.253). Approached from this definition, this thesis has a particular focus on one ecosystem service, ‘flood protection’. Ecosystems provide protection against flooding. However, the ecosystem provides more than just that, and in the GFP-related literature, authors have drawn attention to other benefits that GFP can provide. These include fisheries, water quality, carbon sequestration and recreation, depending on local circumstances (Barbier, 2007; Barbier et al., 2008; Borsje et al., 2011; Hale et al., 2009). This characteristic of GFP

[53] Salinity gradient power relates to energy from the difference in salt concentration between fresh water and seawater and is also known as ‘blue energy’.

implies the involvement of more policy domains than the two used in this research: nature and flood protection.

Although GFP is the subject of this thesis, ‘greening’ is a phenomenon that is not restricted to flood protection. The need or request for greening resonates in many fields, such as agriculture and food production (Tilman, 1998), energy production (Sawin, 2004; Vachon & Menz, 2006), sanitary systems (Hegger, 2007), and urban development. ‘Green roof systems’ are a form of ‘greening’ in urban storm water management and are an alternative solution to the ‘traditional’ drainage system (Palla et al., 2010; Stovin et al., 2013; Stovin et al., 2012). Indications can be found in a range of fields on the challenge of implementation despite available ideas, for example, in the fields of green roofs or green energy production (Vachon & Menz, 2006). The widespread phenomenon of greening and challenges in implementation in practise suggest that a knowledge arrangement framework may provide additional insights on how to enable realisation.

Looking beyond flood protection and greening initiatives, multifunctional approaches are receiving increasingly more attention in spatial planning. This attention is the result of increasing pressure on the (limited) available space in the Western (urban) world (Priemus et al., 2004; Van Broekhoven et al., 2014) and induced by external developments such as climate change (O'Farrell & Anderson, 2010; Swart et al., 2013). In multifunctional approaches, actors from different domains need to coordinate and integrate their activities. Multifunctional approaches to spatial planning are a novel development characterised by serious governance challenges (Van Broekhoven & Vernay, 2011) and a lack of actual implementation (O'Farrell & Anderson, 2010).

In sum, the framework of interacting knowledge arrangements may have a broader application range than just the field of GFP decision-making, as the plurality of policy domains that interact is a widespread phenomenon.

6.4.3 Reflection on methods

In this thesis, a case study approach was employed. This approach was considered the most appropriate in order to study GFP decision-making as a real-life phenomenon that is strongly dependent on a particular context (Yin, 2009). Three flood protection projects were analysed, of which only one turned out to be an example of actual GFP in a flood protection projects. This result was possible because the case studies were selected before the outcomes of the projects were known. Although only one project showed GFP in a flood protection project, the attempts in the other two case studies revealed insights into the dynamics and enabling and constraining conditions of knowledge in GFP decision-making.

The conceptual framework of interacting knowledge arrangements was the central theory in this research. It was not only based on existing models on knowledge in decision-making but also informed by three characteristics regarding knowledge in GFP decision-making and the need to apply the model in case study research. The three characteristics – based on literature – thus played a decisive role in understanding knowledge in GFP decision-making. For example, if GFP decision-making were found not to involve policy domain interactions, it would directly undermine the theory. The three assumptions were not explicitly 'tested' in this research. However, the case studies were consistent with all three assumptions (see section 6.1.3).

A conceptual challenge in the case studies was the identification and delineation of the knowledge arrangements. The identification and drawing of the boundaries of a particular knowledge arrangement is strongly dependent on the perspective and interpretation of the researcher, who can easily be misguided to see what she wants to see. Knowledge arrangements are not 'out there' waiting to be found; rather, they result from a particular way of analysing and looking at the projects under study. How valid was the conclusion that knowledge arrangements were found in the three case studies? I used three strategies to provide validity on this account. First, the analyses of all three case studies were discussed with key informants in the case. This check provided insight into the validity of the results. Second, I followed the conceptual framework in the analysis of the cases to prevent subjective interpretation. Third, multiple data sources were used (see section 1.5.3).

In the case study methodology, 'analytical' generalisability was strived for; thus, the results should contribute to a broader theory. In this research, the case studies contributed to a theory on knowledge in GFP decision-making in Dutch flood protection projects. Thus, it has not been the ambition of this research to directly conclude on the potential for GFP decision-making in the Netherlands. Nonetheless, it is interesting to reflect on what the case study results may show us about the Dutch situation regarding GFP decision-making. The three case studies cover different parts of the Dutch flood protection domain. The Sand Engine is in the field of coastline maintenance, the Afsluitdijk is one of the 'projects' of the Ministry of Infrastructure and Environment (responsible for flood protection), and the Markermeer dikes project is a project within the second High Water Protection Program (HWBP-2). Some other significant projects and programmes are not represented in this thesis, such as the 'Room for the River' programme (involving 30 separate projects), the 'weak links' (10 projects) along the coastline and the new High Water Protection Programme (over 60 projects). Moreover, the HWBP-2 covers a total of 88 (!) projects, and between 2012 and 2015, on 40 different locations, sand will be nourished

(Rijkswaterstaat, 2014). Each project or programme has (slightly) different institutional characteristics[54], and each project will have its own particular context, providing different opportunities for GFP. It is attractive to conclude from the three case studies that GFP decision-making in Dutch flood protection projects is yet a bridge too far (only the Sand Engine succeeded, and this was an experiment, placed outside the daily flood protection regime). All in all, the strong institutionalisation of the flood protection domain is applicable beyond the single projects (possibly inhibiting integration), and the amount of actually realised GFP decision-making in flood protection projects supports such a statement (see chapter 1). However, this is not what I have been researching, and there are signs that things change (the Sand Engine being one example). Therefore, I decided to be modest in drawing conclusions here. Each project has its own particular context and opportunities. GFP decision-making is far from mainstream, but when there is a will, there may be a way.

6.5 Greening Flood protection: an outlook

This chapter and thesis are completed with my personal outlook on Greening Flood Protection decision-making in the Netherlands. Where do we stand at the moment? Where do we go from here?

Not yet mainstream in the Netherlands

GFP is a challenging exercise in the Dutch flood protection arena and remains far from mainstream. Some examples are emerging, but these represent a very small part of the total of flood protection projects. Are we heading towards a flood protection domain in which GFP becomes a mainstream practise? A number of authors have addressed changes in the policies and practises in the Dutch water management field (van den Hurk et al., 2014; Van Der Brugge et al., 2005; Wiering & Arts, 2006; Wiering & Crabbe, 2006). Research has been performed on whether changes towards more integrated and multifunctional practises are actually occurring. These authors have concluded that changes occur on some but not on all dimensions of the policy domain, and the dominant position of flood protection largely remains in place.

Entirely new forms of knowledge

GFP is not about putting together existing knowledge; it is about creating a new form of knowledge, which is greater than the sum of its parts. Moreover, GFP design solutions

[54] For example, the Room for the River programme had a double objective that combined flood protection and spatial developments.

relate to the specific situation of application, to the local ecosystem, and to the local natural dynamics. These local conditions are not just external parameters to be taken into account, for example, when a dam is being built; rather, these conditions become *part* of the design. Therefore, there is no ready-to-use blueprint on how to do it, and this puts the development of GFP knowledge under pressure. GFP is innovative, it is largely unproven, and it requires new forms of knowledge development and new parties and disciplines to be taken into account. It is anything but the simple story of putting two types of knowledge together. These 'old' disciplines should be thrown away, and the designers need to start from scratch. When knowledge is not present, it cannot and will not be considered in decision-making, as was demonstrated in the Markermeer dikes projects.

On-going experimentation

Experiments are, in this stage, the first way forward. In the GFP community, people are well aware of this fact. Primarily inspired by knowledge, research projects and programmes – e.g., the Ecoshape BwN programme, NWO research, and Naturecoast – pilots, showcases and experiments are on the agenda. In the first BwN programme, the device was 'show that it works'; now, in the second BwN programme, a 'make it happen' discourse dominates the discussion (Ecoshape, 2014b). Realising GFP in flood protection projects will benefit from this practical orientation. A primary risk, however, is in the way these practical experiments are approached. These experiments should be more than knowledge-driven initiatives by researchers; they should also involve the policy and project processes. This is also demonstrated by the conceptual framework of interacting knowledge arrangements. Moreover, in addition to an orientation on the technical aspects in such pilots, these should include a governance orientation. In this research, it was exposed how governance aspects such as actors and coalitions and the division of resources are central to the feasibility of GFP decision-making.

Adaptive management

This study has highlighted the difficulties of implementing GFP in Dutch flood protection projects. Strict conditions for both decision-making and knowledge make it difficult to introduce natural dynamics (which are uncertain and unpredictable) and to combine them with other functions, such as nature. The possibility of 'adaptive management' has received limited attention in the discussion so far. Such an approach strongly suits GFP design solutions, given the natural dynamics and associated on-going development of the design. GFP design solutions are not finished upon project completion (De Vriend et al., 2014) but continue developing as a form of 'self-design' (Odum & Odum, 2003). They involve continuous monitoring and decision-making. Some informative examples of adaptive management are available and should be used to draw lessons in this area. The organisation of Dutch coastline maintenance is highly instructive because it is organised in an adaptive manner by means of continued monitoring, decision-making and nourishment interventions. These lessons should be further studied and employed in the Dutch flood protection domain for the benefit of GFP. This example is even more valuable because it is part of Dutch flood protection practise, which should enable easier knowledge transfer to other parts of this domain.

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Appendices

Appendix I Interviews and meetings

Sand Engine case study

Interviews held in Sand Engine case study

Date	Organisation respondent	Position respondent
05-Oct-09	Deltares	Researcher (also involved with Sand Engine as a former employee of RWS)
10-Feb-10	DGW	Coordinator coastal policy, part of project team since 2008
10-Feb-10	Consultant	Advisor project team Sand Engine
16-Feb-10	PZH	Project manager Sand Engine
17-Feb-10	Consultant	Principle researcher consultant for EIA development
11-Mar-10	RWS	Two respondents: representative in core team Sand Engine and RWS coordinator of the Sand Engine project
17-Mar-10	RWS	Senior advisor flood protection
19-Apr-10	Deltares	Researcher (also involved with Sand Engine as a former employee of RWS)
23-Apr-10	Deltares	Researcher
28-Apr-10	RWS	Coordinator EIA content
22-Jun-11	Consultant	Ecologist
10-Aug-11	Consultant	Ecologist
15-Aug-11	PZH	Member project team Nature and Recreation

Meetings attended in the Sand Engine case study

Date	Event / meeting
6-Oct-09	Introduction meeting
23-Nov-09	Project team Sand Engine
25-Nov-09	Meeting on Monitoring plan
7-Jan-10	Core team Sand Engine
11-Mar-10	Public consultation meeting
1-Apr-10	Excursion with project participants to MVII
2-Nov-10	Public consultation meeting
31-Aug-11	Excursion to the completed Sand Engine with project participants and stakeholders

Afsluitdijk case study

Interviews held in Afsluitdijk case study. The informal meetings are not in this list.

Date	Organisation respondent	Position respondent
02-Nov-11	Programme 'Naar een Rijke Waddenzee'	Manager
01-Nov-11	Rijkswaterstaat/ Afsluitdijk project team	Technical manager
08-Nov-11	Rijkswaterstaat/ Afsluitdijk project team	Director
17-Nov-11	Consultant/ Afsluitdijk project team	Project team member
25-Nov-11	Province/ Afsluitdijk project team	Project team member, provincial coordinator
17-Dec-12	Market party	Developer integral Afsluitdijk vision
21-Jan-13	VBIJ (NGO)	Director

Meetings attended in Afsluitdijk case study

Date	Event / meeting
18-Aug-10	Introduction meeting
20-Sep-10	Planning session project team Afsluitdijk
25-Oct-10	Core team meeting project team Afsluitdijk
28-Oct-10	Project team meeting project team Afsluitdijk
3-Nov-10	Meeting on Afsluitdijk master plan
18-Nov-10	Project team meeting project team Afsluitdijk
6-Jan-11	Work session project team Afsluitdijk
10-Mar-11	Project team meeting project team Afsluitdijk
16-Mar-11	Meeting to discuss Afsluitdijk 'ambitions'
7-Apr-11	Project team meeting project team Afsluitdijk
16-Jun-11	Project team meeting project team Afsluitdijk
1-Sep-11	Project team meeting project team Afsluitdijk

Markermeer dikes case study

Formal interviews held in the Markermeer dikes case study

Date	Organisation respondent	Position respondent
16-May-13	HHNK	Advisor nature legislation
23-May-13	Consultant for HHNK	Consultant
23-May-13	Ministry I&M	project manager shelter measures
27-May-13	Consultant for HHNK	Consultant
28-May-13	HHNK	Technical manager
6-Jun-13	HBWP	Manager examination
13-Jun-13	RWS	Project member synergy project
13-Jun-13	Nature NGO	Director
2-Jul-13	Deltares	Researcher

Informal interviews held in the Markermeer dikes case study

Date	Event / meeting
17-Dec-12	Introduction meeting project
17-Jan-13	Catch-up meeting project
5-Mar-13	Catch-up meeting project
4-Apr-13	Catch-up meeting project
7-May-13	Catch-up meeting project
1-Jul-13	Catch-up meeting project
29-Jan-14	Evaluation meeting paper
18-Mar-14	Presentation and discussion analysis

Meetings attended in the Markermeer dikes case study

Date	Event / meeting
2-Oct-12	Shore dike workshop Ecoshape
26-Mar-13	Design workshop shore dike
9-Apr-13	Design workshop shore dike Hoorn-Edam
11-Apr-13	Design workshop shore dike Edam-Amsterda
25-Apr-13	Design workshop shore dike

Appendix II Interview questionnaire

Below, example questionnaires are presented, which are representative for each case study. The specific questions asked have been different in each particular interview depending on the position of and acquaintance with the respondent and the setting of the interview. As elucidated in the research approach (section 1.5), the interviews in the Afsluitdijk case study and the Markermeer dikes case study are informed by the ‘clean language approach’. This approach employs ‘ultra-open’ questions. The interview is structured by four types of questions: some introduction questions, one central question, clarification questions and a checklist of the topics that should be covered. As of this approach the example questionnaires of the Afsluitdijk and Markermeer dikes case studies are similar.

Sand Engine case study – example questionnaire

1. Introduction
    - Introduction respondent and researcher
    - Duration of interview
    - Interview report
    - What is your role in the project?
    - What is the interest of your organisation in the project?
2. Building with Nature (BwN)
    - Are you familiar with BwN? What does it mean to you?
    - What BwN characteristics are found in the Sand Engine?
    - How is the Sand Engine different form ‘Building in Nature’ and ‘Building of Nature’?
3. Uncertainties
    - Are uncertainties inherent in BwN?
    - What uncertainties are found in the Sand Engine?
    - What role do uncertainties have in the project?
    - How is dealt with uncertainties in decision-making?
4. Integration of knowledge disciplines
    - Is integration of knowledge inherent in BwN?
    - Did knowledge disciplines integrate?
    - What disciplines were integrated?
5. Role of knowledge
    - What knowledge questions have been asked?
        - i. What parties were involved?
        - ii. What did the process look like?
        - iii. How was the interaction between parties?
    - How is knowledge developed?

    i. What parties were involved?
    ii. What did the process look like?
    iii. How was the interaction between parties?
- How was knowledge used?
    i. What role did knowledge have in the selection of the preferred design?

6. Project outcome
    - How did the Sand Engine come about?
    - What factors determined the outcome?
7. End of interview
    - Do you have any other comments?
    - Report will be send for check.
    - Names will not be included in the analysis, but organisation and position are. Do you agree?
    - Who else could be interviewed regarding this topic?

Afsluitdijk case study – example questionnaire

Introduction questions:

- How and how long are you involved in the Afsluitdijk project?
- What is your position?

Central question:

- How is dealt with the combination of nature and flood protection in the Afsluitdijk project and what is the role of knowledge herein?

Clarification questions (source: www.cleanlanguage.co.uk):

- And is there anything else about (that) [x]?
- And what kind of [x] (is that [x])?
- And where/whereabouts is [x]?
- And that's [x] like what?
- And is there a relationship between [x] and [y]?
- And when [x], what happens to [y]?
- And what happens just before [event x]?
- And then what happens? / And what happens next?
- And where could/does [x] come from ?
- And what would [you/x] like to have happen?
- And what needs to happen for [x] to [intention of x]?

- And can [x] [intention of x]?

Checklist:

- Which stakeholders are involved and in what manner?
- What knowledge is developed and used?
- Who has what resources?
- What discourses are employed?
- What rules and regulations apply?

Markermeer dikes case study – example questionnaire

Introduction questions:

- How and how long are you involved in the Markermeer dikes project?
- What is your position?

Central question:

- How is dealt with the combination of nature and flood protection in the Markermeer dikes project and what is the role of knowledge herein?

Clarification questions (source: www.cleanlanguage.co.uk):

- And is there anything else about (that) [x]?
- And what kind of [x] (is that [x])?
- And where/whereabouts is [x]?
- And that's [x] like what?
- And is there a relationship between [x] and [y]?
- And when [x], what happens to [y]?
- And what happens just before [event x]?
- And then what happens? / And what happens next?
- And where could/does [x] come from ?
- And what would [you/x] like to have happen?
- And what needs to happen for [x] to [intention of x]?
- And can [x] [intention of x]?

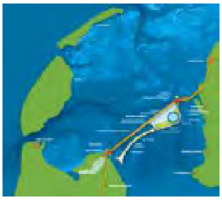
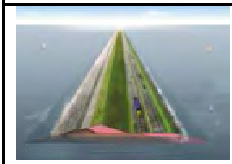
Checklist:

- Which stakeholders are involved and in what manner?
- What knowledge is developed and used?
- Who has what resources?

- What discourses are employed?
- What rules and regulations apply?

Appendix III Overview integral visions and reference designs Afsluitdijk case study

Summary of the four integral visions and two governmental reference designs, highlighting the main elements (Rijkswaterstaat et al., 2009)

	Monument in balance (in Dutch: Monument in Balans) The flood protection level of the dam is reinforced by means of a 'storm shield'. Spatial developments are located at the ends of the dam. Space is created for a sustainability centre and an innovation island. The vision includes a 'fresh-salt passage' and replacement of bridges and sluices by means of a naviduct. Copyright picture: Antea Group (formerly Oranjewoud)
	Natural Afsluitdijk (in Dutch: Natuurlijk Afsluitdijk) This vision combines nature development and energy production south of the Afsluitdijk. It includes a 'blue energy' power station (energy from using the difference in potential of fresh and salt water) and power storage by means of a 'fall-lake'. Flood protection is achieved by means of a traditional increase of the dam. A second 'nature dam' is located south of the Afsluitdijk. The vision includes a sustainability centre and a naviduct.
	Wadden Works (in Dutch: Waddenwerken) WaddenWorks reinforces the Afsluitdijk by means of sand nourishment at the Wadden Sea side of the dam. Areas of salt marshes emerge improving the natural value. A 'fresh-salt passage' is created in the Wadden Sea. This vision foresees a blue energy power station and bridges to improve mobility.
	Water machine (in Dutch: Watermachine) Flood protection is improved by means of an 'overflow resistant' dam (in Dutch: overslagbestendige dijk). An 'in-between' lake is created, with a nature dam and a gradual fresh-salt transition. Furthermore, the vision includes a power station using tidal energy, small scale recreation, salt-water agriculture and a naviduct.
	Governmental reference design: Basis alternative overflow-resistant dam The covering of the entire dam surface is reinforced and made overflow resistant. In the exceptional case of overflow, the salt water will not damage the dam. The inside slope of the dam is faded. A new bicycle track is developed on the 5 m additional width.
	Governmental reference design: 2100 Robust traditional dam increase In this design the dam is heightened 2.5 m and broadened 30 m.

Appendix IV Project documents Afsluitdijk case study

Overview of the main project documents, advices, and integral visions in the design phase of the project Future Afsluitdijk.

Type	Title	Author	Date
Project document	Toekomst Afsluitdijk, resultaten van een participatieve verkenning	Instituut SMO	Mar-08
Project document	Toekomst Afsluitdijk Acht integrale visies, resultaten van een marktverkenning (fase 1)	Rijkswaterstaat, provincie Fryslân provincie Noord- Holland	Aug-08
Advice	Beoordelingsadvies Adviescommissie Afsluitdijk	Adviescommissie Afsluitdijk	Aug-08
Advice	Review rapportage fase 1 in het kader van de marktverkenning Afsluitdijk	Innovatieplatform	Sep-08
Advice	Onderzoek integrale verbetering Afsluitdijk	College van Rijksadviseurs	Sep-08
Integral vision	Waddenwerken, een veilige kering die meegroeit met de zee	DHV B.V., IMARES, Bureau Alle Hosper	Nov-08
Advice	Vervolgproces Afsluitdijk: Advies Adviescommissie	Adviescommissie Afsluitdijk	Nov-08
Integral vision	Monument in Balans - Integrale visie op de Afsluitdijk	CE Delft, GDArchitecten, NoordPeil landschap&stedenbouw, Ingenieursbureau Oranjewoud B.V.	Dec-08
Integral vision	Afsluitdijk 21e eeuw, Voltooiing Zuiderzeewerken: van dam naar watermachine	ARCADIS, Dredging International, Nuon in samenwerking met H+N+S landschapsarchitecten	Dec-08
Integral vision	Natuurlijk Afsluitdijk	Royal Haskoning, Wubbo Ockels, BAM, Eneco, Lievense, Rabobank, Van Oord	Dec-08
Project document	Toekomst Afsluitdijk Vier visies, resultaten van een marktverkenning (fase 2)	Rijkswaterstaat, provincie Fryslân provincie Noord- Holland	Dec-08

Overview of the main reviews, project documents, research reports, advices, and expert sessions in the assessment phase of the project Future Afsluitdijk.

Type	Title	Author	Date
Review	Reactie op uitwerking vier consortia in tweede fase Marktverkenning Afsluitdijk - review cultuur	Rijksdienst voor archeologie, cultuurlandschap en monumenten	Jan-09
Review	Technische haalbaarheid. Review rapportages fase 2 in het kader van de marktverkenning	TU Delft	Jan-09
Review	Advies over eindrapportages marktverkenning Afsluitdijk - review innovatie	Innovatieplatform	Feb-09
Review	Evaluatie marktverkenning	Rijksuniversiteit Groningen, Netwerk Deltatechnologie	Feb-09
Project document	Dijk en Meer; Eindrapportage verkenning Toekomst Afsluitdijk	Rijkswaterstaat, provincie Fryslân provincie Noord-Holland	Mar-09
Review	Duurzame energieopties bij integrale verbetering van de Afsluitdijk - review duurzame energie	ECN	Mar-09
Review	Toekomstperspectieven Afsluitdijk - review natuur ecologie	Dienst landelijk gebied	Mar-09
Review	Review vier visies Afsluitdijk - review ruimtelijk	College van Rijksadviseurs	Mar-09
Research report	Agenda voor de Afsluitdijk. Een maatschappelijke vergelijking van vier visies voor de toekomst van de Afsluitdijk (kengetallenkosten-batenanalyse KKBA)	Decisio in cooperation with Tauw	Mar-09
Project document	Kostenvergelijk ramingen visies en overheidsalternatieven	project team	Mar-09
Review	Beheerderadvies Rijkswaterstaat IJsselmeergebied bij de vier visies voorgekomen uit marktverkenning “Onderzoek Integrale Verbetering Afsluitdijk” - review beheer onderhoud	Rijkswaterstaat IJsselmeergebied	Mar-09
Advice	Eindadvies adviescommissie verkenning Toekomst Afsluitdijk	Adviescommissie Afsluitdijk	Mar-09
Review	Review ‘Waddenwerken’ – Morfologie	TU Delft	Mar-10
Expert session	Expertsessie natuur	Project team	Mar-10
Expert session	Expertsessie Duurzaamheid	Project team	Apr-10
Research	Verkenning zilte landbouw.	Grontmij	Apr-10

Type	Title	Author	Date
report	Mogelijkheden van zilte landbouw en aqua-cultuur binnen de vier visies van het Afsluitdijkproject		
Research report	Karakteristieken van duurzame energie in relatie tot de Afsluitdijk; Kostendata en andere parameters voor de evaluatie van duurzame energieopties in verband met integrale verbetering van de Afsluitdijk	ECN	May-10
Research report	MKBA Afsluitdijk - Uitwerking van de "ambitiecomponenten" concept	Decisio	May-10
Project document	Ingevuld Afweegkader Toekomst Afsluitdijk “Kernen en componenten langs de meetlat”	Project team	May-10
Review	Review Afsluitdijk: Stormschild	TU Delft	Oct-10
Advice	Briefadvies Afsluitdijk vanuit Waddenperspectief	Raad voor de Wadden	Oct-10
Advice	Advies MER Afsluitdijk	College van Rijksadviseurs	Oct-10
Advice	Gezamenlijk advies stakeholders	Stakeholders	Nov-10
Advice	Advies van de Adviescommissie Toekomst Afsluitdijk	Adviescommissie Toekomst Afsluitdijk	Nov-10
New ideas	Schetsboek Afsluitdijk	Waddenvereniging	Nov-10
Advice	Visie op de Afsluitdijk	Energy Valley	Nov-10
EIA	Plan-MER Toekomst Afsluitdijk (Environmental Impact Assessment, EIA)	Grontmij	Dec-10
Research report	Natuurwaardenindicator Toekomstvisie Afsluitdijk. MKBA van huidige en te verwachten natuur in de Waddenzee en IJsselmeer als gevolg van het project Afsluitdijk	Grontmij	Dec-10
Research report	Risicobeoordeling Natura2000 Toekomst Afsluitdijk	Grontmij	Dec-10
CEA	Een kosten-effectiviteitsanalyse naar de toekomstige inrichting van de Afsluitdijk (Cost Effectiveness Analysis, CEA)	Centraal Planbureau	Jun-11

Overview of the main project documents and advices in the decision-making phase of the project Future Afsluitdijk.

Type	Title	Author	Date
Advice	Afsluitdijk - Advies Commissie van Deskundigen	Commissie van Deskundigen - Afsluitdijk	May-11
Advice	Adviescommissie Toekomst Afsluitdijk Eindadvies	Adviescommissie Toekomst Afsluitdijk	Jun-11
CEA	Een kosteneffectiviteitsanalyse naar de toekomstige inrichting van de Afsluitdijk	Centraal Planbureau	Jun-11
EIA	Plan-MER Toekomst Afsluitdijk	Grontmij	Jun-11
Advice	De Afsluitdijk	College van Rijksadviseurs	Jun-11
Project document	Ontwerp Structuurvisie Toekomst Afsluitdijk	Ministerie van Infrastructuur en Milieu	Jun-11
	Ambitie Agenda Afsluitdijk, triple A	Provincie Noord-Holland, Provincie Fryslân, Gemeente Wieringen, Gemeente Súdwest-Fryslân, Gemeente Harlingen	Dec-11
Project document	Bestuursovereenkomst Toekomst Afsluitdijk	Ministerie van Infrastructuur en Milieu, Provincie Fryslân, Provincie Noord-Holland, Gemeente Súdwest-Fryslân, Gemeente Wieringen	Dec-11

Summary

Greening flood protection (GFP) reflects a novel approach in flood protection projects and management. Instead of using hard construction to guarantee protection against flooding, 'soft' and more nature-friendly solution are employed to attenuate waves, counteract erosion and foster sedimentation processes. GFP has three characteristics. First, natural dynamics are included in the flood protection design and contribute to the flood protection function. Natural dynamics include biotic processes, such as vegetation processes or shellfish dynamics, and abiotic processes, such as wind and wave dynamics. Second, GFP enhances the (local) ecosystem. This can be in the form of restoration, preservation and improvement of existing ecosystems or the creation of a new ecosystem. Three, GFP combines flood protection and nature functions. The combination may be direct, for example when multiple project objectives are explicitly formulated, or indirect. While knowledge development and policy and political support GFP have grown rapidly over the last decade, realisation of GFP in flood protection projects is far from mainstream in the Netherlands and abroad. Knowledge is an essential factor in GFP decision-making, but has remained largely unaddressed. The objective of this thesis is: *to improve the understanding of knowledge in GFP decision-making and learn how knowledge in GFP decision-making can be improved to support GFP in flood protection projects.*

Knowledge in GFP decision-making is characterised by the involvement of the policy domains nature and flood protection as these reflect the nature and flood protection functions of GFP. These policy domains are characterised by nested knowledge and knowledge processes. Moreover, introducing an innovation like GFP in flood protection projects is expected to result in dynamics in the flood protection domain. These three characteristics of knowledge in GFP decision-making informed a literature review towards the construction of the conceptual framework. The resulting conceptual framework of interacting knowledge arrangements is designed along the lines of the Ways-of-Knowing (WoK) model (Feldman et al., 2006; Lejano & Ingram, 2009; Schneider & Ingram, 2007; Van Buuren, 2009) for knowledge in decision-making and operationalised by means of the four dimensions of the concept of a policy arrangement (Arts & Leroy, 2006; Van Tatenhove et al., 2000). A knowledge arrangement is the dynamic interdependent constellation of a (redefined) policy arrangement (involving knowledge and policy processes) and a knowledge base within a policy domain. Four different modes of interaction may emerge between the boundaries of interacting knowledge arrangements: 'separation' when there is no connection between boundaries; 'cooperation' when

boundaries are connected; ‘integration’ when boundaries are blurred temporarily or; ‘unification’ when boundaries are blurred permanently.

The conceptual framework of interacting knowledge arrangements is applied to three Dutch flood protection projects that had an ambition for GFP: the Sand Engine, the Afsluitdijk and the Markermeer dikes project.

The Sand Engine is a large-scale, hook-shaped, 21.5Mm^3 sand nourishment, which was realised in front of the Dutch coastline in 2011. The Sand Engine design met all three GFP characteristics: wind and waves facilitate the natural dispersal of the nourished sand; it creates a new and temporary nature area where nature can naturally evolve, and; it is a multi-functional solution having four different goals including nature and flood protection. In the Sand Engine project a nature and flood protection knowledge arrangement merged into an integrated Sand Engine knowledge arrangement. Flexibility of the integrated knowledge arrangement was central to the effectiveness of the integration. This was found in an adaptive actor coalition, open and unspecific formulation of project objectives and the exclusion of core values of the initial nature and flood protection knowledge arrangements. Moreover the project was set-up as a pilot.

The Afsluitdijk project constitutes the reinforcement of the 32 km long Afsluitdijk dam in the north of the Netherlands. While initially an integral strategy of ‘doing more than just flood protection’ was employed, in December 2011 a hard mono-functional design was selected: the overflow-resistant dam design, which met none of the GFP characteristics. Over the course of the project three successive different interaction modes between knowledge arrangements were found. At the start of the project integration was found. But this failed due to a lack of institutionalisation: at policy level integration lacked structural embedding; integral knowledge was developed at large distance from the policy domain and; in order to enable assessment, all (integrated) knowledge was split op. Separation between a nature and flood protection knowledge arrangements emerged. The flood protection knowledge arrangement was powerful and strongly institutionalised, whereas the nature knowledge arrangement was initially almost non-existent. In response to the phase of separation and strict conditions posed by the flood protection project, the nature knowledge arrangements germinated and developed into an ambitious field. This enabled cooperation between knowledge arrangements, in which the flood protection and nature ambitions are developed in parallel.

The Markermeer dikes project constitutes the reinforcement of a 33 km dike trajectory between Amsterdam and Hoorn. In this project an innovative dike design was proposed: the shore dike. Despite the ambition of the Ministry and the possibilities of the shore dike for ecology, in 2013 the project continued with a bare or basic shore dike not comprising any of the three GFP characteristics. In the project a hybrid interaction mode between the nature and flood protection knowledge arrangements was found, combining elements of cooperation and separation. Actors communicated and aligned (some) activities, reference was made to the other domain in the discourses and reports were shared and referenced. However, rules and regulations, resources and accountability structures remained separate.

Conclusions are drawn based on a cross-case comparison of the three case studies. From this analysis it became apparent that the three case studies show consistency with the conceptual framework of interacting knowledge arrangements. Besides unification – which is not expected to emerge in projects given that projects have a temporary nature – all interaction modes were found. Particular knowledge processes and knowledge bases could be related to the interaction modes (see table below).

Interaction mode	Knowledge in GFP decision-making: knowledge processes and knowledge base
Integration	One knowledge base Integral design development Sectoral and attuned design assessment and optimisation
Cooperation	Two knowledge bases Sectoral and attuned design development, assessment and optimisation
Separation	Two knowledge bases Sectoral and discordant design development, assessment and optimisation

From the cross-case comparison I conclude that integration of knowledge arrangements enables GFP in flood protection projects. Integration allows for multidisciplinary and multi-actor knowledge processes and integral GFP designs. Integration is enabled by: 1) dependency between knowledge arrangements, whereas in contrast, the independency and dominance of one knowledge arrangement over the other inhibits integration; 2) a GFP solution with value for both domains, and; 3) interaction processes that foster change in the relative position between knowledge arrangements (as in the Afsluitdijk project). Integral design development should be a multi-actor and multidisciplinary exercise. Focusing on multidisciplinary only may inhibit the uptake of the integral designs by actors (as in the Afsluitdijk project).

Flexibility in integration enables GFP in flood protection projects. A central challenge for flexibility is the strict organisation of the flood protection domain in terms of objectives, criteria and time schedules. The inclusion of flexibility in the Sand Engine provides a valuable lesson here.

Integrated approaches in design assessment and design optimisation processes were not found in the three case studies (even when integration was found between knowledge arrangements). This indicates a difficulty in organising knowledge assessment and optimisation in an integral manner as a result of the perceived need for in-depth assessment of separate aspects. The tension between integral assessment and the need for detailed knowledge on effects was handled elegantly in the Sand Engine project. The integral nature of the designs was secured by the multi-actor and multidisciplinary assessment of all knowledge documents in the project team.

Cooperation or separation between knowledge arrangements is insufficient to result in GFP in flood protection projects, given the development of multiple knowledge bases and knowledge processes from different perspectives and in different locations. Nevertheless, cooperation can enable parallel development, whereas for separation, it is more problematic given the lack of attuning (knowledge) developments.

Samenvatting (Dutch summary)

Vergroening van kustverdediging (VGK)[55] is een nieuwe trend in waterveiligheidsbeleid en -projecten. In plaats van harde constructies voor de bescherming tegen overstromingen, worden zachte en meer natuurvriendelijke oplossingen ontwikkeld om golven te dempen, erosie tegen te gaan en sedimentatie processen te ondersteunen. VGK heeft drie specifieke eigenschappen:

- VGK laat natuurlijke dynamiek toe in het ontwerp van de waterveiligheidsoplossing. Hier gaat het zowel om biotische processen, zoals de ontwikkeling van vegetatie of schaaldieren, als om abiotische processen, bijvoorbeeld wind en golfslag.
- VGK levert een bijdrage aan het (lokale) ecosysteem. Dit kan door middel van restoratie, behoud of verbetering van een bestaand ecosysteem, maar ook door het aanleggen of creëren van een nieuw ecosysteem.
- VGK combineert functies, zoals natuur en waterveiligheid.

In het afgelopen decennium is veel kennis ontwikkeld over VGK, terwijl in het beleid en de politiek het draagvlak voor VGK groeit. Toch is het realiseren van vergroening in nationale en internationale waterveiligheidsprojecten allesbehalve vanzelfsprekend. Kennis is een essentieel onderdeel van VGK besluitvorming, maar daar is tot nu toe weinig aandacht aan besteed. Het doel van deze studie is daarom zowel het vergroten van inzicht in kennis in VGK besluitvorming als het verbeteren van kennis om VGK in waterveiligheidsprojecten mogelijk te maken.

Bij kennis in VGK besluitvorming zijn twee verschillende beleidsdomeinen betrokken: waterveiligheid en natuur. Ieder van deze domeinen kent specifieke kennis en kennisprocessen. Bovendien brengen de drie eigenschappen van VGK veranderingen in het beleidsdomein waterveiligheid teweeg, bijvoorbeeld in het omgaan met dynamiek in het ontwerp en het betrekken van andere actoren. Op basis van deze inzichten is in dit onderzoek een conceptueel raamwerk van kennisarrangementen ontwikkeld om de rol van

[55] In deze samenvatting wordt gesproken over VGK (vergroening van kustverdediging) als ook de term ‘vergroening in waterveiligheidsprojecten’ gebruikt. Met beide termen wordt hetzelfde bedoeld.

kennis in VGK besluitvorming in waterveiligheidsprojecten te kunnen analyseren. Het raamwerk bouwt voort op het ‘Ways of Knowing’ (WoK) model (Feldman et al., 2006; Lejano & Ingram, 2009; Schneider & Ingram, 2007; Van Buuren, 2009) voor kennis in besluitvorming. In het WoK model wordt kennis gezien als een inherent onderdeel van een bepaald beleidsdomein en vormt de grens tussen kennis uit verschillende beleidsdomeinen een barrière. Er wordt daarbij niet uitgegaan van een ‘gat’ tussen kennis en besluitvorming zoals in andere modellen wel gebruikelijk is. Om expliciet aandacht te kunnen besteden aan meerdere beleidsdomeinen en het WoK model verder te operationaliseren wordt het WoK model aangevuld met de dimensies van de beleidsarrangementen benadering (Arts & Leroy, 2006; Van Tatenhove et al., 2000): discoursen, actoren, hulpbronnen, en wet en regelgeving. Het conceptueel raamwerk bestaat uit twee ‘kennisarrangementen’ – ieder bestaande uit een beleidsarrangement en de bijbehorende kennis basis – die met elkaar interacteren. Met andere woorden, kennis inherent aan het beleidsdomein natuur en kennis uit het beleidsdomein waterveiligheid, ‘botsen’ of ‘interacteren’ bij VGK besluitvorming in waterveiligheidsprojecten. De interactie tussen kennisarrangementen kent vier vormen: ‘scheiding’ wanneer er geen interactie en uitwisseling bestaat tussen de grenzen van kennisarrangementen; ‘samenwerking’ wanneer er afstemming plaats vind tussen de grenzen; ‘integratie’ wanneer de grenzen vervagen; en ‘unificatie’ wanneer de grenzen permanent vervagen en verdwijnen.

Het conceptueel raamwerk draagt bij aan het begrip van kennis in VGK besluitvorming in waterveiligheidsprojecten en wordt in deze studie gebruikt als analytische lens voor het bestuderen van drie case studie: de Zandmotor, de Afsluitdijk en de Markermeerdijken. In ieder van deze waterveiligheidsprojecten is sprake van een VGK ambitie.

De Zandmotor is een grootschalige (21,5 Mm^3) zandsuppletie in de vorm van een haakvormig schiereiland voor de kust van Zuid-Holland. Het project voldoet aan de drie VGK eigenschappen: door wind en golven wordt zand op natuurlijke wijze verspreid; de ontwikkeling van nieuwe en tijdelijke natuur wordt gefaciliteerd, en; het is een multifunctionele oplossing waarmee vier verschillende doelen (waaronder natuur en waterveiligheid) worden beoogd. In dit project zijn een natuur- en een waterveiligheidskennisarrangement versmolten en geïntegreerd in een ‘Zandmotor’ kennisarrangement. Dit geïntegreerde kennisarrangement was zeer effectief, onder meer vanwege het flexibele karakter ervan: de actor coalitie was adaptief, de projectdoelen open en weinig specifiek, en de kernwaarden uit de oorspronkelijke kennisarrangementen zijn buiten het nieuwe kennisarrangement gelaten. Daarnaast is het project vormgegeven als pilot.

De versterking van de 32 kilometer lange Afsluitdijk in het noorden van Nederland is de tweede case studie. Dit project had bij aanvang de doelstelling om ‘meer te doen dan alleen veiligheid'. Ondanks dit streven, is in december 2011 gekozen voor een monofunctionele oplossing in de vorm van de overslagbestendige dijk. Dit ontwerp bevat dan ook geen VGK eigenschappen. In de loop van het project hebben drie verschillende interactievormen tussen kennisarrangementen elkaar afgewisseld, te weten: integratie, scheiding en samenwerking. Bij de start van het project was er wel sprake van een geïntegreerd kennisarrangement; waterveiligheid en natuur gingen hand in hand. Deze opzet faalde omdat integratie op beleidsniveau niet was verankerd, geïntegreerde ontwerpen te ver af stonden van besluitvorming en deze vervolgens werden opgesplitst omwille van een objectieve beoordeling. Als gevolg hiervan ontstond er 'scheiding' tussen de kennisarrangementen waarbij het waterveiligheidskennisarrangement machtig en sterk geïnstitutionaliseerd was, terwijl het natuurkennisarrangement aanvankelijk nauwelijks bestond. In deze periode was natuurdomein op zichzelf aangewezen en ging het zichzelf ook sterker organiseren in termen van onder andere actoren, kennis en ambities. Dit ontwikkelde arrangement maakte 'samenwerking' met het waterveiligheidsarrangement mogelijk en heeft geleid tot het parallel ontwikkelen van natuur- en waterveiligheidsfuncties.

Het project Markermeerdijken gaat over de versterking van een traject van 33 kilometer dijk tussen Amsterdam en Hoorn. In dit project is een innovatief dijkontwerp voorgesteld: de oeverdijk. Ondanks de ambities van het ministerie en de mogelijkheden voor ecologie bij de oeverdijk, is in 2013 toch gekozen voor de sobere variant zonder elementen van VGK. In het project was sprake van een hybride interactievorm tussen de kennisarrangementen met zowel kenmerken van 'scheiding' als ook van 'samenwerking': hoewel actoren onderling communiceerde en activiteiten werden afgestemd, bleven wet- en regelgeving, middelen en verantwoordelijkheden strikt gescheiden.

Op basis van een analyse van deze drie case studies zijn conclusies getrokken. Afgezien van de interactievorm 'unificatie' – onwaarschijnlijk gezien het tijdelijke karakter van projecten – komen alle interactievormen voor in de case studies. Voor ieder van de drie interactievormen zijn specifieke kennis en kennisprocessen geïdentificeerd (zie tabel).

Interactie vorm	Kennis in VGK besluitvorming: kennisprocessen en kennisbasis
Integratie	Een kennisbasis Integrale ontwerpaanpak Sectorale, afgestemde aanpak bij beoordeling en optimalisatie van ontwerpen
Samenwerking	Twee kennis basissen Sectorale, afgestemde aanpak bij ontwikkeling, beoordeling en optimalisatie van ontwerpen
Scheiding	Twee kennis basissen Sectorale en botsende aanpak bij ontwikkeling, beoordeling en optimalisatie van ontwerpen

Uit de analyse blijkt dat integratie tussen kennisarrangementen vergroening in waterveiligheidsprojecten mogelijk maakt: het voorziet in één kennis basis, in multidisciplinaire kennisprocessen en in een integrale ontwerp aanpak. Dit in tegenstelling tot samenwerking of scheiding, hierbij blijven verschillende kennis basissen bestaan en wordt kennis sectoraal ontwikkeld, beoordeeld en geoptimaliseerd. Integratie tussen kennisarrangementen kan gerealiseerd worden door: 1) een afhankelijkheidsrelatie tussen kennisarrangementen; 2) een VGK oplossing die meerwaarde biedt in beide domeinen; 3) interactieprocessen tussen kennisarrangementen waarbij er verandering optreedt in de individuele kennisarrangementen (zoals in het project Afsluitdijk).

Daarnaast blijkt dat integratie op een flexibele manier organiseren ook een belangrijke bijdrage levert aan het mogelijk maken van vergroening. Dit kan door middel van het open formuleren van projectdoelen of de actorcoalitie dynamisch houden. Hierdoor ontstaat ruimte om verschillende functies samen te brengen in het ontwerp. Het organiseren van flexibiliteit is niet eenvoudig gezien de strikte organisatie van het waterveiligheidsdomein in termen van doelen, criteria en planning. De Zandmotor kan hier als waardevol voorbeeld dienen.

Een integrale aanpak bij de beoordeling en optimalisatie van ontwerpen komt niet voor in de drie case studies (ook niet wanneer er sprake was van geïntegreerde kennisarrangementen). Dit geeft aan hoe moeilijk het is om beoordeling en optimalisatie van ontwerpen op een integrale wijze te organiseren. De oorzaak daarvan ligt in de behoefte om de verschillende elementen van een ontwerp tot in detail te kennen. In de Zandmotor is op een elegante manier omgegaan met de spanning tussen enerzijds de behoefte aan specialistische kennis en anderzijds een ontwerp integraal te willen beoordelen. Het integrale karakter van de Zandmotor ontwerpen is gewaarborgd door specialistische en monofunctionele kennis voor te leggen in het multidisciplinaire projectteam.

Samenwerking en scheiding tussen kennisarrangementen is onvoldoende om VGK in projecten mogelijk te maken. Kennis en de kennisprocessen vinden op meerdere plekken plaats en wordt vanuit verschillende perspectieven benaderd. Niettemin kan samenwerking wel leiden tot parallelle ontwikkeling van verschillende functies (zoals in de Afsluitdijk). Bij scheiding is dit problematischer omdat (kennis) ontwikkelingen hier minder of niet worden afgestemd.

About the author

Stephanie K.H. Janssen (1981) was born and raised in Venray, the Netherlands. After completing secondary school (Gymnasium at Raayland college), she moved to Delft to study System Engineering, Policy Analysis and Management at Delft University of Technology. Part of this training was spent in Ankara, Turkey, to study water management at the Middle East Technical University (METU). Her master thesis on the cooperation between client and contractor in dredging projects was written during an internship at dredging contractor Boskalis. In 2007 she obtained her Master's degree (MSc) with a specialization in water management.

Stephanie started her professional career at Rijkswaterstaat (Ministry of Infrastructure and Environment, The Netherlands). She was involved in water construction projects as a risk manager. This useful practical experience was taken along in a more 'knowledge' oriented position at Deltares. Working as a researcher and advisor since 2008, she developed as a specialist in the fields of Governance and Building with Nature (BwN) or Nature-based flood defences. Her passion and ambition are in the co-creation of knowledge, in bridging multiple disciplines and interests and in developing knowledge that is relevant and useful for decision-making. This is reflected in both her PhD thesis and her activities as a researcher and consultant for Deltares. In 2009 she started her PhD research at the Environmental Policy Group (ENP) at Wageningen University and combined it with working on Deltares projects. Stephanie has scientific as well as practical experience in a variety of projects on BwN knowledge use. These include: research on knowledge in BwN projects (Sand Engine, Afsluitdijk and Markermeer dikes, this thesis); organising and evaluating social learning processes among stakeholders and experts to develop solutions for water use and distribution; assessment of governance potential of BwN solutions in Singapore; the organisation of a BwN course and delta governance conference, and research on BwN in the Dutch IJsselmeer area including involvement in a BwN community of practice.

Today Stephanie fulfils positions at Deltares and at Delft University of Technology. At the latter she works as a post-doc researcher in the project 'BE SAFE'. This project intends to contribute to the implementation of BwN solutions in flood risk management. Stephanie focuses on the understanding and development of useful institutional arrangements for BwN solutions. At Deltares, she continues to work on enabling BwN solutions in practice.

List of publications by the author

Journal papers

Janssen SKH, Mol APJ, van Tatenhove JPM, Otter HS (2014) The role of knowledge in greening flood protection. Lessons from the Dutch case study future Afsluitdijk. Ocean & Coastal Management 95 (0):219-232.

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- Environmental Research in Context (2010)
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Other PhD and Advanced MSc Courses

- General methodology, Netherlands Institute of Government (2009)
- Philosophy of science, Netherlands Institute of Government (2009)
- Workshop Advanced searching for researchers, TU Delft (2009)
- Workshop Endnote, TU Delft (2009)
- Writing in English, TU Delft (2010)
- Summer School in Comparative Social Science Studies, University of Oslo (2010)
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Management and Didactic Skills Training

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