Building with Nature & Beyond

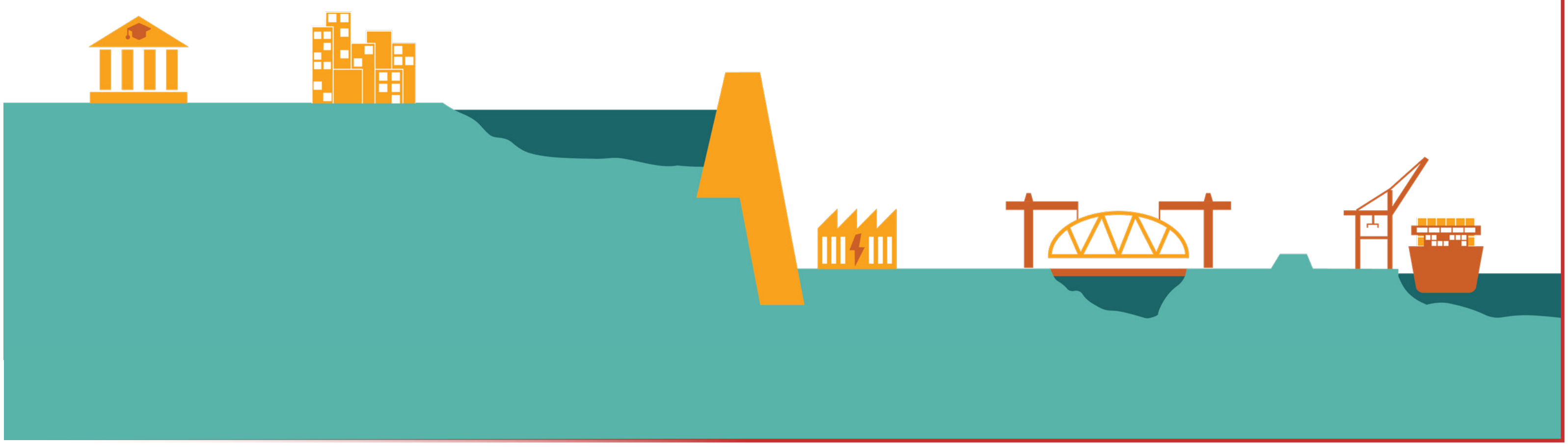
Jill Slinger

TU Delft open

Building with Nature & Beyond

Principles for Designing Nature Based Engineering Solutions

Jill Slinger (Principal Author and Editor)
with contributions of others



Editorial Team

About Jill Slinger

The primary author and editor, Prof. Jill Slinger is a Building with Nature specialist at Delft University of Technology where she holds an Associate Professorship in the Policy Analysis section of the Faculty of Technology, Policy and Management. She is also Visiting Professor at the Institute for Water Research at Rhodes University in South Africa. Her research in water and coastal management utilises both qualitative and quantitative methods to advance stakeholder-inclusive, model-based decision making and co-design. She teaches post-graduate courses in Policy Analysis in Multi-Actor Systems, Building with Nature, and Advanced System Dynamics Modelling.

She is a member of the coastal working group of the advisory body Expertise Network for Flood Safety (ENW) in the Netherlands and the National River Programming Committee. Prof. Slinger serves as co-Editor in Chief of the journal Environmental Development and is an Associate Editor for the International Journal of Water Governance.

About Martijn Vos

The visual designer and editor, engineer Martijn Vos holds a degree in Architecture from Delft University of Technology. He specialised in the strategic role of urban design and spatial planning in relation to the changing interlinkages between nature, society, and (geo)politics in lowland water and delta regions. He published with colleagues from the department of Management in the Built Environment, Faculty of Architecture and the Built Environment, Delft University of Technology about the evolution of policy discourses with regard to Circular Area Developments in the Netherlands.

Since 2016, he is involved in the development and teaching of Massive Open Online Courses (MOOCs) and online Professional Education for multiple faculties within TU Delft.

After graduation Martijn started his own graphic and architectural design studio, called Brût Design. brutdesignstudio.com

Colophon

Kothuis, B., Slinger, J. (2018). *Voices on sustainable ports in Africa. Stories from Tema Port, Ghana*. Delft University Publishers, Delft, Netherlands. ISBN 978 94-6186-945-6. 76pp

This book is available in print and as an interactive e-Book. For full functionality we recommend using the free e-Book version. To use the interactive elements in the e-Book (i.e. exercises and assignments) you need Adobe Acrobat Reader, which is freely available for download for Windows and MacOS at https://get.adobe.com/uk/reader/. The print version of the book does not contain answers to some of the quizzes. The answers are available as PDF on the open textbook website.

All the assignments can be made in the book. However, if you want to make use of multiple assignment forms (e.g. for more than one case, or for use in your education), these are available for selected assignments on the open textbook website.

Title Open Textbook: Building with Nature & Beyond: Principles for Designing Nature Based Engineering Solutions

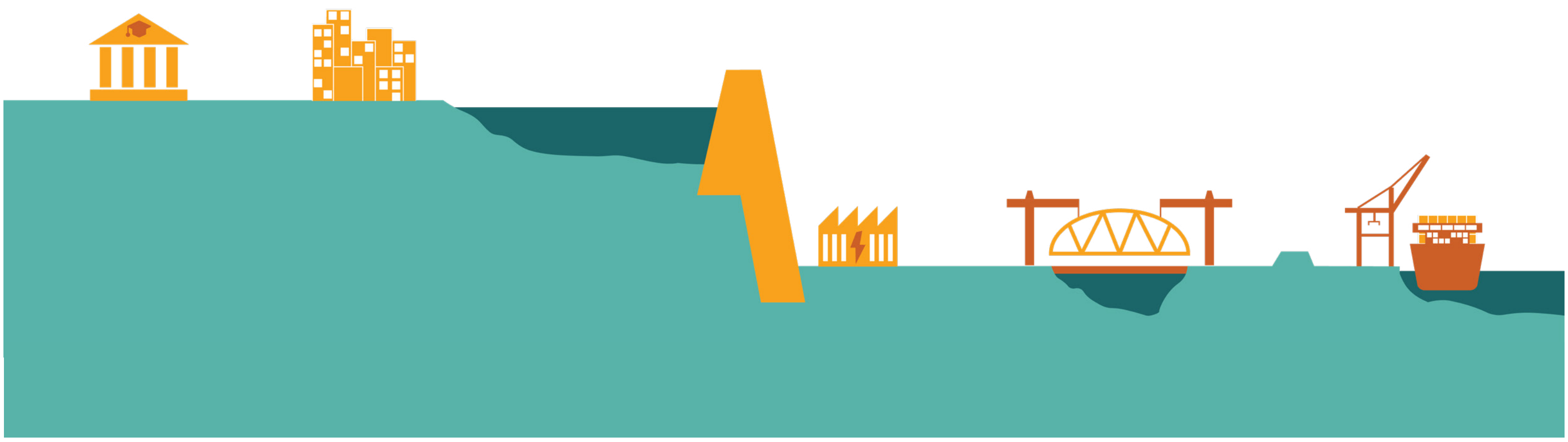
Principal Author and Editor: Jill Slinger
Visual Design and Editing: Martijn Vos
Cover and Title Page Image: Martijn Vos
Cover and Title Page Image License: CC-BY-NC-ND 4.0

Chapter Icons Chapter 1-5: Anne van Loenen
Chapter Icons Chapter 6-10: Martijn Vos

Publisher: TU Delft Open
Year of Publication: 2021

ISBN (Paperback): 978-94-6366-458-5
ISBN (E-book): 978-94-6366-457-8
DOI: https://doi.org/10.5074/T.2021.006

Table of Contents



Preface

Introduction

Welcome to Building with Nature and Beyond!

Building with Nature is a comprehensive engineering approach that seeks to enhance the use of natural ecological processes to achieve sustainable hydraulic infrastructural designs. It rests on the seminal work of Waterman (2008) who describes the approach as striving for “a flexible integration of land in water and water in land using interactions and materials present in nature”. Accordingly, this book explores the interface between hydraulic engineering, nature and society, focusing on the use of natural materials and ecological processes in achieving effective and sustainable hydraulic infrastructural designs with, and for, society.

The first part of the book familiarises the reader with the Building with Nature ecosystem-based design concept and its applications in water and coastal systems. You will explore the use of natural materials and ecological processes in achieving effective and sustainable hydraulic infrastructure designs, applying the Engineering and Ecological Design Principles distilled in this course to a number of case studies. However, if you are a practicing coastal engineer, ecologist or planner, you already know that engineering and ecological principles are not enough to realise nature-friendly solutions in practice. You need people on your side!

The missing element of Social Design Principles is taught in the second part of the book. Here, you will learn how to build a relevant coalition of stakeholders to support the design and implementation of ecosystem-based hydraulic infrastructures. After learning basic stakeholder mapping and game theory techniques, and receiving instruction in stakeholder-inclusive social design principles, you will apply the Social Design Principles to a Building with Nature ecosystem-based design case. This will equip you to identify promising collaborative arrangements for your future engineering, environmental science or planning practice.

What you will learn

The goal is that you will learn the Engineering (H), Ecological (E) and Social (S) Design Principles, the S-H-E Principles, be able to explain why they are important, and learn how to apply them in practice on a number of case studies. We will not address whether hydraulic infrastructure should be built or not, nor will we deal with assessing the impact of infrastructure on the natural and social environments. Similarly, we will not evaluate the goods and services deriving to humans from ecosystems. Instead, we will focus on the conceptual challenge of stakeholder-inclusive, integrated design of ecosystem friendly hydraulic infrastructures. In essence, you will learn:

- Basic engineering design principles, ecological principles, and social design principles relevant to the Building with Nature approach
- To assess which principles are applied in several case studies and so form your own opinion on whether the hydraulic infrastructure is meeting engineering, ecosystem and societal goals
- To apply your new knowledge in the integrated design of potential Building with Nature solutions
- To identify and analyse the power and interests of stakeholders relevant for the design and implementation of nature friendly hydraulic infrastructure.
- To apply basic game theory in combination with stakeholder analysis to determine potential coalitions in a Building with Nature project case.
- To evaluate the suitability of coalitions for designing and implementing a particular Building with Nature project case.

In summary, this book seeks to teach comprehensive, stakeholder-inclusive and nature friendly engineering design in water, coastal and delta systems. It embodies the claim of Slinger and Vreugdenhil (2020) that a metamorphosis in hydraulic engineering is underway, as engineers seek to design and build nature friendly infrastructure with, and for, society. Through the educational material in this book, you are invited to join a new generation of engineers, ecologists, planners and environmental and social scientists actively applying Building with Nature principles. You will learn that Building with Nature requires building with people. It is not necessarily about getting others to share your viewpoint or designing the optimal solution, but about creating a multidisciplinary design space in which a diversity of viewpoints and knowledge sources are welcomed. This will pave the way for creating new types of nature based solutions.

Book structure

The book is divided into two parts, as depicted in the learning path in the figure below. The first part deals with the interface between engineering and ecology in designing nature friendly hydraulic infrastructures, while the second part of the book teaches stakeholder-inclusive and context sensitive approaches to Building with Nature. A more detailed guide to the structure of the book is provided per chapter hereafter.

PART 1 - Engineering: Building with Nature

Chapter 1: Introduction to Building with Nature

The Building with Nature concept and its importance are introduced through a number of dramatic examples. Hydraulic engineering infrastructures are identified, and readers explore diverse standpoints on the ecological effects of interventions in the natural world.

Chapter 2: Engineering design principles

The engineering design process is explained and the underlying principles are distilled. Readers familiarise themselves with the material through classification exercises.

Chapter 3: Ecological design principles

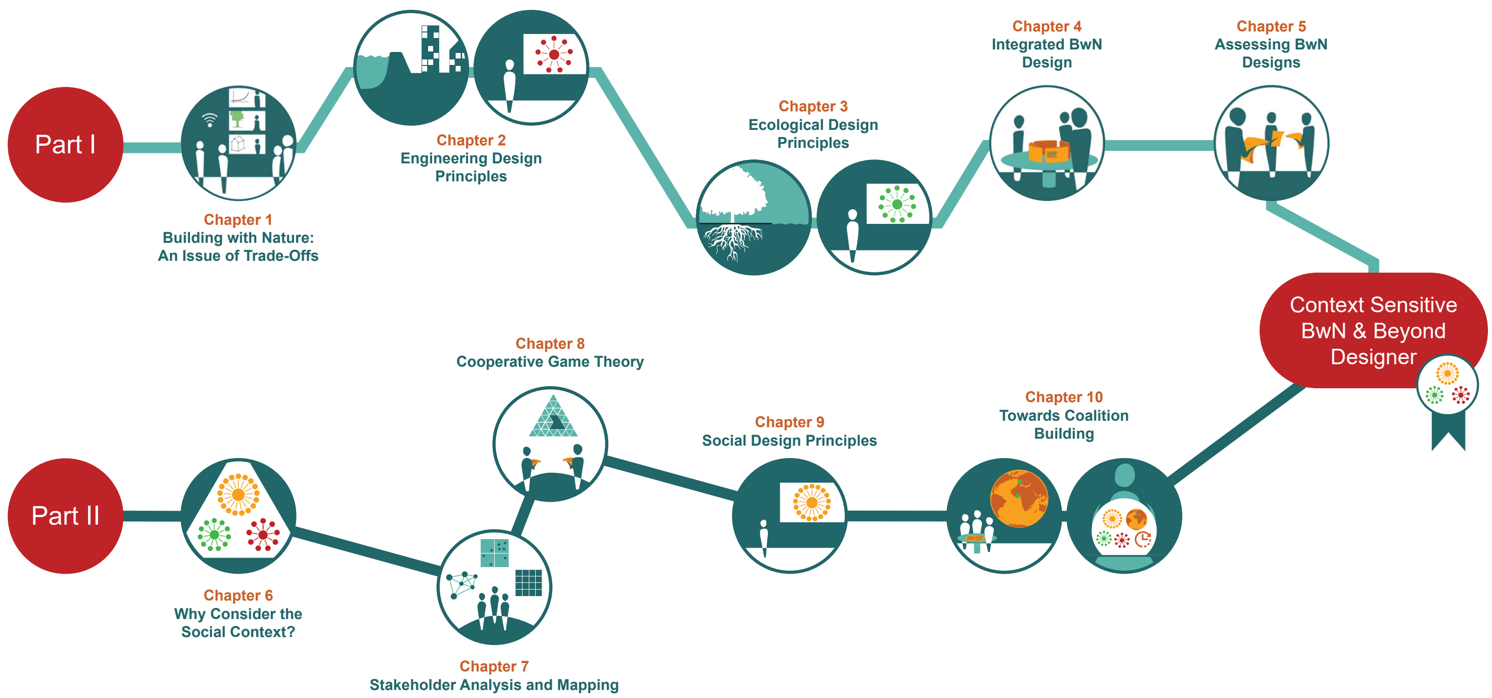
The concept of designing in accordance with ecological principles is explained. Readers identify different types of aquatic ecosystems and distil principles on the basis of ecosystem character and functioning.

Chapter 4: Integrated design

Readers apply their new knowledge in designing potential integrated Building with Nature solutions in pre-prepared case studies, or in their locality. Trade-offs in applying engineering and ecological principles are explicated, and the opportunities for nature are clarified.

Chapter 5: Integrated design review

A critical evaluation of whether hydraulic infrastructure is fit for purpose in meeting engineering, ecological and societal goals is undertaken through a self-review of the case study undertaken in Chapter 4. In particular, students assess the coherence between the infrastructure design and the ecosystem character and function using the hydraulic Engineering (H) and Ecological (E) Design Principles. Material on all pre-prepared case studies is provided.



PART 2 - Beyond Engineering: Building with Nature

Chapter 6: Why Beyond Engineering?

The importance of taking the social context into account in Building with Nature is introduced. The issue of when to include stakeholders in complex public decision making and Building with Nature design processes is tackled. Diagnostic questions for determining strategies for stakeholder engagement are applied to examples from port and delta management, highlighting the value of including different knowledge sources in ecosystem-based engineering design and adaptive delta management.

Chapter 7: Stakeholder Analysis and Mapping

Stakeholder analysis and the added value of working with stakeholders are explained in a video lectures. Readers then apply their learning to material on the case of the Maasvlakte 2 extension to the Port of Rotterdam, identifying relevant stakeholders, mapping their power and interests, and analysing their interdependence. Next, the issue of scale is addressed in a video lecture and a reading.

Chapter 8: Cooperative Game Theory

The fundamentals of Game Theory and Cooperative Game Theory Models are explained in a video lecture. Next, the insights deriving from the application of cooperative Game Theory to the Great Brak estuary in South Africa are explained in a video lecture. The Self Sustaining River Systems Innovation Team is also used to illustrate coalition forming. Participants familiarise themselves with the concepts through a series of quiz questions and a reading task on coalition forming in Building with Nature.

Chapter 9: Social Design Principles

Renowned experts in transdisciplinary science and social impact assessment use illustrative cases from South Africa and Indonesia in their video lectures to explain the principles guiding their practice. A case study from Sierra Leone is explored. Then drawing on experiences in Ghana, and normative principles for stakeholder-inclusive, ecosystem-friendly design deriving from the Sustainable Ports in Africa project, the Social (S) Design Principles are distilled in a video lecture.

Chapter 10: Towards Coalition Building

Course participants apply their new knowledge in evaluating the potential for coalition building in a Building with Nature approach to the case study of the Tema in Ghana. They familiarise themselves with this case through extensive visual material and documentation and then apply the S-Principles in their analysis to design a stakeholder-inclusive, ecosystem-based approach.

Learning materials

The envisaged learning path comprises a number of video lectures, quizzes and assignments per week over a period of 10 weeks (2 x 5 weeks). The schedule of assignments is listed in Table A. This material is intended either to accompany on-campus teaching or to be used in blended courses or for self study. You are free to work through the material at your own pace using the book. All of the deep case materials and skills-based assignments are designed to challenge you, the reader, to move beyond engineering in your Building with Nature practice. To help you in this, links to additional materials are provided throughout the book. In addition, blank forms on which to complete assignments are provided as downloads on TU Delft Open, as is a set of example answers for use in the self-assessment of your Building with Nature Design Assignment from Chapter 4.

We invite you to work through the material in the book and join us in becoming one of a new generation of engineers, ecologists, planners, environmental and social scientists who view the Building with Nature integrated design approach as fundamental to the future of hydraulic engineering, nature and society.

Jill Slinger

Principle Author and Editor
Building with Nature and Beyond

Table A: Schedule of Assignments and Grading

Chapter	Ass. nr.	Assignment title	Maximum grade
1	-	Exercise Questions	ungraded
	1.1	Is this an Example of Building with Nature?	5%
	1.2	Questionnaire on Views on Nature and Sustainability	ungraded
2	-	Exercise Questions	ungraded
	2.1	Form, Function & Character of Hydraulic Infrastructures	5%
	2.2	Engineering Design Principles	5%
3	-	Exercise Questions	ungraded
	3.1	Form, Functioning of Wetland Ecosystems & Ecological Character of Hydraulic Infrastructures	5%
	3.2	Ecological Design Principles	5%
4	-	Exercise Questions	ungraded
	4.1	Building with Nature Design Assignment	25%
5	5.1	Self-Assessment of the Building with Nature Design Assignment	
6	6.1	Situation diagnosis	ungraded
	6.2	Reading + Quiz	10%
7	7.1	Stakeholder Identification and Mapping	ungraded
	7.2	Reading + Quiz	10%
8	8.1	Quiz: Cooperative Game Theory	ungraded
	8.2	Reading + Quiz	10%
9	9.1	Quiz: Social Impacts of Hydropower - Sierra Leone	ungraded
10	10.1	Evaluating Coalition Building Potential - Tema, Ghana Self-Assessment of Evaluating Coalition Building Potential	20%

Bibliography

Waterman, R.E. (2008) *Integrated Coastal Policy via Building with Nature®*, Opmeer Drukkerij b.v., The Hague.
ISBN/EAN 978-90-805222-3-7

Slinger, J.H., Vreugdenhil, H.S.I. (2020). Coastal engineers embrace nature. Characterising the metamorphosis in hydraulic engineering in terms of four continua. *Water 2020, 12,* 2504;
https://doi.org/10.3390/w12092504

Acknowledgements

This Building with Nature education endeavour rests firmly upon the seminal work of world-renowned engineering Dr. Ronald Waterman, who has kindly granted the Delft University of Technology the right to use the registered trademark Building with Nature® and the Building with Nature© in Massive Open Online Courses (MOOC's) and other teaching materials. In addition, Dr. Waterman is thanked most sincerely for many inspiring and thought-provoking meetings held with the principal author over and beyond his specific contributions to the book.

Many leading engineers, environmental and social scientists have collaborated internationally in generating the material for the MOOC's Engineering: Building with Nature 1x and Beyond Engineering: Building with Nature 2x that form the basis of this book. Contributions to the first part of the book by the following people are particularly acknowledged:

Prof. (em.) Marcel Stive, Prof. (em.) Huib de Vriend, Dr. Heleen Vreugdenhil, Dr. Bregje van Weesenbeeck, Prof. Mark van Koningsveld, Dr. Elisabeth Ruijgrok, Dr. Mark Voorendt, engineers Ad van der Toorn and Henk Jan Verhagen, Prof. Tinka Murk, Dr. Ronald Osinga, Dr. Brenda Walles, Drs. Michelle Marijt, Dr. Martin Baptist, Dr. Wouter van der Star, Dr. Lotte Bontje, Ir. Graciela del Carmen Nava Guerrero, engineers Ana Colina Alonso, Ilse Caminada, Stefan Jammers and engineer Anne van Loenen for the design of the chapter icons of chapters 1 to 5, that formed a visual basis for the design of the succesive chapter icons and the design principles icons.

Contributions to the second part of the book by the following people are specifically acknowledged:

Prof. Carolyn (Tally) Palmer, Dr. Athina Copteros, Prof. Susan Taljaard, Dr. Heleen Vreugdenhil, Prof. Tiedo Vellinga, Prof. Kwasi Appeaning Addo, Dr. Edem Mahu, Dr. Baukje Kothuis, Dr. Sharlene Gomes, Drs. Jacobiene Ritsema, Drs. Abel Knipping, Dr. Floortje d'Hont, and engineers Aashna Mittal and Cyntha Nijmeijer.

This educational endeavor has been guided throughout by the Extension School of the Delft University of Technology. Particular thanks are owed to Danika Marquis whose patient and insightful guidance has been invaluable. Indeed, thanks are extended to all involved from backroom scripting and programming, through educational advice and support, to the financial and marketing management. Similarly, a debt of gratitude is owed to the staff of the New Media Centre who guided the video

production process to a successful conclusion in such a friendly and efficient manner.

The contributors represent multiple organisations contributing material to this book, notably the Ecoshape Foundation, Deltares, Witteveen+Bos, Van Oord, Boskalis, Wetlands International, the University of Ghana, CSIR in South Africa, the Institute of Water Research at Rhodes University, Wageningen University and Research, and of course, Delft University of Technology. In addition to their contributions of expertise and materials, the following project-based financial contributions are acknowledged:

The start-up financial contributions of the Delft University of Technology to the production of educational materials for the massive open online courses Engineering: Building with Nature and Beyond Engineering: Building with Nature are gratefully acknowledged. Moreover, Deltares, Witteveen+Bos and the Regional Development Fund of the European Union contributed financially to this collaborative endeavour via the Ecoshape Foundation in 2015 and 2016. More recently in 2019, financial contributions from the Dutch Sustainable Water Fund and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), allowed for the inclusion of the Indonesian case study material in collaboration with Building with Nature Indonesia. The inclusion of some of the African material was enabled by the UKRI "Water for African SDGs" Capacity Development Project of the Water Centre of Excellence of the African Research Universities Alliance.

Finally, we have drawn upon materials of the project 'Integrated and Sustainable Port Development in Ghana within an African Context' (W 07.69.206), funded under the Urbanising Deltas of the World 2 Programme of the Dutch Science Foundation (NWO), to develop these educational components for the Design for Inclusive and Adaptive Delta Management (DIADeM) project (W 07.6919.306), funded under the Urbanising Deltas of the World 3 Programme. The latter funding, in particular, has enabled the publication of this book.

EcoShape
building with nature

NWO

S.P. AFRICA
SUSTAINABLE PORTS IN AFRICA

IWR

ARUA Water CoE

UNIVERSITY OF GHANA
INTEGRI PROCEDAMUS

RHODES UNIVERSITY
Where leaders learn

CSIR
our future through science

Witteveen + Bos

WAGENINGEN
UNIVERSITY & RESEARCH

Wetlands
INTERNATIONAL

Deltares

Europese Unie
Europees Fonds voor Regionale Ontwikkeling

TU Delft

Part I - Engineering: Building with Nature

1-1. Mangrove tree, Iriomote Island. © Kentaro Ohno

Chapter 1
Building with Nature: An Issue of Trade-Offs

1.1 Introduction

Can ecological structures like mangroves save a town from flooding as well as any dike? In 2012, in Indonesia, a village was protected from coastal flooding by their mangroves, reinforcing a change in thinking about hydraulic engineering structures.

Building with Nature is a new approach to combining hydraulic engineering and ecology. You build *with* nature rather than just building *in* nature, working with ecologists and stakeholders to realize nature friendly hydraulic infrastructures. *Building with Nature is about using natural materials and working with natural interactions and processes in hydraulic design. It not only solves problems for nature that are created by infrastructural projects, it also seeks to create opportunities for nature, or restore ecosystems, while enhancing the design, operation and maintenance of the infrastructure.*

Welcome to the adventure of **Building with Nature**!

This education endeavour rests firmly upon the seminal work of Dr. Ronald Waterman, who has granted TU Delft the right to use the registered trademark Building with Nature® and the Building with Nature© in this and other teaching material.

We will explore the concept ‘Building with Nature’, and how this can change the way hydraulic engineers design. The first video clip by Prof. Jill Slinger deals with this worldwide trend. Next, we have three video clips in which the concept is explained (i) by Dr. Ronald Waterman, (ii) by Dr. Mark van Koningsveld, a hydraulic engineer, and (iii) by Dr. Bregje van Wesenbeeck, an ecologist. After hearing these different perspectives on Building with Nature, Assignment 1 will help you build your initial interpretation of the concept and the World Views Questionnaire will invite you to reflect on it. Feedback is available for Assignment 1 as well as a description of the different World Views. Enjoy the chapter!

1.2 Building with Nature - a Worldwide Trend

1-16

Video: Building with Nature - a Worldwide Trend

This section contains a video presented and written by **Prof. Jill Slinger** and written by **Jill Slinger** and **Bregje van Wesenbeeck**. She will introduce the concept of Building with Nature as a worldwide trend.

You can cite this video as:

Slinger, J.H. (Jill), van Wesenbeeck, B.K. (Bregje) (2016). *Engineering: Building with Nature 101x video #03 - Building with Nature - a worldwide trend.* 4TU.Dataset. https://doi.org/10.4121/uuid:bfd188fd-c978-4774-8c4f-72586c0a9faf

Video Transcript

Presented by Prof. Jill Slinger

Can you recall recent flooding disasters? They're engrained in my memory.

The Asian Tsunami on December 26, 2004 that resulted in the deaths of over 300 000 people and left hundreds of thousands of people homeless.

Think of Hurricane Katrina, striking the Gulf Coast of America and flooding New Orleans in August 2005 with over 1800 fatalities. Or, Hurricane Ike that made landfall in the Galveston-Houston Bay area in September 2008. The storm surge destroyed the homes of many people.

Or, what about, the destructive force of Hurricane Sandy impacting on New York in October 2012?

Can you also remember the distressing images of the Japanese tsunami in March 2011. Perhaps the flooding and destruction from Typhoon Haiyan striking the Philippines in 2013.

All of these disastrous floods have happened fairly recently. Earlier floods, such as the 1953 flood that impacted England and the Netherlands, displacing over 100 000 people, made the Netherlands realise they had to act. They responded with a comprehensive plan to improve their flood defences, constructing levees, dikes, and storm surge barriers over the next 50 years.

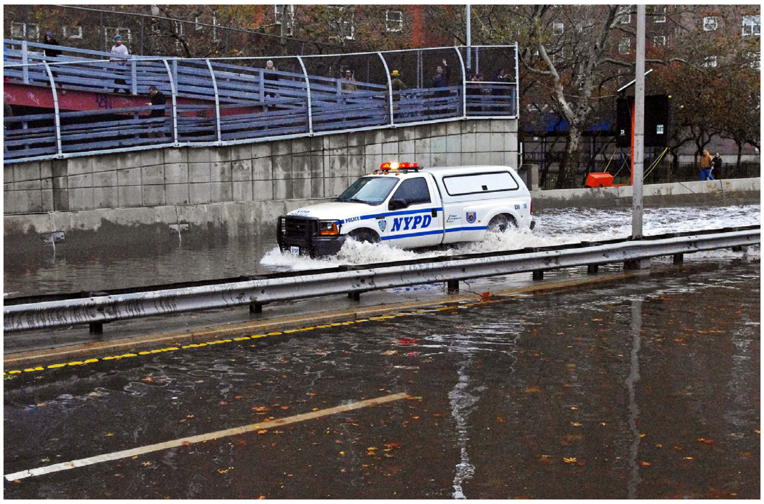
I expected a similar response to the recent flooding disasters. What do you think? I expected the different countries to design and construct hydraulic structures to improve their flood defences. But, let's examine what actually happened. How did these countries respond?

Well, we see a number of newspaper headlines showing that natural or ecosystem-based alternatives are considered **in addition to hydraulic structures**.

In the Philippines a town was saved by their mangroves. This made such an impression that mangrove areas are being restored as part of the flood defences in the Philippines, and in Vietnam and Indonesia.

1-2. *Asian Tsunami 2004. © U.S. Navy / Philip A. McDaniel*

1-3. *Hurricane Katrina. 2005. © U.S Navy / Gary Nichols*



1-4. *Hurricane Sandy, 2012. © David Shankbone*

We see a similar trend in America, with **"natural infrastructure"** forming the focus of the many recovery efforts after Hurricane Sandy, and many people getting involved in restoring dunes. In Louisiana, the state in which New Orleans is located, they also opted for a combined strategy – building levees and restoring marsh areas, to bring their flood defences up to acceptable levels.

What about the Dutch? They are moving from building hard hydraulic structures to including nature-based alternatives. Look at the Sand Engine in South-Holland. It uses natural dynamics to distribute a huge sand nourishment along the coast, preventing erosion and improving flood safety.

Clearly, "Building with Nature" is a worldwide trend in hydraulic engineering. But what is it exactly? And how can you design Building with Nature solutions?

Well, in the 4th chapter of the course you'll be making your own Building with Nature design by applying the engineering and ecological principles you've learnt.

I'm looking forward to a great course!

1-5. Maeslantkering, Dutch storm surge barrier. Beeldbank.rws.nl, Rijkswaterstaat

1-6. Mangrove restoration in Vietnam. © Trowel Development Foundation

1-7. Sand Engine, The Netherlands. © De Zandmotor

1.3 Perspectives on Building with Nature

Video: BwN Specialist/Scientist - Ronald Waterman

So what is Building with Nature?

On the next pages, we have 3 different experts explaining their perspectives on the concept.

1. First, Dr. Ronald Waterman, an engineer and founder of the Building with Nature concept, describes the core concepts and its application along the South-Holland coast. While we encourage you to watch the whole video, you can find the key definitions within the first 4 minutes.
2. Next we hear from Dr. Mark van Koningsveld, a coastal engineer from the EcoShape Consortium.
3. Finally, a scientist from Deltares, Dr. Bregje van Wesenbeeck, explains the ecologist's perspective on Building with Nature.

Enjoy the videos!

Below each video are exercise questions to help you check your understanding of key concepts.

You can cite this video as:

Waterman, R. (Ronald) (2015). *Building with Nature. Using materials & Forces / interactions present in Nature. Integrating land into water and water into land. Striving for dynamic equilibrium coastlines.*

Video Transcript

By Dr. Ronald Waterman

Eighty percent of all major world cities are situated in a coastal or delta zone. These areas offer little space for living, working, recreation or infrastructure. At the same time there is a growing need to maintain and, if possible, expand environmental nature and landscape values.

All in all this means that space is in ever greater demand. Another fundamental aspect is safety. The globe is in the grip of climatological changes that lead to flooding. We need measures that guarantee the safety of communities living in Delta and coastal zones. The greatest challenge of this century is to develop and implement solutions that not only optimise the available space, but also boost the economy, guarantee safety, and improve the living environment.

The solutions to these challenges can be found close to home. Over 35 years ago Ronald Waterman successfully formulated a plan to expand the Dutch coast. Integral coast and Delta policy via Building with Nature. In these densely populated areas there's only a little space available for living, working, tourism, recreation, and infrastructure. And at the same time there's the need to preserve or expand valuable environment, nature, and landscape. For this scarcity of space there are three solutions. One is using more than before the third dimension. Using height and depth, and multifunctional use of the existing space. The second solution is looking at possibilities in the existing hinterland, and a third solution is in the direction of the sea. By introducing the principle of Building with Nature, no longer dominant dams and dikes as bulwalks against the sea, but instead introducing dunes and beaches in harmony with the sea, we have the possibility of a whole series of functions in the new land. And, at the same time we increase the safety for the existing hinterland; everything in harmony with nature.

Building with Nature makes far greater use than before of inorganic and organic materials present in nature, and the forces and interactions acting on them. Inorganic materials include sand from fine to coarse, silt, clay and gravel. The organic materials are the flora and fauna abundant on land and in the sea. More precisely landside vegetation varying from Marram grass to mangrove, and marine organisms, varying from micro and macro algae and seagrass to molluscs and worms. **The forces and interactions are wave and tidal movements,**

gravity, wind, ocean currents other than tides, river discharges, rain, sun, dune-vegetation interaction, and complex interaction between marine organisms and sand or silt. Another vital aspect is coastal type and a genesis of the coast and seabed; the bio-geomorphology and geo-hydrology of coast and seabed. This strategy says no to building more dams and dikes as dominant bulwarks against the sea, and yes to dunes and beaches in harmony with the sea. The strategy is more energy efficient and good for nature, and the environment. The strategy also aims to achieve a new flexible, dynamic balanced coastline consisting of dunes and beaches with a minimum of hard sea defence elements. A coastline where growth and erosion exist in equilibrium, minimally maintained by periodical sand suppletion. Thereby integrating land in sea, but also integrating water in the new land, in the form of lagoons, lakes, harbour basins, and freshwater lenses under the dunes. Such an approach based on Building with Nature integrates land in sea and water in the new land.

Building with Nature is inextricably linked with integral coast and delta policy. Integral coast and delta policy answers the question 'How can we solve a series of existing and future problems in relation to each other, and in relation to the existing hinterland on the one hand, and the adjacent sea on the other, while creating added value?

The solution is found by taking many functions, and hence many disciplines into consideration: from coastal defences to environment, nature, and landscape, from water resource management to energy, from building locations for living and working, to infrastructure and recreation, from participative stakeholders to social health and welfare, and everything in between. Waterman's plan aimed at a series of sustainable, multifunctional land reclamations along the Dutch coast - all based on the principle of Building with Nature! Thousands of hectares of new land as well as new sea reserves have already been realised this way.

All the reclamations optimise the available space, but also boost the economy, guarantee safety, and improve the living environment. For instance, in the mid-nineteen eighties the Slufter dam was created in a two-step process, complete with dune and beach boundaries. This was followed by Maasvlakte 2 with a similar dune and beach boundary, extending 7.5 kilometres along the west flank. The area covers a total of 2800 hectares of new land, including harbor basins. This new unique part of the Netherlands creates port and port-related activities for the municipality of Rotterdam, complete with multimodal connections with the hinterland. The 7.5 kilometre dune and beach boundary on the west side of Maasvlakte 2 provides safety and recreational use.

Adjacent to it, on the southern side, a new terrestrial nature reserve for flora and fauna and again safety, has been created on land belonging to the municipality of Westvoorne. This landside nature reserve, borders on the evolving Slufter - a seascape acting as a meeting and breeding ground for marine organisms and the birds that feed on them. This Slufter is part of an assigned total of 25 000 hectares of sea reserve.

The largest plan aims to restore the approximate historic coastline of the early 17th century between Scheveningen and Hoek van Holland. The coast that existed then has been lost due to rising sea levels, storm floods, the changing course of rivers and land subsidence. The aim is a step-by-step restoration of the coast with a new hollow coastline complete with ports, infrastructure, living space and facilities for recreation, in combination with large nature reserves.

As a first step, the van Dixhoorn triangle at Hoek van Holland originated in the nineteen seventies when Maasvlakte 1 was created. The Hoek van Holland site on the North Sea at the outflow of two major European rivers the Rhine and the Maas with the Rotterdam agglomeration in the hinterland is unique. It justifies further expansion with a tidal lagoon complete with a multifunctional marina, homes and facilities, multimodal infrastructure and a substantial nature reserve on the northern side. A hotel conference center with a high quality revolving restaurant offers a panoramic view of this unique area. An expansion of the dunes and beach on the Delftland coast between Hoek van Holland and Scheveningen creates extra safety as well as space for recreation, infrastructure, and nature development. Between 2008 and 2012 along a seventeen kilometer stretch between Hoek van Holland and Scheveningen the dunes on the seaside were expanded with the new beach front. This involved the creation of Spanjaards Dune at s'Gravenzande as nature compensation for Maasvlakte 2.

In the next 20 years this area will become a larger dune area of rich and moist dune valleys. A new cycle path overlooking dune, beach and sea has been built between Kijkduin and Hoek van Holland at the transition between old and new dunes.

In Scheveningen the realisation of the De Sola Morales plan with an attractive Boulevard connected to a beach expansion and elevation has resulted in a generous coastal zone with a hollow coastline. In the protected axle of the extended northern harbor mole there is space for a line of dunes, which protect the beach sports stadium behind it and its corresponding facilities.
Further plans for Scheveningen involve the creation of a fourth Scheveningen port to the south of the extended southern harbour mole, including a marina, if desired a cruise terminal, and a nature zone connecting with western park and a new south-oriented beach, can also be created. The new water defences at Katwijk integrate a garage and dike construction protecting the vulnerable center with dunes. The development of a marina with broader dunes on both sides and space for a portage or sluice, connects the old Rhine with the sea. The resulting development offers an attractive place to live and will boost the local economy.

Adjacent to the marina, the existing dune natural reserve area between Katwijk and Noordwijk will be significantly extended towards the North Sea. Between September 2007 and April 2008, the coast of Noordwijk was already reinforced by a dike-in-dune construction. The dunes were made 42 metres wider with a new beach in front of them. The new dunes are the same height as the current ones. The projected dune beach extension between Katwijk and Noordwijk will result in a new hollow coast line between Katwijk and IJmuiden.

The IJmuiden seaport marina, south of the extended southern harbour mole, is a coastal location with a marina, nautical centre, apartments, shops, restaurants, a hotel, parking facilities and public transportation amenities, as well as Kennemer Lake and the adjoining nature reserve. The inner side of the southern harbor mole has a third port outside the sluices of IJmuiden with port-related activities and a so-called perched beach with two rows of beach huts. The existing solid Hondsbossche Pettermer Zeewering is reinforced through Building with Nature. This is realised by a dune-beach expansion in front of this sea barrier, with an overall span of 11 kilometres.

This expansion has a width of 200 meters at a central stretch of seven kilometres, with a tapering off on two sides of two kilometres each. This solution combines safety, nature development, and recreation.

Further successful implementation of Building with Nature relies on good coordination between governments, knowledge institutes, education centres and on the corporate sector with the emphasis on environment, nature, landscape, and on the social sphere.

We are now poised to take advantage of unprecedented opportunities for future sustainable spatial developments through Building with Nature. The principles set out in Building with Nature and integral multifunctional coast and delta policy can also be applied to areas other than coastal zones.

Perfect analogies exists between living coasts, space for the coast, living rivers, space for the river, and living deltas, space for the delta. The principles maintained can be applied not only to the Netherlands, but also to other regions in the world with vulnerable densely populated coastal and delta zones.

The flexible integration of land in water and water in the new and old land offers countless possibilities - all based on Building with Nature!

Exercises

On the next page you will find some questions to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

The French coast of Brittany (image on the side) provides an example of the forces and interactions described by Dr. Ronald Waterman. From this image, select all the forces and interactions that apply.

- [ ] Tidal action (ebb and flood)
- [ ] Wave action and swell action
- [ ] Sea currents and other tidal currents
- [ ] River outflow
- [ ] Gravity
- [ ] Wind
- [ ] Rain
- [ ] Solar radiation
- [ ] Interactions in the water column and the substrate (e.g. marine organisms, silt, and salt)

Show Answer

1-8. The coast of Britanny, France. © 24219

Question 2

The coast of the Whitsundays (image on right), in Australia, provides an example of the forces and interactions described by Ronald Waterman. Select all the applying forces and interactions.

- [ ] Tidal action (ebb and flood)
- [ ] Wave action and swell action
- [ ] Sea currents and other tidal currents
- [ ] River outflow
- [ ] Gravity
- [ ] Wind
- [ ] Rain
- [ ] Solar radiation
- [ ] Interactions in the land-water marginal zone (e.g. dunes-vegetation or coastal zone-salt marsh)
- [ ] Interactions in the water column and the substrate (e.g. marine organisms, silt, and salt)

Show Answer

1-9. Whitehaven Beach, Australia. © Wicker Paradise

1-24

Video: BwN Engineer - Mark van Koningsveld

In this section you can see a video presented by an engineer in the field of Building with Nature: **Dr. Mark van Koningsveld.** This video is written by **Mark Koningsveld** and **Jill Slinger.**

You can cite this video as:

(Adapted from) van Koningsveld, M. (Mark), Slinger, J.H. (Jill) (2015). *Building with Nature video #03 - The Building with Nature Philosophy @ TU Delft 2015.* 4TU.Dataset. http://dx.doi.org/10.4121/uuid:dbb2fe8f-bb3b-4fc4-b6ac-8c088b1d1047

Video Transcript

Presented by Dr. Mark van Koningsveld

Hydraulic engineering infrastructures are of concern to many people and are likely to interfere with the environment. Both in a negative way, but also in a positive way. Moreover, they are supposed to keep on functioning for many years; that is they have a long life time.

In times of rapid societal and environmental change this implies that sustainability and adaptability are important attributes. These are central to Building with Nature, an innovative approach to hydraulic infrastructure development and operation.

Starting from the natural system and making use of nature's ecosystem services (use the force), Building with Nature attempts to meet society's needs for infrastructural functionality, and to create room for nature development at the same time (let it grow).

By including natural components in infrastructure designs, you gain flexibility and adaptability to changing environmental conditions. Extra functionalities and ecosystem services can also be achieved. This can lead to lower costs on a life-cycle basis than 'conventional' engineering solutions.

Designing with the Building with Nature philosophy requires a different way of thinking, acting and interacting.

The new thinking doesn't start from a certain design concept focusing on the primary function, but you start from the natural system instead, using its dynamics, functions and services. You also take account of the diverse interests of stakeholders. Within this context, you seek optimal solutions for the desired infrastructural functionality.

Also the project development process requires you to act differently, because it is more collaborative and extends beyond the delivery of the engineering object. The natural materials and processes of the project take time to develop, and you have to make sure they function as expected. Post-delivery monitoring and projections into the future are integral parts of the project. This also creates opportunities to learn a lot more from such projects than from traditional ones.

Now the different ways of interacting: Building with Nature project development is a matter of co-creation between experts from different disciplines, problem owners and stakeholders. This requires a different attitude of all parties involved and different ways of interacting. You can no longer work alone, you have to work with others in a multidisciplinary setting.

To cope with accelerated sea level rise, climate change and reducing biodiversity we need you to be able to design and realise hydraulic engineering infrastructures that are sustainable and adaptable. Your involvement can change the future.

Thank you for your attention!

Exercises

In this section you will find some questions to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**.

Question 1

In the video, what does engineer Mark van Koningsveld mean with the phrase "let it grow"? Note: Make sure you select all of the correct options. There may be more than one!

- [ ] Stimulating economic growth
- [ ] Creating room for nature
- [ ] Aiming for sustainability
- [ ] Using natural forces to increase efficiency
- [ ] Not cutting vegetation down but letting it grow

Show Answer

Question 2

From an engineering perspective, who should be involved in the design of a Building with Nature infrastructure? Note: Make sure you select all of the correct options. There may be more than one!

- [ ] Multidisciplinary experts
- [ ] Problem owner/client
- [ ] Stakeholders
- [ ] Regional economic experts
- [ ] Environmental NGO's

Show Answer

Video: BwN Ecologist - Bregje van Wesenbeeck

Above is a video presented by an ecologist in the field of Building with Nature: **Dr. Bregje van Wesenbeeck**, followed by some questions to test your understanding.This video is written by **Bregje van Wesenbeeck** and **Jill Slinger**.

You can cite this video as:

(Adapted from) van Wesenbeeck, B. K. (Bregje), Slinger, J.H. (Jill) (2015). *Building with Nature video # 06 - Ecological processes in Building with Nature @ TU Delft: Part 1 2015.* 4TU.Dataset. http://dx.doi.org/10.4121/uuid:d4b327cf-e3c9-49b6-b210-feea772186ca

Video Transcript

Presented by Dr. Bregje van Wesenbeeck

Building with Nature solutions can include a naturally present ecosystem, and then aim to conserve and manage that ecosystem for its function.

However, if an ecosystem is degraded or lost, the BwN solution can aim for recovery or restoration of the ecosystem. Basically, ecosystem restoration focuses on restoring abiotic conditions in such a way that ecosystems can re-establish naturally, or will be aided in their recovery.

What do I mean by conservation and restoration in the context of Building with Nature? For instance in Indonesia, mangrove forests are often removed for fish and shrimp farming. This makes coastal communities vulnerable to flooding. By conserving a stretch of mangrove forest and by putting a small earthen levee behind it people are safer and the mangrove is conserved as a component of a mangrove-levee coastal defence strategy.

Restoration comes into play when the mangrove has already been destroyed. Then, you need to rebuild it to implement the mangrove-levee combined defence strategy.

Building with Nature solutions work with these aspects to aim at conservation or restoration of ecosystems for functional purposes. So, how do we enable an ecosystem to perform desired functions? We have to take care that the external conditions that we can influence are optimal for development of healthy, biodiverse and resilient ecosystems. Only then can the ecosystem perform the desired functions to an optimal extent.

Exercises

In this section you will find some questions to help you check your understanding of key concepts explained in the video.

Question 1

Dr. Bregje van Wesenbeeck, an ecologist, describes a flood defence system along the Indonesian coast. Which elements constitute this system? Note: Make sure you select all of the correct options. There may be more than one!

- [ ] Dunes
- [ ] Levees
- [ ] Breakwater
- [ ] Mangrove forest
- [ ] Groynes

Show Answer

Question 2

What are the primary goals of Building with Nature, from an ecological perspective? Note: Make sure you select all of the correct options. There may be more than one!

- [ ] Coastal defence
- [ ] Economic resilience
- [ ] Conservation
- [ ] Supporting livelihoods
- [ ] Restoration

Show Answer

1.4 Assignment 1.1

Introduction

In this exercise, we want you to indicate whether you consider the following images to represent examples of Building with Nature or not.

Please respond to the opinion poll next to each image, then move to the next one until you've finished all. At the end of the chapter there is a feedback section with our views on the poll including explanations.

Breakwaters

Question 1

Is the **Breakwater** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-10. Breakwater. ⓪

Locks

Question 2

Is the **Lock** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-11. Lock. ⓪

Dikes

Question 3A

Is the **Dike** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-12. Dike A.

Question 3B

Is the **Dike** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-13. Dike B.

Groynes

Question 4A

Is the **Groyne** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-14. Groyne A. Iain Lees

Question 4B

Is the **Groyne** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-15. Groyne B. ⓪ Lekies

Question 4C

Are the **Groynes** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-16. Groynes in the Dutch Rhine. 🅭 Mohamed F.M. Yossef

Jetties/Piers

Question 5

Is the **Jetty/Pier** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-17. Jetty/Pier. ⓪

Sluices/Weirs

Question 6A

Is the **Sluice** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-18. Sluice. ⓪

Question 6B

Is the **Weir** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-19. Weir. ⓪ MakyFoto

Dams

Question 7A

Is the **Dam** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-20. Dam. ⓪ Alex Rotlex

Question 7B

Is the **Spillway** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I’m not sure

1-21. Spillway. ⓪ Leoderuntz

Ports/Harbours

Question 8A

Is the **Quay wall** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I’m not sure

1-22. Quay wall. (cc) Graciela del Carmen Nava Guerrero

Question 8B

Is the **Port area** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I’m not sure

1-23. Port area. ⓪

Coastal Flood Defences

Question 9A

Is the **Sand nourishment of beach and dunes** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-24. Sand suppletion. tacowitte

Question 9B

Are the **Dunes and Groynes** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-25. Dunes and Groynes.

Storm Surge Barriers

Question 10A

Is the **Storm surge barrier** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-26. Oosterscheldekering surge barrier. Vladimír Šiman

Question 10B

Is the **Storm surge barrier** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-27. Maeslantkering, Nieuwe Waterweg Closed. © World66

Waterways

Question 11A

Is the **Canal** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-28. Yongdinghe River Waterway from Muxidiqiao Bridge. © Soramimi

Question 11B

Is the **River** in the image on the right an example of Building with Nature?

- ◯ Yes
- ◯ No
- ◯ I'm not sure

1-29. River. © Anelka

1.5 World Views

Assignment 1.2: What is Your View on Nature?

By Elisabeth Ruijgrok and Jill Slinger

Now that you have heard 3 different perspectives on Building with Nature, we invite you to explore your own view on nature and then discuss this with your peers.

Please complete this short questionnaire based on the work of Dr. Elisabeth Ruijgrok of Witteveen+Bos. The questionnaire presents you with a series of choices that will help you learn about your own view on nature.

For each question, choose the answer that is closest to your opinion. Remember, there are no right or wrong answers.

After obtaining your result, you can consult the following tab to learn how your view of nature compares with the five possible world views, and then move on to the discussion. You can complete the questionnaire by clicking the link below or by scanning the QR Code. If you don't have an internet connection, for completeness we have listed the questions of the questionnaire in this sections as well.

https://tudelft.fra1.qualtrics.com/jfe/form/SV_6xvNLLw6GGWzOQZ?amp%3Buser_id=%25%25USER_ID%25%25&amp%3Bcourse_id=BwN101x&amp%3Bcourse_type=MOOC&amp%3BQ=1T2016&Q_JFE=qdg

Questionnaire: What is Your View on Nature?

By Dr. Elisabeth Ruijgrok

Question 1

How do you feel that trade-offs between economic interests and nature interests should be made?

A. There can be no trade-off. Human life on earth depends on nature.
B. We should protect nature from economic activities, as they are the cause of ecosystem degradation.
C. We should increase nature restoration as protection of nature is not sufficient.
D. We should try to find a balance between nature and economic activities e.g. by allowing for economic activities in one place and compensating for the environmental losses that they cause in another place.
E. We should prioritise economic activities because we need to survive today.

Question 2

May we intervene in natural processes such as succession or extinction?

A. No, if humans intervene, the outcome is no longer natural. It is cultural.
B. Yes, nature management is a good way to preserve ecosystems and ensure full representation of successionary stages.
C. Yes, the best way is to create favourable abiotic conditions so that nature can take its own course.
D. Of course humans may influence nature, as long as there is mutual benefit. We form part of nature. The earth is not only for humans.
E. Yes, naturalness is an illusion. Humans are creative and able to engineer their living environment to fulfil human needs. We just have to make sure that we do not 'bite our own tail'. Technology is the key to managing potential negative consequences.

Question 3

How should we value ecosystems?

A. We should not value ecosystems in any way because this makes them comparable to other things encouraging substitution.
B. On an ecological basis: ecosystems that are rich in species have a higher value than ecosystems that are not and should therefore receive extra protection.
C. On an ecological basis: ecosystems that exhibit many processes have a higher value than those that do not: functioning processes are the best guarantee for species diversity.
D. On a socio-economic basis: the value of ecosystems is more than the market value of the commodities that they produce. Also other services that do not generate cash flows in the market, such as the provision of clean air, need to be taken seriously.
E. On a financial basis: the value of nature is simply equal to the income that people can derive from it.

Questionnaire: Interpretation

By Dr. Elisabeth Ruijgrok and Prof. Jill Slinger

Your view on nature: Results and interpretation

Your view on nature determines what you regard as sustainable, and how you feel that nature should be valued. Which of the 5 views of nature do you hold?

The 5 views differ in regard to their acceptance of human intervention in natural systems, from the Hands-off view which rejects human intervention to the Functional view which indulges in all possible forms of intervention. The Classical ecological view, the Developmental view and the Co-evolutionary view fall in between. The Hands-off, Classical and Developmental views can be regarded as eco-centric, whereas the Co-evolutionary and Functional views are anthropocentric.

To help you determine how your view of nature relates to five different world views, all questions provided you with five options. Each option, belonged to one particular world view. In the end, the questionnaire determined your view based on the type of answer that you selected in the majority of cases. Therefore, if you filled in mostly Type 1 answers **(A)**, you have a predominantly Hand's off view. Similarly, if you filled in mostly Type 2 **(B)**, then you evince a predominantly Classical view. Mostly Type 3 **(C)** is a predominantly Developmental view, mostly Type 4 **(D)** is a predominantly Co-evolutionary view and mostly Type 5 **(E)** is a predominantly Functional view. If you selected three very different answers, then your view on nature is undetermined at this stage.

Have a look at the descriptions of the views to see the full range of views that course participants may hold. How does your view compare with that of others?

As you progress in the course, and you learn more about the principles underlying ecological and engineering design, you will be able to determine more clearly what you regard as sustainable, and how you feel that nature should be valued. We encourage you to return to re-examine the views later in the course and see whether your viewpoint has shifted.

Note that we do not strive for a particular viewpoint in this course. Although the Building with Nature philosophy is closest to the Co-evolutionary view, we seek to work respectfully and professionally with people holding a diversity of viewpoints. This acceptance of multiple views lies at the heart of the working successfully in multidisciplinary projects.

Type 1: Hands-off View

People with a Hands-off view on nature value naturalness - the extent to which nature is free from human interventions. In this view, human intervention is believed to always reduce the naturalness of an ecosystem. So, the best way to conserve nature is not to interfere, but rather to rely on the natural restoration capacity of ecosystems. Any form of maintenance or intervention, even those activities aimed at stimulating natural processes, are in conflict with naturalness. Underlying this thinking is the belief that humans are not part of nature, but that they have a moral responsibility to behave as partners on the basis of intrinsic equality.

Examples of the Hands-off approach are hard to find in practice. Generally speaking, nature conservation organisations consider biodiversity and rare species more important than naturalness and they often resort to interventions aimed at protecting species rather than allowing nature to take its course.

Type 2: Classical View

People with a Classical ecological view strive to conserve and restore existing natural areas in accordance with an historical reference situation. Whether human intervention are incorporated or not, is not an issue. What matters is to protect (and isolate) existing nature (maintaining biodiversity, protecting rare species and unique landscapes) from further harm. Active human intervention is considered necessary since nature cannot defend itself against the threats from society. In this view, humans should act as stewards of the environment, and naturalness is a subordinate issue.

This view represents a reactive and defensive stance against economic activities that harm nature. Examples of the Classical ecological approach are found in the work of non-governmental nature conservation organisations, who may purchase and manage natural and cultural sites to protect them from destruction.

Type 3: Developmental View

In the Development view, both the protection of existing natural areas and the development of new natural sites are the main objectives. Sustainability cannot be realised simply by keeping one's hands off nature or by protective interventions, but it also requires the development of new natural sites. Core issues are the desire to enhance naturalness and wilderness, to give space to natural processes, to enhance the systems' diversity rather than only to conserve rare species. Whether it is by reducing maintenance, removing previous interventions e.g. barrages across a river, or by creating favourable physical conditions for biota, all the interventions are aimed at enhancing naturalness. The development of ecological networks, which help to enhance the natural resilience of ecosystems, is encouraged. Basically, interventions are driven by the desire to provide more space for nature rather than by the wish to realise utility for society. Humans are expected to act as partners for nature.

In this view, increasing the quantity and quality of nature requires ecological networks and opportunities for natural processes in addition to protection and isolation. An example of the Development view is the Dutch national ecological infrastructure - a connected network of nature areas with target types of nature specified per geographical region in terms of both naturalness and species diversity.

Type 4: Co-evolutionary View

For people with a Co-evolutionary view, the primary objective is to maximise the social welfare derived from nature, while maintaining ecological qualities. This welfare can be derived both through direct use (resource extraction) or indirect use (regulatory mechanisms), as well as through non-use (social preferences attached to nature's existence). In nature areas, user functions which do not seriously damage the natural system are allowed, such as recreation and sustainable forms of harvesting. Although naturalness is considered desirable, it is not considered to exclude human activities, as humans are viewed as part of nature. A balanced interaction between nature and society is advocated.

Humans should act as the partners of nature, or at the least act as stewards. Both society and nature are allowed to change and to inflict change upon each other, as long as neither suffers serious damage, nor threats to their existence.

In the Co-evolutionary view, the separation of ecology and economy is neither favourable to nature nor to society, since the two are interdependent. Opposition to this interdependence is seen as unrealistic. Examples of the Co-evolutionary view are nature reserves in which recreation is allowed. Another recent example of the Co-evolutionary view is the Dutch 'Room for the River' programme in which rivers receive more space so as to accommodate high flood flows. Sacrificing land at suitable locations in this way is compensated by advantages such as reduced flood risks and increased natural beauty which can be enjoyed by visitors. In this plan, a balanced interaction between society and nature is advocated to generate mutual advantages.

Type 5: Functional view

People with a Functional view on nature, consider that nature's value lies in the benefit that humans derive from nature. In this view, people may act to control and build (or destroy) nature. The Functional view rests on a strong belief in technological progress. Since naturalness is considered illusionary, humans may control and even construct nature to meet societal needs with the help of ecologically-sound civil engineering. Although humans can destroy nature through technology, people can also create favourable conditions for nature by means of technology. Nature can be man-made and abiotic conditions do not pose restrictions since these can be adjusted too.

In this view, as it has not yet been demonstrated unequivocally that critical thresholds have been encountered, and society has survived so far, it is unclear whether such thresholds actually exist for humans. Examples of a purely Functional view include companies which pollute the environment (e.g. river nearby) with the argument that technology will be developed to clean up at a later date.

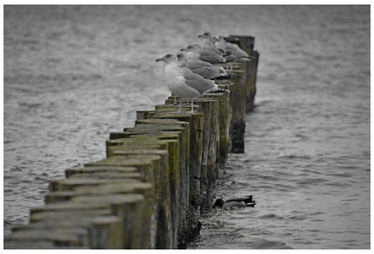
1.6 Feedback

Feedback on Assignment 1.1

During the course, you will learn that Building with Nature is an issue of trade-offs within the design process. This means that when an infrastructure exhibits **both** Building with Nature and conventional engineering properties, ecosystem-based trade-offs were made in the design process. In contrast, when an infrastructure **only** exhibits sound engineering properties, the trade-offs involved in the design process were orientated to societal needs and reasonable costs rather than the ecosystem.

In the feedback table on the next page we share our thoughts as instructors on the Building with Nature character of the images in Assignment 1. For each image, we supply arguments for its having a Building with Nature character, and/or arguments against.

Infrastructure	Yes BwN	No BwN
Breakwater 	• Rocky/concrete material forms a hard substrate that provides opportunities for colonisation by marine species. • Rocks/concrete blocks of the breakwater form sheltered areas with less wave action. This can prevent erosion of the coastline and can create pockets in which sediments can accrete rather than erode.	• The material used for the breakwater is not local nor is it natural to the ecosystem. • Rocky/concrete material could act as a hard substrate for alien vegetation. • Hard structure. • The rocks/concrete blocks forming the breakwater interrupt naturally occurring exchanges (e.g. water and sediments) in the ecosystem.
Lock 		• Controls variability in water level. • Hard structure. • Walls are made of materials that are not local nor are they natural to the ecosystem. • Design for a single-actor and single value (i.e. safe navigable connection between water bodies). • The volume of water and sediments exchanged between the two water bodies is reduced and its frequency is altered.
Dike A 		• Hard structure. • Revetment is made of material that is not local nor is it natural to the ecosystem. • Wave-breaking structures are located along the dike. • Built primarily for flood defence, although evidently also used as cycling track or road.
Dike B 	• Grass has been used on the upper part of the dike, providing a grazing environment for sheep. • Below the waterline, hard substrate provides opportunities for colonisation by marine species.	• Hard structure. • Concrete revetment is made of material that is not local nor is it natural to the ecosystem. • Wave-breaking structures are located along the dike. • Built primarily for flood defence.

Infrastructure	Yes BwN	No BwN
Groyne A 	• Constructed with local materials such as wood. • Allows the passage of sediments deeper in the sea through the open poles in the final segment of the structure. • The wooden poles act as a substrate that provides opportunities for colonisation by marine species (e.g. mussels).	• Inhibits wind- and wave-driven transport of sediments on the beach and in the intertidal zone. • Woody material could act as a substrate for alien species.
Groyne B 	• Although it is not clear in the image, there are spaces between the poles. Thus, although the structure can inhibit the exchange of water and sediments, it does not completely impede such exchange. • Constructed with local materials such as wood. • Provides resting sites for birds.	• If there had not been spaces between the poles, the structure would have impeded the exchange of water and sediments.

Infrastructure	Yes BwN	No BwN
Groynes C 	• Groynes prevent bank erosion. They form sheltered areas where sediments can accrete rather than erode. • Rocky material acts as a hard substrate that provides opportunities for colonisation by riverine species.	• Groynes are made of rocky material that is not local nor is it natural to the ecosystem. • The groynes may serve as a substrate for colonisation by alien vegetation.
Jetty/Pier 	• Enables the exchange (e.g. water and sediments) between the two sides of the structure. • The poles act as hard substrate that provides opportunities for colonisation by marine species in the intertidal zone.	• Materials are not local nor are they natural to the ecosystem. • May influence the longshore sediment transport and currents in the area. • The poles could act as a substrate for colonisation for alien vegetation.

Infrastructure	Yes BwN	No BwN
Sluice 	• Allows overtopping (water to flow over the sluice). • The right side of the image suggests that the passage of sediments is enabled to some extent. • The fact that the sluices can vary or even control the amount of water that passes suggests that they might be used to manage for environmental flow.	• Interrupts the river continuum by impeding the passage of water, sediments and species, particularly upstream migration.
Weir 	• Does not necessarily interrupt the river continuum.	• Does not represent a functional infrastructure. Supply of water is not assured.
Dam 	• Increases the limnological habitat in the area.	• Interrupts the river continuum by impeding the passage of water, sediments and species, particularly upstream and downstream migration. • Materials are not local nor are they natural to the ecosystem. • Controls variability in flow to assure water supply. • Hard structure. • Forms a deep reservoir with hypoxic bottom water and anoxic sediments. • The variation in the volume of the reservoir forms a “dead zone” around the dam margins where natural vegetation cannot grow. • Decreases the riverine habitat in the area.

Infrastructure	Yes BwN	No BwN
Spillway 	• Permits connection between the downstream sandy riverbed and the upstream reservoir (e.g. the structure of the spillway could enable an eel to migrate upstream). • If the structure had had riffles or ponds, it could have enabled upstream migration of other species. • The hard walls and bed of the spillway prevent erosion.	• Represents an artificial discontinuity belt between the downstream river and the upstream reaches. • It does not allow pull passage of water and sediments, particularly when the water level in the upstream reservoir is low.
Quay Wall 	• The tyre provides resting habitats • for seals. • The tyre act as hard substrate that provides opportunities for colonisation by marine species in the intertidal zone. • The walls of the quay are made from local stone natural to the ecosystem.	• The tyre is not naturally occurring in the ecosystem. • The marine species colonising the tyre could be alien.
Port Area 	• Does not impede opportunities for marine and estuarine species. • Does not necessarily block connectivity between marine and riverine species.	• Does not necessarily increase opportunities for marine and estuarine species. • Could provide habitats and hubs for alien species. • Does not provide resting spaces for species.
Sand Nourishment 	• By undertaking shore face nourishment by ships from the sea, direct disturbance of the shoreline is prevented, erosion is diminished and opportunities for colonisation by local species are provided.	• Sublittoral ecosystems could be impacted by artificial changes of sediments. • The grain size of the discharged sediments could be different from the size of those naturally occurring.

Infrastructure	Yes BwN	No BwN
Dunes and Groyne 	• Groynes have been used to prevent coastal erosion. • Dunes function as a natural coastal defence. • The image shows evidence of two rows of dunes: one row of pioneering species and one row of more established species. • Although human activity is present (e.g. transport on top of the dunes), it does not appear to impede natural dune processes.	• The rocks forming the groyne interrupt naturally occurring exchange (e.g. water and sediments) in the ecosystem.
Storm Surge Barrrier A 	• It does not impede the exchange (e.g. water and sediments) between the estuary and the sea.	• The volume of exchange (e.g. water and sediments) between the estuary and the sea is lower than the typical situation. • Hard and fixed structure. • Built with materials that are not local nor natural to the ecosystem. • It affects the entire bay.
Storm Surge Barrier B 	• It does not significantly alter the exchange (e.g. water and sediments) between the estuary and the sea. • It does not affect the entire waterway. It has reinforcement in the bed but only in the edges of the waterway.	• Hard structure. • Built with materials that are not local nor natural to the ecosystem.

Infrastructure	Yes BwN	No BwN
Waterway A 	• Trees surrounding the waterway are willows, which are natural to the ecosystem. • Might use the natural course of the river.	• Hard structure. • The hard interface between water and land blocks the interactions between terrestrial and riverine ecosystems. • A uniform cross-section eliminates natural fluvial geomorphology. • Walls are made of materials that are not local nor natural to the ecosystem. • Single-value and single-actor design (e.g. safe access to harbours)
Waterway B 	• Natural course of the river is not significantly altered. • No hard materials are used in the margins of the river.	• Heavy transport might alter naturally occurring processes in the river.

1.7 Bibliography

Figures

1-1. Mangrove tree, Iriomote Island: Mangrove, Iriomote Island by Kentaro Ohno is licensed under CC BY 2.0.

1-2. Asian Tsunami 2004: Indian Ocean (Jan. 2, 2005) – A village near the coast of Sumatra lies in ruins after the Tsunami that struck South East Asia by U.S Navy / Philip A. McDaniel is in the Public Domain.

1-3. Hurricane Katrina. 2005: New Orleans (Sept. 2, 2005) - Four days after Hurricane Katrina made landfall on the Gulf Coast, many parts of New Orleans remain flooded by U.S Navy / Gary Nichols is in the is in the Public Domain.

1-4. Hurricane Sandy, 2012: Hurricane Sandy NYPD FDR Flood 2012 2 by David Shankbone is licensed under CC BY 3.0.

1-5. Maeslantkering, Dutch storm surge barrier: Maeslantkering in de Nieuwe Waterweg. Luchtfoto, kering in gesloten stand. by Rijkswaterstaat. Retrieved from https://beeldbank.rws.nl/MediaObject/Details/439459

1-6. Mangrove restoration in Vietnam: This image is Copyright protected. © Trowel Development Foundation. All Rights Reserved.

1-7. Sand Engine, The Netherlands: This image is Copyright protected. © Zandmotor. All Rights Reserved.

1-8. The coast of Britanny, France: This image by 24219 is in the Public Domain, CC0

1-9. Whitehaven Beach, Australia: This image by Wicker Paradise is licensed under CC BY 2.0

1-10. Breakwater: This image is in the Public Domain, CC0

1-11. Lock: This image is in the Public Domain, CC0

1-12. Dike A: This image is in the Public Domain, CC0

1-13. Dike B: This image is in the Public Domain, CC0

1-14. Groyne A: Groyne, Aberdeen Beach by Iain Lees is licensed under CC BY-SA 2.0

1-15. Groyne B: This image by Lekies is in the Public Domain, CC0

1-16. Groynes in the Dutch Rhine: "Groynes in the Dutch Rhine" by Mohamed F.M. Yossef is licensed under CC BY-SA 3.0.

1-17. Jetty/Pier: This image is in the Public Domain, CC0

1-18. Sluice: This image is in the Public Domain, CC0

1-19. Weir: This image by MakyFoto is in the Public Domain, CC0

1-20. Dam: This image by Alex Rotlex is in the Public Domain, CC0

1-21. Spillway: This image by Leoderuntz is in the Public Domain, CC0

1-22. Quay wall: "Cape Town - Seal" by Graciela del Carmen Nava Guerrero is licensed under CC-BY-NC-SA 4.0

1-23. Port area: This image is in the Public Domain, CC0

1-24. Sand suppletion: Sand Suppletion by tacowitte is licensed under CC BY 2.0.

1-25. Dunes and Groynes: This image is in the Public Domain, CC0

1-26. Oosterscheldekering surge barrier: "overall view of Oosterscheldekering surge barrier" by Vladimír Šiman is licensed under CC BY 3.0

1-27. Maeslantkering, Nieuwe Waterweg Closed: Maeslantkering closed by World66 is licensed under CC BY-SA 1.0.

1-28. Yongdinghe River Waterway from Muxidiqiao Bridge: Yongdinghe River Waterway from Muxidiqiao Bridge (north) by Soramimi is licensed under CC BY-SA 4.0.

1-29. River: This image by Anelka is in the Public Domain, CC0

2-1: Eastern Scheldt Storm Surge Barrier. Beeldbank.rws.nl, Rijkswaterstaat / Rens Jacobs

Chapter 2
Engineering Design Principles

2.1 Introduction

What is the essence of engineering design? What are the principles upon which it is based?

Answering these two questions enables the connection to ecological design, or nature-friendly design. If engineers can explain why they think and act in a particular way when designing, and if other professionals understand what motivates engineers, a multi-disciplinary negotiation space emerges.

Welcome to this second chapter on the adventure of learning Building with Nature. We will be exploring the conventional hydraulic engineering design process. First, there is a video by Prof. Jill Slinger, then Dr. Ad van der Toorn and Dr. Mark Voorendt explain the Engineering Design Process for storm surge barriers and dikes, respectively. Additional material on breakwater design presented by Dr. Henk Jan Verhagen and on multi-functional design and the Dutch Water Act are provided. Next, Prof. Jill Slinger distills the Engineering Design Principles.

After hearing about the process and principles of Engineering Design, Assignment 2.1 will test your knowledge on the Form, Function and Character of hydraulic infrastructures. Once you have completed the assignment, you are free to consult the feedback and discuss your thoughts with your peers.

Finally, in Assignment 2.2 you apply the Engineering Design Principles and conclude the chapter by assessing your own work.

Enjoy the material in this chapter!

2.2 Engineering Design Process

2-50

Video: Engineering Design Process

This section contains a video presented and written by **Prof. Jill Slinger**. She will present the conventional Engineering Design Process.

You can cite this video as:

Slinger, J.H. (Jill) (2016). *Engineering: Building with Nature 101x video #04 – Engineering design process.* 4TU.Dataset. http://dx.doi.org/10.4121/uuid:a37479d8-4324-410c-a8a0-e3827e5f52f6

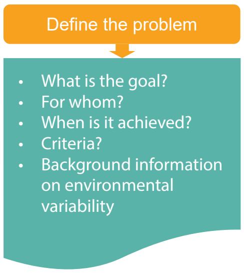
Video Transcript

Presented by Prof. Jill Slinger

Engineers move through a series of steps to design a product or artifact to solve a problem. In our case, this is a hydraulic structure that it is feasible to construct, operate and maintain, and that meets the functional requirements.

Major steps in the engineering design process are:

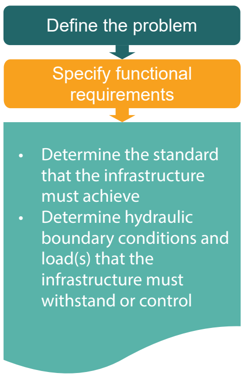
- Define the problem
- Specify the functional requirements
- Sketch and describe preliminary designs
- Select the most promising design(s)
- Test/verify, through prototyping or modelling
- Refine the design, or Re-design
- Select the final design



2-2. *Define the Problem. ⓒ Jill Slinger*

1. Define the problem

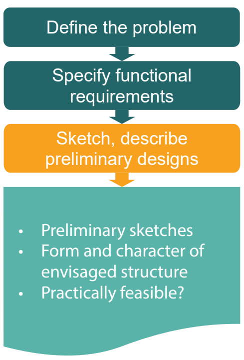
What is the goal, for whom and when is it achieved? So this includes defining criteria to be used in the evaluation of the design. It also involves collating background knowledge on the environment and its dynamic variability.



2-3. *Specify the functional requirements. ⓒ Jill Slinger*

2. Specify the functional requirements

This involves determining the hydraulic boundary conditions or the forcing which the envisaged structure must withstand or control, and the standard or level to which this should be achieved.



2-4. *Sketch, describe preliminary designs. ⓒ Jill Slinger*

3. The next step involves sketching a design - a first idea of a design.

So its preliminary. In the sketching process the hydraulic boundary conditions are connected to the form and character of the structure envisaged to perform the required functions. This is an important step, which is not mentioned explicitly in most descriptions of the engineering design process. The preliminary designs are then specified in more detail to establish whether they are practically feasible and can be constructed, operated and maintained at reasonable cost. Sometimes this specification step brings problems to light and re-design occurs or designs are eliminated from consideration.

4. Then the most promising preliminary designs are selected on the basis of their potential success in meeting the functional requirements and the evaluation criteria.

5. The next step involves detailed testing and verification of the most promising preliminary design(s).

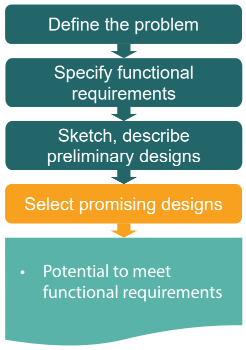
This can involve building a physical prototype, but nowadays generally involves detailed calculations, and mathematical modelling and simulation. The final design which emerges is often a modified form of the preliminary design, taking the insights generated in the detailed testing phase into account. So, the precise orientation of a breakwater to the coast may change following this phase, for example.

6. The final design is selected on the basis of its success in meeting the functional requirements and the evaluation criteria.

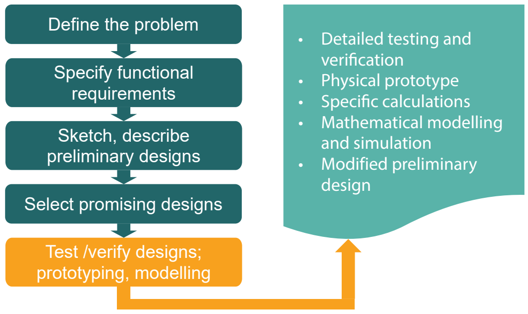
It is then usually released to tender by construction companies, who then offer to build the structure specifying their materials, construction methods and costs. The design process is usually considered to end here with the final design being realised.

These steps are not always followed one by one, in order. Sometimes, an engineer makes a design, but when it's tested there's a problem. So, he or she iterates through the design process, going back to an earlier step to reconsider or even re-design. So, iteration between the levels occurs as more detailed knowledge reveals incompatibilities or inadequacies. This means that although the full engineering design process is often depicted as a sequence of steps, it is actually iterative. Some see it as a pyramid with detailed specification as the foundation. I think of it as a funnelling process in which progressive focus towards the selection of the final design is achieved.

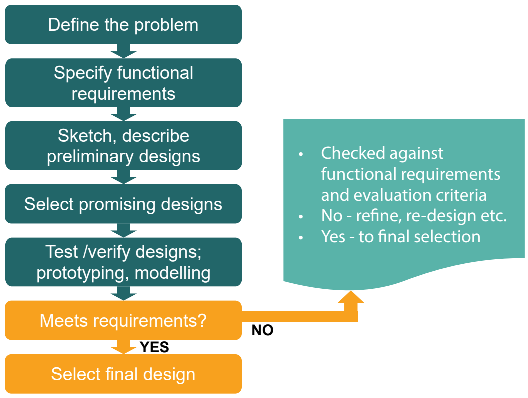
What do you think? Enjoy exploring engineering design further!



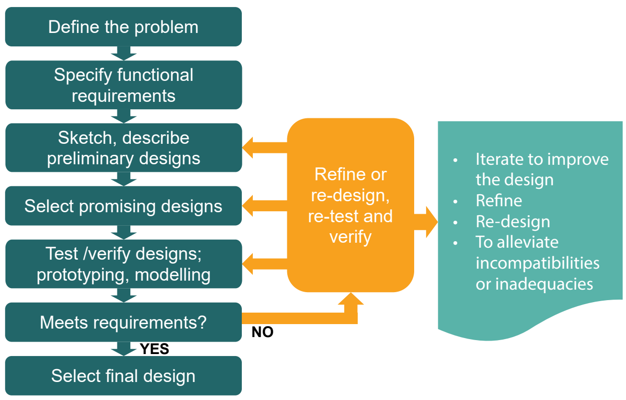
2-5. *Select promising designs. © Jill Slinger*



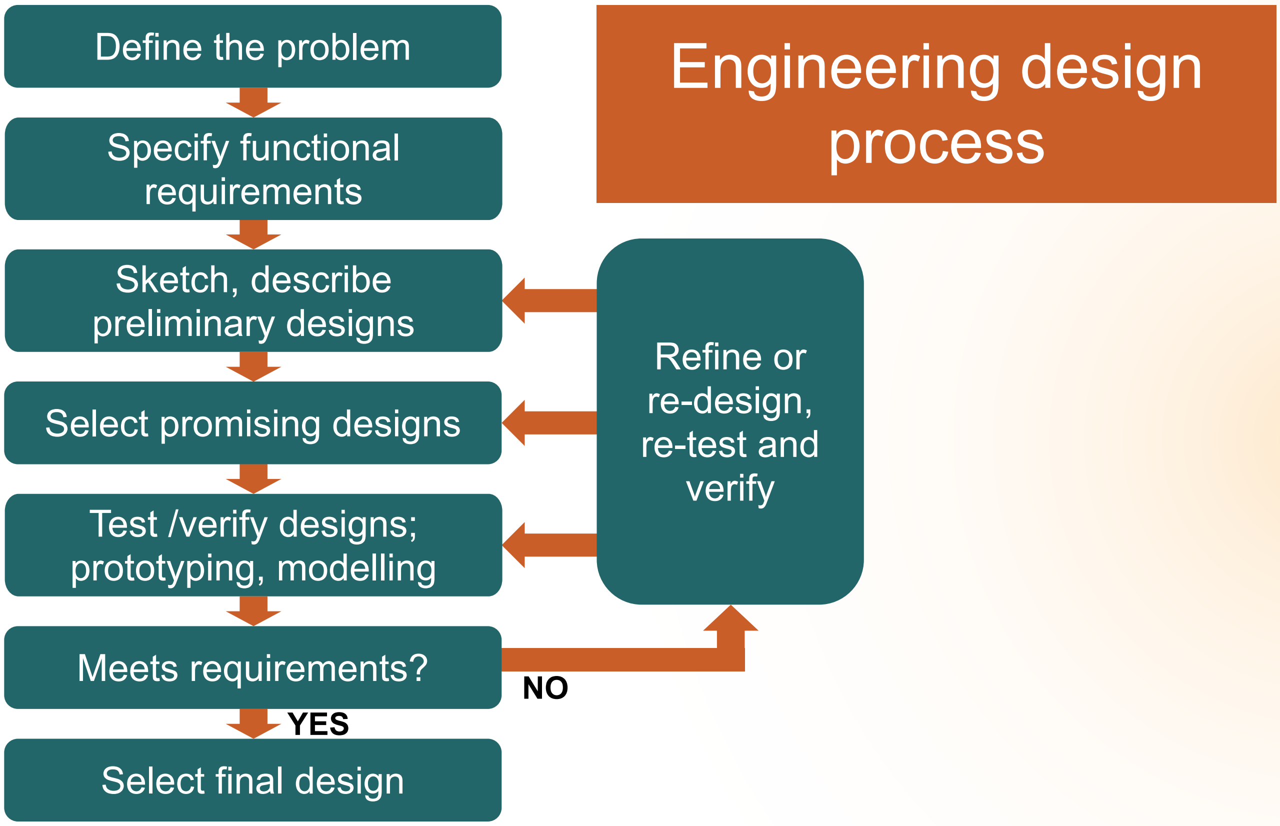
2-6. *Test /verify designs; prototyping, modelling. © Jill Slinger*



2-7. *Selection of final design. © Jill Slinger*



2-8. *Designing is an iterative process. © Jill Slinger*



2-9. *The engineering design process.* 🅭 *Jill Slinger*

Exercises

In this section you will find some questions to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

From the options below, select the activities involved in the first Step 1, Problem Definition:

- [ ] Definition of the project goal
- [ ] Definition of the functional requirements
- [ ] Definition of the problem owner
- [ ] Definition of a preliminary design idea
- [ ] Definition of the success criteria

Show Answer

Question 2

From the options below, select the major factors that influence the selection of a final design.

- [ ] Minimising costs
- [ ] Minimising environmental impact
- [ ] Meeting functional requirements
- [ ] Integration of innovative construction methods
- [ ] Meeting evaluation criteria

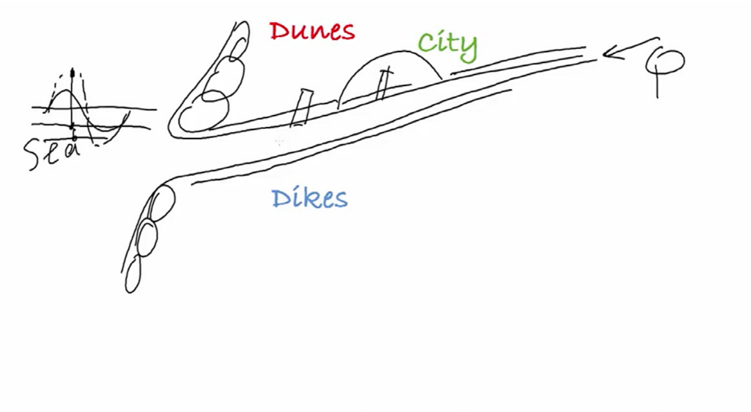
Show Answer

Video: Designing Storm Surge Barriers

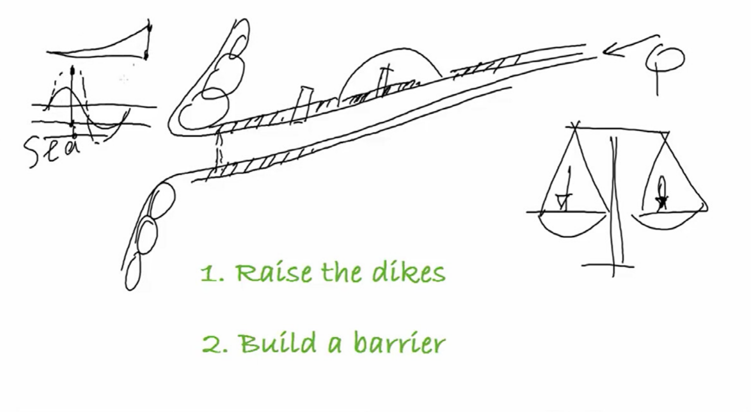
This section contains a video by presented an **engineer** from Delft University of Technology, **Ad van der Toorn**, and is written by **Ad van der Toorn** and **Jill Slinger**. He is a specialist in the field of hydraulic structures. In the video he explains how to design a storm surge barrier that can close when necessary.

You can cite this video as:

van der Toorn, A. (Ad), Slinger, J.H. (Jill) (2016). *Engineering: Building with Nature 101x video #05 – Engineering design principles. Storm surge barriers.* 4TU.Dataset. https://doi.org/10.4121/uuid:adc0c12d-4a11-4fee-9ba4-13103e43f834



2-10. Situation sketch. ⓒ Ad van der Toorn



2-11. Macro level solutions. ⓒ Ad van der Toorn

Video Transcript

Presented by Ad van der Toorn

The Dutch are famous for their storm surge barriers, but how do they really design them? Well, I am Ad van der Toorn, I am a lecturer on storm surge barriers here in the Technical University. I want to tell you something about a storm surge barrier. How to design it, and let me sketch a first drawing of the situation.

Maybe this is a river with a certain discharge coming from maybe Germany. You have the sea on the other side with a certain tide, but of course you have some spring tide over it, and maybe there is some sea level rise in the future. So you have an extra high tide within a few years. Maybe there is some subsidence, so there could be an extra level added to it. And then of course the first question is: Do we have a problem if the sea level rises?

And we have this situation with dunes on the outside and some dikes on the inside. Maybe this is a city like Rotterdam. This is the harbour inside and some new harbours outside.

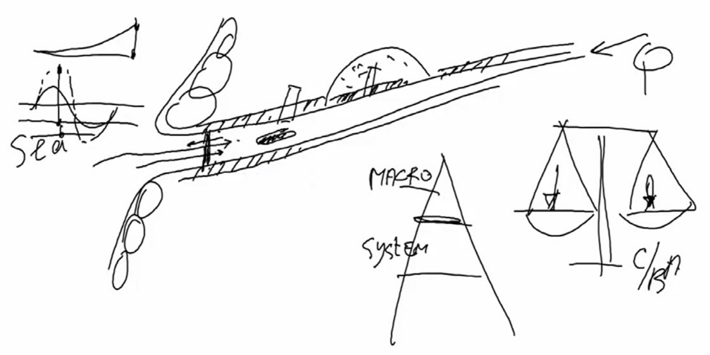
If the sea level rises, then of course we have the problem of flooding. So, we could have two main options on the macro-system level. We could balance them. Maybe we raise the dikes and of course this is problematic, because here you have to raise the dikes in the city, which costs you a lot more per meter to raise the dikes. And the second option is to build a kind of barrier, which could be open under normal conditions, but it could be closed if the high tide is there, and there is some storm surge with an extra height.

If you make a kind of decision about these two options, of course you could find out in a cost benefit analysis that maybe the barrier is the best option. So, because you have to raise a long stretch of dike and you only have to build a few small barriers in this situation. If you decide, you then come to the next system level. First you decide on the macro-system level, but now you come to the system level. And then the question is: what kind of barrier do you need?

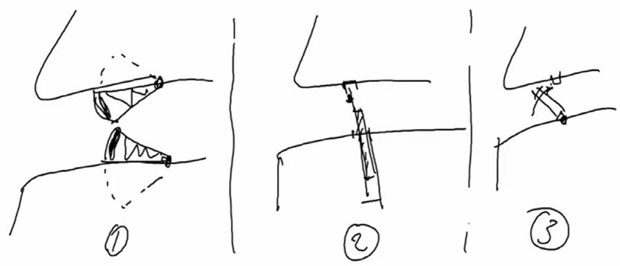
And of course you have to think about the vessels, which enter the ports in this city. And, you have to think about the discharge of this river. And maybe you have to think about the tide which comes in and out and, of course, gives you a nice environment. So what kind of barrier should we build there? And there are a few options. Build a kind of barrier, which looks like the barrier in Rotterdam, with two big arms swinging around the vertical axis, which has some parking docks, where you can maintain them. So they are strong barriers - a proven technology.

We have another option, which is more like a simple stretch solution with a rolling door in this direction. With a kind of recess on the opposite side. So, connecting these two sides in times of storm. And we have the other option, which gives a kind of barge swinging, or barge door. It swings around one axis, a vertical axis, and closes also the river in times of storm. And of course if you have these three alternatives you have to work them out.

First you have to work them out on a certain technical level, so that you have some idea about the amount of steel and concrete and what the price should be. And then you have to look to other criteria like reliability. So the first variant is a little bit complex, because you have to float the barrier, the arms of the barrier, up and then swing them in and then lower them down. So that is a complex movement, which gives you a low



2-12. *What kind of barrier do you need?* 🅭 *Ad van der Toorn*

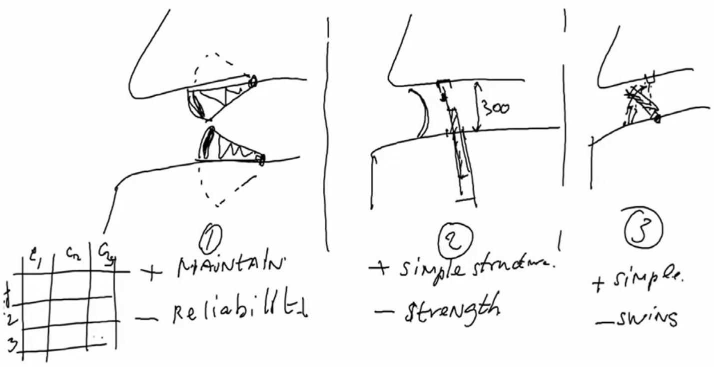


2-13. *Three variants for storm surge barriers.* 🅭 *Ad van der Toorn*

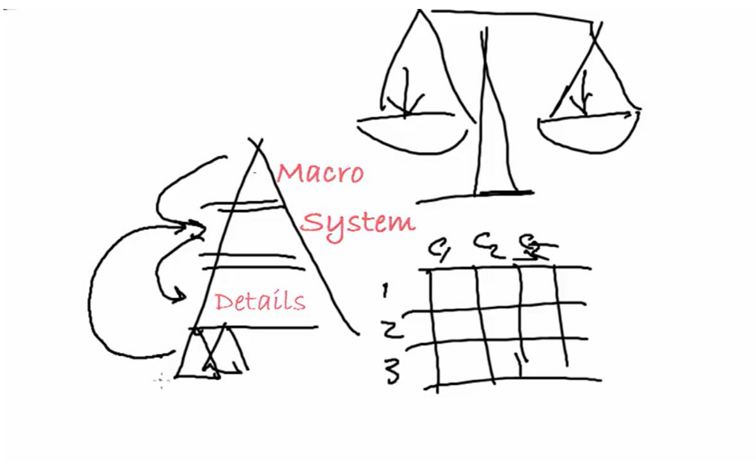
reliability. So reliability is not that high, but of course this is easy to maintain. So, it is easy to maintain.

If we look to the second option, we have a very simple structure. So that is a plus - simple structure. But of course there is always some negative side. There is a lot of bending moment, if this is for instance 300 meter, like in Rotterdam, then you have a lot of bending moments in your solution. So, the strength of this structure could be a problem.

And of course this swinging door - the third option - is a simple one, because it looks like a very big crude oil carrier, but it has to swing around one point. And of course you have to guide it, by cables etcetera to bring it in the right position. So, the swing is a little bit problematic, but it is a simple structure. And of course there are more arguments to give, but at the end you have to make a kind of multi-criteria evaluation, with three variants on one side and some criteria on the other side, which could be reliability etcetera. These are the criteria. And,



2-14. *Multi-criteria evaluation.* 🅭 *Ad van der Toorn*



2-15. *Steps to a first barrier design sketch. © Ad van der Toorn*

at the end you can give them some grades and end up with one or two favourites, which you want to work out.

So that is the way you try to come up with barrier design. You start at macro-level, then you go to a system level and at the end, of course, you have to work out all the different details. And maybe some elements, and at the end maybe, you can find that you have a wrong solution and, you have to go back, and look around, till you find the right solution in all details. After the first look you have a first sketch for your barrier.

2-16. *View of the closed Maeslant storm surge barrier near Rotterdam, The Netherlands. Beeldbank.rws.nl, Rijkswaterstaat*

Exercises

In this section you will find some questions to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**.

Question 1

Specialist Ad van der Toorn describes a typical engineering design process for one type of hydraulic infrastructure: a storm surge barrier. From the options below, select the principles that are mentioned or described in his answer.

- ☐ Financial Feasibility
- ☐ Reliability
- ☐ Environmental friendliness
- ☐ Safety
- ☐ Connectivity of waterways

Show Answer

Question 2

In the following four questions, we ask you to type the word that best completes the following phrase.

"According to the speaker, when engineers design infrastructures, such as a storm surge barrier, they make choices at four levels. If the most general level is number one and the most specific level is number four,

The first level of choices is called:

The second level of choices is called:

The third level of choices is called:

The fourth level of choices is called:

Show Answer

Question 3

In addition to the principles motivating the design of the storm surge barrier, which hydraulic boundary conditions and/or loads are taken into account?

- ☐ Navigability of the waterway
- ☐ River discharge
- ☐ Harbors' functionality
- ☐ Tidal dynamics
- ☐ Cost-benefit analysis

Show Answer

Before you continue...

Before moving on to the next section of this book, think about the following statement:

"Engineering design is an iterative process."

You may wish to discuss this with your peers.

Video: Designing Dikes

This section contains a video presented by an **engineer** from Delft University of Technology, **Mark Voorendt**, and is written by **Mark Voorendt** and **Jill Slinger**. He is a specialist in the field of hydraulic structures. In the video he explains how to design a dike that can effectively prevent flooding.

Voorendt, M. Z. (Mark), Slinger, J.H. (Jill) (2016). *Engineering: Building with Nature 101x video #06 – Engineering design principles*. *Dikes.* 4TU.Dataset. http://dx.doi.org/10.4121/uuid:4d8dd355-b8bf-4c9c-a38a-3d600082b0f5

Video Transcript

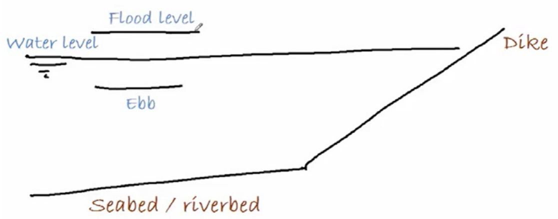
Presented by Mark Voorendt

Hello, my name is Mark Voorendt, I'm a researcher and lecturer at the Hydraulic Engineering Department of Delft University of Technology. I will explain the basics of dike design. I will concentrate on the hydraulic engineering part. In reality, urban, spatial quality, urban and ecological aspects have also to be taken into account.

The purpose of a dike is to reduce flood risks by protecting land from being covered by water. The higher the dike, the better it can resist higher water levels, and the lower the flood risk becomes. To determine how high the dike should be, the consequences of the flood are compared with investments needed to prevent it. A maximum acceptable flood probability level comes out. Because there is a relation between flood probability and extreme water level, the design height of a dike can then be determined.

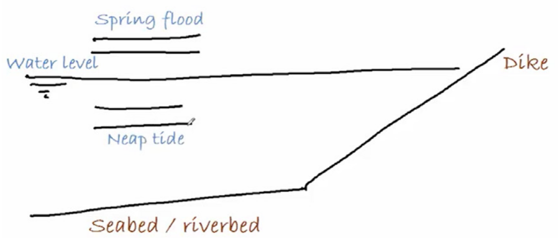
The height of a dike is the basic design parameter. Other properties such as the geometry, the shape and materials have to be designed in such a way to ensure the dike is sufficiently stable. So we start with determining the crest height of a dike, it should be higher than the design water level.

So I start painting foreland – actually the bed of the river or the sea, and then here is the slope, the outer slope of the dike. Somewhere here is the water level, which we indicate like this.



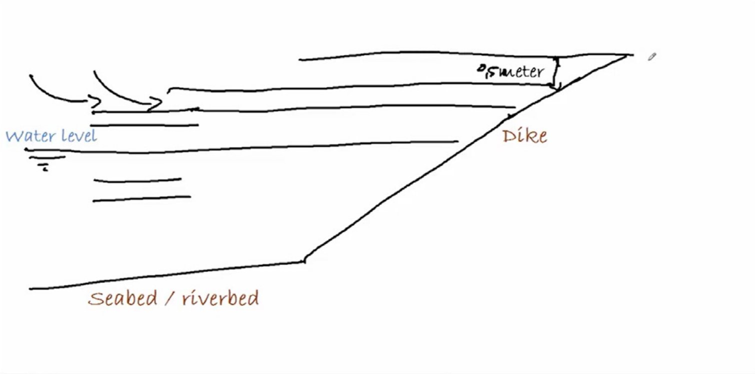
2-17. *Design water level & tidal differences.* ⓒ *Mark Voorendt*

This water level shows some variations, of course, because there is some tidal differences. So we have a minimum which we call ebb, and we have a flood level, and even these astronomical tides show differences, because sometimes we have a larger flood, called a spring tide, and we have a neap tide – depends on the position of the sun and moon relative to the earth. And we should of course design a dike in such a way that it resists the higher water levels and then it will resist the lower water levels as well. So we could extend this line to the dike here.

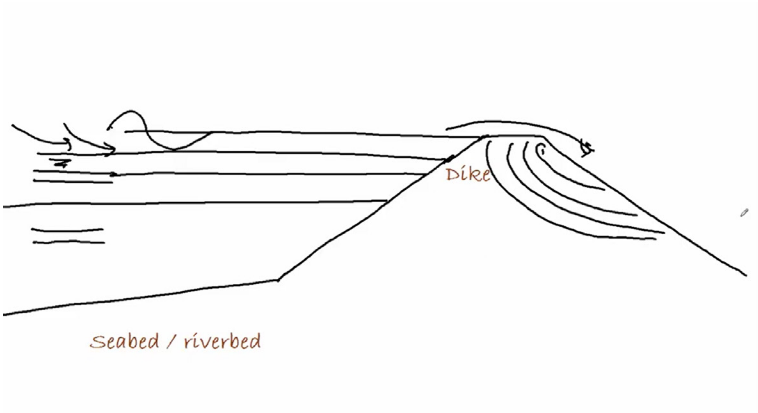


2-18. *Astronomical tidal extremes.* ⓒ *Mark Voorendt*

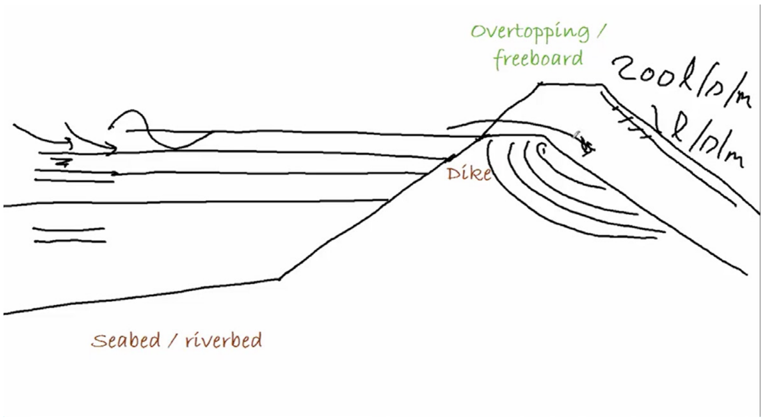
It can even be higher than this highest astronomical level because during storms there is lots of wind, which blows over



2-19. *Effect of wind and sea level rise on dike height.* 🅭 *Mark Voorendt*



2-20. *Dike erosion due to water overtopping.* 🅭 *Mark Voorendt*



2-21. *Freeboard height.* 🅭 *Mark Voorendt*

the water and it pushes up the water levels – it can be up to one or two or even three meters higher than the spring tide, so our dike needs to resist that level as well. And we should also look ahead in time because during the referencing period /lifetime period of a dike we can expect some sea-level rise or even in the rivers – higher river discharges – so we have to add, let's say, another half-meter. For instance, it is not sure, we have uncertainties about sea-level rise because we don't know how much it will be – this is dependant on scenarios – but we have to take this into account in the dike height over the lifetime period.

But even now we are not ready because these are still water levels and we have a lot of waves on top of these still water levels and the waves can overtop the dike. And we have to restrict the amount of water flowing over a dike because it will lead to erosion of the inner slope. So the amount of water going over won't immediately lead to flooding of the hinterland, but erosion of the inner slope is much worse because it can undermine the stability of our dike and then you have floods immediately.

So that has to be restricted, and you can restrict the amount of water flowing over by making it higher – like this. The height needed for that – we call that the overtopping height or free-

board – depends on the protection of the inner-slope. When it is really well protected, we can allow up to 200 litre per second per meter dike. If it is only grass or sand, it is up to 1 litre per second per meter which we can allow, but that depends on the height of the crest of the dike.

So this is actually our crest level of the dike – it consists of the still water level, extreme water level plus some overtopping height for the waves, but when you add extra weight on the subsoil (this level), you have extra weight because of the mass of all the soil in the dike body, you get some settlements of the soil below the dike a compaction of this soil, and when it goes down, also the crest height will go down. So you have to compensate for this during construction – so you have to put extra height on top of the dike so that at the end of the lifetime it will reach the design crest height.

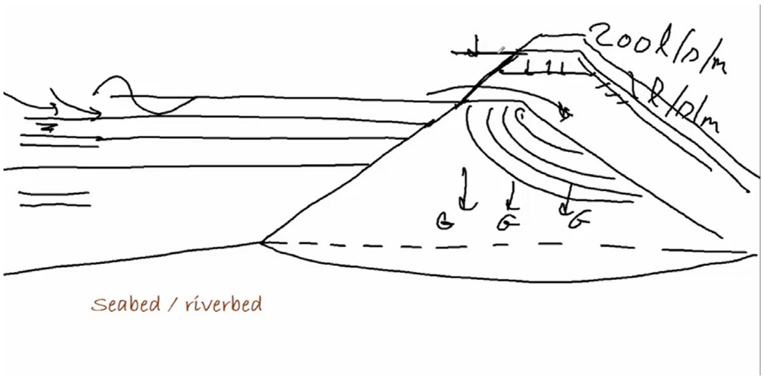
The height of a dike can be lower if the waves are dissipated. You can do that by constructing an outer berm, so in front of a dike here, so the waves that are coming in will break here. The wave energy will dissipate so it will reduce the amount of water going over a dike. So this means that to reach the same allowable overtopping discharge you can lower the crest height of a dike, so you can save this part - save costs because you have this height – but you have extra costs by constructing the berm over here. So you have to balance also here the costs of reduction that you gain by lowering the dike, by constructing the berm, including the revetment.

And of course you have better view over the flood defence, of course here, so that has extra value by lowering it, but that is difficult to quantify in the cost-benefit calculation.

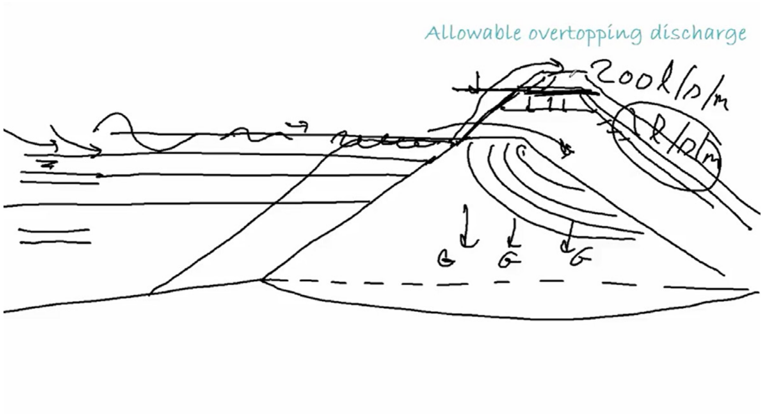
I think I should start with a new drawing now. I have drawn the outer-berm as you can see here, and it is applicable to sea dikes mainly because along the coast we get a lot of waves – it can be really high waves – and the overtopping height can be up to 5 meters, so it could double the height of the crest of the sea dike. But along rivers we don't have those high waves – it can be up to half a meter, so we don't need an outer-berm along rivers. But sometimes we even see berms on the inner slope of a dike and these are mainly used for stability. After heavy rainfall or after a high water level, the soil becomes saturated here and because of its weight, it starts sliding in a

rotational way. So you could say this is the centre of the rotational movement (the radians), and the berm counter-acts this movement. So it is extra weight on that side of the slope and it provides extra stability. Sometimes we need a piping berm, it is much lower and much longer, also on the inside of the dike, and that prevents seepage under a dike. So it makes the seepage length much longer, and seepage is actually a failure mechanism when water flows under a dike from one side to the other side, and seepage is not a problem, but when small grains start extruding from these small tunnels, you could say, that could undermine a dike, so you get failure and you have a breach, and then the polder will flood. So actually we have 3 kinds of berms on a dike – so in sea dikes we have a berm on the outer slope, and we can have a stability berm on the inner slope, or a much lower and longer piping berm also on the inner slope.

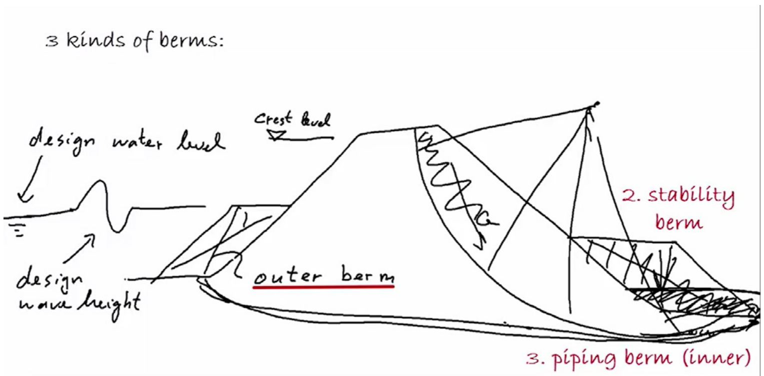
Thank you for your attention.



2-22. Soil settlement caused by dike mass. 🅭 Mark Voorendt



2-23. Allowable overtopping discharge. 🅭 Mark Voorendt



2-24. Three kinds of dike berms. 🅭 Mark Voorendt

Exercises

In this section you will find some questions to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**.

Question 1

According to the speaker, what aspects, other than hydraulic engineering, have to be taken into account while designing a dike?

- [ ] Urban development
- [ ] Financial feasibility
- [ ] Spatial quality
- [ ] Ecological aspects
- [ ] Public acceptance

Show Answer

Question 2

According to the speaker, the height of a dike is the basic design parameter. Other design parameters include:

- [ ] Geometry
- [ ] Cost
- [ ] Shape
- [ ] Location
- [ ] Materials

Show Answer

Question 3

According to the speaker, the height of a dike typically correlates positively with:

- [ ] Risk of flood
- [ ] Safety levels
- [ ] Investments in the infrastructure
- [ ] Resistance to high water levels
- [ ] Public acceptance

Show Answer

Question 4

Failure mechanisms should always be considered, so that the design can be adjusted in such a way that this mechanism can be prevented. Which failure mechanism is mainly caused by wave impact?

- ○ Piping
- ○ Erosion of outer slope
- ○ Erosion of inner slope
- ○ Macro instability

Show Answer

Question 5

Select which of the following statement(s) is/are true:

I. Overtopping does usually not lead to piping

II. A sheet pile does not influence the seepage length

- ◯ Only I is true
- ◯ Only II is true
- ◯ I and II are true
- ◯ None of the above

Show Answer

Before you Continue...

Before moving on to the next section of this book, think about the following question:

Does a grassed dike always fail when it is overtopped?

You may wish to discuss this with your peers.

Additional Materials

Click the titles in this section to download the material or scan the QR Code with a QR Code reading device.

The Delft Design Method for multi-functional hydraulic design

The Dutch Water Act

Note: The material of T*he Delft Design Method for multi-functional hydraulic design* does not cover Building with Nature design fully, but is represents an extension of conventional engineering design to deal with multi-functionality.

Video: Designing Breakwaters

The video presented by **engineer Henk Jan Verhagen** provides additional information on how to create a traditional breakwater design. You can view the video by clicking the play button or scanning the QR Code. Since this video is additional material, no transcript is provided in this book.

You can cite this video as:

Verhagen, H.J. (Henk Jan) (2015). *Engineering: Building with Nature 101x supplementary video - Breakwater Barriers. 4TU. Dataset.* https://dx.doi.org/10.4121/17027168

2.3 Engineering Design Principles

Introduction

In this section you will find a video by Prof. Jill Slinger, a specialist at Delft University of Technology and coordinator of this course. She will explain the principles that underpin the design of hydraulic infrastructures and that should also be incorporated in any Building with Nature solution.

Below the video, you can view a summary of the Engineering Design Principles (H-principles).

Video: Distilling Engineering Design Principles

The video in this section is presented and written by **Prof. Jill Slinger**. She will distill Engineering Design Principles. Click on the play button or scan the QR Code to start the video, or read the transcript on the next pages.

You can cite this video as:

Slinger, J.H. (Jill) (2016). *Engineering: Building with Nature 101x video #07 – Distilling Engineering Design Principles.* 4TU.Dataset. http://dx.doi.org/10.4121/uuid:f9099686-7dab-42ec-8da9-8cc961f393f3

Video Transcript

Presented by Prof. Jill Slinger

What is the essence of engineering design? And what are the principles upon which it is based?

I searched for an answer to this question. Because, if engineers can explain why they think and act in a particular way when designing - it can open up negotiation space with other disciplines, and vice versa. When other disciplines understand what motivates engineers, it can open up the multi-disciplinary design space. So, in this video, I'm going to distil design principles - the essence of engineering design.

When designing, each engineer seeks to reconcile the function required of the infrastructure with the hydraulic boundary conditions and load that it will experience. They do this

- to a required standard, and
- at reasonable cost.

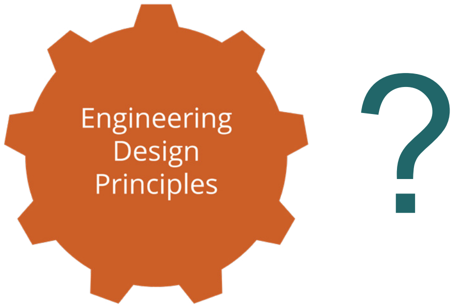
So, these represent 2 principles of engineering design.

- First, designing to meet a Requisite standard. That is, the structure should withstand all conditions apart from those exceeding the design criteria. Examples are dikes built to withstand a certain water level, or breakwaters built to withstand particular wave conditions.

- Second, Reasonable cost. This is a pragmatic consideration that it behoves an engineer to take into account. After all, an unnecessarily expensive structure won't get built. And, a cost-cutting version may not continue to meet the safety standard in the long term. A professional engineer is responsible for minimising cost, while maintaining standards.

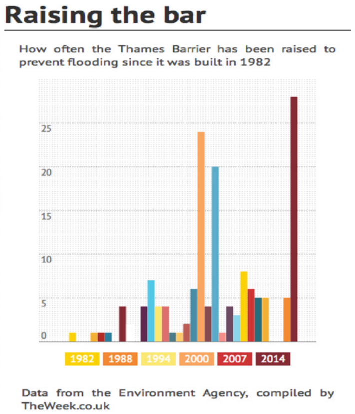
But how is this done? Well, each engineer considers how the hydraulic structure can fail – the failure mechanisms – and the means to prevent such failure. This leads to 2 further engineering design principles:

- The third principle, Structural integrity. That is, the structure should be built of appropriate material and in an appropriate fashion, so that it doesn't become unsteady or unbalanced, but retains its resistance to loading: that is its structural integrity – its strength, stability, stiffness - its position. Not like at Peacehaven in England. So, you can't place large rocks or concrete blocks for a

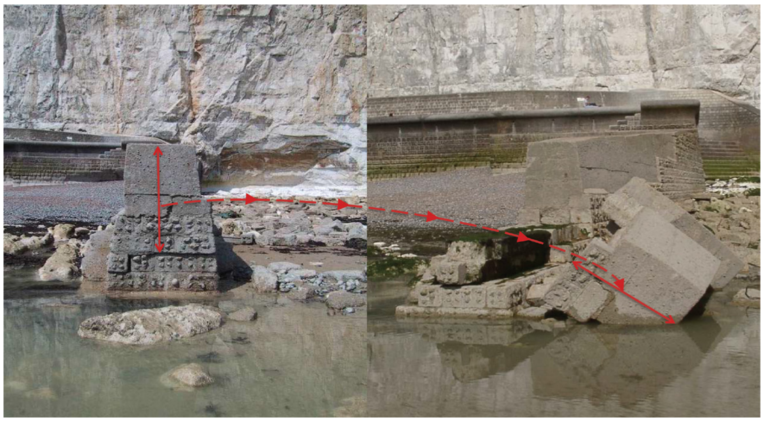


2-25. *Engineering Design Principles? ⓒ Martijn Vos and Jill Slinger*

2-26. *Vicksburg USA. ⓒ Michael Barera*



2-27. *Raising the Thames Barrier Bar. Ⓒ TheWeek.co.uk*



2-28. *Structural Integrity: Peacehaven. © Global Studies, Geography Department, University of Sussex*

2-29. *Reliability: Blocked lock in France. © Michael Traum*

2-30. Reliability: Repaired lock in France. © Michael Traum

2-31. Control environmental variability. © Michael Traum

2-32. Control environmental variability: Israel. © paul_krems

breakwater directly onto a muddy substrate, for example. They will become unstable and subside or slump as time passes.

- The fourth, Reliability. That is, the structure should continue to function smoothly and well and should not require many repairs. Unlike the lock in France where plant matter jammed the mechanism. In general, the simpler the structure, the more likely it is to be reliable. This principle incorporates the idea of maintenance – that a structure can be maintained so that it remains reliable.

Further engineering design principles stem from the functions of the infrastructure and revolve around the requirement to Control (environmental) variability so as to ensure access, connection or supply.

- So, for instance, a lock is designed to connect two bodies of water in such a way that ships can move from one body of water to the other, by the control of the water level within the lock.
- A breakwater has a dual function - withstanding variability (to a requisite safety standard) and ensuring accessibility by controlling the variability of the wave conditions behind the breakwater.
- A major dam in a river, is designed to control the variability in river flow by storing water to ensure supply. The more variable the river flow, the larger the dam needed to provide a particular assurance of supply.

The functional requirements to Control (environmental) variability and to meet a Requisite standard (by withstanding variability) are two sides of the same coin. They are only separated here for clarity.

Next, practical considerations related to the construction and operation play a role. The underlying design principle here is Implementibility. Tried and tested methods are generally preferred above entirely novel ones. An exception is the Eastern Scheldt storm surge barrier, for which many new design and construction methods had to be developed. This principle entails checking whether it is feasible and reasonable to build and operate the structure.

Another principle, that is not commonly applied is that of Adaptability. This means taking potential future changes in the function of an infrastructure into account in the design phase.

Engineering Design Principles

So designing a quay, for instance, so that it can be raised or re-used at a later stage to accommodate the next generation of ships, with deeper draughts.

And, it is possible to distinguish one more design principle – Resilience. Resilience is the capacity of the engineering structure to withstand a second shock, or sudden high load, of similar magnitude to the first and yet retain its structural integrity and continue to meet the functional requirements. An example is a flood protection barrier successfully withstanding first one flood without significant structural damage, then being subjected to another big flood, and successfully withstanding this. To summarise: so far, I have distinguished 8 hydraulic engineering design principles. If we regroup these slightly, we have:

1. Requisite standard
2. Control of (environmental) variability
3. Reasonable cost
4. Structural integrity, such as strength and stability
5. Reliability
6. Implementibility
7. Adaptability
8. Resilience

This is by no means an exhaustive list. But it does indicate the often implicit trade-offs that engineers are making in their designs.

Each principle requires you to think about the abiotic environment and its variability. Maybe by withstanding, controlling or regulating the variability, or considering the types of materials at the site or nearby. This brings us to the 9th and most fundamental engineering design principle, understanding the abiotic environment sufficiently to determine appropriate hydraulic boundary conditions and loads.

9. Appropriate hydraulic boundary conditions and loads

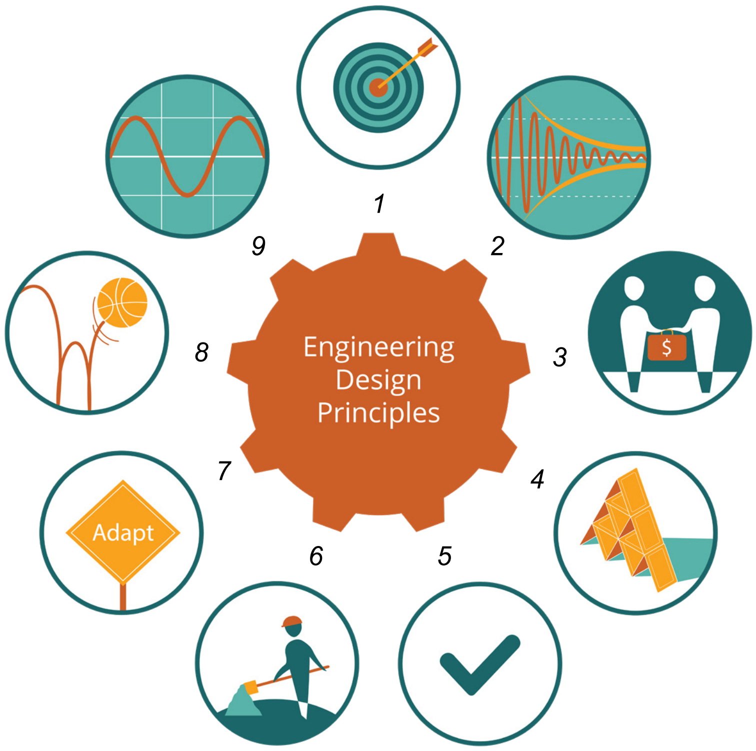
For the non-engineers amongst you - Its all about FAILURE! And, for the engineers - you may not have realised that other disciples just don't know that engineers think like this, and that you care that infrastructures don't fail.

So, to return to the original question: "what is the essence of engineering design?" Engineers apply design principles to prevent FAILURE! It's all about preventing FAILURE!

Thank you for your attention.

2-33. *Control environmental variability: Arizona.* 🅭 *Adam Kliczek*

2-34. *Implementability: Eastern Scheldt. Beeldbank.rws.nl, Rijkswaterstaat*



2-35. *Engineering design principles.* 🅭 *Martijn Vos and Jill Slinger*

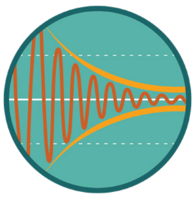
Reading Material: Engineering Design Principles (H-Principles)

What is the essence of engineering design? What are the principles upon which it is based? Answering these two questions enables the connection to ecological design, or nature-friendly design. If engineers can explain why they think and act in a particular way when designing, and if other professionals understand what motivates engineers, a multi-disciplinary negotiation space emerges. Therefore, this document attempts to answer the questions by expounding a set of eight Engineering Design Principles. Each of these principles describes an aspect that an engineer considers when designing infrastructure.

1. Requisite standard

A structure should withstand all conditions apart from those exceeding the design criteria. Examples include Dutch dikes which are built to withstand a 1 in 10 000 year storm surge.

2. Control of (environmental) variability



Control of environmental variability to ensure access, connection or supply. For instance, a lock is designed to connect two bodies of water in such a way that ships can move from one body of water to the other, by the control of the water level within the lock. A breakwater has a dual function - withstanding variability (to a requisite safety standard) and ensuring accessibility by controlling the variability of the wave conditions behind the breakwater. A major dam in a river is designed to control the variability in river flow by storing it to ensure supply. The more variable the river flow, the larger the dam needed to provide a particular assurance of supply.

3. Reasonable Cost

A pragmatic consideration of the costs and the benefits of certain infrastructure. While an unnecessarily expensive structure is not likely to be built, a cost-cutting version may not continue to meet the safety standard in the long term. A professional engineer is responsible for the trade-off between minimising costs while maintaining standards.

4. Structural integrity, such as strength and stability

A structure should be built of appropriate material and in an appropriate fashion to prevent unsteadiness or imbalance, yet retaining its resistance to loading. This requires the maintenance of structural integrity: strength, stabilityand stiffness. The structure should remain in position. For example, when large rocks or concrete blocks of a breakwater are placed directly on a sandy substrate, the structure can become unstable and subsides or slumps as time passes.

5. Reliability

A structure should continue to function smoothly and well, and should not require many repairs. In general, the simpler the structure, the more likely it is to be reliable. This principle also incorporates the idea of maintenance: a structure can be maintained so that it remains reliable.

6. Implementability

Checking whether an infrastructure is feasible and reasonable to construct and operate. Tried and tested methods are generally preferred above entirely novel ones. An exception is the Eastern Scheldt storm surge barrier, for which many new design and construction methods had to be developed.

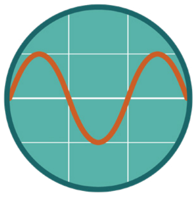
7. Adaptability

Taking potential future changes in the function of an infrastructure into account in the design phase. Applying adaptability to the design of a quay, for instance, would consider the need to raise and/or re-use it at a later stage to accommodate the next generation of ships, with deeper draughts.

8. Resilience

Capacity of an engineering structure to withstand a second or further shock, or sudden high load, of similar magnitude to the first and yet retain its structural integrity and continue to meet the functional requirements. An example is a flood protection barrier successfully withstanding first one flood without significant structural damage, then being subjected to another big flood, and successfully withstanding this.

9. Appropriate boundary conditions and loads



When designing each engineer seeks to reconcile the function required of the infrastructure with the hydraulic boundary conditions and load that it will experience. They do this to a required standard, and at reasonable cost.

Further Reading

Voorendt, M.Z. (2015). *The 'Delft design method' for hydraulic engineering*. Technical report, Delft University of Technology. Delta Technology, Design & Governance Series. Bee's Books, Amsterdam. ISBN/EAN: 978-90-74767-19-4

Dym, C. L., & Little, P. (2004). *Engineering design: A project-based introduction*. Wiley.

2.4 Assignment 2.1

Assignment: Form, Function & Character of Hydraulic Infrastructures

This exercise consists of a total of 12 questions, divided into three blocks. Block 1 will test your knowledge of the *Form* of an infrastructure. Block 2 will deal with their *Function*. Finally, Block 3 will deal with their engineering *Character*.

If you are an engineer or if you are familiar with hydraulic infrastructures, you should find this assignment relatively easy and you might even be willing to answer some of the questions of non-engineers with your peers. However, the objective of this assignment is to allow **all readers** of this book to explore Engineering Design even if they do not have an engineering background.

Developing an understanding of Engineering Design Principles will allow us to bridge across to Ecological Design Principles in the next chapter. So, the logic underlying this assignment is mirrored in Chapter 3, when we will explore Ecological Design Principles using the same framing of Form, Function, and Character.

For each of the images on the next pages you will be presented with a question. After answering each question in the block, move to the next block of questions until you've finished all three.

2.4 Assignment 2.1

Assignment 2.1 Block 1: Form

Next to each image you will find a multiple choice question. From the options provided, select the name of the infrastructure in the image. After you have answered the four questions, move on to the next page where you'll find the second block of questions.

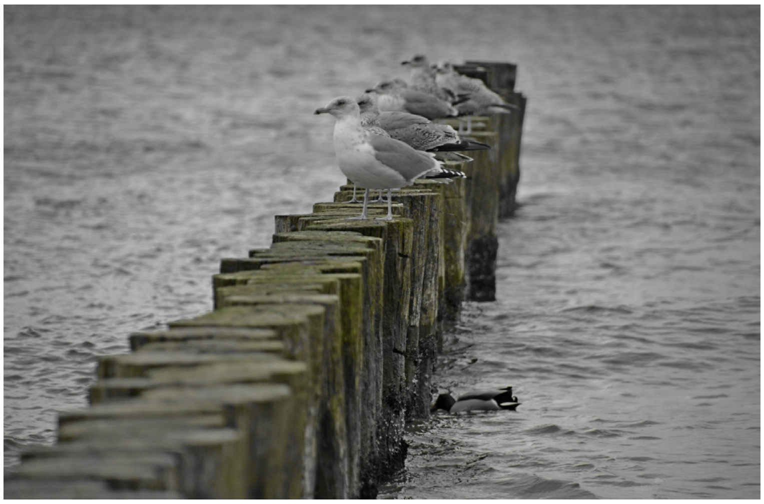
To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

What is the name of the infrastructure?

- Dam
- Lock
- Sea groyne
- Quay wall

Show Answer



2-36. Question 2.1.1.1. ⓪ Lekies

Question 2

What is the name of the infrastructure?

- Quay wall
- Breakwater
- Lock
- Weir

Show Answer

2-37. Question 2.1.1.2. ⓪

Question 3

What is the name of the infrastructure?

- ◯ Pier
- ◯ Groyne
- ◯ Lock
- ◯ Sluices

Show Answer

2-38. Question 2.1.1.3. Lekies

Question 4

What is the name of the infrastructure?

- ◯ Groyne
- ◯ Sluices
- ◯ Quay wall
- ◯ Surge

Show Answer

2-39. Question 2.1.1.4. Graciela del Carmen Nava Guerrero

Assignment 2.1 Block 2: Function

Next to each image you will find a checkbox question. Select **all the functions** that the infrastructure in the image provides.

To check your answer click on the button **Show Answer**.

Question 1

What functions does the infrastructure provide?

- ☐ Access
- ☐ Navigability
- ☐ Connection
- ☐ Control of water level
- ☐ Assuring supply (goods or energy)

Show Answer

2-40. Question 2.1.2.1.

Question 2

What functions does the infrastructure provide?

- Safety
- Navigability
- Connection
- Erosion control
- Assuring supply (goods or energy)

Show Answer

2-41. Question 2.1.2.2. ⓪

Question 3

What functions does the infrastructure provide?

- Navigability
- Connection
- Control of water level
- Erosion control
- Assuring supply (goods or energy)

Show Answer

2-42. Question 2.1.2.3. ⓪

Assignment 2.1 Block 3: Character

Below each image you will find a checkbox question. Select **all the Engineering Design Principles** represented by the infrastructure in the image.

Hint: think about which principles have not been taken into account in the design of the depicted infrastructure - these need not be checked.

To check your answer click on the button **Show Answer**.

Question 1A

Which of the Engineering Design Principles are represented by the infrastructure in the image on the right?

- ▢ Requisite standard
- ▢ Control variability
- ▢ Reasonable costs
- ▢ Structural integrity

Show Answer

2-43. *Question 2.1.3.1.* 🅭 *Vladimír Šiman*

Question 1B

This is part 2 of the same question: After examining the same image, now consider which of these Engineering Design Principles are represented by the infrastructure in the image?

- ▢ Reliability
- ▢ Implementability
- ▢ Adaptability
- ▢ Resilience
- ▢ Boundary conditions and loads

Show Answer

Question 2A

Consider the following engineering design principles. Which of these are represented in the image on the right (check all that apply)?

- ▢ Requisite standard
- ▢ Control variability
- ▢ Reasonable costs
- ▢ Structural integrity

Show Answer

2-44. *Question 2.1.3.2.*

Question 2B

This is part 2 of the same question:

After examining the same image, now consider which of these Engineering Design Principles are represented by the infrastructure in the image?

- [ ] Reliability
- [ ] Implementability
- [ ] Adaptability
- [ ] Resilience
- [ ] Boundary conditions and loads

Show Answer

Question 3A

The image right shows the Hoover Dam (also known as the Boulder Dam) on the Colorado River, a permanent river. The location of the dam wall is indicated by the arrow in the original design sketch on the next page. The dotted lines behind the dam indicate the original path of the Colorado River, now covered by a large body of water (termed the reservoir area in the design sketch).

Which of the Engineering Design Principles are represented by the infrastructure in the images on the right?

- [ ] Requisite standard
- [ ] Control variability
- [ ] Reasonable costs
- [ ] Structural integrity

Show Answer

2-45. Question 2.1.3.3A. Ⓑ Alex Rotlex

Question 3B

This is part 2 of the same question:

After examining the same images, now consider which of these Engineering Design Principles are represented by the infrastructure in the images?

- [ ] Reliability
- [ ] Implementability
- [ ] Adaptability
- [ ] Resilience
- [ ] Boundary conditions and loads

Show Answer

2-46. Question 2.1.3.3B. © Los Angeles Times

2.5 Feedback

Feedback on Assignment 2.1

by Prof. Jill Slinger and Ir. Graciela del Carmen Nava Guerrero

Assignment 2.1 consisted of three blocks: Form, Function and Character. In Block 1, Form, you identified four hydraulic infrastructures by their names: a sea groyne, a breakwater, sluices and a quay wall. In Block 2, we asked you to identify, from a given set of functions, those that the infrastructure in the image provided. Finally, in Block 3, we asked you to select the Engineering Design Principles that were represented by the infrastructure in the image.

In this feedback section, we share our thoughts on Block 2 and Block 3. First, for Block 2 we will explain the reasons to include or exclude functions for each image. Second, for Block 3 we will provide insight on the character of traditional hydraulic infrastructures as well as some Building with Nature infrastructures.
You will find the feedback for Blocks 2 and 3 on the next pages.

Feedback on Block 2: Function

Lock	Function	Yes	No
	Enables access	The lock enables the passage of vessels from one body of water to another.	Not Applicable
	Ensures navigability	The lock ensures that ships can pass from one waterway to another by controlling water levels	Not Applicable
	Connects	Two bodies of water are connected via the lock.	Not Applicable
	Controls water level	By controlling the water level within the lock, the infrastructure enables the passage of vessels.	Not Applicable
	Assures supply (goods or energy)	Not Applicable	Trading vessels may use the lock; however, this is not the primary aim of the infrastructure

Dike	Function	Yes	No
	Ensures safety	The dike prevents flooding of the hinterland from very high tides and from coastal storm surge	Not Applicable
	Ensures navigability	Not Applicable	Because this dike blocks the natural passage of a waterway (not evident from the photo) it does not enable navigability. A lock located in the dike would ensure navigability.
	Connects	The dike acts to span a waterway (not evident from the photo) and connect land on either side. However, it acts to disconnect the two bodies of water that it separates.	Not Applicable

Controls erosion	The dike prevents coastal erosion by acting as a barrier to tidal action.	Not Applicable
Assures supply (goods or energy)	Not Applicable	Flood protection is the primary function that dikes aim at fulfilling.

Port

Function	Yes	No
Ensures navigability	The port enables the passage and mooring of vessels. It has to be deep enough to be navigable.	Not Applicable
Connects	The port enables the passage and mooring of vessels from one waterway to another.	Not Applicable
Controls water level	Not Applicable	The port does not control the water level of the ocean nor the riverine inflows.
Controls erosion	The breakwaters of the port and quay walls can prevent coastal erosion by inhibiting sediment transport and acting as protective barriers against tidal action.	Harbour moles /breakwaters can also act to enhance erosion on adjacent beaches. These effects often have to be compensated by bypass schemes and disposal of dredged sediments in beneficial locations.
Assures supply (goods or energy)	The port enables the trade and exchange of products and services associated with trading vessels. This is its primary function.	Not Applicable

Feedback on Block 3: Character

The third block of the assignment presented you with two hydraulic infrastructures and a natural coastal defence. Did you notice that the storm surge barrier and the dam fulfilled almost all the Engineering Design Principles? This means that engineers do their jobs well by designing to prevent failure. The resulting hydraulic infrastructures meet the requisite standards, optimise the control of variability, ensure structural integrity, are implementable and select appropriate boundary conditions and loads. When designing conventional hydraulic infrastructures, there is often a trade-off between achieving the previous principles and keeping costs low, maximising resilience and enhancing adaptability. This poses two major types of challenges: the first one is economic and the second one is ecological. You will learn more about the second trade-off in the next chapter.

2.6 Assignment 2.2

Introduction

In Chapter 4 you will be working on your own Building with Nature Design. The assignment in this section acts as practice for the assignment in Chapter 4, in which you will need to report and explain how you apply the Engineering Design Principles in your proposed / sketched design. The reporting format that you use in Assignment 2.2 forms a component of your Chapter 4 Assignment when you will apply it to your own Building with Nature design.

To get ready for Assignment 4, we ask you to practise by completing the exercise in the next section.

2-47. *Assignment 2.2.* ⓔ

Assignment 2.2 (As Practice for Assignment 4)

This assignment has two stages:

Stage 1:
Have a look at the image above and reflect on which **Engineering Design Principles** are represented in the **infrastructure**, these are listed on the next page.

Hint: *Just as in Assignment 2.1 Block 3 it is helpful to think first about which principles were NOT taken into account, or were LESS relevant in the design choices.*
Afterwards, complete the form on the next page by scoring and explaining each principle.

Stage 2:
Once you have completed the form, check the next page for the model answer. Consider the model answer in relation to your own submission, and give yourself a grade.

Please note that self-assessment is built on trust. While you could view the model answer before completing your own work, we hope that you will take the time to first consider your own solutions.

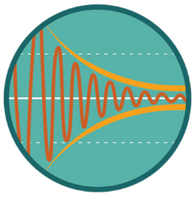
This assignment will help you prepare for the Building with Nature Design Assignment in Chapter 4 with its self review. The grading is as follows:

Poor: Less than 4 engineering principles are scored highly (in the last 2 boxes), and/or no explanations are included.
Fair: At least 4 engineering principles are scored highly (in the last 2 boxes), but 2 explanations are missing from those 4 and/or the explanations are very different from the model answer.
Good: At least 4 engineering principles are scored highly (in the last 2 boxes), and explanations are included for at least these 4 that are similar to the model answer.

2.6 Assignment 2.2

Assignment Form

Consider the following principles, then rate (with an X in 1 of the 5 boxes) the extent to which they have been taken into account in the infrastructure in the image. Then explain why you have rated the infrastructure in this way. Click in the empty fields to start typing.

Engineering principles	**Checkboxes** *Minimum-maximum*	**Explanation**
1. Requisite standard 	○ ○ ○ ○ ○	
2. Control variability 	○ ○ ○ ○ ○	
3. Reasonable Cost 	○ ○ ○ ○ ○	
4. Structural integrity, such as strength and stability 	○ ○ ○ ○ ○	

Engineering principles | **Checkboxes** *Minimum-maximum* | **Explanation**

5. Reliability

○ ○ ○ ○ ○

6. Implementability

○ ○ ○ ○ ○

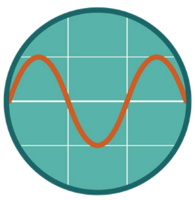
7. Adaptability

○ ○ ○ ○ ○

8. Resilience

○ ○ ○ ○ ○

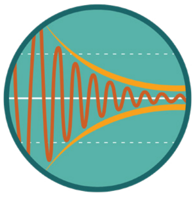
9. Appropriate boundary conditions and loads



○ ○ ○ ○ ○

Model Answer

Consider the following principles, then rate (with an X in 1 of the 5 boxes) the extent to which they have been taken into account in the infrastructure in the image. Then explain why you have rated the infrastructure in this way.

Engineering principles	Checkboxes *Minimum-maximum*	Explanation
1. Requisite standard 	○ ○ ○ ◉ ○	The structure seems to be able to withstand waves, tidal variation and currents. It appears robust to storm conditions (apart from those exceeding the design criteria).
2. Control variability 	○ ◉ ○ ○ ○	The structure has been designed to provide accessibility, rather than to control environmental variability per se.
3. Reasonable Cost 	○ ○ ○ ◉ ○	No information is supplied about the costs. However, the structure seems to be cost-effective.
4. Structural integrity, such as strength and stability 	○ ○ ○ ◉ ○	The strength and stability of the structure seem appropriate. The structure is not unsteady nor imbalanced, and there is no evidence of any loss of structural stiffness nor resistance to loading. It seems to be maintaining its position.

Engineering principles	Checkboxes *Minimum-maximum*	Explanation

5. Reliability

○ ○ ○ ● ○

The structure is simple, and there are no mechanical parts, suggesting that it is reliable. At present, little maintenance is needed, but piers and jetties generally require maintenance as they age.

6. Implementability

○ ○ ○ ● ○

The design of the infrastructure is not new; it has been built many times.

7. Adaptability

○ ○ ● ○ ○

The structure does not seem to be adaptable. However, its height above mean sea level is sufficient to ensure that it can cope with sea level rise. It is not clear whether it is sufficiently robust to increased storminess.

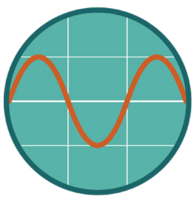
2-87

8. Resilience

○ ● ○ ○ ○

The structure appears able to withstand more than one storm and remain functional. It is unclear how it would cope with an extreme storm.

9. Appropriate boundary conditions and loads



○ ○ ○ ● ○

The structure appears to be dimensioned to cope with waves, tides, currents and storms. Without further information it is difficult to determine precisely whether the hydraulic boundary conditions and load are appropriate or not.

2.7 Bibliography

Figures

2-1. Eastern Scheldt Storm Surge Barrier: Een van de bekendste fotoseries gemaakt bij Storm en hoogwater bij de Oosterscheldedam waarvan de schuiven zijn gesloten. by Rijkswaterstaat/ Rens Jacobs. Retrieved from https://beeldbank.rws.nl/MediaObject/Details/166514

2-2. Define the Problem: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-3. Specify the functional requirements: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-4. Sketch, describe preliminary designs: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-5. Select promising designs: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-6. Test /verify designs; prototyping, modelling: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-7. Selection of final design: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-8. Designing is an iterative process: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-9. The engineering design process: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-10. Situation sketch: This image by Ad van der Toorn is licensed under CC-BY-NC-SA 4.0

2-11. Macro level solutions: This image by Ad van der Toorn is licensed under CC-BY-NC-SA 4.0

2-12. What kind of barrier do you need: This image by Ad van der Toorn is licensed under CC-BY-NC-SA 4.0

2-13. Three variants for storm surge barriers: This image by Ad van der Toorn is licensed under CC-BY-NC-SA 4.0

2-14. Multi-criteria evaluation: This image by Ad van der Toorn is licensed under CC-BY-NC-SA 4.0

2-15. Steps to a first barrier design sketch: This image by Ad van der Toorn is licensed under CC-BY-NC-SA 4.0

2-16. View of the closed Maeslant storm surge barrier near Rotterdam, The Netherlands: Maeslantkering in de Nieuwe Waterweg. Luchtfoto, kering in gesloten stand. by Rijkswaterstaat. Retrieved from https://beeldbank.rws.nl/MediaObject/Details/439459

2-17. Design water level & tidal differences: This image by Mark Voorendt is licensed under CC-BY-NC-SA 4.0

2-18. Astronomical tidal extremes: This image by Mark Voorendt is licensed under CC-BY-NC-SA 4.0

2-19. Effect of wind and sea level rise on dike height: This image by Mark Voorendt is licensed under CC-BY-NC-SA 4.0

2-20. Dike erosion due to water overtopping: This image by Mark Voorendt is licensed under CC-BY-NC-SA 4.0

2-21. Freeboard height: This image by Mark Voorendt is licensed under CC-BY-NC-SA 4.0

2-22. Soil settlement caused by dike mass: This image by Mark Voorendt is licensed under CC-BY-NC-SA 4.0

2-23. Allowable overtopping discharge: This image by Mark Voorendt is licensed under CC-BY-NC-SA 4.0

2-24. Three kinds of dike berms: This image by Mark Voorendt is licensed under CC-BY-NC-SA 4.0

2-25. Engineering Design Principles: This image by Martijn Vos and Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-26. Vicksburg USA: "Yazoo River Levee in Vicksburg, Mississipi (USA)" by Michael Barera is licensed under CC BY-SA 4.0

2-27. Raising the Thames Barrier Bar: "Raising the bar" by TheWeek.Co.Uk is in the Public Domain

2-28. Structural Integrity: Peacehaven: This image is Copyright protected. © Global Studies, Geography Department, University of Sussex. All Rights Reserved.

2-29. Reliability: Blocked lock in France: This image by Copyright protected. © Michael Traum. All Rights Reserved.

2-30. Reliability: Repaired lock in France: This image by Copyright protected. © Michael Traum. All Rights Reserved.

2-31. Control environmental variability: This image by Copyright protected. © Michael Traum. All Rights Reserved.

2-32. Control environmental variability: Israel: "Ashkelon Marina Breakwater Light 2008-03-15" by paul_krems is licensed under CC BY 3.0

2-33. Control environmental variability: Arizona: Lake Powell seen from Glen Canyon Dam by Adam Kliczek is licensed under CC BY 3.0

2-34. Implementability: Eastern Scheldt: Noord Beveland, Schouwen, kust, strand, Noordzeekust, Oosterschelde, Oosterscheldekering. by Rijkswaterstaat. Retrieved from https://beeldbank.rws.nl/MediaObject/Details/420282

2-35. Engineering design principles: This image by Martijn Vos and Jill Slinger is licensed under CC-BY-NC-SA 4.0

2-36. Question 2.1.1.1: This image by Lekies is in the Public Domain, CC0

2-37. Question 2.1.1.2: This image is in the Public Domain, CC0

2-38. Question 2.1.1.3: This image is in the Public Domain, CC0

2-39. Question 2.1.1.4: “Cape Town - Seal” by Graciela del Carmen Nava Guerrero is licensed under CC-BY-NC-SA 4.0.

2-40. Question 2.1.2.1: This image is in the Public Domain, CC0

2-41. Question 2.1.2.2: This image is in the Public Domain, CC0

2-42. Question 2.1.2.3: This image is in the Public Domain, CC0

2-43. Question 2.1.3.1: ”overall view of Oosterscheldekering surge barrier” by Vladimír Šiman is licensed under CC BY 3.0.

2-44. Question 2.1.3.2: This image is in the Public Domain, CC0

2-45. Question 2.1.3.3A: This image by Alex Rotlex is in the Public Domain, CC0

2-46. Question 2.1.3.3B: Boulder dam site sketch is in the Public Domain

2-47. Assignment 2.2: This image is in the Public Domain, CC0

3-1. Cape Town Seal: © Graciela del Carmen Nava Guerrero

Chapter 3 Ecological Design Principles

3.1 Introduction

What does nature-friendly design mean? What are the principles upon which it is based?

Answering these questions enables a multi-disciplinary negotiation space to emerge between ecology, environmental science and engineering design.

Welcome to this third chapter on the adventure of learning Building with Nature. In this chapter, you will learn how to make design choices that accord more fully with the character and functional integrity of natural ecosystems.

First, Prof. Tinka Murk and Dr. Ronald Osinga will introduce the abiotic (non-living) and biotic (living) natural aspects that are important for ecosystem development and health. Then, you can read about an international classification of wetland ecosystems – the primary sites of hydraulic infrastructures! These activities will prepare you to learn about the Ecological Design Principles, presented by Prof. Jill Slinger.

Afterwards, Assignment 3.1 will test your knowledge on the Form, Functioning and Character of wetland ecosystems. Once you have completed the assignment, you are free to consult the feedback, discuss your thoughts and post comments in the discussion forum.

For Assignment 3.2, you are asked to apply the Ecological Design Principles and to conclude the chapter by assessing your own work.

Enjoy the content of this chapter!

Video: Oyster Reefs - An Inspiring Example

Now for an example of eco-engineering - an oyster reef.

In the following video, **Dr. Brenda Walles** will take you to an estuary in the southern part of the Netherlands. She will explain how oyster reefs can protect tidal flats from erosion, and how they can be employed for this purpose. You will learn how oyster reefs grow with nature through annual recruitment, and so succeed in controlling erosion, and how the heights of the reef and tidal flats are monitored. The need for system understanding, the use of species and the role of monitoring are emphasised in this Building with Nature example.

You can cite this video as:

Walles, B. (Brenda) (2019). *Engineering: Building with Nature 101x. Oyster reefs – an inspiring example*.

Video Transcript

Presented by Dr. Brenda Walles

Today we are standing here at the Eastern Scheldt Estuary.

This estuary faces major problems with a process called 'sand starvation'. In the 1980s we constructed the Storm Surge Barrier which protects the southern part of the Netherlands against flooding. But due to the construction of this dam, we saw a reduction of the tidal currents and tidal flow. This has an impact on the morphology of the system.

Due to this reduced energy, there is a continuous erosion of the tidal flats, whereas there is not enough energy to place the sand back from the gullies onto the tidal flats.

Tidal flats are important for several reasons: one is safety and the other one is biodiversity. If you have a tidal flat like this one connected to the dike, what we see is that the tidal flats themselves, they reduce wave energy. And with such a tidal flat in front, dikes need to be less reinforced to protect the hinterland against flooding.

They are also important for biodiversity. They are a feeding ground for migratory birds and they also provide resting areas for seals. To protect these tidal flats against erosion, we investigated if oyster reefs could be an interesting Building with Nature tool.

So let's have a look.

We are now standing at a natural oyster reef. Here you see an example of a small natural oyster reef. They are very interesting because they make this 3D structure and with having this 3D structure, they change the way water flows over them. So if waves travel over a reef, they become smaller and the reef attenuates the wave energy.

While doing this, it also changes the sediment deposition behind the reef. What you see here is this reef and I am standing on this area which is a little bit more elevated compared to the surrounding of the reef.

Oysters are known as being ecosystem engineers. So, by altering the water flow, they changed the sediment. So they changed their own environment.

We want to make use of this quality of oysters to use them as a Building with Nature solution. We also applied this quality of these oysters in an artificial reef.

So we are going to see how that looks like on a larger scale.

Oysters need hard substrate in order to create these 3D structured reefs which we can use as a Building with Nature solution. So, in order to get an oyster reef here at a very highly dynamic location, what we did is, we constructed an artificial reef using gabions.

Inside those gabions we placed oyster shell material from the specific oyster Crassostrea gigas. This oyster is an invasive species to this area. It is introduced in the 1960s for aquacultural purposes and afterwards it established itself throughout the whole estuary.

We are making use of this invasive species because every year it recruits and these recruits can settle on the substrate we offer here. And by having multiple years of recruitment, it becomes a living self-sustainable reef, which can add to tidal flat protection in this erosive area.

In order to understand if this reef can be a self-sustainable reef, we have to monitor how it's developing. So what we do is looking every year at how much the reef has grown over time.

Where we started was over here. This is what the initial height was of the artificial structure. And due to natural recruitment events, we have every year an extra layer of shell on top. And oysters, when they look for a suitable substrate to settle on, they cement themselves.

So oysters cement themselves on top of each other, forming this package of oyster shells. And that's also making this a nice Building with Nature solution, because due to natural recruitment events this structure is able to grow with sealevel rise. We can still see some gabions over here. This has to do with the location. We are at a very high hydrodynamic location and the front of the reef needed some extra maintenance. So, we added this extra structure to provide this stable substrate for oysters to settle on.

You can see it is already integrated into the reef further on. So, yearly, we visit in winter this oyster reef to measure how many recruitments settle on this reef structure.

But we also measure the length of the oysters to understand how much they grow in time. So what we do: we measure their total length which gives us an indication of how much they can grow and how much, in total, the reef can accrete. Furthermore, we monitor how efficient artificial reefs are in stabilising the tidal flat and protecting it against erosion. So what we do on a yearly basis is, we measure the height development of this area. Therefore we use the DGPS which will allow us to monitor morphological changes on a level of one centimeter accuracy.

Up to now, we see that the reef is able to affect the morphology and reduce erosion over a large distance of 100 up to 300 meters behind the reef.

Oyster reefs have shown that they can successfully reduce tidal flat erosion. However success of delivering this service depends on system settings. Therefore system knowledge is important to successfully be able to build with nature.

Exercises

In this section you will find some questions to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

In the previous video, Dr. Brenda Walles indicates that the oyster reefs increase in height over time. This is caused by the following process:

- ○ Sediment deposition
- ○ Ground subsidence
- ○ Wave energy
- ○ Recruitment

Show Answer

Question 2

Oyster reefs are effective in reducing erosion of tidal flats. They do this by:

- ○ Filtering water
- ○ Reducing wave energy
- ○ Providing food for wading birds
- ○ Preventing boats from accessing the tidal flats

Show Answer

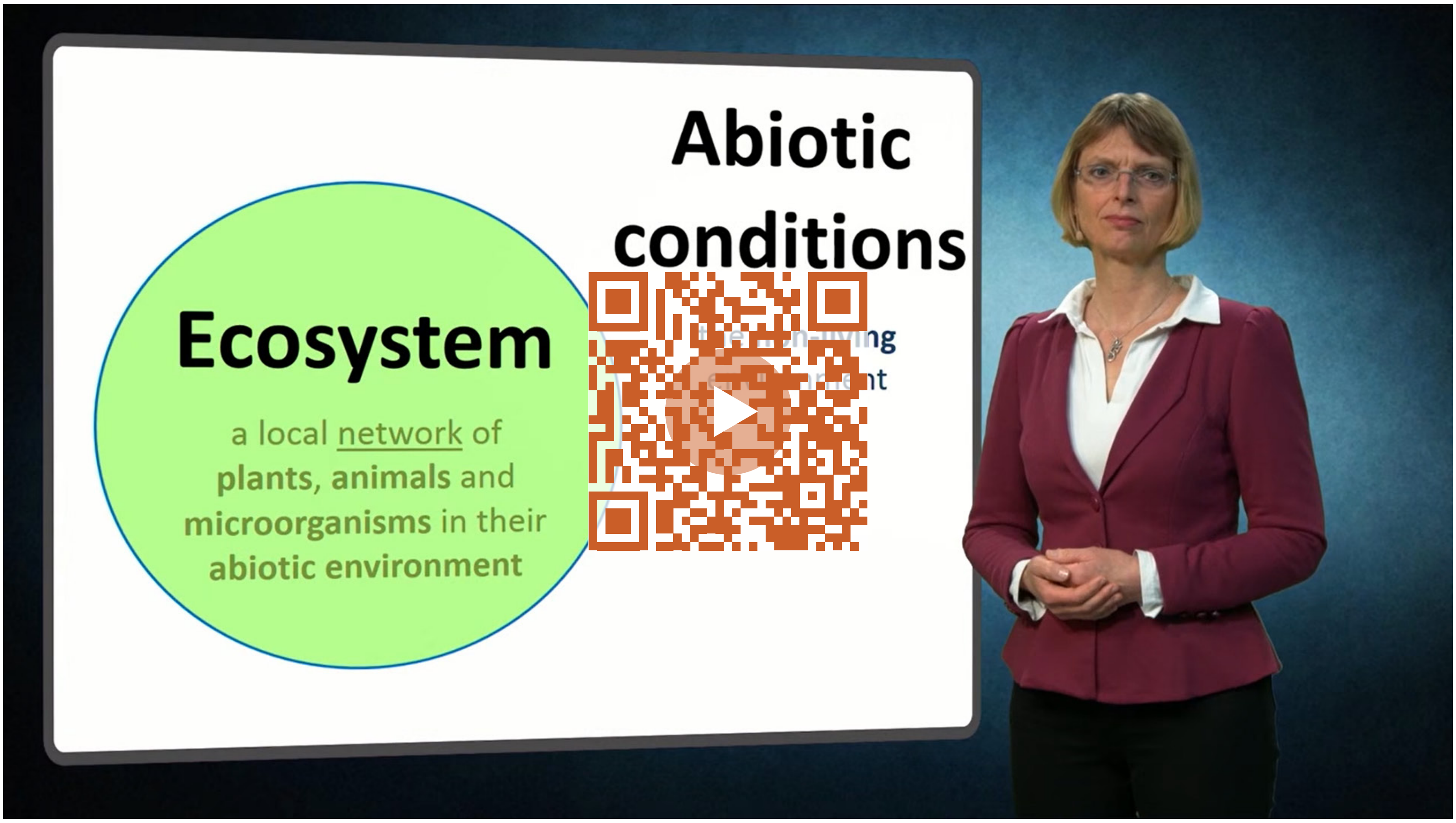
3.2 Understanding Ecosystems

Introduction

Just as you learnt about the character of hydraulic infrastructures - the principles that underpin their design - by first learning about their Form and Function, in this section you will also first learn about the Form and Functioning of wetlands and other water-related ecosystems.

This section contains 4 video's presented by Prof. Tinka Murk and Dr. Ronald Osinga from Wageningen University to explain important conditions and concepts for ecosystem development and health. Below each video you can test your knowledge using a small set of ungraded questions. Finally, we ask you to read and reflect on reading materials that explain the Form and Functioning of some wetlands and other water-related ecosystems.

After this you may move to the next section, where we will expound on Ecological Design Principles.

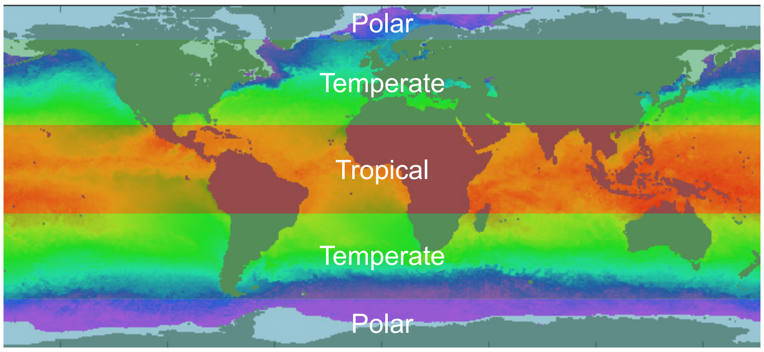


Video: Ecosystems: Abiotic Boundary Conditions

This section contains a video presented by **Prof. Tinka Murk** from Wageningen University. She is head of the Marine Animal Ecology research group and specialises in the adaptation of marine organisms to changes in their environment. In this video, she will explain which non-living (abiotic) conditions are important for the formation and health of an ecosystem.

You can cite this video as:

Murk, T. (Tinka), Osinga, R. (Roland), Marijt, M. (Michelle), Slinger, J.H. (Jill) (2019). Engineering: Building with Nature 101x. Ecosystems: Abiotic boundary conditions. **Adapted from:** van Wesenbeeck, B.K., Slinger, J.H. (2015). *Building with Nature video #07. Ecological processes in Building with Nature @ TU Delft: Part 2.* 4TU.ResearchData. http://doi.org/10.4121/UUID:A86B2F92-51FC-4F44-A36D-83E7DBBB9106



3-2. *Climate zones.* NASA

3-3. *Salinity zones in river mouth.* NASA

3-4. *Effect of wave exposure on ecosystem.*
Left: WUR. *Right:* *Смок Ваевльский*

Video Transcript

Presented by Prof. Tinka Murk

Before we can 'build with nature' it is important to understand key factors in the formation and functioning of ecosystems. An ecosystem is a local network of different organisms such as plants, animals and microorganisms that live in interaction with each other and with their non-living, abiotic environment. I will now discuss six abiotic factors that largely determine the abiotic boundary conditions for ecosystem development in coastal and riverine areas.

If we take a very large spatial scale, the first factor that determines ecosystem development is temperature. For example, most mangrove species do not tolerate temperatures below zero degrees Celsius and reef building corals can't tolerate water temperatures below 18 degrees Celsius. We can roughly distinguish three climatic zones, a polar zone, a temperate zone and a tropical zone, each zone having its own characteristic ecosystems. If we zoom in to a more detailed scale, the second main determinant of ecosystem type is salinity.

Ecologist distinguish the following salinity classes, namely fresh, brackish and salt water ecosystems. Each of these en-

vironments is inhabited by different species, dependent on their salinity tolerance. The salinity tolerance of some species is very narrow and for others, such as salmon or eel, it is very broad. Along coasts, river banks and lake shores a third determinant is wave exposure. Systems with limited wave exposure, so called sheltered systems, are dominated by fine sediments. The salt marsh is an examples of an ecosystem that requires a sheltered environment. In wave exposed areas, mostly sandy or rocky shores occur.

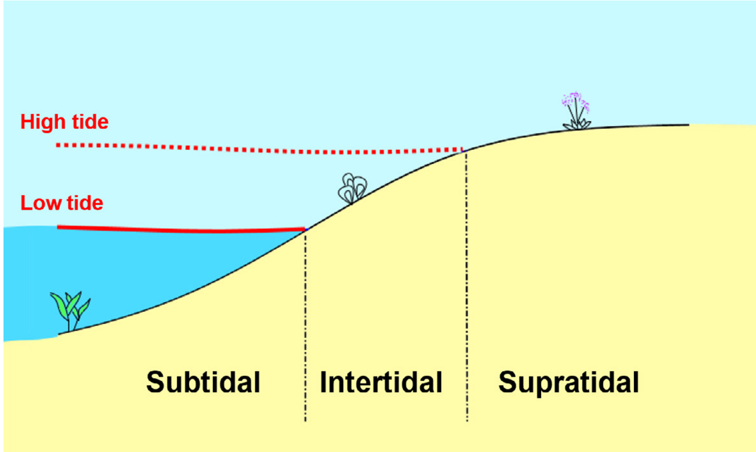
A fourth abiotic factor relevant to ecosystem development is submergence time. Submergence time is reflected in tidal zonation. The lower tidal area that is constantly submerged is termed 'subtidal'. Here we can find seagrasses and coral reefs. The upper area that is rarely submerged is called the 'supratidal' area. Here we can find species that can tolerate an occasional salty bath such as the purple sea lavender. The area in between is the intertidal. This area is air-exposed during low tides and submerged during high tides. Oysters and mussels, are able to live in this area as they can tightly close their shells to withstand low tide dryness.

The fifth important abiotic factor is light availability. This factor is a strong determinant of the formation of ecosystems, particularly in water. Corals and submerged plants such as seagrasses depend on light to perform photosynthesis. Light availability in water is correlated with water depth and turbidity. The amount of light absorbing materials in the water is turbidity. In clear and shallow waters, light availability is high, promoting the formation of coral reefs, seagrass beds and other types of submerged vegetation.

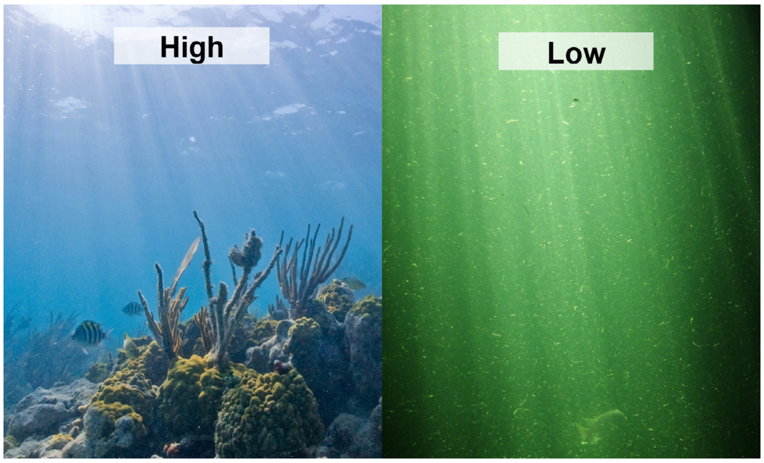
Finally, the sixth important abiotic factor is nutrient availability. Inorganic nutrients and minerals such as nitrogen, phosphorous and iron are necessary for the growth and survival of plants and phytoplankton. The amount of nutrients in the system can depend on the soil type, the upwelling of nutrient-rich deep waters, and river run-off. Systems with a high amount of nutrients are termed eutrophic, and systems with a low amount of nutrients are termed oligotrophic. These systems are usually associated with clear water.

We have distinguished six abiotic factors that determine the abiotic boundary conditions for ecosystem development in coastal and riverine areas: temperature, salinity, wave exposure, submergence time, light availability and nutrient availability. These factors can vary greatly over different seasons. In particular, temperature and the availability of light and nutrients can vary from summer to winter.

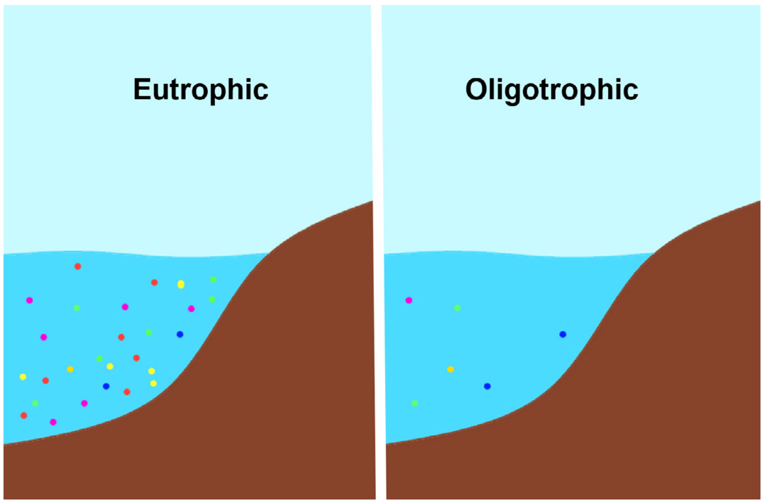
The six abiotic factors and their seasonal variations primarily determine which species are able to survive at a specific locality. So, they determine what type of ecosystem can develop. In practice, this means that not every ecosystem can be created everywhere, simply because we are not able to control all these abiotic factors. However, if abiotic conditions are suitable, we can use ecosystem functions for 'building with nature'. Oyster reefs and coral reefs for instance are effective in breaking waves. And sea grass beds, salt marshes and mangrove forests are very effective in protecting sediment against erosion. The appropriate ecosystems to consider in a building with nature design process will depend on both the abiotic boundary conditions and the desired functions of the ecosystems within your engineering design.



3-5. *Tidal zonation. WUR*



3-6. *Light availibility. Left: National Park Services. Right: Sarah KlockarsClauser*



3-7. *Nutrient availability. WUR*

3-8. *6 Abiotic conditions. © Reef: David Burdick. Dune: WUR. Mangrove: Ukik. Marsh: Смок Ваевльский*

Exercises

In this section you will find some questions to help you check your understanding of key concepts explained in the video.

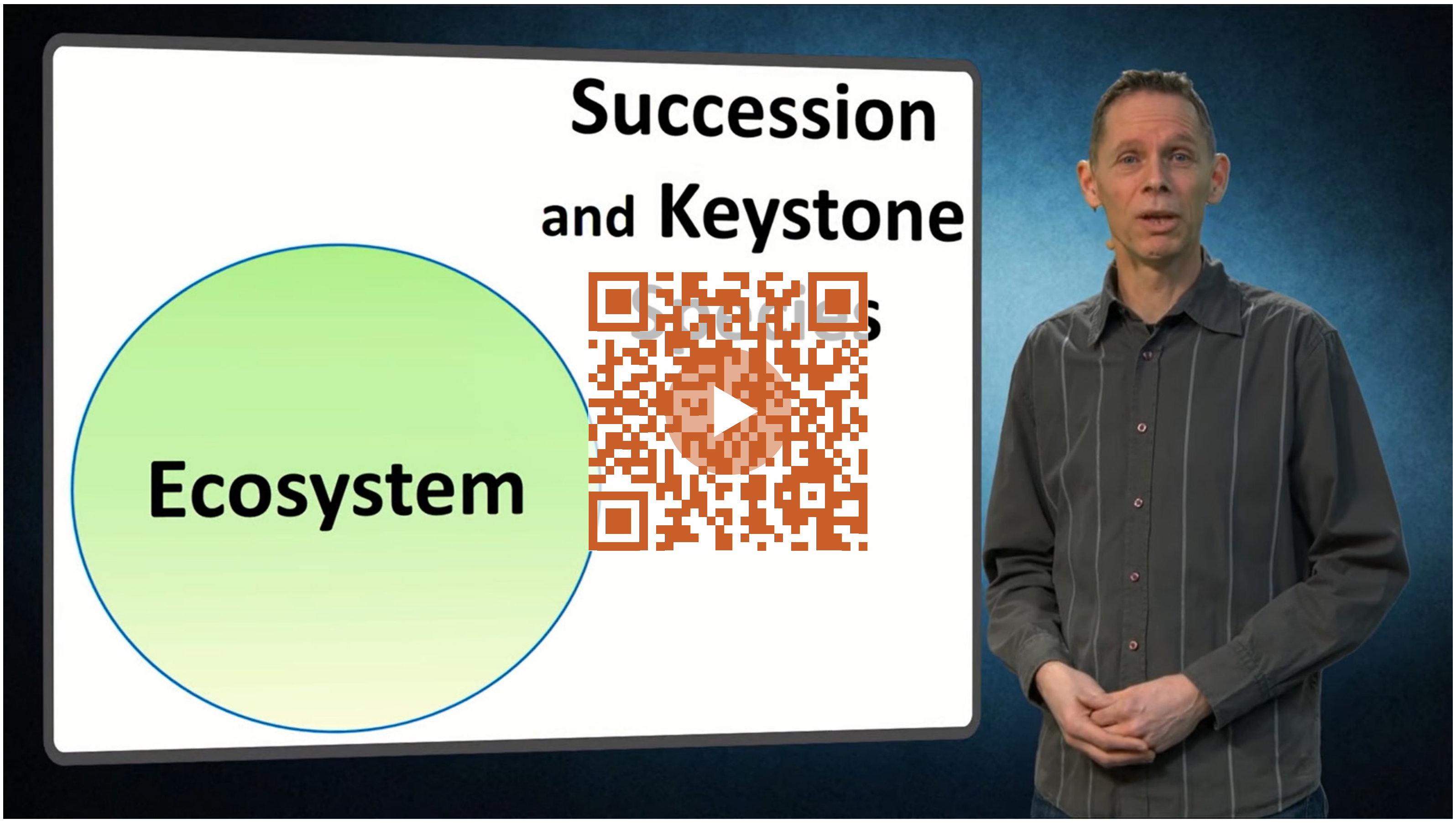
To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

Which of these variables are described as determining the type of ecosystem that can develop? (You may check more than one)

- ☐ Temperature
- ☐ Salinity
- ☐ Overfishing
- ☐ Size
- ☐ Nutrient availability

Show Answer



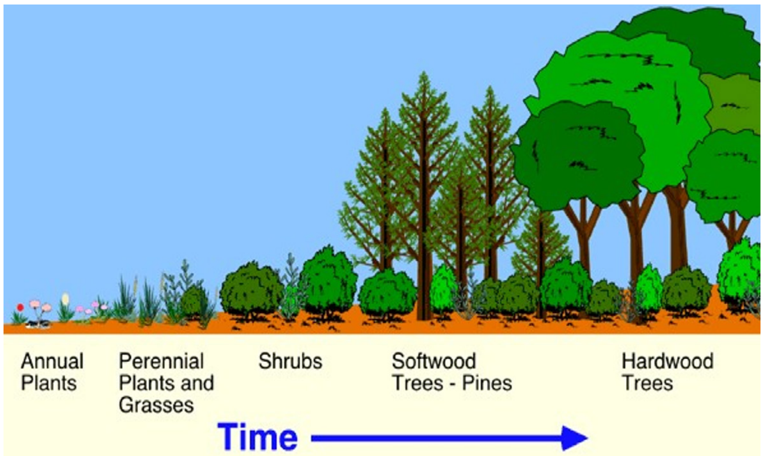
Video: Succession and Keystone Species

This section contains a video presented by **Dr. Ronald Osinga** from Wageningen University. He is a marine biologist, specialised in corals and sponges. He will explain how ecosystems are formed by biota (animals, plants and micro-organisms), introducing the ecological concepts of succession and zonation. He will also illustrate ecosystem maintenance using examples of keystone species and eco-engineers.

You can cite this video as:

Osinga, R. (Ronald), Murk, T. (Tinka), Marijt, M. (Michelle), Slinger, J.H. (Jill) (2019). Engineering: Building with Nature 101x. Succession and keystone species. **Adapted from**: van Wesenbeeck, B.K., Slinger, J.H. (2015). *Building with Nature video #07. Ecological processes in Building with Nature @ TU Delft: Part 2.* 4TU.ResearchData. http://doi.org/10.4121/UUID:A86B2F92-51FC-4F44-A36D-83E7DBBB9106

3-9. *Dune grass: pioneer species.* ⓒ *WUR*



3-10. *Species succession.* ⓒ *Bregje van Wesenbeeck*

3-11. *Pioneer species in low intertidal marsh.*
ⓒ *Left: Jürgen Howaldt. Right: OliBac*

Video Transcript

Presented by Dr. Ronald Osinga

Within abiotic boundary conditions, ecosystems are formed and maintained by biota, the living organisms. Every ecosystem is unique, as it contains its own specific combination of plants, animals and microorganisms that interact with each other.

Ecosystems form and evolve through succession. Succession refers to the sequence of, mostly, plant species that succeed each other as the ecosystem matures in situations where external conditions stay more or less the same. Ecological succession is started by pioneer species, these are species that are the first to colonise an area. Pioneer species generally are specialists that can survive harsh conditions.

The grasses that colonise beach areas to set off dune formation are good examples of pioneer species. Terrestrial pioneer plant species often are annual species. They ameliorate the environment so that other species, that are secondary in succession, can start establishing themselves, too. These secondary succession species are often perennial plants, such as herbs and small woody plants. They are followed by shrubs and the final stage of succession often contains trees.

The final stage of succession is generally called the climax stage. Animals depend on plants for food and habitat, therefore also animal species composition often changes with the succession process. Often, succession can be visible as zonation in ecosystems. We speak of succession zonation when the different stages of succession can be seen in spatially separated zones. For instance, succession zonation often occurs within temperate saltmarshes, from the intertidal flat towards the land.

The closest zone to the intertidal flat is called the pioneer zone and is inhabited by pioneer species such as English cord-grass and glasswort. Next to the pioneer zone comes the lower marsh zone, which is inhabited by secondary succession species. This is followed by a very diverse middle marsh, which contains a lot of different species and colourful flowers.

Most land inwards we find the high marsh, which is often dominated by grass species that form a rather homogeneous vegetation cover. This zone is only submerged a couple of times per year by really high tides. In the end the high marsh will naturally develop into land with herbaceous forest on it.

Here, a different ecosystem develops as it is no longer occasionally submerged under sea water. Zonation also often is visible on sandy and rocky shores where submersion time, salinity and temperature determine which plant and animal species are able to survive in that area.

An example is the barnacle that is able to withstand hours of exposure to air and heat at low tide, whereas other animals such as sponges need constant submersion. Ecosystems are not only formed, but also maintained by biota. Species that play a large role in functioning of the ecosystem are called the keystone species.

The keystone species are crucial for ecosystem functioning. Their effect on the ecosystem is often larger than one would expect based on their abundance. The term originates from architecture. In big arch constructions, there is a single stone in the middle that holds together the entire arch. If this stone is removed, the arch collapses.

Similarly, if keystone species are removed from an ecosystem due to for example a disease or overfishing, the ecosystem collapses and shifts towards a different type of ecosystem. Keystone species can fulfil a crucial role in the food web. They can be small predators or herbivores that prevent fast growing species to overwhelm the system. A good example are sea urchins on coral reefs. Fast growing macro-algae live on coral reefs; they can overgrow and smother coral.

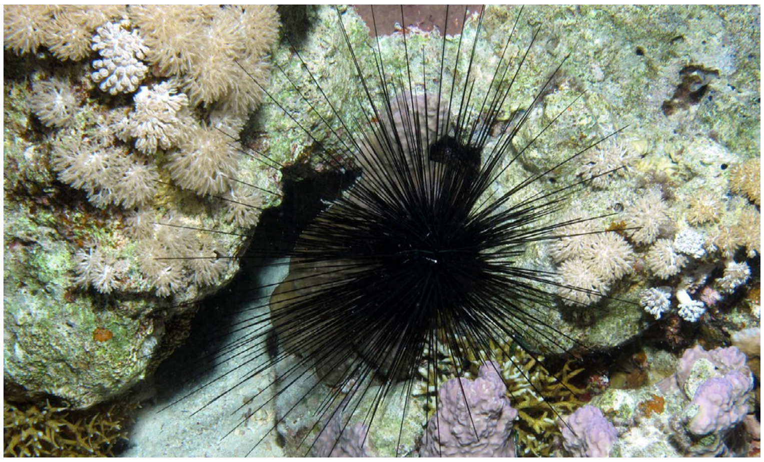
Fortunately sea urchins graze on these algae, thus keeping the coral clean and healthy. Due to mass mortality of sea urchins, algae became dominant on many reefs in the Caribbean, covering the corals, making it impossible for them to catch light and filter water.

Among the different ecosystems, various species can perform different keystone functions. Apart from keystone species for food web functions, we can also distinguish ecosystem engineers or eco-engineers. With this term, we are not

3-12. Species in middle and high intertidal marsh. ⓒ Samantha DeWitt

3-13. Zonation on rocky shores. Ⓟ Mark A. Wilson

3-14. Keystone in arch. ⓒ anoldent



3-15. *Keystone species in reefs: Sea urchin. © Derek Keats*

3-16. *Oysters: Ecosystem engineers. © NoSpicyFood*

referring to human engineers trying to use the building with nature technique.

We are referring to plant or animal species that can change the abiotic environment in such a way that it affects the conditions for many other species. Mangroves and oysters are good examples of this. The roots of mangroves create nursing grounds for fish species and habitat for other crustaceans and many other animal species.

Oysters filter the water and thereby have a large effect on water quality. Additionally, oyster reefs create structures that can reduce wave energy and alter sediment flow.

You have learned that ecosystems evolve through succession. When creating a Building with Nature design, be specifically aware of the roles of pioneer species, keystone species and ecosystem engineers as they are the creators and maintainers of a healthy ecosystem.

Exercises

In this section you will find two questions to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**.

Question 1

Keystone species are crucial to ecosystem functioning. If you remove them the ecosystem may collapse. This term is drawn from an analogy in the field of:

- ◯ Economics
- ◯ Architecture
- ◯ Mining
- ◯ Mathematics
- ◯ Pharmaceutics

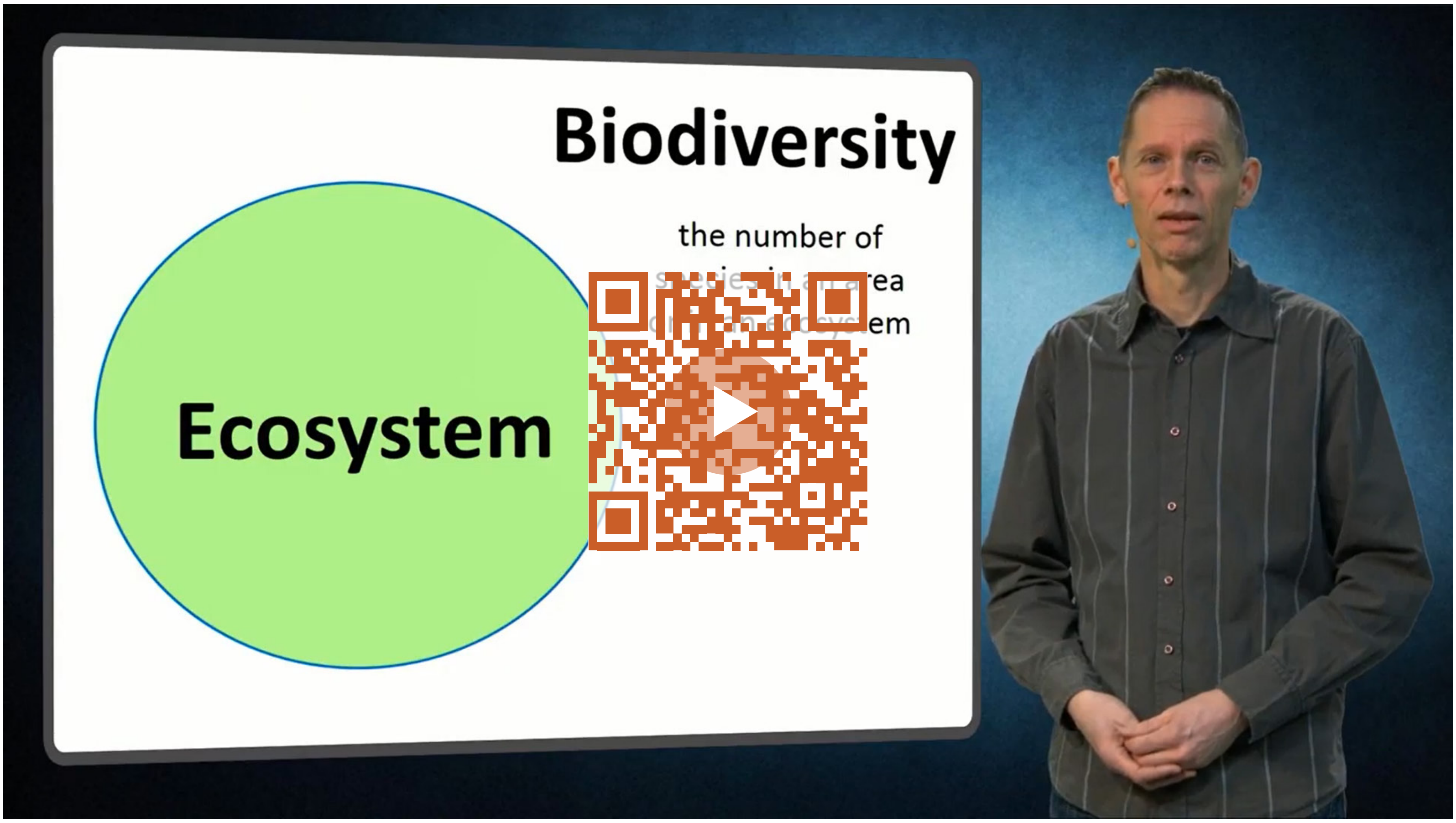
Show Answer

Question 2

The term pioneer species is mentioned in the video. Which of the following characteristics typify pioneer species? (You may check more than one)

- ☐ First to colonise
- ☐ Can tolerate harsh conditions
- ☐ Often are perennial plants such as herbs, or small woody plants
- ☐ Highly productive
- ☐ Comprise herbaceous forests

Show Answer



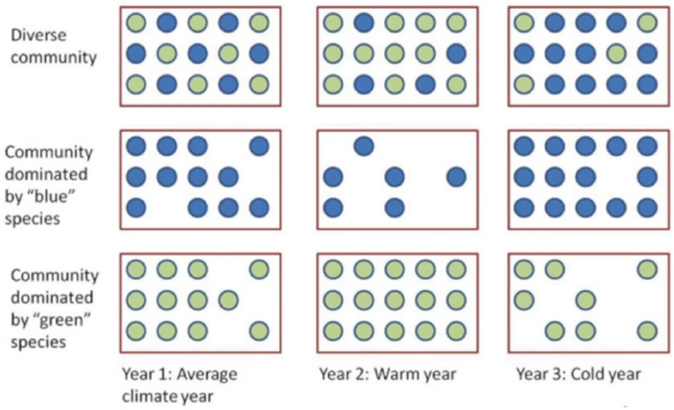
Video: Biodiversity

You have learned about the importance of certain species in the formation and maintenance of an ecosystem. In this section, **Dr. Ronald Osinga** will explore the implication of biodiversity (species diversity) for ecosystem stability, productivity and resilience.

You can cite this video as:

Osinga, R. (Ronald), Murk, T. (Tinka), Marijt, M. (Michelle), Slinger, J.H. (Jill) (2019). Engineering: Building with Nature 101x. Biodiversity. **Adapted from:** van Wesenbeeck, B.K., Slinger, J.H. (2015). *Building with Nature video #07. Ecological processes in Building with Nature @ TU Delft: Part 2.* 4TU.ResearchData. http://doi.org/10.4121/UUID:A86B2F92-51FC-4F44-A36D-83E7DBBB9106

3-17. *Biodiversity in a coral reef.* 🅭 *Wise Hok Wai Lum*



3-18. *Productivity and stability of ecosystems.* 🅭 *Bregje van Wesenbeeck*

3-19. *Las Tablas de Daimiel: Mixed species grassland.* 🅭 *untipografico*

3-20. *Non-resilient forest ecosystem.* 🅭 *Charles Knowles*

Video Transcript

Presented by Dr. Ronald Osinga

You have learned that plants, animals and microorganisms are able to form and maintain an ecosystem. It is therefore important to know which species are present in the area and what role they play within the ecosystem.

The number of species within an ecosystem is called Biodiversity. Biodiversity is one of the fundaments of ecology and of life. Species diversity is an essential element of ecosystem functioning. It generally enhances productivity of ecosystems and increases stability of ecosystems.

This can be illustrated by a simple example. Imagine, we have a grassland with two species: a blue and a green species. The blue species is more productive when it is colder and the green species is more productive when it is warmer. When the grassland only contains the blue species, the grassland will lose productivity under sub-optimal, warm, temperatures. However, in mixed grasslands, the other species can take over. In this way a grassland with two species with different traits has a more stable productivity.

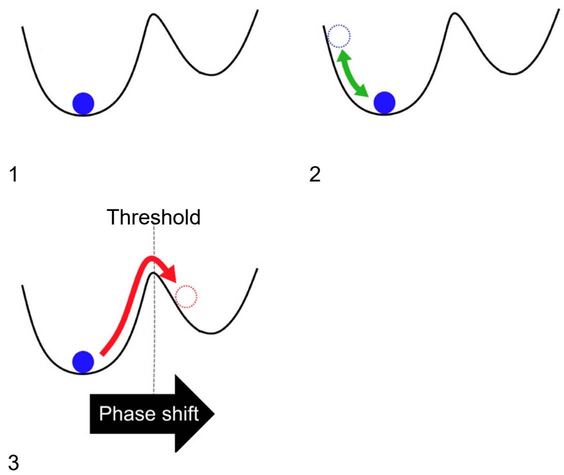
The system is also more resilient to temperature changes. Additionally, overall annual productivity of the mixed species grassland may be higher, as the growing season of both species may not completely overlap. This allows them to partly replace each other within a year. In this way the productivity and stability of this grassland increases. In addition, biodiversity is also considered to increase the resilience of ecosystems.

The term resilience refers to the capacity of an ecosystem to accommodate disturbances. It is easy to understand why biodiversity increases ecological resilience: a forest with only one single type of tree species is very vulnerable to diseases or to storms that can wipe out the whole forest. In a multiple-species forest, a disturbance will not affect all species in a similar way, increasing the survival chances of the forest.

A resilient ecosystem is able to bounce back to the original ecosystem state after a foreseeable disturbance. This ecological resilience can be envisaged as a ball in a bowl. With each disturbance the ball is pushed out of equilibrium, but will roll back to its original position. However, if this ball is pushed too hard, it will be pushed out of the bowl. In analogy, if the disturbance is too strong, the ecosystem cannot recover and will shift towards another state. This is also called a phase shift.

In the previous video, we have already discussed such a phase shift. When small herbivores were removed from a coral reef, the ecosystem shifted from a coral dominated system, to an algae dominated system. We have talked about productivity, stability and resilience of ecosystems in the light of biodiversity. However, ecosystems are never entirely constant. They adapt to perturbations and changes in conditions. Ecosystems are not engineering structures that are solid and stay in place. Dynamics form an intrinsic part of ecosystems and large disturbances of these dynamics could lead to a phase shift towards formation of a different ecosystem.

3-21. *Resilient forest ecosystem.*



3-22. *Excessive disturbance in ecosystems: Phase shift.*

Exercises

In this section you will find a questions to help you check your understanding of key concepts explained in the video.

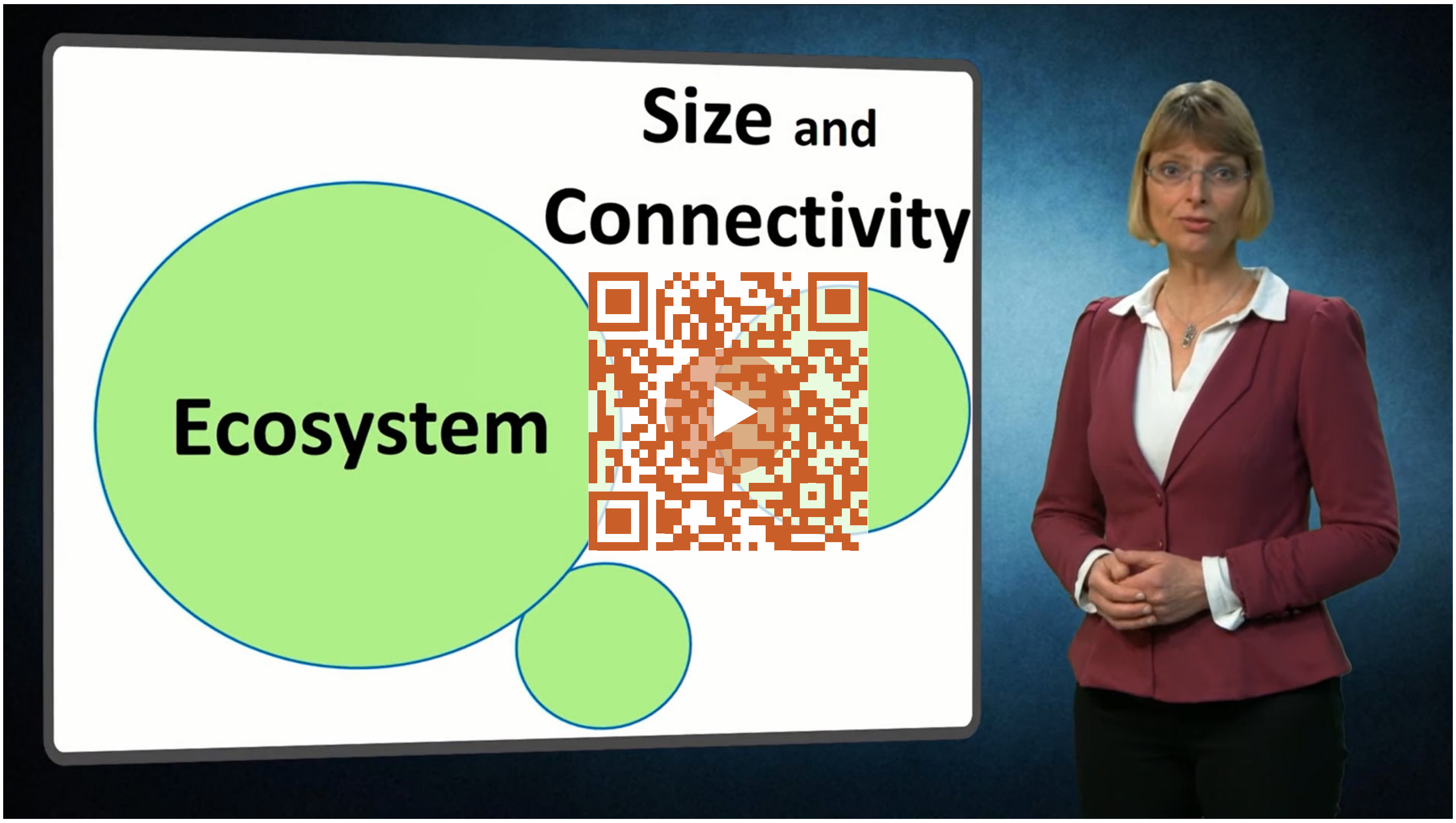
To check your answer click on the button **Show Answer**.

Question 1

Biodiversity refers to ecological diversity across different spatial and temporal scales. In the video, biodiversity is linked to a number of ecosystem properties. Check the ecosystem properties that are linked to biodiversity.

- [ ] Productivity
- [ ] Stability
- [ ] Conservation
- [ ] Resilience
- [ ] Food

Show Answer



Video: Ecosystem Size and Connectivity

In this video, **Prof. Tinka Murk** explains how ecosystem size and ecosystem connectivity influence the practice of Building with Nature. Using an example of mangrove restoration in Indonesia, she recaps on the ecosystem conditions and concepts underpinning this successful Building with Nature project. Finally, she highlights the potential benefits and stresses the importance of ecosystem knowledge in designing integrated Building with Nature solutions.

You can cite this video as:

Murk, T. (Tinka), Osinga, R. (Ronald), Marijt, M. (Michelle), Slinger, J.H. (Jill) (2019). Engineering: Building with Nature 101x. Size and connectivity. **Adapted from:** van Wesenbeeck, B.K., Slinger, J.H. (2015). *Building with Nature video #07. Ecological processes in Building with Nature @ TU Delft: Part 2.* 4TU.ResearchData. http://doi.org/10.4121/UUID:A86B2F92-51FC-4F44-A36D-83E7DBBB9106

Video Transcript

Presented by Prof. Tinka Murk

You have now learned about the abiotic conditions that set the boundaries for ecosystem development and biotic aspects that determine the formation and resilience of ecosystems.

Let us now relate this to coastal engineering design. Suppose wave attenuation and protection against erosion are ecosystem functions that you want to include in your design. The question is, how to create an ecosystem that is resilient and able to fulfil the desired functions?

A crucial consideration is the size of the desired ecosystem. Ecosystem size should be considered from an engineering perspective as well as from an ecological point of view. The ecosystem should be large enough to sufficiently attenuate wave action. In addition it must provide enough space for ecological succession and the formation of suitable habitats. This allows development of a stable and resilient ecosystem.

Related to ecosystem size is the principle of ecosystem connectivity. Ecosystems are often functionally related. For example, they need to be connected because of early life stages of animals. They develop in one ecosystem while adults of the species live in another.

A good example is the nursery function of seagrass beds, which is home to the juveniles of many coral fish species, such as the parrot fish. Without the presence of a healthy seagrass bed, coral reef fishes might not be present to maintain a healthy coral reef. Also, ecosystems need to be able to exchange genetic resources. This gene flow prevents inbreeding, thus contributes to healthy populations. Hence, if connected ecosystems become physically separated, or when the necessary connecting ecosystems are absent, the success of ecological engineering may be seriously compromised.

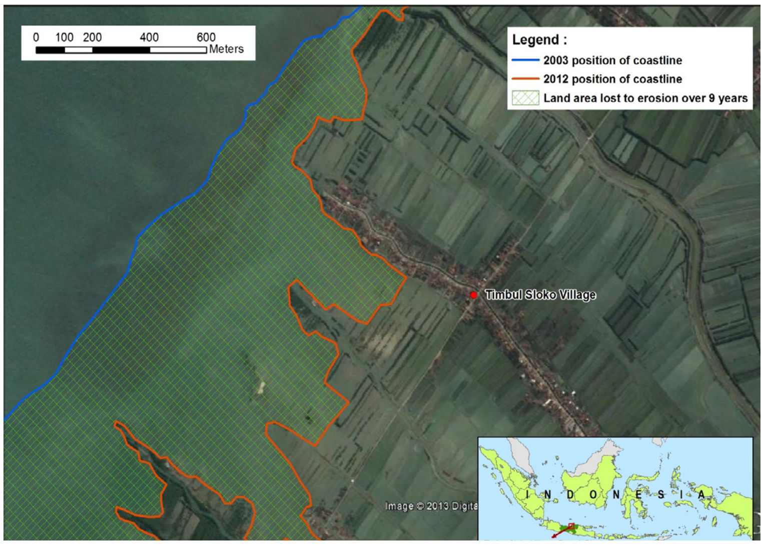
You now know what is important for ecosystem development and functioning. Once you have decided what system you want to develop, a first challenge is: how to kick-start the formation of the desired ecosystem?

Abiotic	**Biotic**
Temperature	Succession
Salinity	Zonation
Wave exposure	Keystone species
Submergence time	Eco-engineers
Light availability	Biodiversity • Productivity • Stability • Resilience
Nutrient availability	

3-23. Connected ecosystems. Ⓟ eismannhans

3-24. Parrot fish. 🅭 Rling / IdLoveOne

3-25. *Physical ecosystem separation.* © *Carlos Delgado*



3-26. *Timbulsloko coastline erosion 2003-2012.* © *Wetlands International*

3-27. *Semi-permeable structures.* © *Nanang Sujana*

3-28. *Mangrove trees.* © *syoclo*

3-29. *Aerial view of semi-permeable structures.* © *Prospek Empat Dimensi*

You can optimise abiotic conditions and let nature follow with pioneer species and subsequent natural succession. You can also actively introduce such pioneer species yourself. If you opt for the latter, which species should be used? Are the current abiotic and biotic conditions suitable for this species?

Let us consider the example of mangrove restoration in Indonesia. In some parts of Indonesia, mangroves were removed to make room for aquaculture ponds. The loss of mangroves, however, resulted in massive land erosion and total villages were forced to move inland. In addition, the important nursery function of mangroves for several fish species was lost.

To restore the mangrove system, it is not possible to simply plant mangroves, as the wave exposure, submersion time and sediment conditions in the eroded area are not optimal anymore. Planting mangroves is often not preferable. Especially if you do not plant the right mangrove species at the right location, this will impair natural mangrove formation and result in a fragile mangrove forest or no forest at all. In this project, temporary brushwood fences were placed to decrease wave energy and to trap finer sediments.

This creates suitable conditions for the establishment of natural pioneer mangrove species. This initiates mangrove ecosystem development through succession. Although challenging, using ecosystems instead of only traditional hydraulic engineering, offers additional benefits.

Examples are habitat creation for ecologically, economically or culturally important species, increased water quality by water filtering organisms and opportunities for recreation. The building with nature strategy can also be a solution to mitigate the possible impact of engineering projects.

This is especially important in or near areas with habitats protected by legislation, such as the Natura 2000 regulations in the European Union.

To summarise: whenever you are Building with Nature, it is crucial to consider the local conditions and opportunities, to understand the requirements for the targeted ecosystems, and to understand the services that can be provided by these ecosystems.

Exercises

In this section you will find a question to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**.

Question 1

You are designing a mangrove restoration project in Indonesia. A part of the natural mangrove forest was removed in the past. This has caused erosion of the coastline and has changed the sediment composition, wave exposure and submersion time at your study site. Now the environment is not suitable for pioneer mangrove species.

Purely from an ecological viewpoint, what is the best option for mangrove restoration? (Choose from the options in the next column)

- ◯ Do nothing and wait for natural establishment of pioneer mangrove species, followed by natural mangrove development through succession
- ◯ Actively plant different mangrove species at the eroded location
- ◯ Create a suitable environment for pioneer mangrove species (by the use of brushwood fences, for instance) and actively plant different pioneer species in the improved environment
- ◯ Create a suitable environment for pioneer mangrove species (by the use of brushwood fences, for instance) and wait for natural establishment of pioneer mangrove species, followed by natural mangrove development through succession

Show Answer

Reading Material: Form and Functioning of Wetlands

The Convention on Wetlands of International Importance, known as the Ramsar Convention (www.ramsar.org), is an intergovernmental treaty that provides the framework for conservation and use of wetlands and their resources. These ecosystems are land areas saturated with water either permanently or seasonally and inhabited by aquatic plants.

In this section, you will study how the Ramsar Convention classifies and describes the Form and Functioning of some wetlands and other water-related ecosystems. Although the RAMSAR classification system comprises more than 30 wetland types, we present you with a selection of these types as an introduction to the topic.

Please note that additional resources are available in the next section. You can use them to learn about the remaining types, and you can consult different classifications.

Marine, Coastal Wetlands

Wetland form	Wetland functioning

Permanent shallow marine waters

3-30. *Dolphins in shallow water.* © *fourteam*

- In most cases less than six metres deep at low tide
- Typically close to estuaries.
- Sea grass often covers these ecosystems.
- Habitats and nursing sites for (keystone) species.
- Highly biologically productive ecosystems.
- Trapping of sediments and stabilisation of shorelines.
- Grass that is severed and carried by the water column forms driftbeds, mats that float near the surface and provide food andshelter for young fishes and nutrients for invertebrates,shorebirds and other organisms.

Sand, shingle or pebble shores

3-31. *Sand shore with dunes.* © *Martijn Vos*

- Includes sand bars, spits, sandy islets, dune systems and humiddune slacks.
- Highly biologically productive ecosystems.
- Habitats and nursing sites for (keystone) species.
- Dunes occur in the inland of the intertidal zone, but commonly in conjunction with beaches and sandy shores.

  - Highly dynamic and mobile.

3-32. *Pebble shore.* © *Bingo_UK*

  - Act as sediment reserves
  - Stabilise coastlines and prevent erosion
  - Provide areas for recreation
  - Support high species diversity

Estuarine waters

3-33. *Estuarine waters, UK.* © *Shaun Ferguson*

- Includes permanent water of estuaries and estuarine systems of deltas.
- Variation of salinity within the brackish water, produced by the meeting of freshwater from the mainland and salt water from oceans.
- Critical to marine systems.
- Permanently or periodically open to the sea.
- Filtering of water pollutants.
- Habitats and nursing sites for (keystone) species.
- Highly biologically productive ecosystems.
- Transition zone between river and sea

Wetland Form	Wetland Functioning
Intertidal mud, sand or salt flats  *3-34. Intertidal mud flat.*	• Pivotal for ocean ecology. • Highly productive and diverse ecosystems. • Critical habitats for benthic organisms and (migrating) shorebirds.
Intertidal marshes  *3-35. Intertidal marsh in the UK. Ⓒ Peter Facey*	• Includes salt marshes, raised salt marshes, tidal brackish and freshwater marshes. • Variation of salinity within the brackish water, produced by the meeting of freshwater from the mainland and salt water from oceans. • Critical to marine systems. • Permanently or periodically exposed to seawater. • Often extensions of bigger estuaries. • Exhibit strong zonation • Filtering of water pollutants. • Habitats and nursing sites for (keystone) species. • Highly biologically productive ecosystems.
Intertidal forested wetlands  *3-36. Mangrove Forest. Ⓒ sarangib*	• Includes mangrove swamps. • Found in intertidal zones and estuarine margins in tropical and sub-tropical regions. • Adapted to brackish water. • Filtering of water pollutants. • Habitats and nursing sites for (keystone) species. • Highly biologically productive ecosystems. • Protect adjacent ecosystems against erosion

Inland Wetlands

Wetland form	Wetland Functioning
Permanent rivers, streams or creeks  *3-37. River in Patagonia, Chile. ⓪ falco*	• Includes waterfalls. • Often connected to other surface water or groundwater. • Resting and breeding areas for migratory waterfowl, birds, and fish. • Saturated with water most of the time.
Seasonal, intermittent or irregular rivers, streams or creeks.  *3-38. Creek in Austria. ⓪ Hans*	• Often connected to other surface water or groundwater. • Resting and breeding areas for migratory waterfowl, birds, and fish. • Saturated with water only during certain seasons. • Highly dependent on rainfall
Freshwater, tree dominated wetlands  *3-39. Tree dominated wetland in Louisiana, USA. ⓪ bobmann*	• Includes seasonally flooded forests. • Bind the soil of banks and protect them from erosion. • Trap sediments from floodwaters. • Habitats and nursing sites for (keystone) species. • Often connected to other surface water or groundwater. • Resting and breeding areas for migratory waterfowl, birds, and fish. • Rich in woody vegetation

Human-Made Wetlands

Wetland Form	**Wetland Functioning**

Aquaculture ponds

3-40. Shrimp aquaculture pond. ⓔ NOAA

- Includes ponds for fish and shrimp production.
- Provide resting and feeding areas for migratory waterfowl and birds.
- May be nutrient-enriched.
- Salinity and temperature values may fall outside of the ranges exhibited by naturally occurring wetlands.

Ponds

3-41. Pond in front of barn. ⓪ HaloJim

- Includes farm ponds, stock ponds and small tanks.
- Provide biotope for fish
- Provide resting and feeding areas for migratory waterfowl and birds

Salt exploitation sites

3-42. Salt pans in Lanzarote, Canary Isl. ⓪ Barni1

- Includes saltpans and salines.
- Salinity and temperature values may fall outside of the ranges exhibited by naturally occurring wetlands.
- Provide niche habitats for salt-tolerant species; e.g. flamingos

Water storage areas

3-43. Wolwedans dam. ⓒ Louis / Alida van der Walt

- Includes reservoirs, barrages, dams and impoundments, generally over 8 hectares.
- Provide habitat for fish.
- Hypoxic or even anoxic sediments and water can occur at depth within a reservoir.
- Temperatures in the water body can fall outside of the ranges exhibited by naturally occurring pools or lakes.

Additional Resources

In this section you can find additional resources on wetland ecosystems. You can also consult classifications other than the one presented in the course.

Types of Wetlands

Wetlands and coral reefs by RAMSAR

Global wetlands outlook by RAMSAR

Wetlands by Wetland International

World's wetlands disappearing by WWF

Definitions and classifications in USA

Decision tools

Coastal management decision tools

TEEB for water and wetlands

Wetlands education

Living Shores

Additional Resources: Ecosystem services

The video above, presented by **Dr. Martin Baptist** and written by **Martin Baptist** and **Jill Slinger**, he introduces the concept of ecosystem services. You can also learn more about the concept by going to this website. You can view the video by clicking the play button or scanning the QR Code. Since this video is additional material, no transcript is provided in the book.

You can cite this video as:

Baptist, M. (Martin), Slinger, J.H. (Jill) (2015). *Building with Nature video #09 - Ecosystem services in Building with Nature @ TU Delft 2015.* 4TU.Dataset. http://dx.doi.org/10.4121/uuid:0f7ad0ca-9437-4e0e-a801-5a83994a935c

You can also watch the following video by CVF about the Millenium Ecosystem Assessment for additional information on the topic.

Millenium Ecosystem Assessment

3.3 Ecological Design Principles

Introduction

- *What does nature-friendly design mean?*
- *What are the principles upon which it is based?*
- *How do you include ecosystem-based thinking in your hydraulic engineering design practice?*

Answering these questions enables a multi-disciplinary negotiation space to emerge between ecology, environmental science and engineering design. In this section you will find a video from Prof. Jill Slinger, expounding a set of Ecological Design Principles (E-principles) to be considered in any Building with Nature solution.

After the video, you can view a summary of the Ecological Design Principles (E-principles). By applying these principles fully across multiple time and spatial scales, you can ensure that the inherent character and functional integrity of the ecosystem is maintained. Remember, we are not focusing on the potential impacts of the infrastructure on the environment, nor are we evaluating the goods and services deriving to humans from an ecosystem. Instead, we are learning how to make design choices that accord more fully with the character and functional integrity of the ecosystem.

If you apply the Ecological Design Principles (E-principles) along with the Engineering Design Principles (H-principles), you connect your hydraulic engineering design choices with choices to conserve, restore or provide opportunities for the ecosystem.

That is, you practise Building with Nature!

3-118

Video: Distilling Ecological Design Principles

This section contains a video presented by **Prof. Jill Slinger** and written by **Jill Slinger** and **Graciela del Carmen Nava Guerrero**. She will distill Ecological Design Principles.

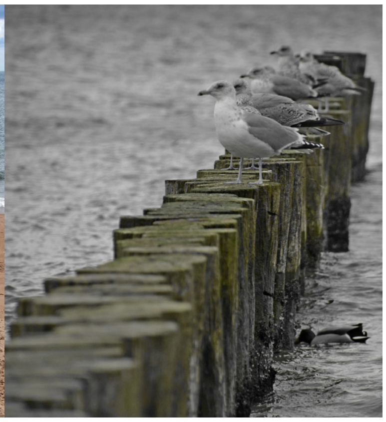
You can cite this video as:

Slinger, J.H. (Jill); Nava Guerrero, G.d.C. (Graciela) (2016). *Engineering: Building with Nature 101x video #08 – Distilling Ecological Design Principles*. 4TU.Dataset. http://dx.doi.org/10.4121/uuid:20576f6c-e439-4a79-abc4-ad13742c7b48

3-44. Ecological Design Principles? © Martijn Vos and Jill Slinger

3-45. Interruption of continuity. © Alex Rotlex

3-46. Closed groyne. © Alan Reid



3-47. Open groyne. © Lekies

Video Transcript

Presented by Prof. Jill Slinger

What does nature-friendly design mean? And what are the principles upon which it is based? How do you include ecosystem-based thinking in your hydraulic engineering design practice? I searched for an answer to these questions, because they enable the connection between ecology, environmental science and engineering design.

In this video, I am going to distil ecological design principles as counterpoints for the engineering design principles. These principles will enable you to make the connection between hydraulic engineering design choices, and choices to conserve, restore or provide opportunities for the ecosystem. That is, Build with Nature!

Remember, we are not discussing the potential impacts of the infrastructure on the environment, nor are we evaluating the goods and services deriving to humans from an ecosystem. Instead we are looking from the outset from an ecological perspective how we can make design choices that accord more fully with the character and functional integrity of the ecosystem.

But, what do I mean by the character and functional integrity of the ecosystem? Let me explain each of the eleven ecological principles. If each of these principles are applied fully across multiple time and space scales, the inherent character and functional integrity of the ecosystem should be maintained.

First, the principle of Continuity. This relates to the continuity of water and sediment flows and land-water interfaces in the ecosystem. An ecosystem could be well connected or very fragmented. For instance, dams can interrupt the continuum of a river, and alter the quantity of water and sediments available in the downstream river. Or, coastal defences such as closed groynes can interrupt the longshore transport of sediments, whereas an open groyne system continues to allow sediment transport.

Second, the principle of No direct human disturbance. This aims to minimise or prevent direct human disturbance on the ecosystem. Where direct disturbance is allowed, the health of the ecosystem may be affected.

The third principle of endogeneity relates to the level of invasion of an ecosystem by exotic species. A high level of indigenous species is preferred above invasive colonisation. For example, the Zebra mussel is an invasive species in European and North American waters. Invasive species can limit the survival opportunities of native species. So, a hydraulic structure or its associated activities should not advantage invasive species above indigenous species.

Fourth, the principle of Viability of Populations. A species is viable when it has the ability to persist. That is, its size exceeds a critical threshold. When its size is below the threshold, the population might face extinction. An infrastructure should not threaten the ability of populations to persist, but instead should provide opportunities for endangered populations and particular species.

This brings us to **the fifth principle of providing Opportunity for Threatened Species**. Because the ability of threatened species to thrive is compromised, particular attention can be paid to creating opportunities for their survival and restoration. Hydraulic infrastructures can help by offering, rather than denying, new habitats, restoring connectivity and improving circulation, for instance.

Sixth, the principle of Trophic Web Integrity. Ecosystems are complex networks in which matter, energy and living beings interact.A fully representative trophic web has all levels and all species interacting in a healthy way. When critical species, also known as keystone species, are missing the integrity of the trophic web is harmed and the ecosystem is no longer healthy. For example, when urchins are missing from a coral reef environment, algae take over and smother the coral.

The seventh principle is Opportunity for Ecological Succession. Ecological succession is the natural change in species present in an ecosystem over time. For instance, pioneer plant species that grow on a newly forming dune are later replaced by secondary vegetation as the dune becomes more stable. Finally, the ecosystem achieves its climax state when tertiary vegetation such as woodland is fully established. According to this principle, opportunities for the process of dynamic change should be ongoing and need to be offered for each and every stage from pioneer to climax.

3-48. Invasive species: Zebra mussel in Europe and North America. © F Lamiot

3-49. Critical for coral reef environments: sea urchins. © raving666

3-50. Pioneer plants species in a dune environment. ©

3-51. Estuarine salt marsh on Texel, The Netherlands. ⓒ Rasbak

3-52. Overgrown dunes limiting sand movement. ⓒ Yinan Chen

The eighth principle of Zone integrity aims to ensure that the natural mosaic of the ecosystem is fully represented. For instance, an estuarine salt marsh is characterised by a continuum from submerged mud flat to the upland zone that is only occasionally inundated.The presence of the full range of zonal diversity is a condition for ecosystem health. When one or more zones are missing, the integrity of the ecosystem is compromised.

Ninth, the principle of Characteristic (in)organic Cycles relates to the integrity of the throughputs of carbon, nitrogen, phosphorous and silicon in an ecosystem. Inorganic and organic cycles that are fully representative, function at all levels within their natural ranges, acting to support and enable ecosystem character and functioning. When the throughputs are disrupted or pushed outside their natural ranges, the character and functioning of the ecosystem can alter. For instance, when dunes receive an excessive supply of nitrogen via air pollution, tertiary dune vegetation growth is over-stimulated and the natural dynamic movement of sand is limited.

The tenth principle of Characteristic physical-chemical water quality aims to ensure that the natural distribution of water quality states is maintained over time and space. When

3-53. Algal bloom. ⓒ Shijan Kaakkara

water quality parameters are within their dynamic natural ranges, ecosystem functions are supported. Otherwise, atypical events can be triggered. For example, when oxygen levels become depleted, algal blooms and even fish kills can occur.

The last principle is that of Resilience. Resilience is the capacity of the ecosystem to maintain its integrity following consecutive disturbances. So, an ecosystem is resilient when it is able to withstand and even benefit from reasonable, foreseeable disturbances. An ecosystem is vulnerable when its character and functional integrity will alter after single disturbances.

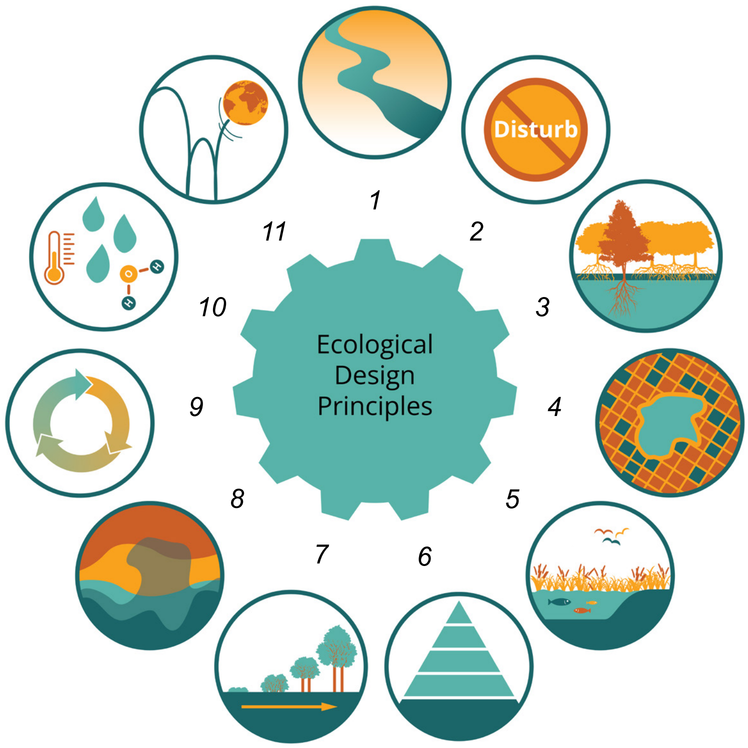
To recap, there are 11 ecological design principles:

1. Continuity
2. No direct human disturbance
3. Endogeneity
4. Population viability
5. Opportunity for threatened species

6. Trophic web integrity
7. Opportunity for ecological succession
8. Zone integrity
9. Characteristic (in)organic cycles
10. Characteristic physical-chemical water quality
11. Resilience

Now that you have learned about ecological design principles - for the non-environmental scientists amongst you – did you notice that it's all about conserving and restoring the dynamics of ecological networks and landscapes over time and space! And, for the environmental scientists - you may not have re-alised that engineers can help in this endeavour. Engineers can learn to design for healthy and functional ecosystems. They can apply these ecological design principles to deliver nature-friendly design!

Thank you for your attention.



3-54. *Eleven Ecological Design Principles.* © *Martijn Vos and Jill Slinger*

Reading Material: Ecological Design Principles

In the table starting on the next page you can find a summary of the Ecological Design Principles that were presented in the video. The contributions of Graciela del Carmen Nava Guerrero and Michelle Marijt are acknowledged.

Continuity of water and sediment flows and land-water interfaces in the ecosystem. An ecosystem can be well connected or very fragmented. A connected ecosystem allows the exchange of both living and non-living resources.

1. Continuity

For instance, dams can interrupt the continuum of a river, and alter the quantity of water and sediments available in the downstream river. This can also impair the migration of fish species such as salmon and trout. Populations of salmon can only thrive when they have access to both fresh and salt water habitats.

In another example, coastal defences such as closed groynes can interrupt the longshore transport of sediments, whereas an open groyne system continues to allow some sediment transport.

Vold and Buffett (2008)
Freeman (1987)
Sheaves (2009)
Bélisle (2005)

2. No direct human disturbance

This aims to minimise or prevent direct human disturbance on the ecosystem.

Where direct disturbance occurs, the health of the ecosystem may be affected. For instance, when dunes are forming, it is important that colonising pioneer plants are not stepped upon and damaged.

Vold and Buffett (2008)
Lotze et al. (2006)
Hannah, Lohse, Hutchinson, Carr, & Lankerani, 1994

3. Endogeneity

Level of invasion of an ecosystem by exotic species, as reflected by the relative abundance of indigenous and invasive species. A high number of indigenous species, that belong in the local environment, is preferred above invasive colonisation. Invasive species can limit the survival opportunities of native species. Therefore, a hydraulic structure or its associated activities should preferably not advantage invasive species above indigenous species. For example, the Zebra mussel is an invasive species in European and North American waters.

Also, in restoring mangroves areas indigenous mangrove species are preferred above non-indigenous species. This has two main reasons; (1) the survival rates of non-indigenous species might differ significantly, and (2) the introduction of non-indigenous species can lead to unwanted 'invasion' of the original ecosystems.

Vold and Buffett (2008)
Lotze et al. (2006)
Alpert, Bone, and Holzapfel (2000)
Suarez, Bolger, and Case (1998)
Gordon (1998)
D'Antonio and Meyerson (2002)
Stohlgren et al. (1999)

4. Population viability

A population is a local, connected group of individuals of the same species that inhabits a specific area. A population is considered viable when it has the ability to persist. The viability of a population is determined by reproduction, growth and death rates and population size. The population size must exceed a critical threshold to be viable. When its size falls below the critical threshold, the population may face extinction owing to a lower reproduction rate (and slow growth rate) in relation to the death rate.

An infrastructure should not threaten the ability of populations to persist, but instead should provide opportunities for endangered populations.

Vold and Buffett (2008)
Boyce (1992)
Akçakaya and Sjögren-Gulve (2000)

5. Opportunity for threatened species

Threatened species are species specifically identified (on the IUCN-red list, for example) as those whose ability to maintain viable populations is compromised. This can be due to habitat loss. Hydraulic infrastructures can help threatened species by offering new habitats, restoring connectivity and improving circulation, for instance.

This criterion focuses specifically on species whose survival is known to be threatened and not on ensuring the viability of the population of all species in a particular location i.e. criterion 4.

Cullen, Fairburn, and Hughey (2001)
Wearn, Reuman, and Ewers (2012)
Possingham, Lindenmayer, and Norton (1993)
Foin et al. (1998)

6. Trophic web integrity

Ecosystems are complex networks in which matter, energy and living beings interact. A fully representative trophic web (food web) exhibits interactions between producers (plants and phytoplankton), consumers (e.g. birds, fish and clams) and decomposers (micro-organisms and insects) that maintain the energy flow within the system.

When critical species, also known as keystone species, are missing the integrity of the trophic web is harmed and the ecosystem is no longer healthy. For example, when herbivores (plant eating organisms) are missing from a coral reef environment, algae take over and smother the coral.

Vold and Buffett (2008)
Mengak, Rutledge, and McDonald (2009)
Kay and Schneider (1992)
Karr (1981)
Pusceddu, Gambi, Manini, and Danovaro (2007)

Ecological Design Principles

7. Opportunities for ecological succession

Ecological succession is the natural change in the species composition of an ecosystem over time. Succession occurs when organisms alter the environment in such a way that they create habitats for other species. For instance, pioneer plant species that grow on a newly forming dune facilitate habitat formation for secondary vegetation as the dune becomes more stable. The ecosystem achieves its climax state when tertiary vegetation such as woodland is fully established.

According to this principle, opportunities for the process of dynamic change should be ongoing and need to be offered for each and every stage from pioneer to climax.

Vold and Buffett (2008)
Sousa (1979)
Sklar, Costanza, and Day (1985)
Ashkannejhad and Horton (2006)
Doing (1985)
Mitsch, Zhang, Anderson, Altor, and Hernández (2005)

8. Zone integrity

Zone integrity aims to ensure that the natural mosaic of the ecosystem is fully represented. The presence of the full range of zonal diversity is a condition for ecosystem health. When one or more zones are missing, the integrity of the ecosystem is compromised.

For instance, an estuarine salt marsh is characterised by a continuum from submerged mud flat to the upland zone that is only occasionally inundated. A missing or underrepresented zone signals an imbalance in the ecosystem, possibly in response to atypical abiotic forcing or habitat disturbance.

Doing (1985)

9. Characteristic (in) organic cycles

This principle relates to the integrity of the throughputs of carbon, nitrogen, phosphorous and silicon in an ecosystem. Inorganic and organic cycles that are fully representative and that function at all levels within their natural ranges, act to support and enable ecosystem character and functioning. When the throughputs are disrupted or pushed outside their natural ranges, the character and functioning of the ecosystem can alter.

For instance, when dunes receive an excessive supply of nitrogen via air pollution, tertiary dune vegetation growth is overstimulated and the natural dynamic movement of sand is limited.

Lotze et al. (2006)
Karr and Dudley (1981)
Mengak et al. (2009)
Rabouille, Mackenzie, and
Ver (2001)

Ecological Design Principles

10. Characteristic physical-chemical water quality

Water quality parameters such as temperature, salinity and dissolved oxygen strongly influence aquatic ecosystem functioning. This principle aims to maintain the water quality states within their natural range of variability over time and space. When water quality parameters are within their dynamic natural ranges, ecosystem functions are supported. Otherwise, harmful atypical events can be triggered.

For example, when water exchange is limited, hypoxic (low levels of dissolved oxygen) or anoxic (no dissolved oxygen) areas can develop. In the ocean, areas in which the dissolved oxygen levels are not sufficient for the crabs, clams and fish to survive are termed “dead zones”.

Lotze et al. (2006)
Karr and Dudley (1981)

11. Resilience

Resilience is the capacity of the ecosystem to recover and maintain its integrity after disturbance(s). Therefore, an ecosystem is resilient when it is able to withstand and even benefit from reasonable, foreseeable disturbances. The effects of disturbances depend on their duration, magnitude and frequency of occurrence. An ecosystem is considered vulnerable when its character and functional integrity will already alter after small disturbances. Vulnerable ecosystems have a low resilience.

Vold and Buffett (2008)
Holling (1973)
Peterson, Allen, and Holling (1998)
Gunderson (2000)

As ecosystems are networks in which matter, energy and living beings interact, the 11 Ecological Design Principles can never be fully independent of one another. For instance, limiting human disturbance (principle 2) can improve opportunities for ecological succession (principle 7), and improving the population viability (principle 4) of a keystone species can have effects on the trophic web integrity (principle 6). In a similar vein, ensuring that characteristic (in)organic cycles (principle 9) are maintained can assist in ensuring that dissolved oxygen levels remain within their naturally occurring ranges, and so ensure characteristic physical-chemical water quality (principle 10).

By applying the 11 Ecological Design Principles fully across multiple time and scales, however, you can connect your hydraulic engineering design choices with choices to conserve, restore or provide opportunities for the ecosystem.

3.4 Assignment 3.1

Introduction

This exercise consists of 12 questions, divided into three blocks. Block 1 will test your knowledge of the *Form* of a wetland ecosystem. Block 2 will deal with their *Functioning*. Finally, Block 3 will deal with the coherence between the hydraulic infrastructure and the ecological *Character* of the wetland ecosystem.

If you are an ecologist or if you are familiar with wetland ecosystems, you should find this assignment relatively easy and you might even be willing to answer some of the questions of non-ecologist peers. However, the objective of this assignment is to allow all course participants to explore Ecological Design even if they do not have an ecological background. Multiple attempts at the assignment are permitted.

Developing an understanding of Ecological Design Principles (E-principles) will allow us to connect to the Engineering Design Principles (H-principles). Therefore, the logic underlying this assignment mirrors that of Chapter 2, when we explored Engineering Design Principles using the same framing of Form, Function and Character.

For each image on the next pages you will be presented with a question. After answering each question in the block, move to the next block of questions until you've finished all three.

Assignment 3.1 Block 1: Form

Next to each image you will find a multiple choice question. Select the name of the wetland ecosystem in the image from the options provided. After you have answered the four questions, move on to the next page where you'll find the second block of questions.

To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

In the image on the side, what is the name of the wetland ecosystem?

- ◯ Freshwater, tree dominated wetland
- ◯ Salt exploitation site
- ◯ Intertidal marsh
- ◯ Intermittent river
- ◯ Intertidal forested wetland

Show Answer

3-55. Question 3.1.1.1. © bobmann

Question 2

In the image on the side, what is the name of the wetland ecosystem?

- ◯ Freshwater, tree dominated wetland
- ◯ Salt exploitation site
- ◯ Intertidal marsh
- ◯ Sandy shore
- ◯ Pebble shore

Show Answer

3-56. Question 3.1.1.2. © Martijn Vos

Question 3

In the image on the side, what is the name of the wetland ecosystem?

- Freshwater, tree dominated wetland
- Salt exploitation site
- Intertidal marsh
- Intertidal mud
- Intertidal forested wetland

Show Answer

3-57. *Question 3.1.1.3.* ⓪

Question 4

In the image on the side, what is the name of the wetland ecosystem?

- Freshwater, tree dominated wetland
- Intertidal marsh
- Estuarine waters
- Intertidal mud
- Intertidal forested wetland

Show Answer

3-58. *Question 3.1.1.4.* *Vladimír Šiman*

Question 5

In the image on the side, what is the name of the wetland ecosystem?

- Freshwater, tree dominated wetland
- Salt exploitation site
- Intertidal marsh
- Intermitted river
- Intertidal forested wetland

Show Answer

3-59. *Question 3.1.1.5.* ⓪ *sarangib*

Question 6

In the image on the side, what is the name of the wetland ecosystem?

- ◯ Freshwater, tree dominated wetland
- ◯ Salt exploitation site
- ◯ Intertidal marsh
- ◯ Permanent river
- ◯ Intertidal forested wetland

Show Answer

3-60. Question 3.1.1.6.

Assignment 3.1 Block 2: Functioning

Next to each image you will find a checkbox question. Select **all the functions** that the infrastructure in the image provides.

To check your answer click on the button **Show Answer**.

Question 1

What options best describe the functioning of the wetland ecosystem?

- ☐ Critical to marine systems.
- ☐ Highly dependent on rainfall.
- ☐ Permanently or periodically exposed to seawater.
- ☐ Rich in woody vegetation.
- ☐ Exhibit strong zonation.

Show Answer

3-61. Question 3.1.2.1. Peter Facey

Question 2

What options best describe the functioning of the wetland ecosystem?

- ☐ Rich in woody vegetation.
- ☐ Provide resting and feeding areas for migratory water fowl and birds.
- ☐ May be nutrient-enriched.
- ☐ Highly dependent on rainfall.
- ☐ Salinity and temperature values may fall outside of the ranges exhibited by naturally occurring wetlands.

Show Answer

3-62. Question 3.1.2.2. Ⓟ NOAA

Question 3

What options best describe the functioning of the wetland ecosystem?

- ☐ In most cases less than six metres deep at low tide.
- ☐ Sea grass often covers these ecosystems.
- ☐ Transition zone between river and sea.
- ☐ Habitats and nursing sites for (keystone) species.
- ☐ Highly biologically productive ecosystems.

Show Answer

3-63. Question 3.1.2.3. Ⓟ fourteam

Assignment 3.1 Block 3: Character

Below each image, you will find a checkbox question. Select **all** of the Ecological Design Principles that are integrated in the design of the infrastructure or coastal defence in the image. **Hint**: The Ecological Principles that were definitely **not** considered in the design of the infrastructure or coastal defence need not be checked.

To check your answer click on the button **Show Answer**.

Question 1A

Which of the Ecological Design Principles are represented by the infrastructure in the image right?

- [ ] Continuity
- [ ] No direct human disturbance
- [ ] Endogeneity
- [ ] Population viability

Show Answer

3-64. Question 3.1.3.1.

Question 1B

After examining the same image, now consider which of these Ecological Design Principles are represented by the infrastructure in the image?

- [ ] Opportunity for threatened species
- [ ] Trophic web integrity
- [ ] Opportunity for ecological succession
- [ ] Zone integrity

Show Answer

Question 1C

After examining the same image, now consider which of these Ecological Design Principles are represented by the infrastructure in the image?

- [ ] Characteristic (in)organic cycles
- [ ] Characteristic physical-chemical water quality
- [ ] Resilience

Show Answer

Question 2A

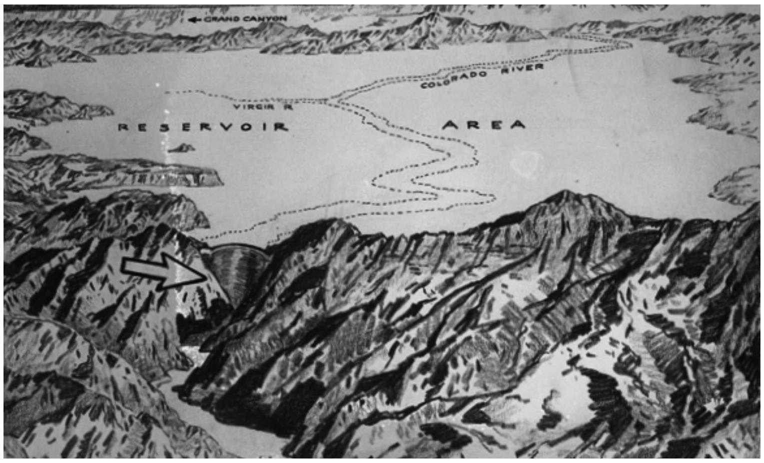
The top image shows the Hoover Dam (also known as the Boulder Dam) on the Colorado River, a permanent river. The location of the dam wall is indicated by the arrow in the original design sketch at the bottom. The dotted lines behind the dam indicate the original path of the Colorado River, now covered by a large body of water (termed the reservoir area in the design sketch).

Which of the Ecological Design Principles are represented by the infrastructure in the image above?

- ☐ Continuity
- ☐ No direct human disturbance
- ☐ Endogeneity
- ☐ Population viability
- ☐ None of the Ecological Design Principles were considered

Show Answer

3-65. *Question 3.1.3.2A.* ⓪ *Alex Rotlex*



3-66. *Question 3.1.3.2B.* ⓪ *Los Angeles Times*

Question 2B

After examining the same image, now consider which of these Ecological Design Principles are represented by the infrastructure in the image?

- ☐ Opportunity for threatened species
- ☐ Trophic web integrity
- ☐ Opportunity for ecological succession
- ☐ Zone integrity
- ☐ None of the Ecological Design Principles were considered

Show Answer

Question 2C

After examining the same image, now consider which of these Ecological Design Principles are represented by the infrastructure in the image?

- ☐ Characteristic (in)organic cycles
- ☐ Characteristic physical-chemical water quality
- ☐ Resilience
- ☐ None of the Ecological Design Principles were considered

Show Answer

Question 3A

Which of the Ecological Design Principles are represented by the infrastructure in the image on the right?

- [ ] Continuity
- [ ] No direct human disturbance
- [ ] Endogeneity
- [ ] Population viability

Show Answer

3-67. Question 3.1.3.3. © Vladimír Šiman

Question 3B

After examining the same image, now consider which of these Ecological Design Principles are represented by the infrastructure in the image?

- [ ] Opportunity for threatened species
- [ ] Trophic web integrity
- [ ] Opportunity for ecological succession
- [ ] Zone integrity

Show Answer

Question 3C

After examining the same image, now consider which of these Ecological Design Principles are represented by the infrastructure in the image?

- [ ] Characteristic (in)organic cycles
- [ ] Characteristic physical-chemical water quality
- [ ] Resilience

Show Answer

3.5 Feedback

Feedback on Assignment 3.1

By Prof. Jill Slinger and Ir. Graciela del Carmen Nava Guerrero

Assignment 3.1 consisted of three blocks: Form, Functioning and Character. In Block 1, Form, you identified six wetland ecosystems by their names: freshwater tree dominated wetland, sandy shore, intertidal mud, estuarine waters, intertidal forested wetland and permanent river. In Block 2, we asked you to identify, from a given set, the items that represented the functioning of the wetland ecosystem in the image. You can compare your answers by consulting the material of Section 3.2. Finally, in Block 3, we asked you to select the Ecological Design Principles that were integrated in the design of the hydraulic infrastructure or coastal defence in the image.

In this feedback document, we share our thoughts on Block 3. We will provide reasons to include, or exclude, functions for each image.

Block 3: Character

The third block of the assignment presented you with two hydraulic infrastructures and a natural coastal defence. Did you notice that the dune system fulfilled almost all of the Ecological Design Principles? If you have a second look at Assignment 2.1, you will remember that the dunes also fulfilled all Engineering Design Principles. Therefore, they provide an example of a naturally occurring Building with Nature design artefact.

In contrast, the dam failed to satisfy the Ecological Design Principles, and the storm surge barrier couldn't satisfy three of them.

These hydraulic infrastructures demonstrate that trade-offs were made - between ecosystem needs and engineering. In particular, it is challenging to keep costs low and satisfy the other engineering and ecological design principles.

In the next pages, we explain our view on whether, and why, the infrastructures and the dune coastal defence system adhere to the Ecological Design Principles.

Dunes

Ecological Design Principle	Integrated? YES	NO	Explanation
Continuity	◉	○	Continuity of water and sediment flows and land-water interfaces in the ecosystem are not interrupted.
No direct human disturbance	○	◉	In the image, there appear to be footprints or hoof prints in the sand. This may mean that the sandy area just behind the first dune ridge is used for walking or horse riding, representing direct human disturbance. However, this is of low intensity and does not appear to be affecting the health of the dune vegetation.
Endogeneity	◉	○	Because dunes occur naturally on sandy shores, they offer biotopes that would have occurred naturally, potentially enhancing endogeneity. Exceptions would be when they are stabilised artificially using exotic species or when there is nitrogen enrichment and the growth of dune thicket is over-stimulated. Neither conditions appear to apply in this case.
Population viability	◉	○	Population numbers of some species requiring embryonic and mobile dunes as habitat, are in the critical zone in Holland. Providing this type of dune habitat could help them to persist.
Opportunity for threatened species	◉	○	Because dunes occur naturally on sandy shores they provide a habitat for threatened species with a preference for this biotope.
Trophic web integrity	◉	○	The trophic web integrity of dune fields that are fixed in one successionary stage is often impoverished.
Opportunity for ecological succession	◉	○	The dynamic nature of dune fields needs to be accepted and accommodated if every successionary stage is to be offered ongoing opportunity. Often it is the pioneer stage that suffers as humans seek to fix dunes in position for their own convenience. This does not seem to be the case in the image.
Zone integrity	◉	○	The beach and dunes are unimpeded in their exposure to winds, waves and surges. This implies that natural zonation can occur.
Characteristic (in)organic cycles	◉	○	Excessive nitrogen pollution in the air can cause the dune ticket to become more dense. However, there is little evidence for this effect in the image.
Characteristic physical-chemical water quality	◉	○	Dunes occur naturally on sandy shores and are important in filtering the rainwater down to the groundwater. On a beach they also help to develop a freshwater lens to combat salt water intrusion in the groundwater. Accordingly, they play an often underestimated role in maintaining characteristic physical-chemical water levels.
Resilience	◉	○	The high mobility of non-stabilised dunes enables the dune ecosystem to maintain its integrity and even benefit from disturbances. The two dune rows evident in the image, mean that the dunes could withstand foreseeable consecutive disturbances from storm surges.

Dam

Ecological Design Principle	Integrated? YES	NO	Explanation
Continuity	◯	◉	The dam interrupts the continuity of water and sediment flows along the river and makes the land-water transitions more abrupt.
No direct human disturbance	◯	◉	The initial construction of the dam can be considered as a major habitat destruction event. Thereafter, the dam and its operation can be considered to represent ongoing human disturbance to the riverine ecosystem.
Endogeneity	◯	◉	During construction and operation, invasive species might be introduced; e.g. fish or seeds.
Population viability	◯	◉	Populations depending on the downstream continuity of water and sediment flows, or biotopes along the river margin may suffer. Populations originally living at the site of the reservoir will probably suffer.
Opportunity for threatened species	◯	◉	The dam does not aim to provide opportunities for threatened species.
Trophic web integrity	◯	◉	The tropic web integrity of the river system is affected by the strong reduction in freshwater flows downstream of the dam. Species dependent on base flows may become stressed, and macrophytic plant growth can be preferred above water column productivity. In contrast, algal and nuisance plant growth can increase in the dam waters. These effects represent effects on the trophic web integrity.
Opportunity for ecological succession	◯	◉	The dam does seeks to control variability and stabilise the environment – this works against opportunities for ecological succession.
Zone integrity	◯	◉	The dam severely affects zone integrity. First, there is a dead-zone near the water's edge. Second, the downstream river margins are inundated less frequently, affecting the zonal integrity of the vegetation and the species colonising it. Finally, the new water body that is formed, will develop its own zonal characteristics over time.
Characteristic (in) organic cycles	◯	◉	By transforming a lotic water body into a lentic one, the dam alters characteristic organic and inorganic cycles in the area.
Characteristic physical-chemical water quality	◯	◉	By transforming a lotic water body into a lentic one, the dam alters the physical chemical water quality and can push it outside naturally occurring ranges e.g. low water temperatures in the deep lake waters, or hypoxic sediments.
Resilience	◯	◉	The downstream area is vulnerable to overtopping, dam failure, water pollution or other plausible disturbances. The vulnerability to overtopping by floods increases downstream over time. As the system becomes accustomed to narrower, more stable conditions, its ability to cope a with a sequence of disturbances is reduced.

Storm Surge Barrier

Ecological Design Principle	Integrated? YES	NO	Explanation
Continuity	◉	○	The design of an open storm surge barrier means that the constraining influence of the structure on the exchange of water and sediment through the inlet is reduced as far as possible. Closure only occurs under extreme storms.
No direct human disturbance	○	◉	The construction of the infrastructure represented a severe disturbance to the ecosystem. Now, the structure can be considered to represent ongoing, although limited, human disturbance to the estuary ecosystem.
Endogeneity	○	◉	There is little information on this aspect, and no reason to suspect that the structure has preferred exotic species above indigenous species.
Population viability	◉	○	There is little information on this aspect, and no reason to suspect that the structure has threatened the viability of populations. There is evidence that ensuring the survival of estuarine populations played a role in the choice for an open barrier
Opportunity for threatened species	◉	○	Following the closure of many of the Dutch coastal inlets by barrier dams, providing opportunities for estuarine species played a role in the choice for an open barrier.
Trophic web integrity	◉	○	By designing an open barrier, the effects on the functional integrity of the ecosystem are limited.
Opportunity for ecological succession	○	◉	The design of the structure does not explicitly consider opportunities for primary, secondary or tertiary species to thrive.
Zone integrity	◉	○	The open structure reduces tidal action somewhat, yet allows intertidal zone integrity to be retained. It does not impede the land-water transitions, and accommodates longitudinal variations in salinity from marine waters to brackish zones.
Characteristic (in)organic cycles	◉	○	Because the sea-estuary connection is retained, the inorganic and organic cycles of the ecosystem are not altered significantly. This played a role in the choice for an open barrier.
Characteristic physical-chemical water quality	◉	○	It is precisely to ensure that representative ranges of physical-chemical water quality were retained in the estuary, so that the associated species could continue to thrive in such an environment that the open barrier was designed and built. The tidal action within the inlet is reduced somewhat, but there are longitudinal variations in salinity from marine waters to brackish zones, as one would expect in such a system.
Resilience	○	◉	This aspect was not considered in the design of the open barrier.

In reality, determining whether the design of a hydraulic infrastructure or a coastal defence adheres to the Ecological Design Principles is not straightforward. It requires the knowledge of an ecologist to complete fully, and usually cannot be answered with "Yes" or "No". To account for this complexity, in Assignment 4, we will ask you to analyse your own design using a slightly different approach. You can learn about it at the end of this chapter, in "Assignment 3.2 in Preparation for Assignment 4".

3.6 Assignment 3.2

Introduction

Assignment 3.2 acts as practice for the Assignment in chapter 4, in which you will need to report and explain how you apply the Ecological Design Principles in your proposed / sketched design. The reporting format that you use in Assignment 3.2 forms a component of your chapter 4 Assignment when you will apply it to your own Building with Nature design.

To get ready for the chapter, we ask you to practise by completing the exercise on the next pages.

3-68. *Assignment 3.2.* Ⓑ *Alex Rotlex*

Assignment 3.2 (As Practice for Assignment 4)

This assignment has two stages:

Stage 1:
Have a look at the image above and reflect on which **Ecological Design Principles** are represented in the **infrastructure**, these are listed on the next page.

Hint: *Just as in Assignment 3.1 Block 3 it is helpful to think first about which principles were NOT taken into account, or were LESS relevant in the design choices.*

Afterwards, complete the form on the next page by scoring and explaining each principle.

Stage 2:
Once you have completed the form, check the next page for the model answer. Consider the model answer in relation to your own submission, and give yourself a grade.

Please note that self-assessment is built on trust. While you could view the model answer before completing your own work, we hope that you will take the time to first consider your own solutions.

This assignment will help you prepare for the Building with Nature Design Assignment in Chapter 4 with its self review. The grading is as follows:

Poor: Less than 4 engineering principles are scored highly (in the last 2 boxes), and/or no explanations are included.
Fair: At least 4 engineering principles are scored highly (in the last 2 boxes), but 2 explanations are missing from those 4 and/or the explanations are very different from the model answer.
Good: At least 4 engineering principles are scored highly (in the last 2 boxes), and explanations are included for at least these 4 that are similar to the model answer.

3.6 Assignment 3.2

Assignment Form

Consider the following ecological principles and rate the extent to which they have been taken into account in the infrastructural design in the image, then provide an explanation. Click in the explanation box on the white space to start typing.

Ecological principles	**Checkboxes** *Minimum-maximum*	**Explanation**
1. Continuity 	○ ○ ○ ○ ○	
2. No direct human disturbance 	○ ○ ○ ○ ○	
3. Indigenousness/ Endogeneity 	○ ○ ○ ○ ○	
4. Viability of populations 	○ ○ ○ ○ ○	
5. Opportunity for threatened species 	○ ○ ○ ○ ○	

Ecological principles	Checkboxes *Minimum-maximum*	Explanation
6. Trophic web integrity 	○ ○ ○ ○ ○	
7. Opportunity for ecological succession 	○ ○ ○ ○ ○	
8. Zone integrity 	○ ○ ○ ○ ○	

3-142

Ecological principles	Checkboxes *Minimum-maximum*	Explanation
9. Characteristic (in)organic cycles 	○ ○ ○ ○ ○	
10. Characteristic physi-cal-chemical water quality 	○ ○ ○ ○ ○	
11. Resilience 	○ ○ ○ ○ ○	

3.6 Assignment 3.2

Model Answer

Consider the following ecological principles and rate the extent to which they have been taken into account in the infrastructural design in the image, then provide an explanation.

Ecological principles	Checkboxes *Minimum-maximum*	Explanation
1. Continuity 	◉ ○ ○ ○ ○	The dam interrupts the continuity of water and sediment flows along the river and makes the land-water transitions more abrupt.
2. No direct human disturbance  	◉ ○ ○ ○ ○	The initial construction of the dam can be considered as a major habitat destruction event. Thereafter, the dam and its operation can be considered to represent ongoing human disturbance to the riverine ecosystem.
3. Indigenousness/ Endogeneity 	○ ◉ ○ ○ ○	During construction and operation, invasive species might be introduced; e.g. fish or seeds.
4. Viability of populations 	○ ◉ ○ ○ ○	Populations depending on the downstream continuity of water and sediment flows, or biotopes along the river margin may suffer. Populations originally living at the site of the reservoir will probably suffer.
5. Opportunity for threatened species 	○ ◉ ○ ○ ○	The tropic web integrity of the river system is affected by the strong reduction in freshwater flows downstream of the dam. Species dependent on base flows may become stressed, and macrophytic plant growth can be preferred above water column productivity. In contrast, algal and nuisance plant growth can increase in the dam waters.

Engineering principles	Checkboxes *Minimum-maximum*	Explanation
6. Trophic web integrity 	● ○ ○ ○ ○	The trophic web integrity of the river system is affected by the strong reduction in freshwater flows downstream of the dam. Species dependent on base flows may become stressed, and macrophytic plant growth can be preferred above water column productivity. In contrast, algal and nuisance plant growth can increase in the dam waters.
7. Opportunity for ecological succession 	● ○ ○ ○ ○	The dam seeks to control variability and stabilise the environment – this works against opportunities for ecological succession.
8. Zone integrity 	● ○ ○ ○ ○	First, there is a dead-zone near the water's edge. Second, the downstream river margins are inundated less frequently, affecting the zonal integrity of the vegetation. Finally, the new water body will itself develop new zonal characteristics over time.
9. Characteristic (in)organic cycles 	● ○ ○ ○ ○	By transforming a lotic water body into a lentic one, the dam alters characteristic organic and inorganic cycles in the area.
10. Characteristic physical-chemical water quality 	● ○ ○ ○ ○	By transforming a lotic water body into a lentic one, the dam alters the physical chemical water quality and can push it outside naturally occurring ranges e.g. low water temperatures in the deep lake waters, or hypoxic sediments.
11. Resilience 	● ○ ○ ○ ○	The downstream area is vulnerable to overtopping, dam failure, water pollution or other plausible disturbances. The vulnerability to overtopping by floods increases downstream over time. As the system becomes accustomed to narrower, more stable conditions, its ability to cope a with a sequence of disturbances is reduced.

3.7 Bibliography

Literature

Akçakaya, H. R., & Sjögren-Gulve, P. (2000). Population viability analyses in conservation planning: an overview. *Ecological Bulletins*, 9-21.

Alpert, P., Bone, E., & Holzapfel, C. (2000). Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. *Perspectives in Plant Ecology, Evolution and Systematics, 3(1)*, 52-66. doi: http://dx.doi.org/10.1078/1433-8319-00004

Ashkannejhad, S., & Horton, T. R. (2006). Ectomycorrhizal ecology under primary succession on coastal sand dunes: interactions involving Pinus contorta, suilloid fungi and deer. *New Phytologist, 169(2)*, 345-354.

Bélisle, M. (2005). Measuring landscape connectivity: the challenge of behavioral landscape ecology. *Ecology, 86(8)*, 1988-1995.

Boyce, M. S. (1992). Population viability analysis. *Annual review of Ecology and Systematics*, 481-506.

Cullen, R., Fairburn, G. A., & Hughey, K. F. (2001). Measuring the productivity of threatenedspecies programs. *Ecological Economics, 39(1)*, 53-66.

D'Antonio, C., & Meyerson, L. A. (2002). Exotic plant species as problems and solutions in ecological restoration: a synthesis. *Restoration Ecology, 10(4)*, 703-713.

Daehler, C. C. (2003). Performance comparisons of co-occurring native and alien invasive plants: implications for conservation and restoration. *Annual Review of Ecology, Evolution, and Systematics*, 183-211.

Doing, H. (1985). Coastal fore-dune zonation and succession in various parts of the world. *Ecology of coastal vegetation* (pp. 65-75): Springer.

Foin, T. C., Riley, S. P., Pawley, A. L., Ayres, D. R., Carlsen, T. M., Hodum, P. J., & Switzer, P. V. (1998). Improving recovery planning for threatened and endangered species. *BioScience*, 177-184.

Freeman, C. (1987). Technology policy and economic policy: Lessons from Japan. *Frances Pinter, London*.

Gordon, D. R. (1998). Effects of invasive, non-indigenous plant species on ecosystem processes: lessons from Florida. *Ecological Applications, 8(4)*, 975-989.

Gunderson, L. H. (2000). Ecological resilience--in theory and application. *Annual review of Ecology and Systematics*, 425-439.

Hannah, L., Lohse, D., Hutchinson, C., Carr, J. L., & Lankerani, A. (1994). A preliminary inventory of human disturbance of world ecosystems. *Ambio*, 246-250.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual review of Ecology and Systematics*, 1-23.

Karr, J. R. (1981). Assessment of biotic integrity using fish communities. *Fisheries, 6(6)*, 21-27.

Karr, J. R., & Dudley, D. R. (1981). Ecological perspective on water quality goals. *Environmental management, 5(1)*, 55-68.

Kay, J. J., & Schneider, E. D. (1992). Thermodynamics and measures of ecological integrity *Ecological Indicators* (pp. 159-182): Springer.

Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., Jackson, J. B. (2006). Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science, 312(5781)*, 1806-1809.

Mengak, M. T., Rutledge, H. E., & McDonald, B. (2009). Ecological Principles - A Unifying Theme in Environmental Education. *Journal of Extension, 47(5)*.

Mitsch, W. J., Zhang, L., Anderson, C. J., Altor, A. E., & Hernández, M. E. (2005). Creating riverine wetlands: ecological succession, nutrient retention, and pulsing effects. *Ecological Engineering, 25(5)*, 510-527.

Peterson, G., Allen, C. R., & Holling, C. S. (1998). Ecological resilience, biodiversity, and scale. *Ecosystems, 1(1)*, 6-18.

Possingham, H., Lindenmayer, D., & Norton, T. (1993). A framework for the improved management of threatened species based on population viability analysis (PVA). *Pacific Conservation Biology, 1(1)*, 39-45.

Pusceddu, A., Gambi, C., Manini, E., & Danovaro, R. (2007). Trophic state, ecosystem efficiency and biodiversity of transitional aquatic ecosystems: analysis of environmental quality based on different benthic indicators. *Chemistry and Ecology, 23(6)*, 505-515.

Rabouille, C., Mackenzie, F. T., & Ver, L. M. (2001). Influence of the human perturbation on carbon, nitrogen, and oxygen biogeochemical cycles in the global coastal ocean. *Geochimica et Cosmochimica Acta, 65(21)*, 3615-3641.

Sheaves, M. (2009). Consequences of ecological connectivity: the coastal ecosystem mosaic. *Marine Ecology, Progress Series, 391*, 107-115.

Sklar, F. H., Costanza, R., & Day, J. W. (1985). Dynamic spatial simulation modeling of coastal wetland habitat succession. *Ecological Modelling, 29(1)*, 261-281.

Sousa, W. P. (1979). Experimental investigations of disturbance and ecological succession in a rocky intertidal algal community. *Ecological Monographs, 49(3)*, 227-254.

Stohlgren, T. J., Binkley, D., Chong, G. W., Kalkhan, M. A., Schell, L. D., Bull, K. A., Son, Y. (1999). Exotic plant species invade hot spots of native plant diversity. *Ecological Monographs*, 69(1), 25-46.

Suarez, A. V., Bolger, D. T., & Case, T. J. (1998). Effects of fragmentation and invasion on native ant communities in coastal Southern California. *Ecology, 79(6)*, 2041-2056. doi: 10.1890/0012-9658(1998)079[2041:EOFAIO]2.0.CO;2

Vold, T., & Buffett, D. A. (2008). Ecological Concepts, Principles and Applications to Conservation, BC. (pp. 36).

Wearn, O. R., Reuman, D. C., & Ewers, R. M. (2012). Extinction debt and windows of conservation opportunity in the Brazilian Amazon. *Science, 337(6091)*, 228-232.

Figures

3-1. Cape Town Seal: This image by Graciela del Carmen Nava Guerrero is licensed under CC-BY-NC-SA 4.0.

3-2. Climate zones: This image by NASA is in the Public Domain

3-3. Salinity zones in river mouth: This image by U.S. Army Corps of Engineers is in the Public Domain

3-4. Effect of wave exposure on ecosystem: “Salt Marsh” by Wageningen University & Research is licensed under CC BY-NC-SA 4.0, Zwin Belgian Dutch Border by Смок Вавельский is in the Public Domain, CC0

3-5. Tidal zonation: This image by Wageningen University & Research is licensed under CC BY-NC-SA 4.0

3-6. Light availibility: Biscayne underwater NPS1 by National Park Services is in the Public Domain, Sunlight Filters Under Water by Sarah KlockarsClauser is in the Public Domain, CC0

3-7. Nutrient availability: This image by Wageningen University & Research is licensed under CC BY-NC-SA 4.0

3-8. 6 Abiotic conditions: Reef 1448 by David Burdick is licensed under CC BY-SA 2.0, “Dune” by Wageningen University & Research is licensed under CC BY-NC-SA 4.0, Img_3282 Pahawang Trip, by Ukik is licensed under CC BY-SA 2.0, “Salt Marsh” see 3-4.

3-9. Dune grass: pioneer species: This image by Wageningen University & Research is licensed under CC BY-NC-SA 4.0

3-10. Species succession: This image by Bregje van Wesenbeeck is licensed under CC BY-NC-SA 4.0

3-11. Pioneer species in low intertidal marsh: Spartina Anglica by Jürgen Howaldt is licensed under CC BY-SA 2.0, Salicorne / Pickleweed by OliBac is licensed under CC BY 2.0

3-12. Species in middle and high intertidal marsh: A scenic view of a New England salt marsh by Samantha DeWitt is in the Public Domain, CC0

3-13. Zonation on rocky shores: Cornish Barnacles by Wilson44691 is in the Public Domain

3-14. Keystone in arch: Southern gothic 6 by anoldent is licensed under CC BY-SA 2.0

3-15. Keystone species in reefs: Sea urchin: Common Longspined Sea Urchin, Diadema paucispinum at Abu Dabab Reefs, Red Sea, Egypt SCUBA by Derek Keats is licensed under CC BY-SA 2.0

3-16. Oysters: Ecosystem engineers: This image by NoSpicyFood is in the Public Domain, CC0

3-17. Biodiversity in a coral reef: Great Barrier Reef by Wise Hok Wai Lum is licensed under CC BY-SA 4.0

3-18. Productivity and stability of ecosystems: This image by Bregje van Wesenbeeck is licensed under CC BY-NC-SA 4.0

3-19. Las Tablas de Daimiel: Mixed species grassland: Las Tablas de Daimiel grassland by untipografico is licensed under CC BY 2.0

3-20. Non-resilient forest ecosystem: Idaho tree farm by Charles Knowles is licensed under CC BY 2.0.

3-21. Resilient forest ecosystem: Cabinet Mountains from Bull River Road by Forest Service Northern Region is licensed under CC BY 2.0.

3-22. Excessive disturbance in ecosystems: Phase shift: This image by Bregje van Wesenbeeck is licensed under CC BY-NC-SA 4.0

3-23. Connected ecosystems: This image by eismannhans is in the Public Domain, CC0

3-24. Parrot fish: Bicolor parrotfishWB by Rling, Retouched by IdLoveOne is licensed under CC BY-SA 3.0

3-25. Physical ecosystem separation: Presa de El Atazar - 01 by Carlos Delgado is licensed under CC BY-SA 3.0

3-26. Timbulsloko coastline erosion 2003-2012: This image by Wetlands International is licensed under CC BY-NC-SA 4.0

3-27. Semi-permeable structures: "Permeable Dams" by Nanang Sujana for Wetlands International is licensed under CC BY-NC-SA 4.0

3-28. Mangrove trees: This image by syoclo is in the Public Domain, CC0

3-29. Aerial view of semi-permeable structures: This image by Prospek Empat Dimensi for Witteveen+Bos is licensed under CC BY-NC-SA 4.0

3-30. Dolphins in shallow water: This image by fourteam is in the Public Domain, CC0

3-31. Sand shore with dunes: "Beach and dunes on Ameland" by Martijn Vos is licensed under CC BY-NC-SA 4.0

3-32. Pebble shore: This image by Bingo_UK is in the Public Domain, CC0

3-33. Estuarine waters, UK: "Avon Estuary" by Shaun Ferguson is licensed under CC BY-SA 2.0

3-34. Intertidal mud flat: This image is in the Public Domain, CC0

3-35. Intertidal marsh in the UK: Tidal Salt Marsh at Ella Nore by Peter Facey is licensed under CC BY-SA 2.0

3-36. Mangrove Forest: This image by sarangib is in the Public Domain, CC0

3-37. River in Patagonia, Chile: This image by falco is in the Public Domain, CC0

3-38. Creek in Austria: This image by Hans is in the Public Domain, CC0

3-39. Tree dominated wetland in Louisiana, USA: This image by bobmann is in the Public Domain, CC0

3-40. Shrimp aquaculture pond: Shrimp Pond by U.S. National Oceanic and Atmospheric Administration is in the Public Domain

3-41. Pond in front of barn: This image by HaloJim is in the Public Domain, CC0

3-42. Salt pans in Lanzarote, Canary Isl.: This image by Barni1 is in the Public Domain, CC0

3-43. Wolwedans dam: Wolwedans dam, South Africa by Louis and Alida van der Walt is licensed under the CC BY-SA 3.0

3-44. Ecological Design Principles: This image by Martijn Vos and Jill Slinger is licensed under CC BY-NC-SA 4.0

3-45. Interruption of continuity: This image by Alex Rotlex is in the Public Domain, CC0

3-46. Closed groyne: "Groyne on Aberdeen beach" by Alan Reid is licensed under CC BY-SA 2.0

3-47. Open groyne: This image by Lekies is in the Public Domain, CC0

3-48. Invasive species: Zebra mussel in Europe and North America: Moule zébrée Lambersart by F Lamiot is licensed under CC BY-SA 1.0

3-49. Critical for coral reef environments: sea urchins: This image by raving666 is in the Public Domain, CC0

3-50. Pioneer plants species in a dune environment: This image is in the Public Domain, CC0

3-51. Estuarine salt marsh on Texel, The Netherlands: De Slufter, Texel (1) by Rasbak is licensed under CC BY-SA 3.0

3-52. Overgrown dunes limiting sand movement: Indiana Dunes National Lakeshore Forest and Sky by Yinan Chen is in the Public Domain, CC0

3-53. Algal bloom: Algal Bloom by Shijan Kaakkara is licensed under CC BY-SA 3.0

3-54. Eleven Ecological Design Principles: This image by Martijn Vos and Jill Slinger is licensed under CC BY-NC-SA 4.0

3-55. Question 3.1.1.1: see 3-39

3-56. Question 3.1.1.2: see 3-31

3-57. Question 3.1.1.3: see 3-34

3-58. Question 3.1.1.4: "overall view of Oosterscheldekering surge barrier" by Vladimír Šiman is licensed under CC BY 3.0

3-59. Question 3.1.1.5: see 3-36

3-60. Question 3.1.1.6: This image is in the Public Domain, CC0

3-61. Question 3.1.2.1: see 3-35

3-62. Question 3.1.2.2: see 3-40

3-63. Question 3.1.2.3: see 3-30

3-64. Question 3.1.3.1: This image is in the Public Domain, CC0

3-65. Question 3.1.3.2A: This image by Alex Rotlex is in the Public Domain, CC0

3-66. Question 3.1.3.2B: Boulder dam site sketch is in the Public Domain

3-67. Question 3.1.3.3: see 3-58

3-68. Assignment 3.2: see 3-65

4-1. 6 Case Studies. (cc) A: G. Lanting, B: P. van Galen, C: W. Bulach, D: Ceinturion, E. Michielverbeek, F: Wetlands International

Chapter 4 Integrated BwN Design

4.1 Introduction

Welcome to Chapter 4 in our Building with Nature adventure. You have already learned about the Engineering Design Principles in Chapter 2 and the Ecological Design Principles in Chapter 3. Now, it is time to make your own integrated Building with Nature design!

But, how does the Building with Nature Design Process differ from the conventional Engineering Design Process of Chapter 2?

This is explained by Prof. Jill Slinger in the first video. Prof Marcel Stive and others then provide information on the iconic case of the Sand Engine on the South-Holland coast. This is supplemented by additional detailed information so that you can develop a thorough understanding of the design. Next, the Sand Engine is used as the example in a video by Prof. Jill Slinger and Ir. Graciela del Carmen Nava Guerrero on how to complete part 1 of Assignment 4. In this video the application of both the Engineering Design principles (H-principles) and the Ecological Design Principles (E-principles) to the Sand Engine case is explained.

It is the intention that you complete part 1 of Assignment 4 for your chosen case study in Chapter 4. In Chapter 5 you will complete part 2 of assignment 4 by undertaking a self-review of your Building with Nature design assignment. To obtain a final grade, it is essential that you complete both parts of Assignment 4.

Enjoy undertaking your own design, and Good luck!

4.2 Building with Nature Integrated Design Process

4-150

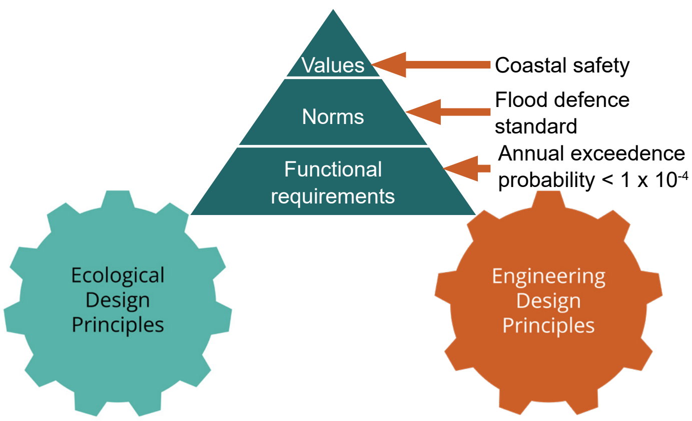
Video: Building with Nature Design Process

This section contains a video presented by **Prof. Jill Slinger** and written by **Jill Slinger** and **Heleen Vreugdenhil**. She will describe the Building with Nature design process and explain how it differs from the conventional Engineering Design Process.

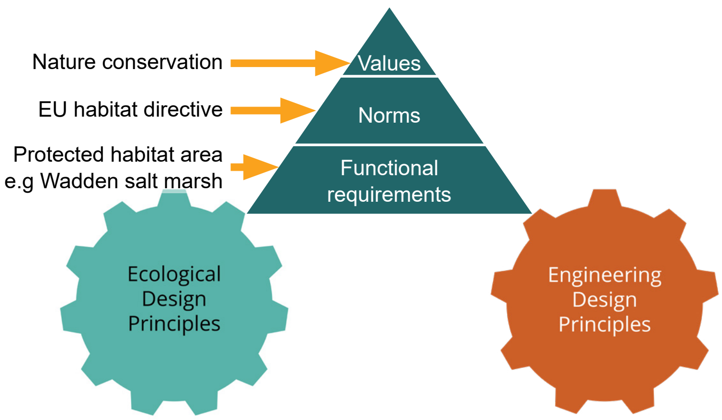
You can cite this video as:

Slinger, J.H. (Jill), Vreugdenhil, H.S.I. (Heleen) (2016). *Engineering: Building with Nature 101x video #09 – Building with Nature design process.* 4TU.Dataset. http://dx.doi.org/10.4121/uuid:d7ee3203-05a4-42d3-99e5-304a31d34870

4-2. Implications for the design process. ⓒ *Jill Slinger and Martijn Vos*



4-3. Conventional design process: from social values to functional requirements. ⓒ *Jill Slinger and Martijn Vos*



4-4. Ecological design? From nature values to functional requirements. ⓒ *Jill Slinger and Martijn Vos*

Video Transcript

Presented by Prof. Jill Slinger

You now know that Building with Nature involves:

the flexible integration of land in water and of water in land, using materials, forces and interactions, present in nature, taking into account both existing and potential nature values, and the bio-geomorphlogy and geo-hydrology of the ambient environment – to paraphrase Dr. Ronald Waterman.

So, it's an integrated design approach that considers hydraulics, morphology, ecology, the societal context and diverse goals.

Building with Nature is hydraulic engineering at the interface between nature and society!

But, what does this imply for your design practice? You now know that Engineering (H-) and Ecological (E-) Principles underpin Building with Nature design, but how does this differ from conventional engineering design?

The conventional engineering design process translates societal norms or standards, deriving from values, into functional requirements that need to be met by the infrastructure. Take the issue of coastal safety – this societal value is captured in a Dutch flood defence standard. For a particular location such as the dunes on the South-Holland coast this is specified further into a functional requirement to withstand a storm surge with an annual exceedance probability of 1 in 10 000. We are very familiar with this process of designing hydraulic infrastructure to meet societal needs.

But, what about meeting ecosystem requirements? Do we also translate these into functional requirements? Let's consider the issue of nature conservation – this societal value is expressed, for instance, in the European Union's Habitat Directive, which is in turn captured in Natura 2000 specified areas in the Wadden Sea for example.

Perhaps you think this solves the issue of the Building with Nature design process? Just specify both the societal and the ecosystem needs in terms of functional requirements and the engineers can then design appropriate hydraulic (infra) structures. But, how do you design for conservation and restoration, or provide opportunities for the ecosystem? Well, you already know that the bridge is formed by focusing on the character of the system – at the level of the Hydraulic Engineering and Ecological Design principles. One level above the functional requirements, and providing a means of checking the effects of any trade-offs on the functional integrity of the ecosystem.

Building with Nature aims to use natural materials, forces and interactions to balance hydraulic infrastructural interventions and the needs and health of ecosystems, as far as possible.

Just like the conventional Engineering Design process, the Building with Nature Design process has 7 steps in an iterative process. These are:

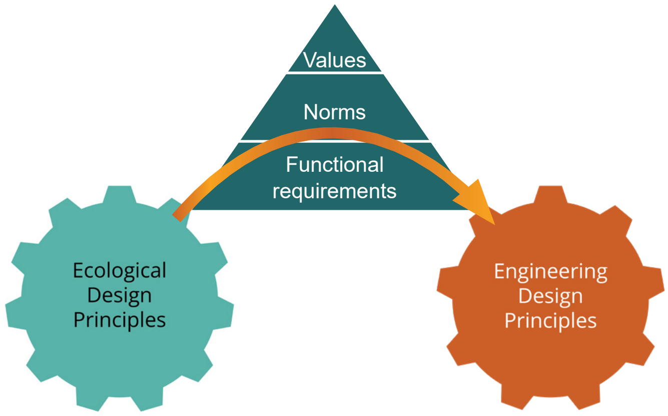
1. Define the multi-actor, multi-value problem
2. Include multi-disciplinary knowledge, apply H-E-principles & specify preliminary functional requirements
3. Sketch and describe preliminary designs
4. Select (diverse) promising designs in terms of H-E-principles
5. Test / verify through prototyping or modelling
6. Incorporate relevant new knowledge / Revise functional

requirements / Refine or Re-design / Re-test and verify in terms of H-E-principles
7. Select the final design for multi-actor evaluation

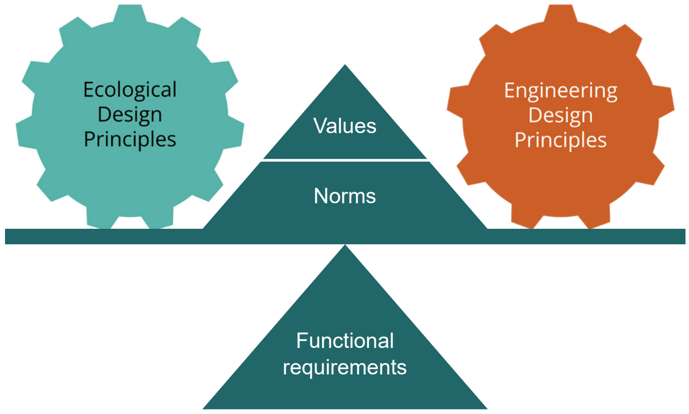
So, how does the Building with Nature Design process differ from the conventional Engineering Design process? Let's move through each step, and clarify the differences.

Step 1: Define the multi-actor, multi-value problem. This means scoping the problem very widely, and taking the diversity of perspectives and values on the issues into account. It represents a fundamentally different starting point in which a single client is not viewed as representing societal or ecosystem needs. There is also an acknowledgement of different sources of knowledge on the environment, varying from that possessed by local residents to official data sources.

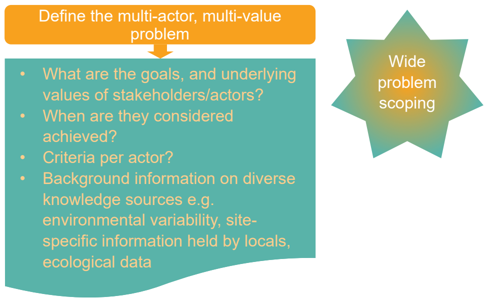
Step 2: Include multi-disciplinary knowledge, apply H-E-principles & specify preliminary functional requirements. Here di-



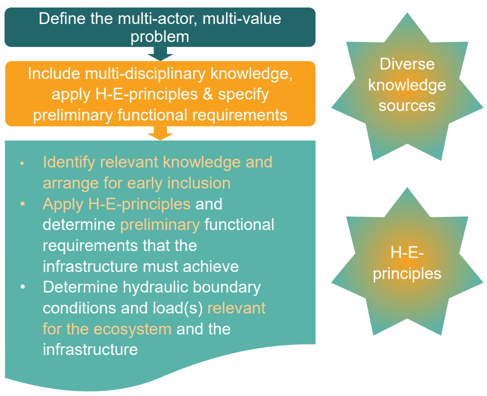
4-5. Building with Nature: integration using H-E-principles 1. © Jill Slinger and Martijn Vos



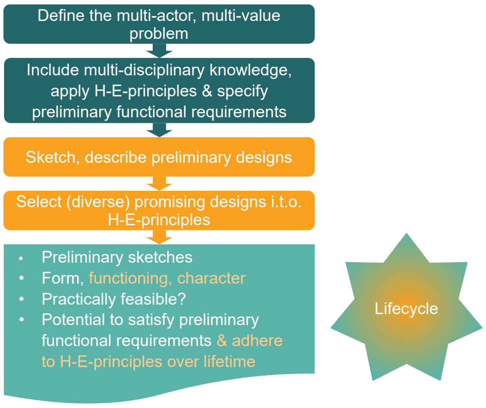
4-6. Building with Nature: integration using H-E-principles 2. © Jill Slinger and Martijn Vos



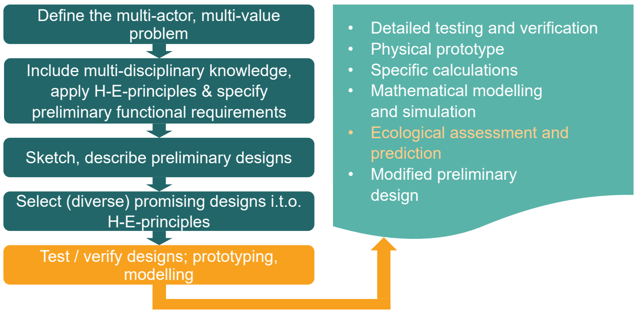
4-7. Building with Nature Design Process: Step 1. © Jill Slinger



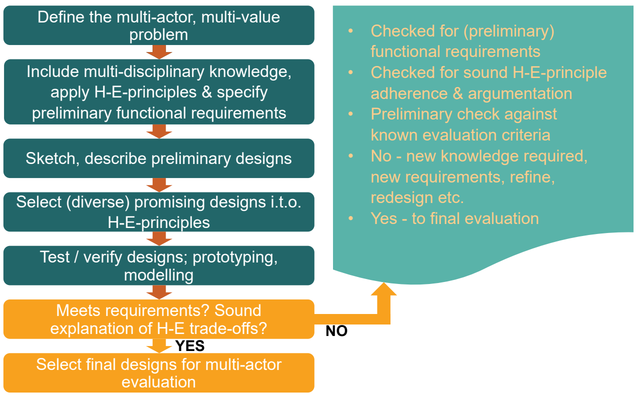
4-8. Building with Nature Design Process: Step 2. © Jill Slinger



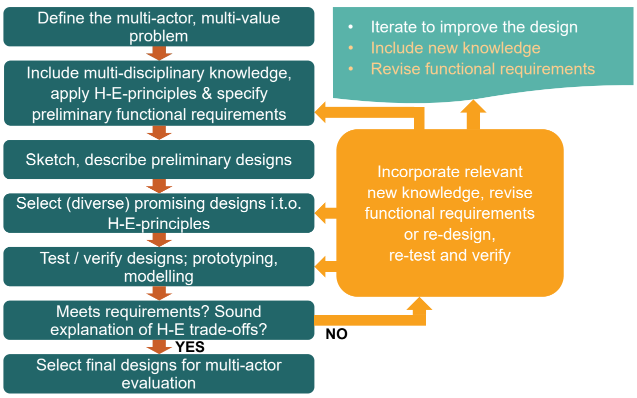
4-9. Building with Nature Design Process: Steps 3+4. © Jill Slinger



4-10. Building with Nature Design Process: Step 5. © Jill Slinger



4-11. Building with Nature Design Process: Step 7. © Jill Slinger



4-12. Building with Nature Design Process: Step 6. © Jill Slinger

verse types of knowledge from ecology to engineering play a role. The environment is described in terms of form and function(ing) and the character in terms of the H-E-principles. Preliminary functional requirements are specified, as are boundary conditions and loads.

The first two steps in the Building with Nature design process are very different to those of the conventional approach because of their wide scope and their explicitly open stance to other and diverse knowledge sources.

Moving on to **Steps 3 and 4**, the sketching and subsequent selection of promising designs. These are similar to the conventional method, except that different knowledge is brought to the table – the functioning and character of the ecosystem is included – and the time horizon covers the lifecycle of the artifact that is being designed.

Step 5: Test /verify designs; prototyping, modelling. Ecological assessment and prediction are the additional elements used in this step.

And, now moving on to **Step 7:** Select the final design for multi-actor evaluation. This step is very different from the conventional engineering design process – it means that we don't

only check whether the functional requirements are satisfied, we cross-check whether the potential solution adheres to the H-E-principles. We also ask for a sound explanation of its performance against the principles – so as to understand where the trade-offs are being made. Only when these aspects are satisfied, are the potential solutions(s) evaluated by stakeholders holding very different perspectives.

If all of these aspects are not satisfied, we move to the iterative step, **Step 6**, where we incorporate relevant new knowledge / Revise functional requirements / Refine or Re-design / Re-test and verify in terms of H-E-principles. This represents the iterations needed to improve a design. The differences here relate to the possibilities of:

1. including new knowledge sources when the design process is ongoing, and
2. revising the functional requirements,

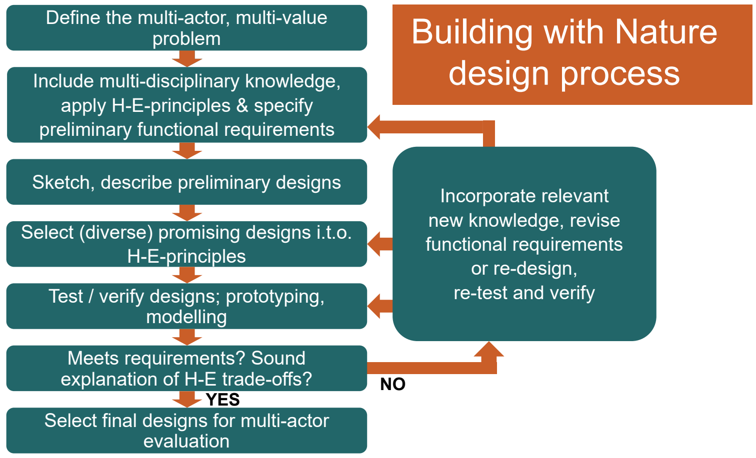
both of which are not routinely included in an engineering design process. So, the Building with Nature Design Process can be depicted like this.

And, the major differences in the two design processes are first, that in Building with Nature, we adopt a stance that acknowledges complexity. We also anticipate the need to include many actors or stakeholders with different perspectives as well as multiple knowledge sources.

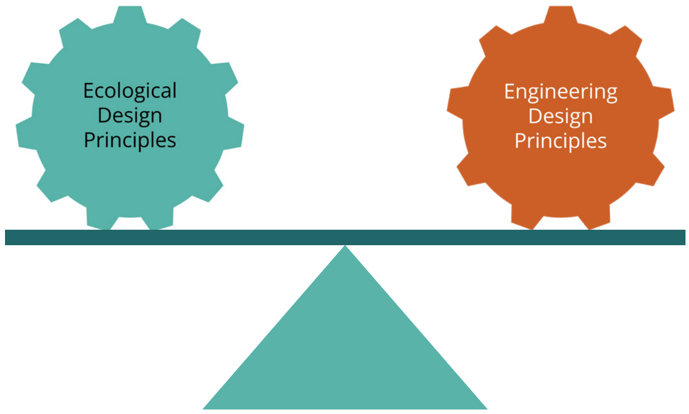
So, we are accepting of uncertainty, recognising that natural systems are dynamic and that ecosystems can have unexpected responses. Yet we think about the long term - about natural dynamics, and the lifecycle of the artifact.

Finally, in Building with Nature we integrate ecology and engineering using the H-E-principles. After all, Building with Nature is a balancing act, involving trade-offs in multi-disciplinary design space.

Thank you for your attention.



4-13. The complete Building with Nature design process. 🅭 *Jill Slinger*



4-14. Building with Nature: a balancing act. 🅭 *Jill Slinger and Martijn Vos*

Exercises

In this section you will find some questions to help you check your understanding of key concepts explained in the video.

To check your answer click on the button **Show Answer**. Click **Hide Answer** if you would like to repeat the question later.

Question 1

From the options below, select those that represent the Building with Nature Design Approach.

- ☐ Considers Engineering Design Principles
- ☐ Considers Ecological Design Principles
- ☐ Integrates only the client's functional requirements
- ☐ Explicates trade-offs made in the design process
- ☐ Acknowledges complexity and uncertainty

Show Answer

Question 2

From the options below, select those that represent the Building with Nature Design Process.

- ☐ Life-cycle design approach
- ☐ The client alone defines the functional requirements
- ☐ Local residents are considered as a source of knowledge
- ☐ The problem is defined narrowly to build a concrete and better solution
- ☐ The design takes ecosystem character into account

Show Answer

4.3 Sand Engine: An iconic case study

Introduction

During the last three chapters you have learnt about the Building with Nature Philosophy, the Engineering Design Process and Principles, the Ecological Design Principles and the Building with Nature Integrated Design Process. In Assignment 4, you will apply your knowledge to one Building with Nature case study.

Before working on Assignment 4, we offer you the opportunity to get familiar with the structure of the assignment by completing a sample case. In this section, you will therefore learn about the Sand Engine, an iconic case of Building with Nature. We will use this as our test case to show you how to complete Assignment 4. This section is broken into 4 parts:

1. Information about the Sand Engine in general (links below)
2. Detailed information on the Sand Engine as our sample case
3. Additional materials on the Sand Engine
4. Instructions on Assignment 4 (part 1)
5. An example of how to complete Assignment 4 using the Sand Engine (part 1) as our test case

Information About the Sand Engine

Below this text you will find a link to a video* that introduces the project. We have also provided links to three official fact sheets from the Sand Engine, which, among other materials, you can access from the official website of the project.

After watching the video and reading the fact sheets, you can move to the following tab. There, you will find more detailed information on the Sand Engine, which you will need to practise for Assignment 4.

Video: The Sand Engine/Motor

**Please note, this supplementary video material is supplied by a third party and is thus only available on YouTube rather than for download.*

Fact sheets

Below you can find links to the three fact sheets mentioned in this section:

Sand Engine - About the project

Sand Engine - Retrospective

Sand Engine - Monitoring and Research

Detailed Information on Sample Case

The information on the following pages provides a synthesis of information on the Sand Engine, the case we use as iconic example of Building with Nature. It has been adapted from the Deltares PublicWiki Case - Sand Engine Delfland, now available on https://www.ecoshape.org/en/cases/sand-nourishment-sand-engine-delfland-north-sea-nl/.

Please note that as you familiarise yourself with the material, and work through the example case for Assignment 4, you may also need to look for additional information. A section with extra additional information on the case is provided later.

Engineering: Building with Nature Case – Sand Engine Delfland

Adapted from the Deltares PublicWiki Case - Sand Engine Delfland, now available on Ecoshape.org, by Ir. Graciela del Carmen Nava Guerrero and Prof. Jill Slinger for use in the MOOC Engineering: Building with Nature 101x of the Delft University of Technology. Title Sand Engine Delfland

Location	Coast of Delfland (Netherlands)
Date	March 2011 – November 2011
Main problem owner	Rijkswaterstraat – the operational arm of the Dutch Ministry of Infrastructure and Water Management
Companies	Province of South-Holland, Ecoshape, DHV, Deltares, Van Oord, Boskalis
Costs	60 million euro for construction, and additional costs for studies and monitoring

4-15. Location of Sand Engine. 🅭 Projectbureau Pilot Zandmotor

1. General description of societal needs

a. Expressed need or required service

The coast of Delfland, a coastal stretch of about 14 km between Hoek van Holland and The Hague (Netherlands), is characterised by dunes, and a net northward longshore transport of sand, driven by predominantly southwesterly winds and waves. The coast is maintained by regular supplies of sand, formerly mostly in the form of beach nourishments, more recently in the form of foreshore nourishments, typically once every 4 or 5 years. The nourishment need for the Delfland coast is in the order of 300 000 to 500 000 m^3 of sediment annually.

Sea level rise will lead to a substantial increase in the nourishment need for two reasons. The first reason is that erosive processes will intensify, meaning that maintaining the present coastline will require more nourishment. The second reason is the Dutch efforts to maintain the entire coastal profile down to the 20-meter depth contour. This concerted effort is in place because the deeper part of the coastal profile (the coastal foundation) is also considered vital for dynamically maintaining the coast, and preventing structural erosion.

In order to maintain the coastline and the coastal foundation of the Delfland stretch while sea level rises during the next 20 years, a sediment volume in the order of 20 million m^3 is needed. The corresponding foreshore nourishments (at intervals of 4 to 5 years) disturb the (underwater) ecosystem significantly. Given that the system is not fully recovered before the next nourishment arrives, the high nourishment frequency means that the system will be in a more or less permanent state of disturbance.

This raises the question of whether the practice of periodic small-scale nourishment is the most suitable or environmentally friendly way of coastal maintenance.

b. Stakeholders who react directly with the ecosystem and how they do this[1]

Inhabitants and tourists of the coast of Delfland undertake both contact (e.g. swimming) and non-contact recreation (walking, cycling). Certain inhabitants derive their income directly from the beaches and people using the beaches e.g. beach restaurant owners. Inhabitants value living near the beach and this is reflected in higher property values closer to the coast, yet protected from flooding. The dunes also act as flood defence barrier for the hinterland, and much of the water supply for South-Holland derives from the groundwater filtering through the dunes. Aesthetic and cultural values are associated with the South-Holland coast.

c. Interested and affected parties.

Inhabitants and tourists of the coast of Delfland, Province of South-Holland, Water Board of Delfland, Ecoshape, consulting engineers (e.g DHV-Haskoning), Deltares, dreging companies (e.g Van Oord, Boskalis), Westland municipality, municipalities of the Hague and of Rotterdam, Milieufederatie Zuid Holland and the World Wildlife Fund.

- The Province of South-Holland wished to give nature and recreation in the area a boost and to have an icon of innovation.
- The Ministry of Infrastructure and Water Management - Rijkswaterstaat is responsible for long-term coastal safety by maintaining the coastline and the sediment volume of the coastal foundation.
- The Water Board of Delfland is responsible for flood defence system maintenance.
- The Westland municipality, the municipalities of The Hague and of Rotterdam, Milieufederatie Zuid Holland, the World Wildlife Fund and Ecoshape were also interested, as were consulting engineers and dredging companies.

d. Sources of ecosystem knowledge and expertise.

Milieufederatie Zuid Holland, the World Wildlife Fund, Research and Education institutions (e.g TU Delft, WUR, Deltares), Inhabitants and tourists of the coast of Delfland, Province of South-Holland, Water Board of Delfland, Ecoshape, consulting engineers and dredging companies, Westland municipality, municipalities of the Hague and of Rotterdam.

2. Project solutions

An alternative to the periodic nourishments (every 4 or 5 years) is a mega nourishment applied every 15 to 30 years. The main advantage of a mega nourishment over periodic smaller-scale nourishment is less ecosystem disturbance. Moreover, the unit price of the large amount of sand is likely to be less than that of smaller amounts at a time. Nature does most of the distribution work and there are additional benefits (recreation, increased nature value, extension of the dune area). Whether this out-

weighs the costs of the earlier capital investment, however, remains to be seen.

To investigate the effectiveness of a mega nourishment, a pilot and demonstration project “Sand Engine” was proposed for the Delfland Coast. It involved depositing a large amount of sand (21.5 million m^3) on the foreshore and letting the forces of nature (waves, tide, wind) distribute it over the coastal profile and along the shore. In this way, mega nourishments gradually feed the dune ridge over a long stretch of coast and over a timespan of a few decades, thus contributing to safety against flooding. Large nourishments also create opportunities for nature development and recreation, important supplementary goals of a mega nourishment.

3. Costs and benefits

Considering only the design and construction costs in the light of the primary function (maintaining the coastal flood defence system), the traditional periodic nourishment practice might be more cost-efficient than a Sand Engine. Yet, there was a strong preference for a mega nourishment, as additionally, this would create an island or peninsula that would create new possibilities for recreation and nature development. These possibilities, the showcasing of (dredging) expertise, the potential learning experiences and the fact that the area might not need maintenance for the next 20 years and so there would be less frequent disturbance of the environment, weighed more heavily than the lower cost-effectiveness for coastal defence in the short term. Whether the Sand Engine will turn out to be a better deal, economically and ecologically, in the long run is the subject of ongoing research and monitoring.

[1] The focus of Part I of this book lies on integrating between engineering and ecosystem design principles and NOT on the societal aspects of BwN. A full application of the Building with Nature concept would require that the societal context and requirements are included fully from the outset, as explained in Part II.

4. Planning and Design

a. Initiation

The first ideas for the Sand Engine date back to the beginning of this century. Initiators were the Province of South-Holland and the Ministry of Infrastructure and Water Management (Rijkswaterstaat). A number of developments were brought together in the initiation phase, which started in 2007:

- The 'Geluk' parliamentary resolution of 2003, requiring the exploration of 'an integral, multifunctional and sustainable, phased expansion of the coast between Hoek van Holland and Scheveningen'.
- The advice of the Tielrooij Committee of the Province South-Holland, in their 'coast booklet' (In Dutch: 'kustboekje') of 2006.
- The development of the idea of mega nourishments in the Rijkswaterstaat innovation program (WINN), reflecting the ambition of Rijkswaterstaat to explore methods to scale up coastal nourishments.

b. Exploration phase

The Province of South-Holland led the exploration phase of the Sand Engine. In a pre-feasibility study (Bruens et al, 2007), different shapes and locations of a Sand Engine were proposed and investigated. Consultant engineers Royal Haskoning were hired to guide the process towards an ambition agreement between the main actors and to design a project development process. In April 2008 the ambition agreement was signed and the planning phase started.

c. Planning phase

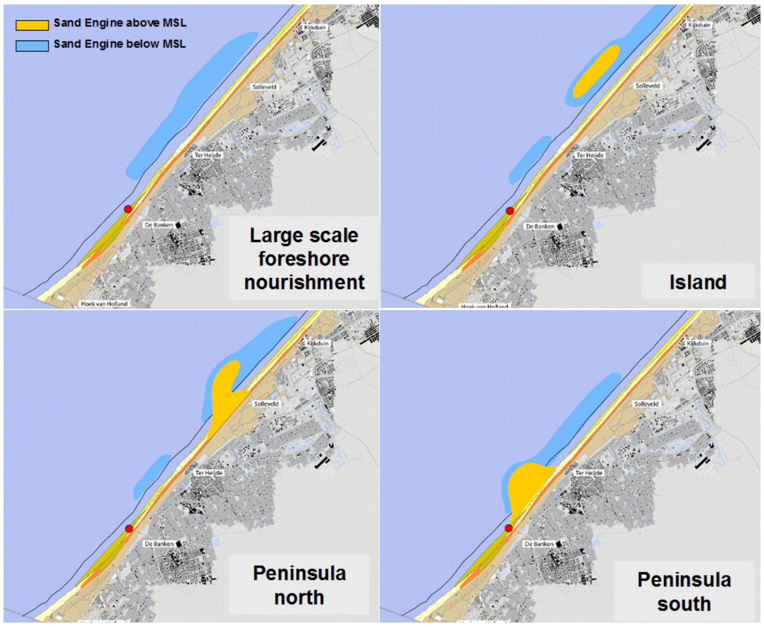
The planning phase included the Environmental Impact Assessment (EIA) process. A strategic impact assessment (Grontmij, 2008) and an Environmental Impact Assessment (DHV, 2009) were carried out. In preparation, several alternative designs of a Sand Engine were studied and several scenarios for sustainable long-term nourishment strategies were evaluated (Mulder et al, 2010). The EIA procedure was meant to identify the most feasible and environmentally friendly alternatives for nourishment-based coastal management. Four alternatives were considered, each with a construction volume of 20 million m^3 of sand (see Figure 4-16):

1. the original nourishment regime (4 to 5 year frequency) with larger amounts of sand,
2. a large foreshore nourishment,
3. a detached island 1 km off the coast, and
4. a peninsula (different locations and shape) attached to the coast.

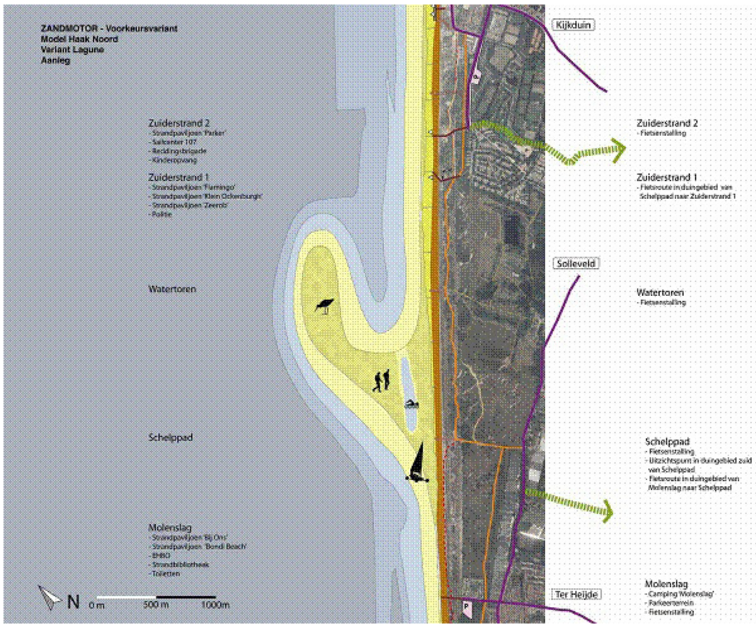
The design challenge was to locate and to design a cost-effective mega nourishment that would serve coastal management

and long-term coastal protection, and offer opportunities to nature and recreation, without having negative impacts on existing nature areas and recreation. Morphological and ecological processes were studied in order to assess the costs and the impacts of these alternatives. The peninsula (see Figure 4-17): had the best scores in the EIA as far as aspects such as safety, recreation and knowledge development were concerned. The shape of a shore-attached hook provided more variation than an island or a foreshore nourishment, as a sheltered zone was created between the hook and the beach which was likely to develop into a temporary lagoon. Several locations were considered for the peninsula. Given the nature of the pilot, the dynamic character of the Sand Engine and the existing functions and infrastructures, the Solleveld reach (between Kijkduin and Ter Heijde) was selected. At this location the Sand Engine would have a limited (direct) effect on areas with extensive recreational functions, whereas the area would still be accessible for recreation and "central enough" to supply sediment to most of the Delfland Coast. The Sand Engine is a pilot project. It is the first mega nourishment of this size and form, with an anticipated functional lifespan of more than 20 years. Until the Sand Engine, the coast was maintained with periodic nourishments parallel to the coast or on the beach. The peninsula-shape is a novelty. The largest periodic nourishments are in the order of 5 to 7 million m^3, with a functional lifespan of 5 to 10 years, at the most.

Final decisions regarding the form, location and volume of the Sand Engine depended on a deep understanding of its anticipated dynamic behaviour over the first 20 years. Accordngly, extensive long term morphological studies were conducted to underpin the initial design, and explore the functioning of the Sand Engine within the first 20 years after construction. An understanding of the bandwidth of uncertainty associated with the dynamic behaviour of the Sand Engine over time was generated. Several aspects critical to beach safety, such as beach development and rip current formation, were handled with smaller-scale morphological models.



4-16. *Alternative nourishment schemes. © Ecoshape*



4-17. *Preferred alternative, Peninsula. © Ecoshape*

Issues that could not be predicted or dealt with in the design were included explicitly in the management and monitoring programmes.

i. Tender request

After the location and volume were determined in the EIA process, the Sand Engine was contracted with a set maximum budget. The Design and Construct contract was awarded to the contractor that could deliver the largest volume of sand for the set price.

ii. Management

Knowledge development in the design phase of the Sand Engine experiment focused on three different activities: design development, design assessment to select the preferred alternative, and the optimisation of the preferred design. Integration of the

design and assessment activities led to a multifunctional design contributing to coastal safety, nature, recreation and knowledge development.

Important enabling factors for realising the Sand Engine in the planning phase were:

1. Involvement of a broad representation of actors and stakeholders in the project. The Province, national ministries, municipalities, an environmental NGO and the Delfland Waterboard, signed the ambition agreement.

   In the project team, these parties are represented and complemented by consultants and knowledge institutes (Deltares), NGOs and other parties relevant to the process. This broad and intensive involvement of authorities and stakeholders turned out to positively influence the general support for the project.
2. The design alternatives for the Sand Engine came from the pre-feasibility study (Bruens et al, 2007) and three design workshops held in the summer of 2008. In addition, experts from several disciplines such as morphology, ecology and dredging operation were also involved.

   During the workshops all identified stakeholders were represented. This integrated approach was instrumental to achieving the necessary multi-functional design.
3. The location of the Sand Engine was subject to few legal restrictions, the only one being that the environment should not be negatively affected

Moreover, there were no immediate coastal safety issues and no specific targets concerning nature or recreation. The open formulation of the goals and the absence of legal restrictions contributed to the feasibility of the pilot project, Sand Engine.

5. Construction

a. Detailed design

After selecting the location (the Solleveld reach, a natural dune area between the recreational beach areas of Kijkduin in the north and of Ter Heijde in the south) and the shape (hook-shaped peninsula), the dimensions of the Sand Engine were determined.

The peninsula extends 1 km into the sea, and has a longshore dimension of 2 km. Its maximum level is 5 m above chart datum (NAP), which means that part of the surface remains above sea level even under storm conditions. The total nourishment volume is 21.5 million m^3 of sand, of which 19 million m^3 is Sand Engine itself. The other 2.5 million m^3 was placed in two foreshore nourishments, one on each side. These two foreshore nourishments are designed to supply sand to the parts of the coast that the redistribution of sands from the Sand Engine will not reach in the initial few years.

The 19 million m^3 of sand resulted in an initial exposed sandy area of 100 Ha. The main part of the nourishment lies within the active coastal profile, which extends down to the 10 to 12 m depth contour, i.e. that part of the foreshore where wave-induced sand movement is most active. After redistribution of the sand, eventually the Sand Engine is expected to generate a total of 35 Ha of new dunes.

At the base of the peninsula, an 8 Ha lake was created. Apart from creating extra morphological and ecological variation, this lake contributes to maintaining the original groundwater level in the existing dune area, thus safeguarding conditions for the commercially exploited groundwater reservoir in the Solleveld reserve behind the dunes.

At a late stage, some initially underestimated potential problems related to the commercial drinking water exploitation in the Solleveld dune area arose. Generally speaking, the gradual extension of the dune area induced by the Sand Engine will increase the fresh water reservoir of the dunes. At first sight, this appeared positive for drinking water exploitation. Yet, the very specific conditions at Solleveld made this problematic. In the existing dunes north of the Sand Engine, polluted rubble was dumped and buried after the war. Widening of the dunes will lead to a seaward expansion of the exploited watershed and may bring the groundwater into contact with the polluted rubble. To prevent this, a system of groundwater pumps was installed around the polluted area, in order to artificially lower the groundwater table and to prevent groundwater flow from the polluted area into the exploited watershed.

b. Project delivery

By November 2011, the total of 21.5 million cubic meters of sand had been dredged and placed in position. The Sand Engine was officially opened on November 24th, 2011.

c. Management

Before construction started slight adjustments were made to the position of the Sand Engine, based on discussions with the municipalities of Westland and The Hague. This resulted in a slight northward shift of the location, so that the Sand Engine is located in both municipalities. They agreed, however, that the management of the entire Sand Engine will be in the hands of the municipality of Westland.

During construction regular management and user meeting were organised to inform the stakeholders. To ensure swimmer and beach safety, the lifeguard brigade was closely involved and organised information meetings.

6. Operation and Maintenance

a. Delivered project

In November 2011 the construction of the Sand Engine was completed. A total amount of 21.5 million m^3 of sand had been placed in front of the Delfland coast, with the objectives to provide long-term safety, to create extra space for recreation and natural development and to learn as much as possible from this pilot project. *Are mega nourishments a good alternative for smaller-scale periodic nourishments?* The first results of the experiment was assessed 5 years after construction. To this end an extensive monitoring program was put in place (see 6c).

During the first year after construction the Dutch coast was exposed to a number of heavy southwesterly storms. As a consequence, the morphological evolution of the Sand Engine proceeded faster than expected, but the shape developed as anticipated, with the tip of the initial hook extending northward and bending towards the shore, creating a tidal lagoon.

In spring 2012, the tip of the Sand Engine extended to enclose a lagoon, and a channel formed running parallel to the beach with its mouth towards the north. The lagoon filled and emptied with the tides. Worried about the further development of this channel, its effects on beach slopes and swimmer safety owing to strong currents, the Province of South-Holland decided to close it off with rocks and create another channel, more remote from the beach. During the summer, dynamic coastal processes drastically altered the lay-out of the channels. As the channels were no longer threatening swimmer safety, the majority of the rock was removed again in September 2012.

b. Strategies

In view of the pilot character of the project an extensive program was set up to monitor the morphological and ecological development of the Sand Engine (RWS, Province Zuid Holland et al. (2013).

Considering that the Sand Engine is meant to redistribute sand along the stretch of coast between Hoek van Holland and Scheveningen, additional maintenance of this stretch by sand nourishment is expected to be limited over the coming 20 years (Mulder and Tonnon, 2010).

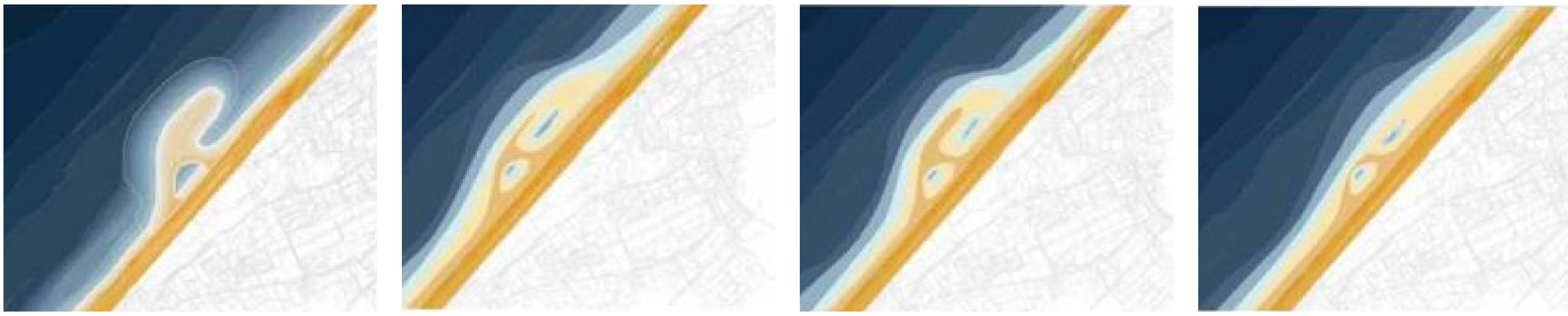
c. Monitoring

The time-evolution of the Sand Engine is carefully monitored year-round. The first step was to map the shape of the seabed, and the existing ecosystem components, before construction. The Sand Engine was monitored during construction and is being monitored after construction, for both management and operational purposes, and to evaluate whether this innovative method of coastal protection actually works. The monitoring program focuses on six areas:

1. Weather, waves and currents
2. Sand distribution
3. Groundwater table and quality
4. Flora and fauna
5. Recreation
6. Management.

Early in October 2012, a 40 m high Argus-mast was placed on the Sand Engine. It is equipped with video cameras to register changes of the Sand Engine continuously; directly by visual monitoring of the exposed parts, and indirectly by monitoring wave behaviour (propagation, breaking).

The research program is divided into two phases: 2011-2016 and 2016-2021. This program is coordinated jointly by the Ministry of Public Works and EcoShape and is funded partly by the European Union under the European Program for Regional Development (EFRO).



0 years 5 years 10 years 20 years

4-18. Impression of the predicted evolution of the Sand Engine. © Projectbureau Pilot Zandmotor

7. End of life

Eventually the sand of the Sand Engine will be redistributed along the coast by wind, waves and currents. It will induce gradual dune formation along a stretch of coast over a few decades, thus contributing to flood safety and dune nature. Since the Sand Engine is designed to disappear, no significant long term maintenance is foreseen.

a. Lessons learned

- Mega nourishments need to be tailor-made; to be successful the relevant site-specific coastal processes, such as hydrodynamics, morphodynamics and ecosystem dynamics, need to be understood.
- The specific properties of a particular location will also determine the design of a mega nourishment.
- Understanding of the ecological and social functions, and

the relevant stakeholders, is a prerequisite to a mega nourishment initiative. These are crucial to the various project phases, as the selection of alternatives is seldom based on cost-effectiveness alone. Instead ecological, socio-economic and political considerations always play a role.

- When considering a mega nourishment it is important to compare the merits, costs and effects of various alternative strategies. Compare the option of a mega nourishment with more traditional alternatives (periodic small-scale nourishments) and identify the pro's and cons of each alternative.
- When considering a mega nourishment it is best to evaluate the design (location, position and volume), implementation and management as one comprehensive set, including the way in which monitoring and risk management can take place.
- Mega nourishments are generally not the most cost-effective means of getting sand onto the beach, and only become a preferred strategy when other benefits are taken into account, such as recreational potential and avoidance of frequent ecosystem disturbances.
- The form of a mega nourishment is a matter of choice, governed by a combination of preferences. On the one hand, a temporary island is less suitable for recreation, since it is difficult to reach, very dynamic, and may create conditions that are unsafe for swimmers. On the other hand, an island is ideal for birds and sea mammals, as it cannot be reached by terrestrial predators like foxes. A peninsula helps in forming a lagoon, which is an asset for recreation as well as nature development. Foreshore nourishment is ideal if the condition of the existing beach is already sufficient. Beach nourishment may be the preferred option if beach sports are to be facilitated that require wide open beaches, but also in situations where tidal currents close to shore make offshore alternatives less cost-effective.
- Morphologically, nourishment within the active coastal profile is advocated, as sand within this zone is most likely to be transported shorewards. If the costs of foreshore and beach nourishment do not differ much, then beach nourishment is to be preferred from a morphological point of view as the sediment losses to deeper water are less.
- Sand properties: using readily available sand is financially often the most attractive. If a choice between different grain sizes is possible, the use of coarser sand below the low water mark is preferred as it will create a steeper stable slope and a smaller total volume is then required. The finer fractions then can be kept for dune formation. If wind-blown sand constitutes problems, e.g. because of nearby roads and houses, coarser fractions may then be preferred.
- Most mega nourishments will be quite dynamic, so their longer-term development is difficult to predict. Close monitoring, adaptive management, scientific supervision and a clear communication strategy with the stakeholder community are necessary to deal with the associated uncertainties.
- To use and learn effectively from such a large-scale experiment, monitoring, data management and generic research need to be specified, arranged and funded before construction.

Further Reading

- http://www.dezandmotor.nl/en
- https://www.rijkswaterstaat.nl/en/water/water-safety/sand-motor
- http://www.dezandmotor.nl/en-GB/downloads
- https://www.flickr.com/photos/zandmotor/
- http://en.wikipedia.org/wiki/Sand_engine
- https://www.youtube.com/user/Zandmotor
- http://www.youtube.com/watch?v=oEhGzxcz3gk (Dutch)

Additional Materials and Videos on the Sand Engine

In this section you will find additional materials on the Sand Engine. Both videos* feature Prof. Marcel Stive explaining the design and realisation of the Sand Engine and what it means for innovation in coastal engineering. You can also find 2 additional papers on the Sand Engine: After watching these videos, you can move to the following section, where you will find the introduction and instruction to practise for Assignment 4.

Enjoy!

Paper: Biographies of the Sand Engine (Bontje and Slinger, 2017)

Video: TU Delft - Building with Nature - Prof. Marcel Stive

Paper: 'Mind the gap' between ecosystem services classification and strategic decision making (not open access)

Video: NatureCoast Sand Engine

Instructions to Practise for Assignment 4

Before working on Assignment 4, we offer you the opportunity to get familiar with the structure of the assignment by completing a sample case. Although Assignment 4 has two parts, an individual assignment and a self-review, we will now work only with **Part 1.**

Part 1 will require you to analyse the particular problem of coastal erosion in the The Netherlands. Then, you are requested to propose a conventional design and a Building with Nature design to address the issue. You will assess your own design based on the Engineering and Ecological Design Principles.

Practise for Part 1 of Assignment 4

If you have already read the fact sheets and detailed information from the previous tabs, you can continue by following the instructions on the next page. If not, please consult the case information on the previous pages first. Start with watching the instruction video about the sample case before continuing to your own assignment.

Video: Part 1 of Assignment 4 - Sample Case

In this section, you will find a video presented by **Prof. Jill Slinger** and **Ir. Graciela del Carmen Nava Guerrero** in which they explain how to fill in the form **Part 1** of Assignment 4 for the sample case, the Sand Engine.

Instructions for your own assignment

First watch the instruction video for the sample case above. Then go to the assignment form at the end of this chapter on page 4-204 and complete the form by either:

- Recommended: Type the answers to the written questions, put an X in the right check boxes, and include your sketches by either:
  - drawing your sketches in another programme like Paint and inserting it as a picture in the form, or
  - drawing your sketches on real paper, then scanning or photographing them and inserting them in the form.
- Print the form and write each question out by hand, before either scanning or photographing each page.

Once your form is complete, save your form. You can then move on to Section 4.4, where you will find additional information on the exercise.

Tip: *When filling in the check boxes, you may not feel that you have all the knowledge that you need. This is part of the Building with Nature process, which requires interdisciplinary collaboration. When you lack information on a certain Principle, please just explain your thinking.*

Assignment 4: Detailed Case Material

4.4 Detailed Case Material for Assignment 4

Introduction

In this section an overview of the six cases is provided, as well as the requirements for your own case. You will also find a map of the Netherlands and an introductory video to the Delta Approach for water management.

Enjoy familiarising yourself with the more detailed material!

Cases

1. Climate-proof Noordwaard

The river Rhine runs through the Netherlands towards the North Sea. During very high discharges the floodwaters needs more space to spread out so as to prevent disastrous downstream flooding. There needs to be more Room for the River! This will be provided by de-poldering the Noordwaard polder, which is situated in the southwestern part of the Netherlands. De-poldering involves allowing controlled flooding of specific areas of the land. Nevertheless, within this de-poldered area, there are location(s) that still have to be protected from flooding. You are required to design a nature friendly solution for this problem, possibly by building a dike.

2. Nijmegen case

On its journey through the Netherlands, the Waal River passes the city of Nijmegen, in the eastern part of the country. To prevent dangerous situations similar to those of 1993 and 1995 when extreme river discharges occurred and major evacuations of people and animals had to be undertaken, more room has to be given to the river near Nijmegen. The proximity to the city means that there is an opportunity to improve the quality of the environment for urban dwellers when you design your nature friendly solution to the flooding safety problem.

3. Fish Manager

Fish Manager – One hundred years ago, a long dike was constructed in the north of the Netherlands to protect large tracts of land from flooding. This barrier dike transformed the Zuiderzee (Southern Sea) into a freshwater lake known as the IJsselmeer (IJssel Lake), and continues to separate the fresh IJssel Lake from the salt water of the Wadden Sea. Sluices in the barrier dike only allow freshwater to drain into the salty sea water, but do not allow salt water to penetrate into the freshwater lake. This means that at present fish cannot migrate from the sea into the lake. You are required to design a nature friendly solution for this problem, with the strong proviso that the flooding safety standard is maintained.

4. Coastal Protection

Regular assessments of the safety of a dike are undertaken in the Netherlands. During such an assessment, the anticipated performance of the dike subjected to a storm surge or flood with an incidence of occurrence of 1 in 10 000 years (the Dutch flood protection standard) is tested. During a recent assessment, the sea defence dike along the North-Holland coast near Petten was deemed not to satisfy the safety requirements. Accordingly, the coastal defences have to be upgraded. You are required to design a nature friendly solution to this problem. You are encouraged to

consider that the North-Holland coast has many naturally occurring dunes and is strongly influenced by the wind and waves.

5. Harlingen Harbour

The harbour of Harlingen is located in the north of the Netherlands, in the tidal basin of the Wadden Sea. The Wadden Sea is a large unbroken system of intertidal mudflats, exhibiting high species diversity. It is considered one of the most important habitat areas in the world for migratory birds. Owing to high sedimentation rates in the harbour of Harlingen, an average volume of primarily fine sediment totalling 1.3 million m^3 has to be dredged annually and is dumped in the vicinity of the harbour. However, instead of continuing with the conventional dredging and disposal strategy, you are required to devise a nature friendly alternative. You are encouraged to consider that this sediment could be useful in extending salt marshes and intertidal mudflats within the Wadden Sea and along the nearby coast.

6. Flood-proof Indonesia

In Indonesia, the northern coastline of the main island of Java faces threats of land subsidence and severe coastal erosion. The conversion of mangrove forest to land for urbanisation, agriculture and aquaculture is widespread. Frequent flooding during high tides, periods of excessive rainfall and storm surges, threaten the lives and livelihoods of local communities. The Building with Nature Indonesia consortium (Wetlands International, Ecoshape, the Indonesian Ministries of Marine Affairs & Fishery and Public Works & Housing, international and local partners, and local communities) are involved in flagship projects in northern Java to counteract coastal erosion, particularly in the Demak district. You are required to design a nature-friendly solution to combat coastal erosion realising that this area was once surrounded by mangrove forests acting as natural flood defences.

7. Individual cases

If you have already selected to work with an individual case, you will need to accumulate background information. Instructions on gathering material are included after the case descriptions.

Introduction to the Netherlands

Welcome to the Netherlands!

The Netherlands, as the main constituent country of the Kingdom of the Netherlands, is located in Western Europe, borders Germany, Belgium and the North Sea, and shares maritime borders with Belgium, the United Kingdom and Germany (see map below). The Kingdom of the Netherlands is a member state of the European Union. People in the Netherlands are called Dutch people and the most spoken language is Dutch. The climate is rather mild and varies on average approximately between 0 and 20 degrees Celsius.

The Netherlands is a small country and part of a low lying delta. In fact, 55% of the country's territory is susceptible to flooding: 26% of the Netherlands is below mean sea level and 29 % is susceptible to river flooding. Despite these evident physical threats, the Netherlands is densely populated with 17.5 million inhabitants.

Clearly, the Dutch have a long tradition of water management. In addition to the national, provincial and municipal government layers, the Netherlands has an additional category of governmental bodies specifically charged with water-related tasks: the water boards (Dutch: waterschappen or hoogheemraadschappen). There are currently 23 water boards that are all responsible for managing the dikes, water barriers, waterways, water levels, water quality and sewage treatment in their regions. These Dutch regional water authorities are among the oldest forms of local government in the Netherlands, dating back to the 13th century.

After suffering a number of coastal storm surges, with the disastrous flooding in 1953 (Dutch: Watersnoodramp) as an absolute low point, the Netherlands sought to improve its flood protection further and to reclaim land for agriculture. In the twentieth century, large hydraulic engineering projects (the Dutch Delta Works and the Zuiderzee Works) were undertaken to shorten the Dutch coastline as part of ambitious plans for improving flood protection and reclaiming land. The construction projects have shaped Dutch flood protection in many ways, allowing Dutch engineers to innovate and deepen their practical knowledge of hydraulic design and construction. Aside from changes in the engineering profession, the physical Delta system, and the institutions of water governance, the infrastructure works also impacted on the environment and society. From the beginning of the twentieth century, Dutch flood protection policies and projects have continued to alter owing to changing social needs (e.g. public opposition to the impacts on historic buildings and the environment)

and changing long-term circumstances (e.g. climate change, sea level rise). This trend continues and is embodied in the Building with Nature philosophy.

The short video from the Dutch Embassy in the United States of America, accessible via the link below, provides an introduction to the Delta Approach, and explains how the Netherlands is protected against high water.

Water Management - The Delta Approach

**Please note, this supplementary video material is supplied by a third party and is thus only available on YouTube rather than for download.*

4-19. Map of the Netherlands. © Scipius

Case 1: Climate-proof Noordwaard

Introduction

This section provides a synthesis of information on Climate-proof Noordwaard, the case you will be using for Assignment 4.

Please note that as you familiarise yourself with the material, and develop an understanding of the case, depending on the background knowledge you have, you may find that you need to look for additional information.

Introduction

The river Rhine runs through the Netherlands towards the North Sea. During very high discharges, which may occur more frequently in future owing to climate change, the floodwaters need more space to spread out so as to prevent disastrous downstream flooding. There needs to be more Room for the River! This will be provided for the New Merwede branch of the Rhine by de-poldering the 4450 Ha Noordwaard **polder***, which is situated in the southwestern part of the Netherlands. De-poldering involves allowing water to stream through and over the Noordwaard polder when the river discharge is very high. By allowing flooding of the land that was previously protected by dikes, the predicted high water levels from river flooding will be reduced by 30 cm at the nearby town of Gorichem.

Nevertheless, within this de-poldered area, there are location(s) that still have to be protected from flooding. For instance, in the northeast corner of the Noordwaard polder, there is a fortress called Fort Steurgat. This fortress has cultural and historical value. This corner is also home to eleven households.

* In the Netherlands, a polder is an area of low land that is protected from river or coastal floods by a ring of dikes.

You are required to design a nature friendly solution for this particular problem, possibly by building a dike. Be aware that Rijkswaterstaat (RWS) requires a design that delivers a protection level comparable to other dikes in this region (1 in 2000 years) while still achieving the overarching goals of the Room for the River programme.

In short, the primary problem owner or client is the Dutch Ministry of Infrastructure and Water Management, who is tasked with ensuring that appropriate planning is undertaken to ensure the safety from flooding in the Netherlands. It is they who commission studies to determine the predicted flood levels, and they who then determine the desired reduction in flood level that must be achieved through actions like de-poldering.

Good luck!

Where is the Noordwaard Polder located?

The Noordwaard Polder, depicted by the purple polygon (area), is situated in the western part of the Netherlands, close to the cities of Dordrecht and Gorichem. The black polygon (area) in the map represents the northeast corner of the Noordwaard Polder, which is the focus of this case. Click on the map to view it online or scan the QR Code.

4-20. Noordwaard Polder location. © Google MyMaps

Would you like to know more about making ‘Room for the River’?

Video: Corporate Clip
Room for the River

Source: Ruimte voor de rivier

What does the Noordwaard Polder look like?

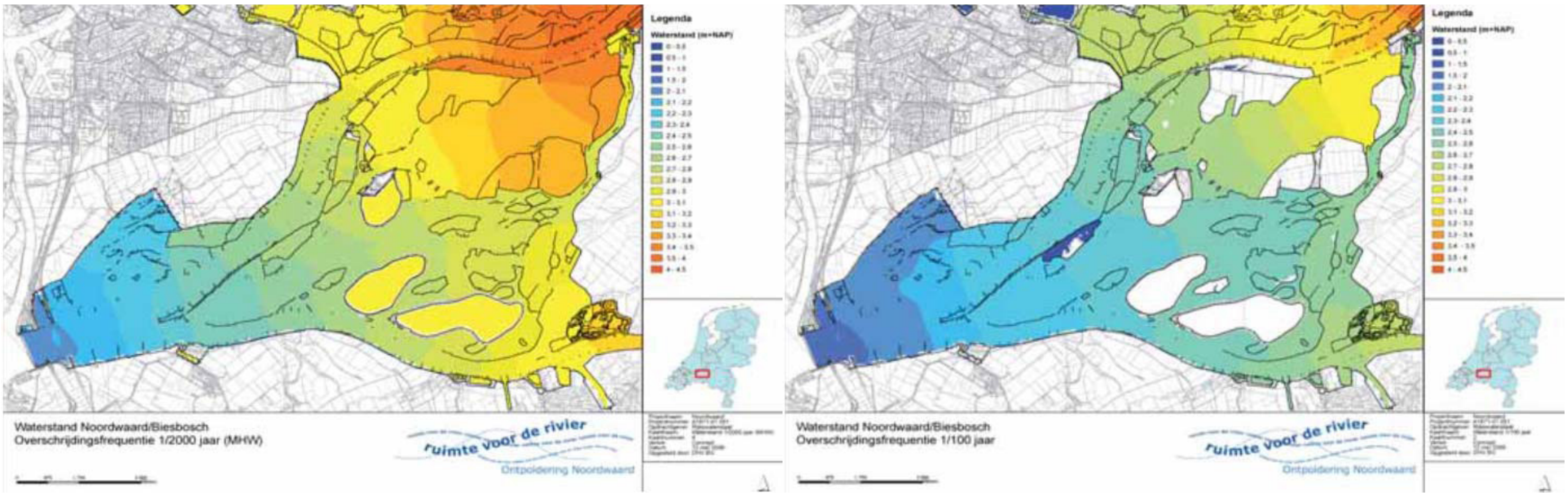
Video: Depoldering Noordwaard

Source: Ipv Delft

Hints and Information for Building with Nature Design

By Prof. Jill Slinger and engineers Stefan Jammers and Ilse Caminada

Before the lowering of the river dike to allow water to flow across the Noordwaard Polder, Fort Steurgat and the 11 nearby households were protected against a flood event with an annual probability of occurrence of 1 in 2000. The desired safety level for Fort Steurgat and the 11 households remains 1 in 2000. **The question is how you can protect this area both from high water levels and from the potential wave effects.** Have a look at the model simulations below (Projectbureau Noordwaard 2007). This will provide you with information on the flood water level that



4-21. *Predicted water levels in the Noordwaard and Biesbosch under the 1 in 2000 year flood (left) and the 1 in 100 year flood (right). The warmer colours represent higher water levels with dark blue representing very little change (almost zero). The upstream water levels (to the north) are about 0.5 m higher than the downstream water levels and water levels in the central area are approximately +3.20 m above chart datum (1 in 2000 year) and +2.80 m above chart datum (1 in 100 year), respectively. The current speeds remain well under 1 m.s^{-1}. © Ruimte voor de Rivier*

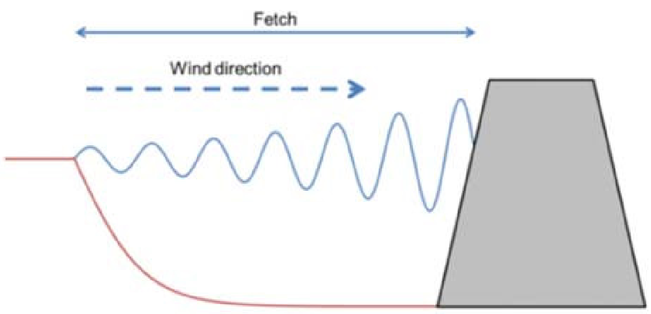
you have to take into account. Also, you will see that under river flood conditions there is a vast expanse of water. Wind blowing across this water will generate waves. As the predominant wind direction is southwest, the effect of the waves in raising the water level, and in potentially impacting the dike must also be taken into account.

Some useful engineering concepts

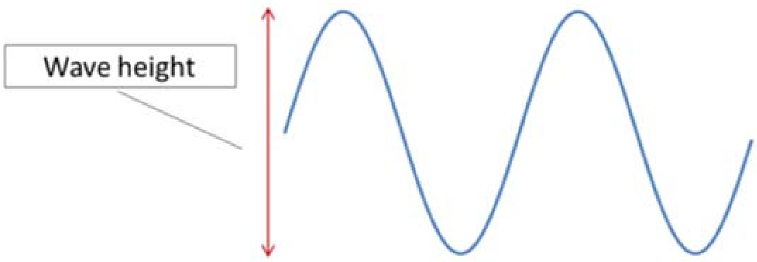
From a safety point of view, the total construction height of a dike is always composed of a design high water level plus a freeboard to reduce overtopping of incoming waves. So, for a simple estimate of the height that the dike would need to have if we adopt a conventional engineering approach, we need to know the *design high water level* (see Figure 4-21) and the freeboard. The design high water level is a chosen flood water level that is determined by a risk analysis in which the required investment in flood protection is balanced against the avoided damage. To determine the necessary construction height of the dike, *the height needed to reduce overtopping by waves* has to be added to the design high water level. The overtopping height is related to the incoming (significant) wave height, but also depends on the shape of the dike. If you are unsure of this , consult the video presented by engineer **Mark Voorendt** in Chapter 2. Compensation also has to be made for aspects such as (i) settling of the dike owing to the weight of material, and (ii) potential sea level rise over the design lifetime of 50 years, and to ensure (iii) that the dike crest is at least half a metre above the sum of all these effects. The compensation for the latter three factors can be taken as 0.95 m for Noordwaard. Now you can work out the necessary crest height at construction of a traditional dike by first working out the wave height as given below.

Fetch

Wind fetch is the (undisturbed) distance over which wind can blow in one direction, causing wind-generated waves in a water body. A longer fetch over a stretch of open water is associated with higher waves. Unlike in the sea, in rivers, dams and lakes the fetch is often limited by the land around the water body.



4-22. *Sketch of wind fetch. © Jill Slinger*



4-23. *Sketch of wave height. © Jill Slinger*

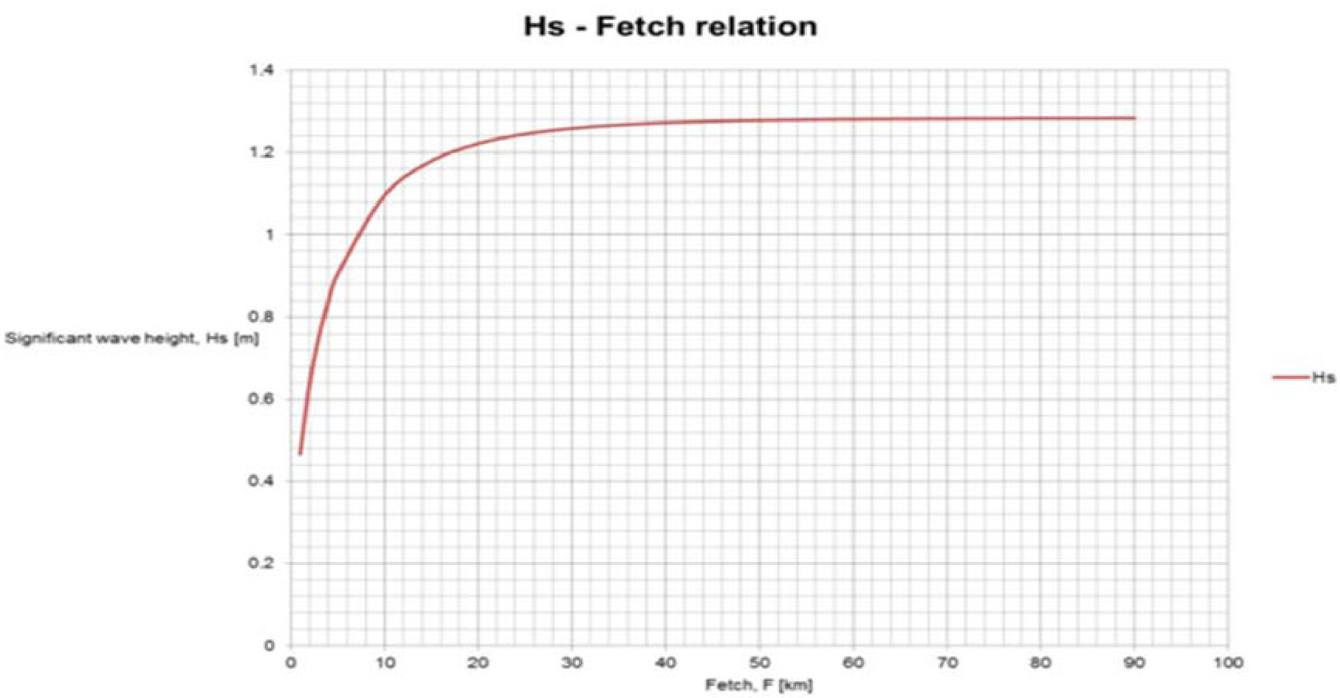
Wave height

The wave height is the distance between the crest and the neighbouring trough of a wave (Figure 4-23). In a water body a variety of waves of different heights occur simultaneously. The significant wave height is a parameter that is often used to characterise the height of the waves in a water body. It is the average wave height of the highest one third of all the waves. The significant wave height is used by engineers in dimensioning a dike.

Wave height - Fetch

If you don't wish to use a formula, you can work out the significant wave height from the graph below (Figure 4-24) and use this to determine how high a dike might need to be. In Figure 4-24, a significant wave height – fetch relationship is presented, it is assumed that the water depth (in case of flooding of the polder) is 3.2 meter and the relevant wind speed is 30 m.s-1. By first estimating the fetch and then using the graph above, the significant wave height can be estimated. Note that the significant wave height is the mean of highest one-third of the waves. In addition the wind speed is measured at a height of 10 m, this value is default for all calculations. These figures are computed based on the safety level of the dike ring (1 in 2000 year).

The width of the dike crest must be at least 3 m and wider if the design includes a road or other functions. At a first estimate the slopes of the inner and outer berms should be 1:3. More gentle slopes are more favourable for the stability and for limiting wave run-up.



4-24. *Significant wave height - fetch relationship, for water depth 3.2 m and wind speed 30 m.s^{-1}. ©*

Useful information about Landscape and Ecology

The Noordwaard area is primarily composed of agricultural polders surrounded by willow trees along the margins of old stream beds. The openness of the grassy, marine clay areas, the raised vegetated stream margins and the lower stream beds characterise the landscape. The landscape is open towards the northeast, while the western and southern areas are more compartmentalised by bushy thickets.

The Noordwaard polder borders the Biesbosch, a protected nature reserve under Dutch and European Law (Natura 2000 area, Ramsar wetland). It is one of the last extensive areas of freshwater tidal wetlands in northwestern Europe. The Biesbosch consists of a rather large network of rivers and smaller and larger creeks with islands. The vegetation is mostly willow forests, although wet grasslands and fields of reed are common as well. The Biesbosch is an important wetland area for waterfowl and has a rich flora and fauna. It is especially important for migrating geese. The protected status was granted because of the presence of characteristic freshwater tidal biotopes, many of which have disappeared in the Netherlands owing to the closure of tidal inlets by dikes and barrier dams. Species such as the beaver and the vole[1] (*Microtus oeconomus*) live in the Biesbosch and have difficulty surviving elsewhere. It is also the habitat of geese and swans with the agricultural and pastoral polders outside of the protected nature area, in the Noordward polder, functioning as a resting and foraging area for the geese and swans. A number of the smaller existing agricultural polders in the Noordwaard have already been turned over to nature via governmental funding to the farmers.

Different species of trees grow in the area. There are two species of willow tree (*Salix alba and Salix viminalis*) which can be inundated several times a year for weeks and still survive. These species are tolerant of high groundwater levels and are quite sturdy.

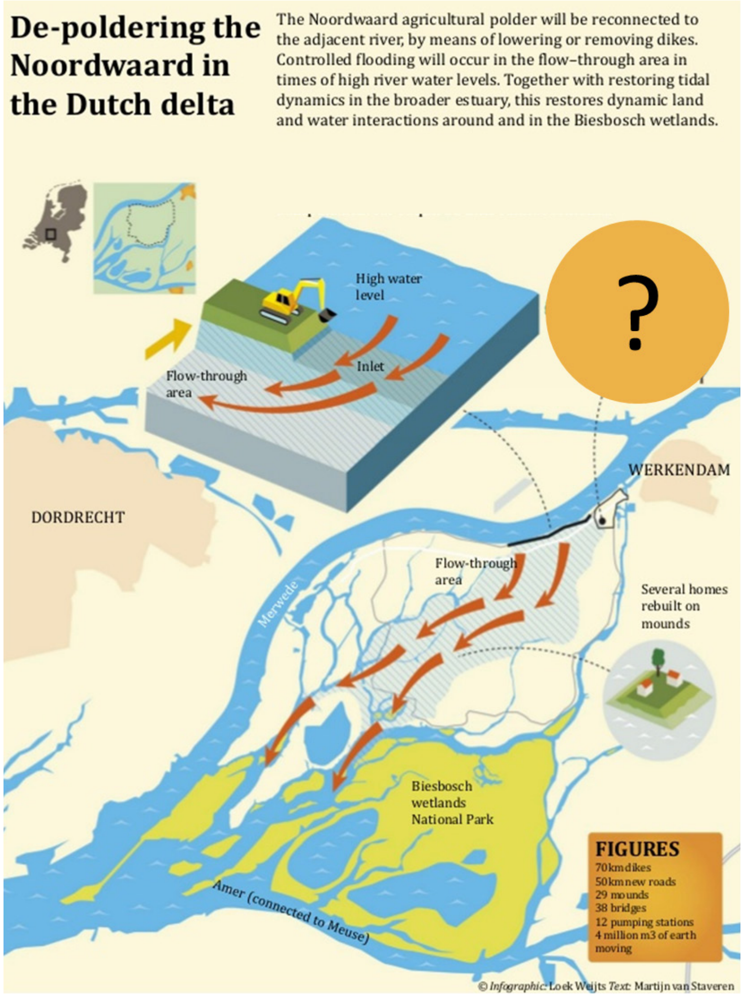
Integrating ecology and engineering

Willow trees and bushy thickets on a floodplain increase the resistance to flow and can increase mean high water levels during floods. However, they can also act as wave breakers when they lie across the direction of propagation of the waves. Although this type of vegetation can reduce the wave effect on a dike, it does not make the dike itself sturdier, nor do they prevent piping effects. Because the 1 in 2000 year flood is likely to occur in combination with heavy storms and strong winds, either a high and broad dike or a broad dike with more wave protection is needed.

The effect of vegetation on wave conditions has been tested using a modified version of the numerical wave model SWAN; a module was added in which the vegetation is represented as a

series of cylindrical obstacles of a particular diameter, density (e.g. number of trees per square meter), height, and drag coefficient. *For willow trees, model results reveal that for a 1 in 2000 year event the reduction of the wave height lies between 60% and 80%.* With this in mind, it looks promising to think of alternatives that reduce the waves. By reducing the wave height it may not be necessary to raise the dike so much, a relief to the people protesting about their loss of view because of the proposed construction of the dike. The breadth of the dike cross-section could then also be smaller by some 15 to 20 m. The costs of expropriating the land, planting 100 m wide willow trees or bushes, and the operational and monitoring costs of such an alternative are € 33 - 55 per m dike. But given that the reduction in wave height occurs in the first 20 m, it is possible that a 50 m wide zone would be sufficient with costs in the order of € 25 – 30 per m dike. These costs are substantially lower than a conventional dike strengthening approach. This usually involves raising the crest of the dike or strengthening the revetment(s), which costs between € 150 - € 1500 per m dike! With this information, you can now design an integrated Building with Nature alternative to the traditional dike.

[1] Occurs in protected areas. It is listed on Appendix III of the Bern Convention. The subspecies *arenicola* (from the Netherlands) is listed on Annex II of the EU Habitats and Species Directive.

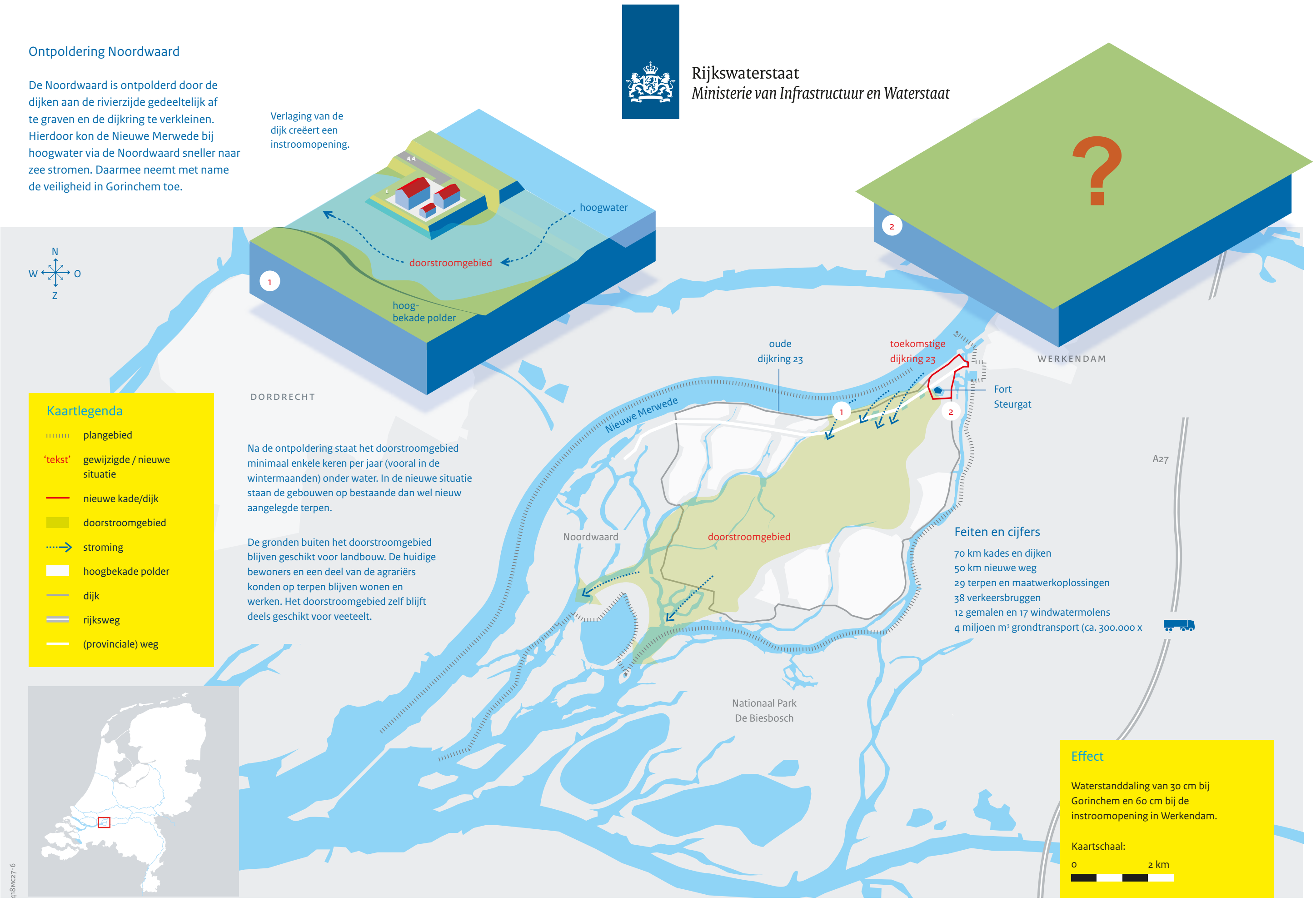


4-25. Noordwaardpolder infographic 1. © Loek Weijts / Ecoshape

Additional Sources

Please be aware that one of the solutions to this problem has already been implemented at Noordwaard. We ask you to only consult this information, and the additional sources, after you have completed your own assignment. This will give you the opportunity to explore your own ideas while designing an original Building with Nature solution.

Ecoshape Case: Noordwaard



4-26. Noordwaardpolder infographic 2. © Ruimte voor de rivier

Additional Knowledge Clips

Have a look at the additional videos on **river systems and river interventions** below. The videos below are part of the MOOC Water and Climate, also from Delft University of Technology. They will provide you with additional knowledge on river systems and river interventions that you can apply to design your own Building with Nature solution.

Video: River Systems

Video: River Interventions

Case 2: City with Nature

Introduction

This section provides a synthesis of information on City with Nature, the case you will be using for Assignment 4.

Please note that as you familiarise yourself with the material, and develop an understanding of the case, depending on the background knowledge you have, you may find that you need to look for additional information.

Introduction

On its journey through the Netherlands, the Waal River passes the city of Nijmegen, in the eastern part of the country. To prevent dangerous situations similar to those of 1993 and 1995 when extreme river discharges occurred and major evacuations of people and animals had to be undertaken, more room has to be given to the river near Nijmegen.

Rijkswaterstaat (RWS), the operational arm of the Dutch Ministry of Infrastructure and the Water Management, has planned to make room for the river in the proximity of Nijmegen. The city of Nijmegen and the district waterboard *Rivierenland* are also involved in the plan.

You are required to design a nature friendly solution that makes Room for the River while maintaining the flood safety standard and improving the quality of the environment for urban dwellers.

Good luck!

Where is Nijmegen located?

Nijmegen is located in the eastern part of the Netherlands (see Figure 4-27). The river Waal, a branch of the river Rhine, flows through the city.

Would you like to know more about making ‘Room for the River’?

Video: Corporate Clip
Room for the River

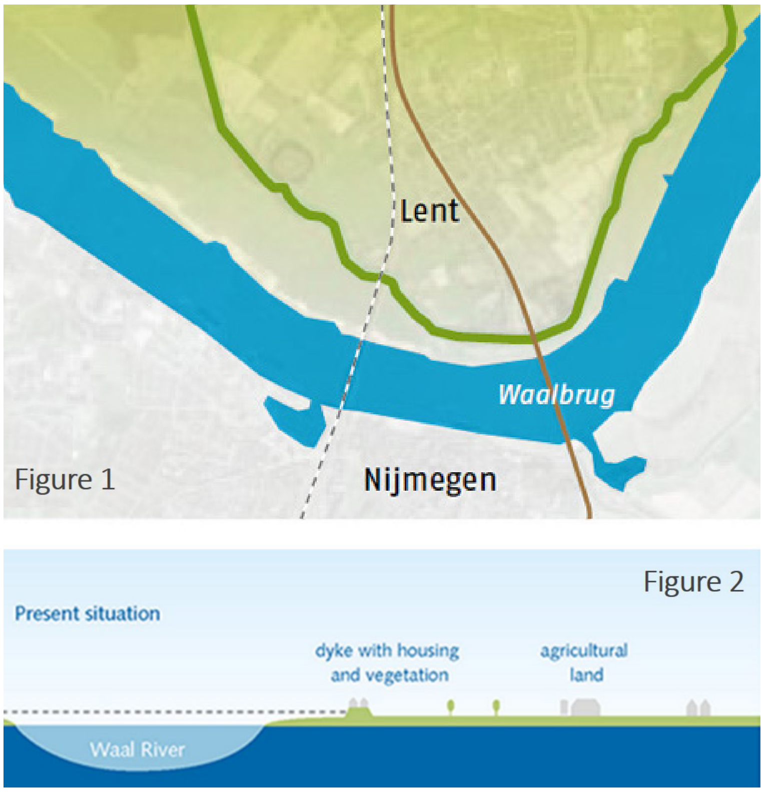
What does the city of Nijmegen look like?

Video: A view on Nijmegen
and the River Waal

Additional information on the problem

- Nijmegen is a 2 000-year-old city with cultural and historical elements such as former fortresses.
- The city is mainly located to the south of the river.
- The River Waal at Nijmegen has one of the narrowest bends in the Dutch river system. While the narrowest point in the river’s floodplain is only 450 meters in Nijmegen, the floodplain is 1500 m and 1000 m wide immediately upstream and downstream of this location.

4-27. Location of Nijmegen and satellite image of the city. © Google



- Because of the narrow bend at Nijmegen, the river is channeled through the narrow waterway in the north area of the city, which results in high water levels and, possibly, in floods.
- The narrow bend close to the city is also known as the bottleneck of Nijmegen and a dike located in this area protects the northern part of the city from flooding. However, because climate change is expected to occasioned even higher water levels in this area, there is no certainty that this dike will prevent flooding in the future.
- There are 50 householders located directly behind the dike, in the residential area of Lent, who will be directly affected by any project related to the river and to the dike.

4-28. De Waal in Nijmegen. On its journey through the Netherlands, the Waal River passes the city of Nijmegen. In Figure 1, the green line represents the dike that protects the city of Nijmegen from flooding. The brown line represents a road that crosses the river Waal. Figure 2 represents a cross section of the river Waal and the city of Nijmegen. Adapted from and © Ruimte voor de rivier

Some hints

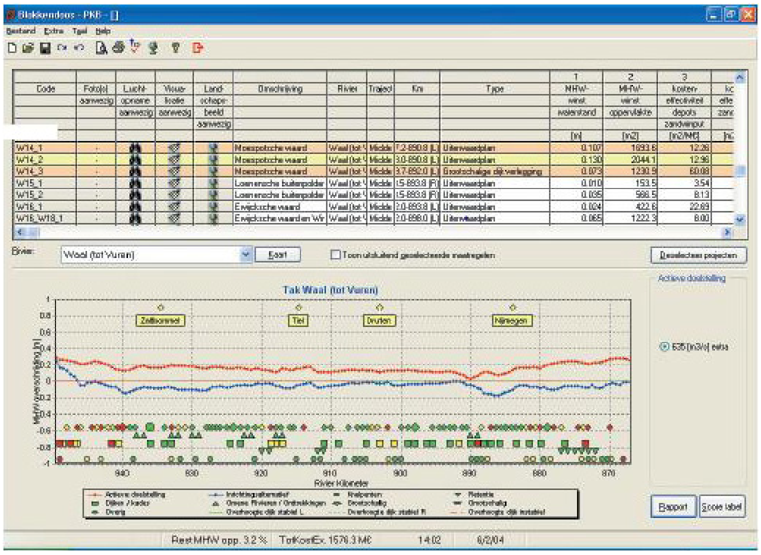
- In order to reduce the risk of flooding in the city of Nijmegen, the predicted high water levels of the river under flood conditions need to decrease by at least 30 cm.
- The solution should not only reduce the risk of flooding, it should also provide added value to the city of Nijmegen and its inhabitants.
- Floodplains, the areas of land adjacent to streams and rivers, usually support productive and diverse wetland ecosystems. Beavers, fish and many other organisms often inhabit these areas.

Hints and Information for Building with Nature Design

By Prof. Jill Slinger and Ir. Graciela del Carmen Nava Guerrero

As part of the Room for the River programme, several alterative interventions were considered for the City with Nature Case. These alternatives were screened using the Dutch planning kit “Blokkendoos” to simulate the effects of different potential interventions on high water level during floods in the Waal River in Nijmegen.

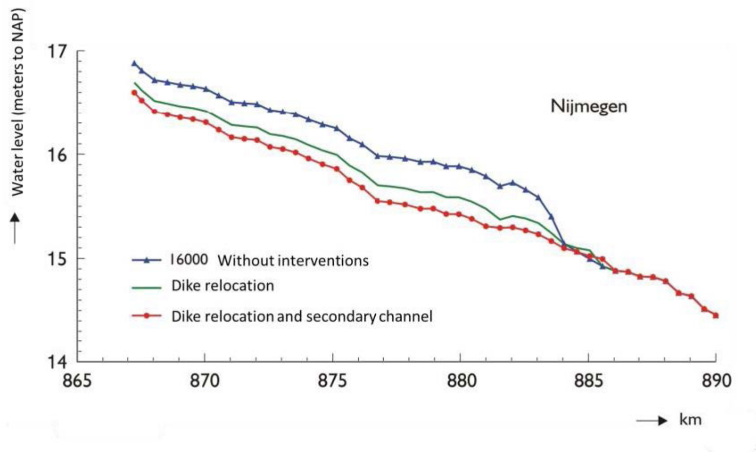
In Figure 4-29, a screen shot of the Dutch planning kit “Blokkendoos” is depicted. The red line represents the predicted high water level which has to be lowered by an average of 30 cm over the whole branch of the river Waal near Nijmegen (to reach the orange line – the desired high water level). The planning kit allows the user to test different interventions and to learn about



4-29. Planning kit output for the River Waal. ⓒ Ruimte voor de Rivier

their effects on the predicted high water levels. The blue line represents one of these tests. The planning kit also allows the user to detail each intervention by including annotated aerial photographs, the cost of the intervention, and the properties that would be affected by the intervention.

When this planning kit was used for the River Waal, it became clear that certain interventions were more successful than others in achieving the reduction in high water levels during floods. This planning kit was used to convince both Houses of Parliament in the Netherlands of the necessity to approve a key planning decision and law that brought the Room for the River programme into being. In particular, the planning tool helped with the difficult decision of how to address the bottleneck at Nijmegen. A number of options were investigated, including deepening of the river bed, raising the dikes along the Waal, and the construction of a secondary channel to increase the discharge capacity of this reach of the Waal river.

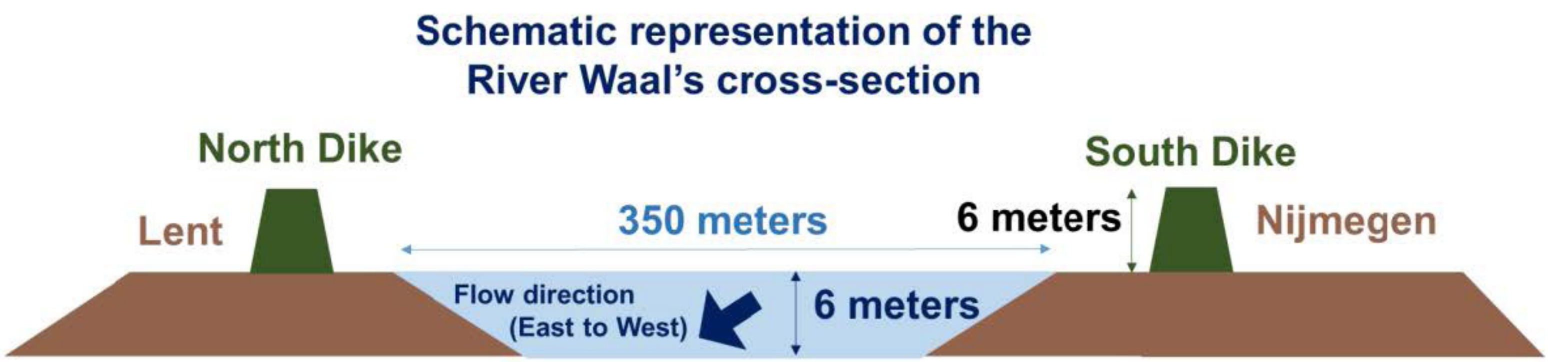


4-30. Effect on water levels of different interventions on the River Waal (Klijn, 2016)

Figure 4-30 represents the water levels on the river Waal between Millingen (at the left margin of the Rhine, kilometer 867) and Beuningen (kilometer 890). The horizontal axis of the graph depicts the kilometer of the Rhine where the water level is predicted. The vertical axis depicts the predicted water level. The blue line represents the water levels under a design discharge of 16 000 $m^3.s^{-1}$ at the Dutch-German border. The sharp change in the gradient of the blue line, at kilometer 884 is the bottleneck effect of Nijmegen, due to the narrowing of the river channel. The green line represents the effect on water levels of the relocation of the dike at Lent (on the north side). The red line represents the effect on water levels of both the relocation of the dike at Lent and the construction of a secondary channel for the river.

The cross section of the river Waal needs to increase by 30% in order to decrease the water level during high discharges by 30 cm. In this assignment, you are required to design a nature friendly solution that delivers this target.

You may assume that the geometry of the channel in this particular reach of the Waal is uniform in shape and depth, and has the measurements specified in Figure 4-31. Note that this figure is a schematic representation and is not necessarily accurate. However, you may use it to make your Building with Nature design calculations, if necessary.



4-31. Schematic representation of the River Waal's cross-section. © Jill Slinger (based on information from Eleftherakis et al. (2012)).

Additional Knowledge Clips

Have a look at the additional videos on **river systems and river interventions** below. These videos are part of the MOOC Water and Climate, also from Delft University of Technology. They will provide you with additional knowledge on river systems and river interventions that you can apply to design your own Building with Nature solution.

Video: River Systems

Video: River Interventions

Additional Sources

Please be aware that one of the solutions to this problem has already been implemented in Nijmegen. We ask you to only consult this information, and the additional sources, after you have completed your own assignment. This will give you the opportunity to explore your own ideas while designing an original Building with Nature solution.

Room for the River

Municipality of Nijmegen

Case 3: Fish Manager

Introduction

This section provides a synthesis of information on Fish Manager, the case you will be using for Assignment 4.

Please note that as you familiarise yourself with the material, and develop an understanding of the case, depending on the background knowledge you have, you may find that you need to look for additional information.

Introduction

One hundred years ago, a long dike was constructed in the north of the Netherlands to protect large tracts of land from flooding. This barrier dike transformed the Zuiderzee (Southern Sea) into a freshwater lake known as the IJsselmeer (IJssel Lake), and continues to separate the fresh IJssel Lake from the salt water of the Wadden Sea. Sluices in the barrier dike only allow freshwater to drain into the salty sea water, but do not allow salt water to penetrate into the freshwater lake. This means that at present fish cannot migrate from the sea into the lake.

The Wadden Sea region is a highly appreciated nature area and various parties are concerned with the connection between the IJssel Lake and the Wadden Sea. Different levels of government (municipality, province and national government) and commercial fishing companies are highly interested in investigating solutions that would restore the connection between the two water bodies while maintaining the safety standard of the barrier.

You are required to design a nature friendly solution for this problem. Your solution must provide ecological opportunities for the Wadden Sea and IJssel Lake while maintaining the flood safety standard and ensuring that the IJssel Lake can still be used for freshwater supply.

Good luck!

Where is the study area located?

The study area is situated in the northern part of the Netherlands, where the IJssel Lake is separated from the Wadden Sea by a 30 km long barrier dam.

Would you like to know how the Wadden Sea Council sees the problem?

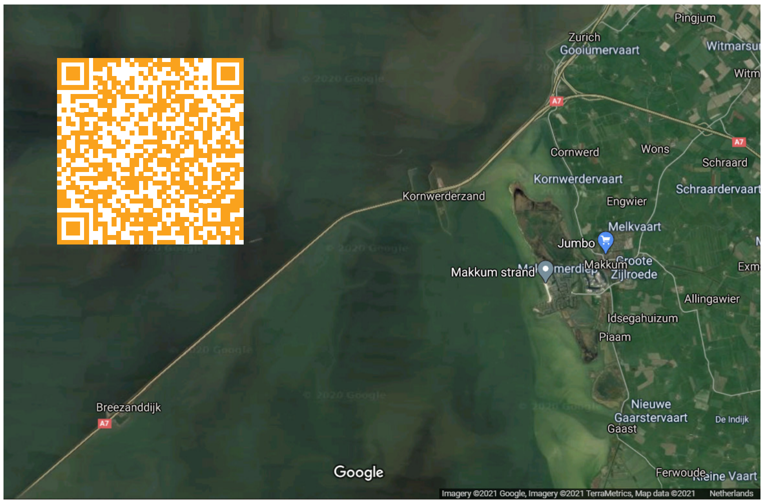
Read this advice published by the Council for the Environment and Infrastructure.

Fresh - Salt. Opportunities for Restoration of Fresh Salt Transitions in the Wadden Region

Alternative link (full report in Dutch, English summary on page 45-47): https://rli.nl/sites/default/files/200802zoetzoutovergangen.pdf

Additional information on the problem

- The Afsluitdijk barrier has two openings: the Stevin locks and sluices at Den Oever and the Lorentz locks and sluices at Kornwerderzand.
- The Afsluitdijk's sluices discharge large amounts of fresh water from the IJssel Lake into the Wadden Sea, but do not permit saline water from the Wadden Sea into the IJssel Lake.



4-32. *Location of the study area. Click on map or scan QR code to view online. © Google*

- The barrier dam forms an obstacle to fish in migrating from the marine environment to freshwater to spawn and reproduce. Particularly herring, anchovies, bone smelt and salmon cannot reach their spawning grounds in the hinterland, and in the upper reaches of the Rhine.
- Fish stocks are also affected by the lack of a salinity gradient. Young fish and larvae also need a brackish water area of about 100 hectares to adapt physiologically from fresh to salt water. Fish-eating bird species are also affected by the declining fish stocks.

- The fresh water discharged from the IJssel Lake attracts migratory fish towards the barrier dam. Even if they could pass through the sluices, the current would be too strong for most fish species. They need places along a migratory route with current speeds lower than 0.5 m.s^{-1} so that they can rest.
- Tidal exchange throughout the year (every day) would be most beneficial to fish.

Some hints

- The construction of the dam affected several species as well as commercial fishing.
- Re-opening the dam is not an option at this stage. The current dam has a safety level of 1 in 10 000 and the protection against safety of large areas of the Netherlands would be affected negatively by its removal. It also provides a traffic connection between the provinces of Friesland and North-Holland.
- Any connection between the Wadden Sea and the IJssel Lake should be long enough to allow a gradual transition between salt and freshwater for fish, but the connection should also allow the IJssel Lake to retain its freshness (not become brackish). Therefore, it is advisable that the sluices are not open (fully) during flood tide in the Wadden Sea.

Some Useful Engineering Concepts and Information on Fish

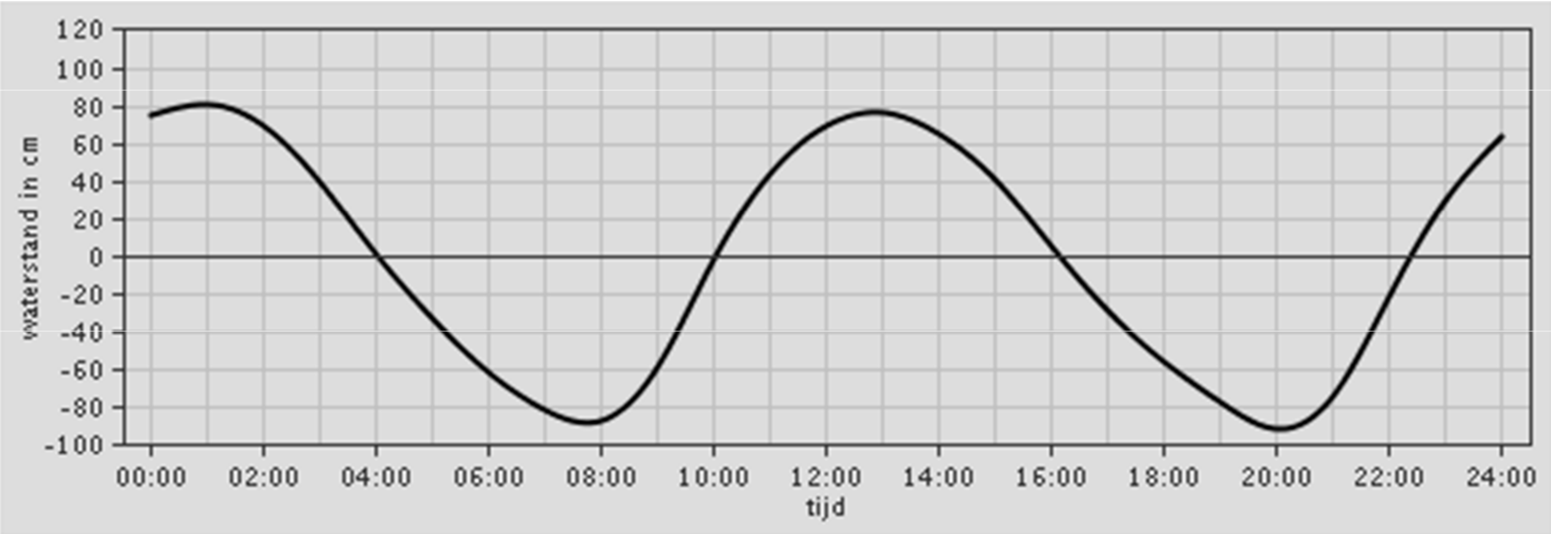
By Prof. Jill Slinger and engineer Ilse Caminada

Tidal variation in the Wadden Sea

The tide in the Wadden Sea varies approximately in the range from -1.20 m (to chart datum – NAP) to +1.20 m to NAP. The figure below is included to provide you with an indication of the tidal variation from high water to low water and back again within approximately 24 hours.

Wind Set-up and Set-down

Differences in water level between the predicted tide and the actual tide can occur. The water level can differ by 0.5 m or more owing to wind set-up or set-down, depending on the direction of the wind. Under northwesterly winds, set-up occurs at the barrier dike and water levels are elevated. Under southeasterly winds set-down occurs at the barrier dike and water levels decrease.



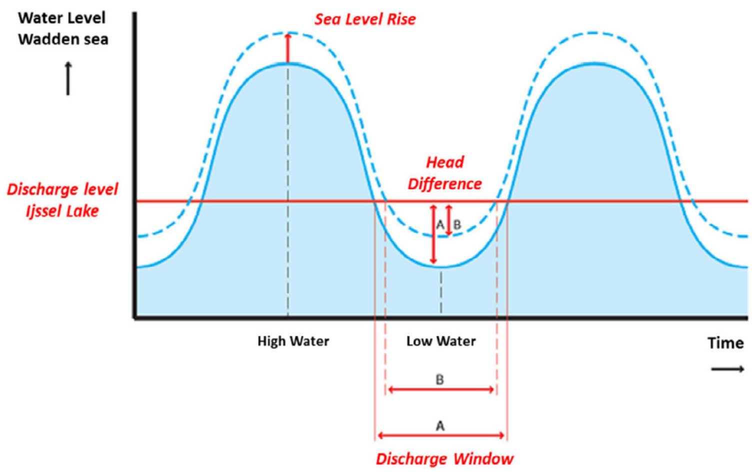
4-33. Indicative semi-diurnal tidal variation in the Wadden Sea at Kornwerderzand (predicted for 1-3-2016). © Rijkswaterstaat (2016a)

Fresh water discharges into the Wadden Sea

The water levels in the IJssel Lake are controlled by pumping the excess fresh water out into the Wadden Sea and by managing the river inflows as far as possible. In winter, the level in the IJssel Lake is maintained at around NAP -0.25 m, while the level is allowed to vary more in summer between NAP -0.10 m and NAP -0.30 m. Throughout the year, the minimum water level should not be lower than NAP -0.40 m to maintain navigability and ensure the safety of the dikes. If dikes become too dry they can become more vulnerable to failure.

However, because it is important that the IJssel Lake remains fresh, water can only be discharged to the Wadden Sea when the water level in the Lake is higher than the water level in the Wadden Sea. As can be seen in Figure 4-34, this occurs for about one third of the tidal cycle, when the water level in the sea is low, the so-called discharge window. Current practice is to close the sluice gates when water levels in the sea are above those of the lake so as to prevent the intrusion of salt water.

The capacity of the sluices and pumps is such that the current speeds near the discharge points are in excess of 0.5 m.s^{-1} when the water is discharged. The pump capacity need not be considered as a limiting factor in your design – you may assume



4-34. Window for freshwater discharge from the IJssel Lake to the Wadden Sea. © Rijkswaterstaat (adapted from 2016b) that the capacity will be adjusted to accommodate your nature friendly solution.

Fish species

There are a number of fish species that will benefit from river-sea connections and associated fresh-salt water gradients. Some of the fish species are threatened or endangered under European and international law. The fish species depicted in the Figure below are:

Sturgeon (Steur; *Acipenser sturio*). Originally occurred in all major European rivers. Now only a few populations in the countries of Georgia and France. As juveniles they live up to 4 years in freshwater, and then take some time to adjust to salt water, while living in brackish river mouths or estuaries. By five years of age they are living in the marine environment. They inhabit the shallow areas of coastal seas.

Sea Lamprey (Zeeprik; *Petromyzon marinus*) The Sea lamprey lives in both marine and freshwater environments and is common in large rivers. To reproduce, they return to freshwater where they make a nest, lay eggs and die.

Sea Trout (Zeeforel; *Salmo trutta trutta*). Migrates from the sea to the river to spawn at about 5 years of age. After one of two years the juveniles migrate to sea. Iconic migratory fish in the Rhine River.

Flounder (Bot; *Platichthys flesus*). Inhabits marine, brackish and freshwater environments, and is tolerant to wide ranges in salinity. Spawns between February and May in freshwater. Juveniles live in shallow areas of estuaries.

European smelt (Spiering; *Osmerus eperianus*). Live in both fresh and marine environments, but migrate upstream to spawn.

Houting (Houting; *Coregonus oxyrinchus*). Salt water fish that spawns in freshwater. Red listed species in Europe.

River lamprey (Rivierprik; *Lampetra fluviatilis*). Bottom dwelling larval phase for 4 years in which it requires flowing water. It then migrates as young adult to the sea, and lives in the marine environment for 2 to 3 years. When fertile the river lamprey migrates upstream to spawn.

Allis shad (Elft; *Alosa alosa*). Juvenile phase is spent in tidal freshwater areas. When they are about 12 cm in length, they migrate to the marine environment. Spawning occurs in quieter stretches of the gravel bed parts of rivers.

Three-spined stickleback (Driedoornig stekelbaarsje; *Gasterosteus aculeatus*). This species usually dies at two years of age, but may make four years. It migrates to freshwater to spawn.

Twait shad (Fint; *Alosa fallax*). Lives in the sea but spawns in river mouths; they deposit their eggs in shallow areas where there is tidal action.

Eel (Paling; *Anguilla anguilla*). Migratory fish that covers large distances from Europe across the Atlantic ocean. The life cycle has many stages and phenologies. Resides in muddy bottom sediments, and is a threatened species.

Atlantic salmon (Zalm; *Salmo salar*). Migratory fish species with larval freshwater and juvenile and adult marine life phases. They spawn upstream in rivers.

4-35. Fish that will benefit from restoration of fresh-salt interfaces. © Rijkswaterstaat (2016b)

Additional Knowledge Clips

Have a look at the videos below on river and coastal systems, and river and coastal interventions. These videos are part of the MOOC Water and Climate, also from Delft University of Technology. They will provide you with additional knowledge on river and coastal systems, and river and coastal interventions. You can apply this knowledge to design your own Building with Nature solution.

Video: River Systems

Video: Coastal Systems

Video: River Interventions

Video: Coastal Engineering

Additional Sources

Please be aware that one of the solutions to this problem has already been implemented at the IJssel Lake. We ask you to only consult this information, and the additional sources, after you have completed your own assignment. This will give you the opportunity to explore your own ideas while designing an original Building with Nature solution.

Afsluitdijk Fish Migration River

Case 4: Coastal Protection

Introduction

This section provides a synthesis of information on Coastal Protection, the case you will be using for Assignment 4.

Please note that as you familiarise yourself with the material, and develop an understanding of the case, depending on the background knowledge you have, you may find that you need to look for additional information.

Introduction

Regular assessments of the safety of a dike are undertaken in the Netherlands. During a recent long term assessment, the anticipated performance of the sea dikes and dunes subjected to a storm surge with an incidence of occurrence of 1 in 10 000 years (the Dutch flood protection standard) was tested.

The sea defence dike along the North-Holland coast near Petten was deemed not to be able to satisfy the safety requirements over the next 50 years. Accordingly, the coastal defences have to be upgraded. Several parties are concerned about this issue, including the water board *Hollands Noorderkwartier*, the Dutch Ministry of Infrastructure and Water Management, the Province of North-Holland, local municipalities and some nature organisations.

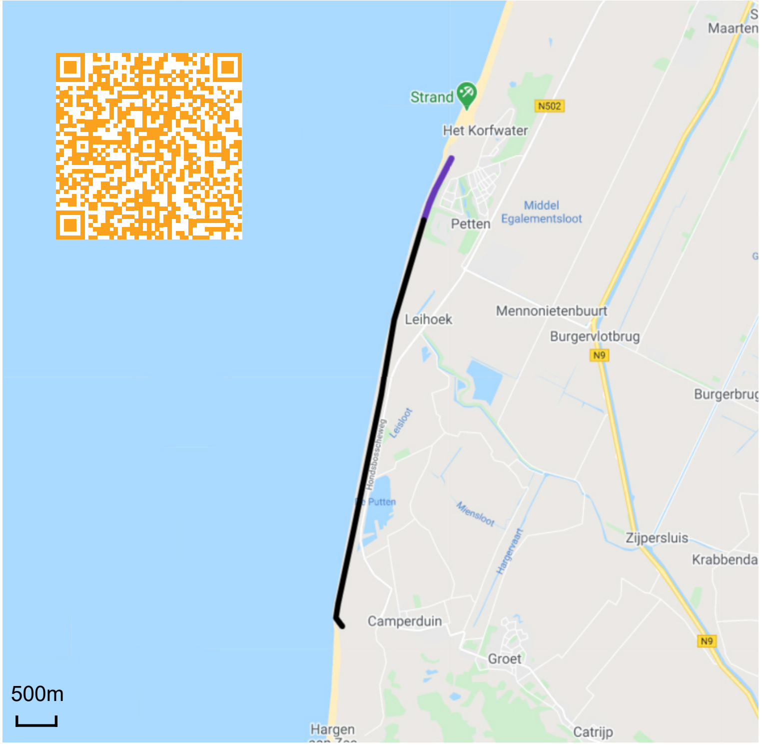
The dike along this stretch of coast is a hard, stone and concrete defence structure. With the new insights on combating the erosion of the Dutch coast by sand nourishment and the experience of the Sand Engine in mind, you are required to design a nature friendly solution to this problem.

You are required to design a nature-friendly solution to ensure the coastal protection of this stretch of coast. An additional requirement is that no maintenance nourishment may occur within the ten year period after construction, so that the ecosystem has time to recover.

Good luck!

Where is the Hondsbossche Pettemer Zeewering located?

The Hondsbossche Pettemer Zeewering is located in the province of North-Holland, as depicted in the map. The coastal defence used to be 2 separate dikes, but over time they have been upgraded to one contiguous sea defence structure. Click on the map to view it online or scan the QR code in the map.



4-36. *Coastal Protection location.* © *Google MyMaps*

What does the coast in the north of the Netherlands look like?

Video: Coast of North-Holland

Some hints

- The North-Holland coast has many naturally occurring dunes and is strongly influenced by the wind and waves.
- This sea defence has an extended history of multiple dike upgrades, and further dike heightening is not desirable.
- A safe design for the next 50 years (without dike heightening) is a challenging task that requires knowledge on how nature will affect your design.
- The effects of some natural processes are easier to predict than others, but many are still uncertain or even unknown. Experience from the Sand Engine and other interventions along the coast is adding to the knowledge of ecosystem responses to mega nourishments.

Hints and Information for Building with Nature Design

In 2003 an investigation into the coastal protection level along the Dutch coast over the next 50 years revealed that there were 10 weak links in the chain of defences. One of these is the 5 km long dike at the Hondsbossche Pettermer Zeewering between Camperduin and Petten. This is the first massive, stone dike ever constructed in the Netherlands. Construction of the dike began after the Sint-Elizabeth flood of 1421, but the sea broke through at times and the dike was repaired and reinforced repeatedly. In 1823, the stone dike was built and in 1977 the dike was raised to meet the safety standards of the time. The Petten of today shelters behind the sea wall, which together with dunes to the south and north, protects the hinterland from flooding. A nearby nuclear power plant, and areas of the province of North-Holland, including large parts of the Dutch capital Amsterdam, may be flooded should this dike no longer be able to withstand the water levels, waves and winds associated with a severe storm of the magnitude that can occur on average once every 10 000 years.

The question arises of how to strengthen this weak link.

You are required to design a nature friendly solution to ensure the coastal protection of this stretch of coast. An additional requirement is that no maintenance nourishment may occur within the ten year period after construction, so that the ecosystem has time to recover.

Client and Stakeholders

The primary problem owners are the Dutch Ministry of Infrastructure and Water Management and their operational arm Rijkswaterstaat, and the district water board Hollands Noorderkwartier tasked with maintaining coastal safety levels. Other stakeholders include the Province of North-Holland, nature organisations, local residents, entrepreneurs, nature lovers, recreants, tourists and the nuclear facility.

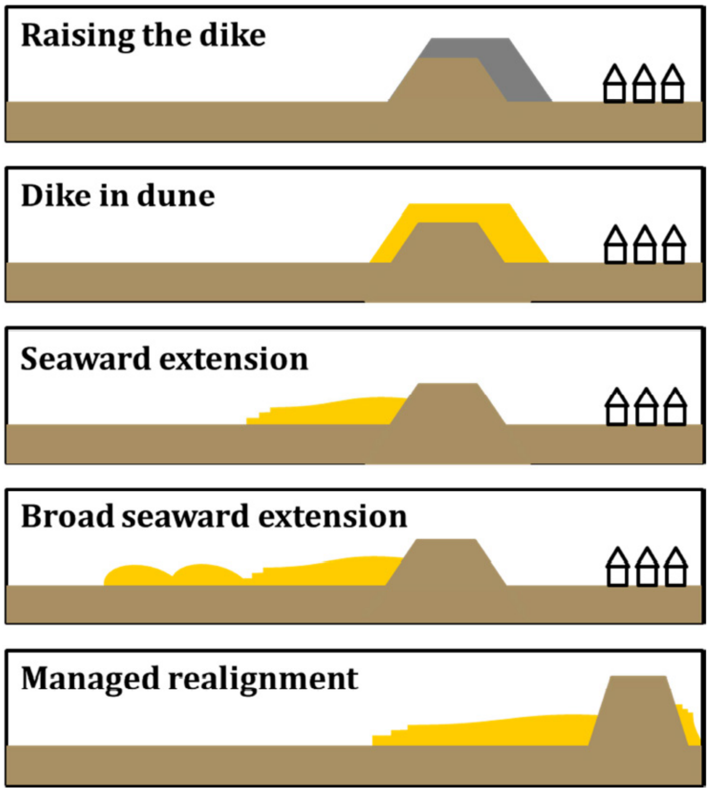
Legal issues

The dune area to the south of the Hondsbossche Pettermer Zeewering is a protected nature area under both Dutch and European Law (Natura 2000 area).

Potential solutions such as managed retreat or raising of the dike (see Figure 4-37) would have consequences for properties on the coast with accompanying costly and lengthy procedures. Seaward there are very few legal issues. There is a strategic environmental decision regarding sand mining from the seabed on the Dutch continental shelf. Particular areas are designated for sand mining, and there are prescriptions on the manner in which this is undertaken. So there are no practical limitations on the availability of sand.

Potential Solutions

A number of potential solutions have been explored for strengthening the coast. Beach nourishment rather than reinforcing or raising the existing sea wall is seen as delivering more opportunities for recreation, tourism, nature and the economy. Similarly, high costs and delays are anticipated with managed retreat. Potential solutions could therefore involve reinforcing the coast with sand. The range of alternatives, depicted in Figure 4-37, includes:



4-37. Potential coastal protection solutions. © Jill Slinger

- **Raising the dike.** This conventional solution would also require dike heightening and broadening of the base of the dike. Investigations of the strength of the dike core would also be needed, given that it is a very old dike. High costs are associated with this approach. Some houses and properties would be affected.

- **Dike in dune.** Burying the dike in sand to create a broad dune encompassing the dike at its core. Investigations of the strength of the dike core would also be needed, given that it is a very old dike. This is unlikely to contribute much ecologically, and some houses / properties would be affected.
- **Seaward extension.** This alternative involves seaward broadening of the dike with a dune field. With this measure the existing dike is retained, but the sharp transition from the dunes to the south to the Hondsbossche Pettermer Zeewering is smoothed. This smoothing of the coastline near the weak point is expected to address the problem of concentration of wave energy at the transition point, and so also reduce coastline maintenance requirements.
- **Broad seaward extension.** This alternative involves the creation of a broad dune field seaward of the dike. It means ignoring the contribution of the dike to coastal defence and using dunes to completely fulfil the safety requirement on their own. The strength of the existing dike then no longer has to be investigated. It leads to broader beaches and dunes, and improves the spatial quality of the area.
- **Managed retreat.** This involves the removal of (part of) the Hondsbossche Pettermer Zeewering and the creation of a wetland and dune system behind the exiting dike. Properties would have to be expropriated and people would have to leave their homes. A new sea dike or alternative defence would have to be constructed further inland, around the wetland/dune system. Lengthy and costly legal proceedings are likely.

Ecological knowledge and expertise

Nature organisations, the Dutch Ministry of Infrastructure and Water Management, universities and research institutes e.g. IMARES and Deltares, amongst others, have knowledge of the dune and sandy beach system.

The initial indications are that a mega sand nourishment (larger volume, for longer time perid) than the present shoreface nourishments at intervals of 3 to 5 years, may have a net positive effect for the ecosystem. However, research is in progress and evidence is still being collected regarding the ecological effects at the Sand Engine[1] on the South-Holland coast.

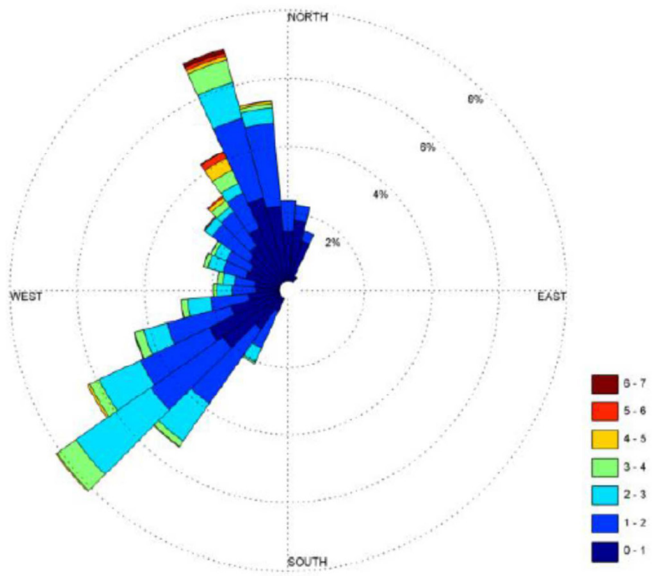
At the Sand Engine, the lagoon is an interesting feature, providing a more diverse abiotic environment for colonisation by species tolerant of a brackish environment. The entrance channel is highly dynamic and the raised areas of the Sand Engine deliver wind-blown sand to the beach and dunes. Pioneer dune areas can start to form in front of established dunes. However, the small groundwater seeps and dune valleys characteristic of wide dune fields are not present, and the species characteristic of these zones are not offered opportunities. These include Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*). The landscape is also not as varied as that of the Schoorl dune field south of the Hondsbossche Zeewering, where dunes achieve heights of 58m above NAP and there is a wide variety of vegetation types.

Some useful engineering concepts and information

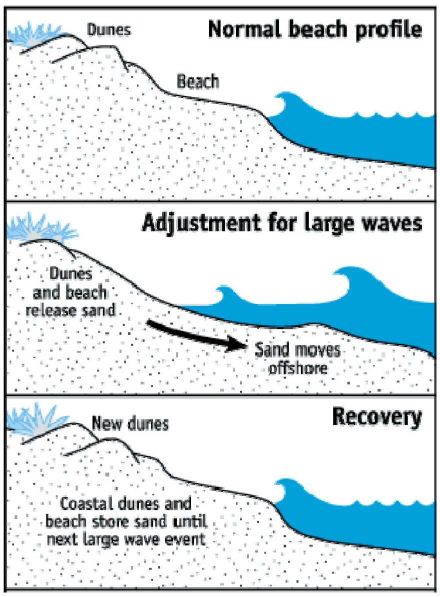
Characteristics of the North-Holland coast:

- Sandy, wave dominated coast
- Microtidal, semi-diurnal tides with a mean tidal range 1.4 m to the north and 1.6 m to the south
- Mean annual wave height of 1.3 m, predominant from the SW and NNW (See wind rose, Figure 4-38)
- Median grain size (D50) between 200 μm and 350 μm

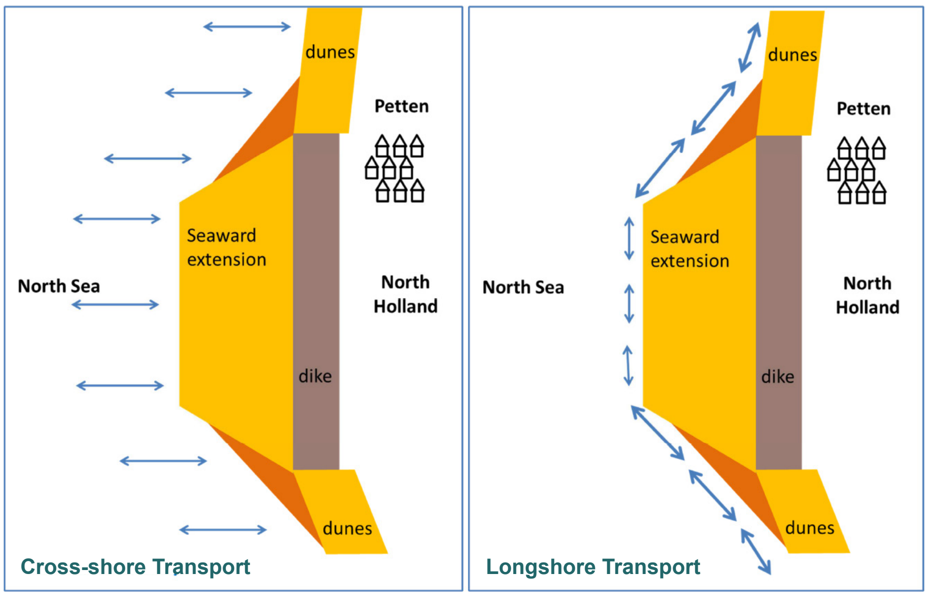
In Figure 4-39, the natural dynamics of a cross-shore profile are shown. In winter, when storm and higher waves are common, the sand is eroded from the beach and deposited on a nearshore bar and in summer the low wave conditions move the sand back onto the beach. Of course, this conceptual model ignores processes such as longshore transport and loss of sand to deeper water, but it does provide the rationale for the shoreface nourishments



4-38. Wind rose for 1995. © Giardino et al. (2012)



4-39. Natural dynamics of a cross-shore profile.



4-40. Plan view of the cross shore and longshore sediment transport processes operating on a seaward sandy extension in front of a dike. © Jill Slinger

[1] You are referred to the material on the Sand Engine and the Building with Nature Design Assignment example case for further information on the ecological consequences of a mega nourishment.

used to maintain the coast. In a shoreface nourishment, the sediment is typically deposited immediately seaward of the outer bar and is transported to the beach under low wave conditions.

So, if you wish to design and undertake a seaward extension or nourishment, it is necessary to determine the length of coast over which this will occur, how much sand is needed for the extension, and how much sand needs to be added as a buffer. **The buffer is needed as no maintenance dredging is allowed within the first 10 years**, so that the ecosystem can start to recover from the initial major disturbance.

You may assume that the complex and site specific transport processes in the coastal zone mean that at this location the minimum sand volumes per meter of coast required to realise a 100 m or 300 m seaward extension are **1000 $m^3.m^{-1}$** and **2500 $m^3.m^{-1}$**, respectively. However, the cross shore sediment profile of the mega nourishment will be steeper than the equilibrium profile (cf. Bruun 1954, Dean 2002). This means that the profile will adjust and that sand will be transported offshore, say a loss of **10 $m^3.m^{-1}$ per year**. You will need a buffer to compensate for these cross-shore losses. Similarly, longshore processes are strongest where the longshore gradients are highest i.e. at the sides of the seaward extension. In this design, the gross longshore transports dominate over the net longshore transports. You may assume a loss of **0.4 million m^3 sand.yr^{-1}** owing to gross longshore transport gradients along the coast. So, it is up to you to **choose the length** of your project area both seawards and along the coast and **how you will distribute the sand**. In designing your Building with Nature solution, you will need to take the longshore and cross-shore processes into account. You will need to calculate how much additional sand you need in your buffer and where you will spread it: everywhere, only in the middle or on the sides of the nourishment? Remember, the buffer will need to see you through the **first 10 years**. You are also advised to include a buffer to address sea level rise (Stive 2004), and to accommodate the uncertainty in the occurrence of storms (**between 0.3 and 0.5 million m^3yr^{-1}**). Enjoy designing your Building with Nature solution!

Additional Knowledge Clips

Have a look at the videos below on coastal systems and coastal interventions. These videos are part of the MOOC Water and Climate, also from Delft University of Technology. They will provide you with additional knowledge on river and coastal systems, and river and coastal interventions. You can apply this knowledge to design your own Building with Nature solution.

Video: Coastal Systems

Video: Coastal Engineering

Additional Sources

Please be aware that one of the solutions to this problem has already been implemented in North-Holland. We ask you to only consult this information, and the additional sources, after you have completed your own assignment. This will give you the opportunity to explore your own ideas while designing an original Building with Nature solution.

Hondsbossche Dunes

Case 5: Harlingen Harbour

Introduction

This section provides a synthesis of information on Harlingen Harbour, one of the cases you can use for Assignment 4.
Please note that as you familiarise yourself with the material, and develop an understanding of the case, depending on the background knowledge you have, you may find that you need to look for additional information.

Introduction

The harbour of Harlingen is located in the north of the Netherlands, in the tidal basin of the Wadden Sea. The Wadden Sea is a large unbroken system of intertidal mudflats that is rich in species. It is considered one of the most important areas for migratory birds in the world.

Currently an average amount of 1.3 million m^3 of mainly fine sediments has to be dredged per year, as a result of high sedimentation rates in the harbour of Harlingen. A conventional dredging strategy in which the sediment is disposed in the vicinity of the harbour is increasingly undesirable, as it is expected that a large amount of the sediment will be returned to the harbour. Besides being economically inefficient, this may also lead to negative ecological effects due to the increased turbidity.

You are required to design a nature friendly dredging and disposal strategy for the next 5 to 15 years. Your solution should maintain the required depth in the harbour, while providing ecological opportunities for the Wadden Sea.

This goal needs to be reached while adhering to Natura 2000 regulations and under existing hydraulic boundary conditions.

Good luck!

Where are the Wadden Sea and Harlingen Harbour located?

The harbour of Harlingen is situated in the northern part of the Netherlands, on the coast of Friesland just east of the Afsluitdijk. The Wadden Sea coast stretches from Den Helder in the west, across the Afsluitdijk separating the IJssel Lake from the Wadden Sea to the Eems/Dollard on the eastern border with Germany. The tidal basin of the Wadden Sea is enclosed on the northeastern boundary by the Wadden islands and on the south by the Friesian coastline and the Afsluitdijk. Click on the map to view it online or scan the QR code in the map.

4-41. *Location of Harlingen Harbour. © Google MyMaps*

What does the coast of the Wadden Sea look like?

World Heritage Mission: Wadden Sea

This link provides you with more information on the (ecological) value of the Wadden Sea. It also contains additional maps, documents and images. This link contains information about the protection and management of the Wadden Sea.

Hints and Information for Building with Nature Design

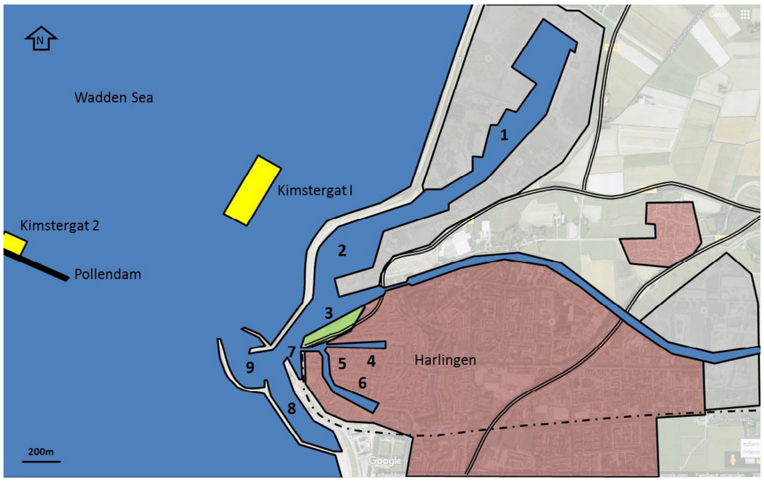
By engineer Ana Colina Alonso and Prof. Jill Slinger

This case concerns the dredging and disposal strategy for Harlingen harbour over the next five to fifteen years. The harbour of Harlingen, which lies on the coast of Friesland, serves industry and the recreational boating sector, and is important to the economic health of western Friesland. Ferries to the Wadden Islands depart from the harbour at regular intervals. The minimum depth of water required to serve the harbour anchorage and transport needs of the region, are maintained by dredging operations.

You are required to design a nature friendly dredging and disposal strategy for the next 5 to 15 years. Your solution should maintain the required depth in the harbour, while providing ecological opportunities for the Wadden Sea.

Harlingen harbour

Annually an amount of approximately 1.3 million m^3 fine sediments has to be dredged to maintain the minimum required



4-42. *Harlingen Harbour schematic overview. © Ana Colina Alonso*

Basin	Rough area (m^2)	Average required depth (m)	Function
1. Industriehaven	400 000	7.50	Industry, multi-purpose
2. Vissershaven	240 000	6.00	Fishing vessels
3. Veerhaven, voorhaven	80 000	7.50	Ferry terminal, inland connection
4. Noorderhaven	85 000	3.00	Pleasure craft, tourism
5. Oude Buitenhaven	85 000	4.50	Pleasure craft, brown fleet
6. Zuiderhaven	85 000	3.50	Pleasure craft, brown fleet
7. Dok	15 000	4.90	Brown fleet
8. Nieuwe Willemshaven	100 000	6.00	Brown fleet, cruise terminal, multi-purpose
9. Harbour entrance	135 000	7.50	Wadden Sea connection
Total Area:	**1 055 000**		

4-43. Overview harbour specification. © Gemeente Harlingen (2016)

depths in the harbour. The layout of the harbour is shown in Figure 4-42. Table 4-43 provides additional information on the different basins in the harbour.

Type of dredger, disposal method and dredging frequency

If you are an engineer you might want to consider the information given in this paragraph. If you are not an engineer you can ignore the following information and simply assume one of the options without further elaboration.

The future dredging activities will be performed with a Trailing Hopper Suction Dredger that has a capacity of approximately 600 m^3. The dredged material can be transported with a pipeline, by rainbowing or by bottom door placement using barges. It is up to you to decide which transportation and disposal is best suited to your design.

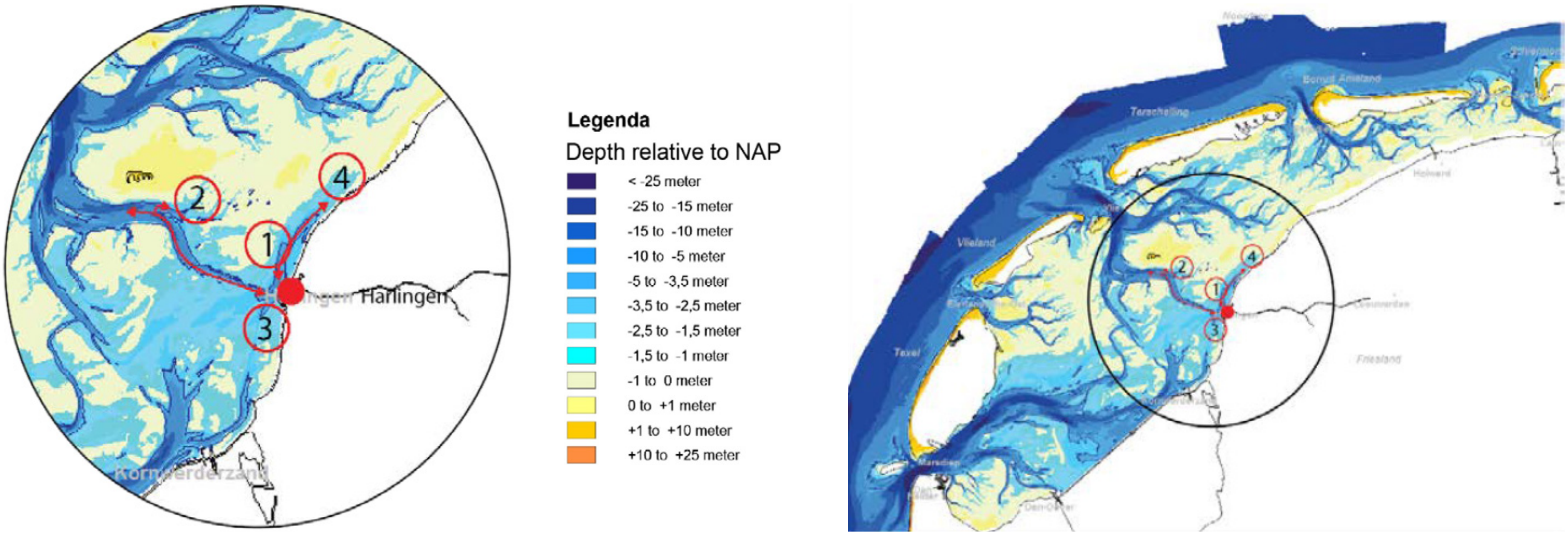
Although the average annual amount om 1.3 million m^3 of sediment that has to be dredged is specified, the frequency or occurrence of dredging activities are not specified. In determining the dredging frequency three important parameters need to be taken into account: the required over-depth, the impact on the environment and the mobilisation costs. Remember that it is perfectly fine to make assumptions for this case study, as long as you clarify them in your design.

Potential disposal locations

Figure 4-44 shows five potential disposal locations for the dredged sediment. These locations have sufficient water depths to be reached by a dredger or disposal barge. It is up to you to decide which location is best for your strategy. You can find more information about the current speeds, water depths and silt dispersal in the videos of Case 5.

Stakeholders

Although a wide range of people are concerned about the harbor of Harlingen, the maintenance dredging strategy and the viability of the urban and natural areas around the harbor, several key stakeholders can be identified. These are the *Harlingen Port Authority*, the *Municipality of Harlingen*, the *Province of Friesland*, *Rijkswaterstaat*, and a number of *Nature organisations*. Municipalities are the third tier of administrative government in the Netherlands after the national government and the provinces. The Harlingen Port Authority has jurisdiction over the harbor area and is responsible for ensuring that health and safety standards are maintained and that harbor operations can continue. They contract dredging companies to ensure that the requisite channel depths are maintained. Municipalities are responsible for a wide variety of public services, including land-use



4-44. Potential disposal locations. © Deltares

planning, public housing, management and maintenance of local roads, waste management and social security. The province of Friesland is responsible for issues that concern the population of Friesland directly. These issues include broader aspects of spatial planning, the environment, landscape and nature, traffic and transport (provincial road network), the economy, welfare, health, and culture. Rijkswaterstaat is the executive agency of the Ministry of Infrastructure and Water Management, responsible for the Dutch main road network, the main waterway network, the main water systems, and the environment in which they are located. Among the nature organisations that are concerned with the dredging and disposal strategy of the harbor are *It Fryske Gea, Natuurmonumenten, Vogelbescherming Nederland,* and the *Waddenvereniging*. It Fryske Gea is the provincial association for nature and landscape conservation in Friesland. Its goal is to protect, maintain and develop nature, landscape and cultural heritage in Friesland. The association currently manages over 50 nature reserves with a total size of 20 000 Ha. Natuurmonumenten is a Dutch organisation that protects and manages nature reserves and cultural heritage sites in the whole of the

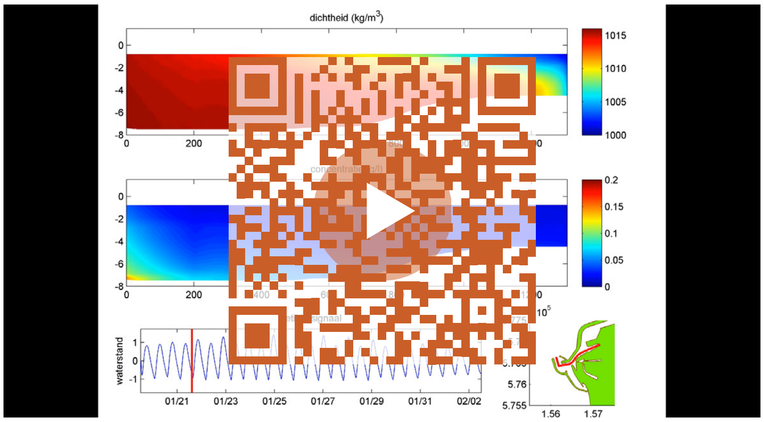
Netherlands, including Friesland. Vogelbescherming Nederland is the Dutch partner of BirdLife International, a worldwide partnership of non-governmental conservation organisations that together seek to conserve all wild bird species and the priority sites (Important Bird Areas) and habitats on which they depend. The Waddenvereniging seeks to protect the characteristic intertidal areas of the UNESCO World Heritage site of the Wadden sea and coast for present and future generations.

Nature Development

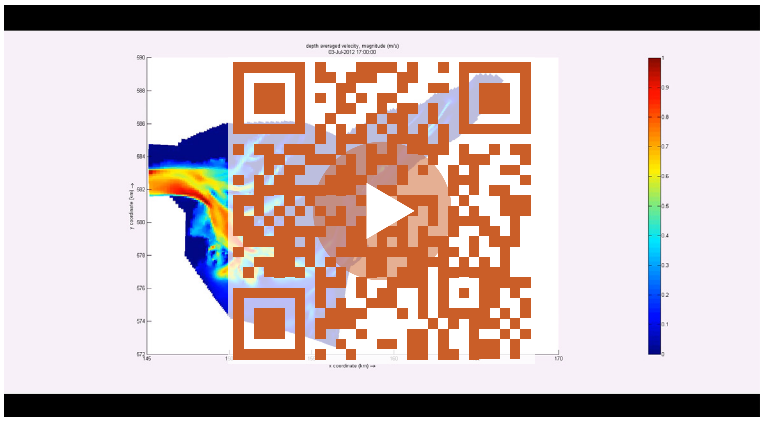
In developing your Building with Nature design keep in mind that not only salt marshes, but also mudflats are of great importance and ecological value in the Wadden Sea. Mudflats are highly productive areas that support large numbers of birds and fish. They provide feeding and resting areas for internationally important populations of migrant and wintering waterfowl. During low tides they provide an extensive and readily available food source. At high tide they serve as nursery areas for flatfish. Salt marshes are also highly valuable habitats and their presence in front of dikes can enhance flood protection.

Enjoy designing your Building with Nature solution!

Additional Information and Hints

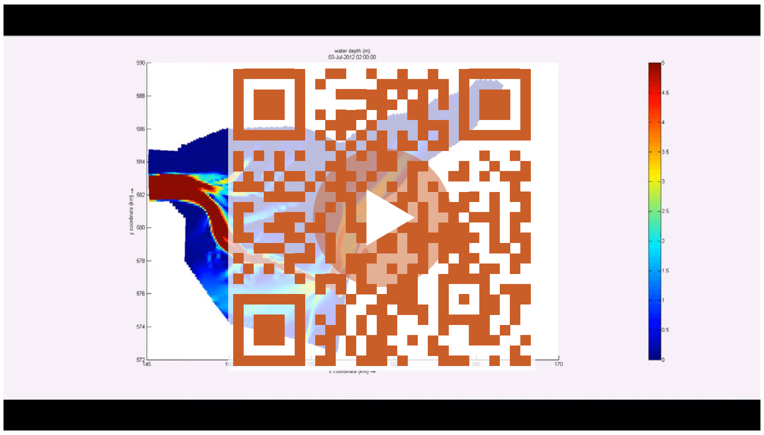


Video: Analysis on the currents at the harbour. © Deltares



Video: Current speeds. © Deltares

Video: Silt dispersal. © Deltares



Video: Water depths. © Deltares

Harbours in muddy waters and salt marsh growth

The two articles available for download on this page contain additional information we recommend you to use for your design.

- The first article treats harbour development combined with a Building with Nature approach in the Wadden Sea. Note that we advise you to understand the concepts treated for the case of Harlingen, yet we expect that your own design will be different from (or more extended than) the solution provided by this paper.
- The second article treats the use of salt marshes to adapt flood defences. Download the articles by clicking the links or scanning the QR codes on the right.

Article: Muddy waters and the Wadden Sea harbours

Article: Salt marshes to adapt the flood defences along the Dutch Wadden Sea coast

Case 6:
Flood-proof Indonesia

Introduction

This section provides a synthesis of information on Flood-proof Indonesia, one of the cases you can use for Assignment 4.
Please note that as you familiarise yourself with the material, and develop an understanding of the case, depending on the background knowledge you have, you may find that you need to look for additional information.

Introduction

In Indonesia, the northern coastline of the main island of Java faces the threats of land subsidence and severe coastal erosion. Frequent flooding, occurring during high tides, periods of excessive rainfall and storm surges, may threaten the lives and livelihoods of local communities. Historically, this area had been surrounded by mangrove forests, that act as natural flood defences. However, land conversion for urbanisation, agriculture and aquaculture practices and climate change threatens the continued existence and health of the mangrove areas.

Several parties are concerned about this issue, including the Indonesian Ministry of Marine Affairs and Fisheries, Indonesian Ministry of Public Works, and knowledge organisations such as Deltares and Wageningen Marine, the nature organisation Wetlands International (The Netherlands and Indonesia Offices) and consultants from Witteveen+Bos. These partners have been involved in recent flagship projects in northern Java that have focused on counteracting coastal erosion and reversing the trends of unsustainable economic development, particularly in the Demak district.

Using practical insights on combating erosion along muddy coasts deriving from the Dutch experience in the Wadden Sea, and theoretical insights from the course videos on mangroves and muddy coasts, you are required to design a nature friendly solution to this problem.

Good luck!

Where is the Demak coast located?

Demak is a district located in the province of Central Java, Indonesia, and lies on the northern coast of the island. As can be seen from the map, the district has a ragged coastline of about 20 km, approximated by the dark blue line. Click on the map to view it online or scan the QR code in the map.

What does the Demak area in Indonesia look like?

Have a look at the video below to understand the challenges faced by the local communities living along the Demak coast (Source: Wetlands International)

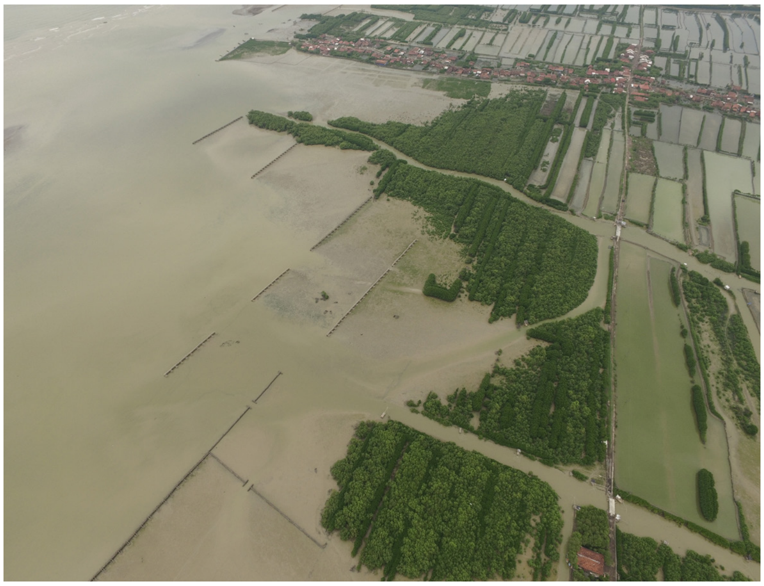
The video in the next column shows an animation of the present situation regarding coastal development in Demak.

4-45. *Location of Demak Coast. © Google MyMaps*

Video: Building with Nature Indonesia: Baseline scenario coastal erosion in Demak, northern Java

Some hints

- The Demak coast, Java, has a muddy substrate and many naturally occurring mangrove forests. However many mangrove areas have been lost in recent years owing to development, breaching of aquaculture ponds and groundwater extraction, among other influences.
- Since 2000, severe coastal erosion of up to 1 km has occurred in places.
- There is ongoing subsidence and the average sea level is rising, exacerbating the problems.
- An effective design to combat ongoing erosion and protect coastal communities from flooding is a challenging task that requires knowledge of how muddy coasts accrete rather than erode, and that takes the flood protection role of mangrove forests into account.



4-46. *Muddy Demak coast showing flooding of the mangrove areas (dark green) and the aquaculture ponds behind them. © Wetlands International*

Conventional solutions tried along the muddy Demak coast include building different types of solid structures and sea walls, as can be seen in the images 4-47 and 4-48 (source: Wetlands International). Owing to interrupted sediment flows and the weight of the structures on the muddy sediment beds, these interventions did not enjoy success.

The video below sheds light on the historical significance of mangroves in Indonesia and their functioning as natural flood defences (Source: Wetlands International).

4-47. Solid structure along the Demak coast. 🅭 Wetlands International

4-48. Failing sea wall along the Demak coast. 🅭 Wetlands International

Hints and Information for Building with Nature Design

By Prof. Jill Slinger and Aashna Mittal, based on the information supplied by Building with Nature Indonesia and Winterwerp et al. (2013, 2014) in particular.

In Indonesia, the northern coastline of the main island of Java faces the threats of land subsidence and severe coastal erosion. Frequent flooding, occurring during high tides, periods of excessive rainfall and storm surges, may threaten the lives and livelihoods of local communities. Historically, this area was surrounded by mangrove forests, that acted as natural flood defences. However, land conversion for urbanisation, agriculture and aquaculture practices, ongoing subsidence and erosion, and climate change threaten the continued existence and health of the mangrove areas. Indeed, the coastal vulnerability index value assigned to the southern part of Demak, which experiences severe erosion, is high for sea level rise.

The usual approach to combat erosion and limit flooding involves designing and constructing (hard) engineering infrastructures. However, this is not feasible for the whole coast owing to expense, the need for costly maintenance, especially on soft, muddy seabeds, and the single purpose orientation of these structures. **Using practical insights on combating erosion along muddy coasts and theoretical insights from the course material on mangroves and muddy coasts, you are required to design a nature friendly solution to the problems of flooding and erosion.**

Client and Stakeholders

The Indonesian Ministry of Marine Affairs and Fisheries and the Indonesian Ministry of Public Works are concerned about this issue. The coastal degradation and erosion of 80 km^2 of land has led to aquaculture farmers in Demak losing between 60% and 80% of their income. Fishermen experienced income losses of between 25% and 50%. It is estimated that at least three thousand villages on Java experience similar losses. In general, the fisheries, aquaculture and coastal agriculture are vulnerable to severe losses if the ongoing degradation and erosion issues are not addressed. This is of great concern to coastal communities in the rural areas (some 30 000 to 70 000 people), while coastal erosion, subsidence and potential flooding also threaten urban areas such as the city of Semarang, northern Java.

Potential engineering solutions

Muddy coasts are found throughout the world, but predominate in tropical regions with many suffering severe erosion. However, most knowledge on combating erosion concerns sandy coastlines rather than muddy coastlines, and to make matters worse the measures to combat erosion on sandy shores don't necessarily work on muddy coasts. This is because the foundational strength of a muddy seabed is usually weak compared with a sandy seabed, making the construction of substantial engineering infrastructures problematic. The wave-induced erosion and sedimentation processes of mud are different and more complex than for sand (Mehta, 2002), indicating that careful design of interventions is required for muddy shores.

Potentially, conventional (hard) engineering solutions remain an option. These include:

- **Constructing dikes** to protect the hinterland from flooding. These dikes can range from large structures to low soil embankments offering protection from more frequent, smaller floods, but failing to protect the hinterland from larger floods.
- **Constructing breakwaters** to create calmer areas, sheltered from high waves so that either sediment can accrue behind the breakwaters or human activities requiring sheltered water can occur, such as harbour activities.

Unfortunately, (hard) engineering structures can cause wave reflection, or interrupt sediment flows, preventing nearshore accretion and worsening the erosion at some locations along the coast. The structures can also become exposed during low tides when the seawater retreats, and can be considered visually unappealing. The engineering structures may slump on the weak muddy soil foundation and become ineffective in controlling erosion. Such structures are also expensive, but are considered potential options when well designed, and when they are protecting areas in which people and activities are concentrated e.g. cities.

A number of other potential solutions to coastal erosion and flooding in muddy, tropical areas can be applied individually or in combination. These are termed the Hybrid Engineering approach by Winterwerp et al. (2014) and all are oriented to increasing the

accretion of muddy sediments along the coast by strengthening the natural processes by which this occurs.

- **Placing permeable structures of brush-wood** in the nearshore areas, analogous to the centuries-old tradition of using permeable structures of hardwood to reclaim land from the sea in the northern temperate regions along the Dutch, German and English coasts. These permeable structures dissipate wave energy, but do not block sediments, creating sheltered areas near the coast for accretion.
- **Agitating the seabed** to increase fine sediment concentrations in the water column in the foreshore area. Where there is sufficient depth this can be undertaken using agitation dredging, when fine sediments are dredged from the bottom, pumped into a barge, and then disposed again into the water column. In very shallow areas suitable for mangroves, mechanical stirring is more problematic.
- **Muddy sediment placement / nourishment**, bringing mud to the area where it is required. This solution may be required where severe erosion has occurred or where the onshore transport of fine sediments by the tide is problematic.
- **Constructing or restoring cheniers**, the narrow lenses of sand lying on top of a muddy seabed. Cheniers can cause the waves to break, dissipating some of their erosive energy, and so creating quieter areas near the coast for accretion.

All of these potential solutions, seek to strengthen the onshore transport of sediment by waves, while limiting the erosive force of large breaking waves at the coast.

Ecological knowledge and expertise

Nature organisations, such as Wetlands International (Dutch and International offices), and proponents of nature based solutions like Deltares, and partners in the Ecoshape Consortium, such as IMARES and Witteveen+Bos, have knowledge of muddy sedimentary systems and their mangrove forests, as do many organisations in Indonesia.

This has led to more nature friendly solutions, such as restoring mangroves through replanting of seedlings, or allowing re-colonisation from nearby seed banks. The latter option can only be exercised when there are reasonably healthy mangrove forests nearby and a sheltered area where sediment is accreting. Many mangrove rehabilitation efforts involving the planting of *Rhizophoramucronata* have been launched. These rehabilitation efforts are successful in sheltered and accreting area. In areas with a disturbed sediment balance, the tidal flat needs to be restored first or rehabilitation will fail.

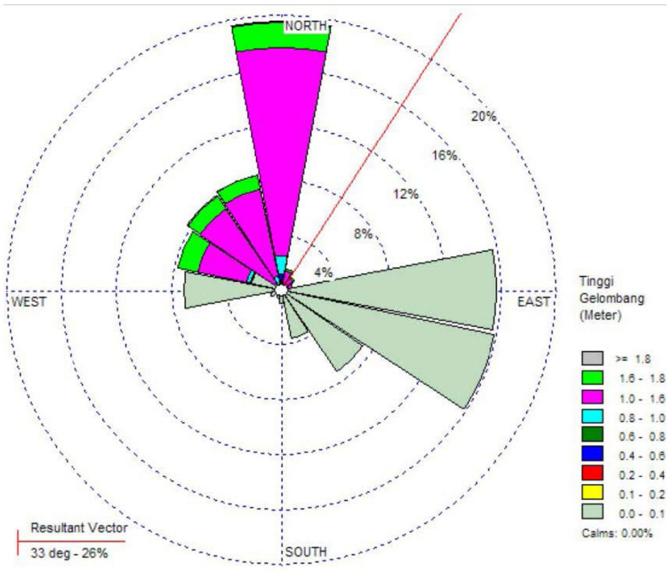
Ecologically, planting mangroves is a less favoured solution owing to the degree of disturbance of the muddy sediments and their biota when planting occurs. It may, however, be necessary to sow propagules and/or plant when there are no healthy mangrove forests nearby. If such an initiative is undertaken, pioneer mangrove species need to be used. The pioneer zone usually consists of *Avicennia, Zonerasia* species, that are more adapted to wet conditions and salt water so that they can grow closest to the sea in the intertidal zone. Planting of *Rhizophora* or *Bruguiera* is not advised as they usually grow in the zone behind the pioneer zone.

Some useful engineering concepts and background information on the Demak coast

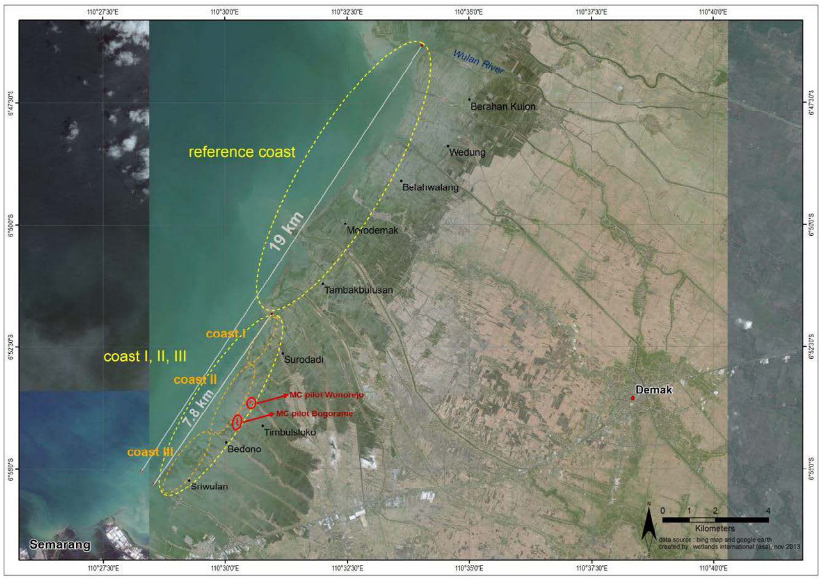
The tide is predominantly diurnal, with a small semi-diurnal component and a neap-spring tidal signal varying from 0.4 m to 0.6 m. This means that when the diurnal and semi-diurnal components synchronise at spring tide, the full tidal variation can be as large as 1.2 m. The high high water spring (HHWS) level can therefore be taken as 0.6 m above mean sea level (MSL), and the mean high water level (MHW) as 0.25 m above MSL. There are few data on tidal currents, but these appear to be directed predominantly east to southeast, almost perpendicular to the coastline with maximum speeds of about 15 $m.s^{-1}$.

The residual ocean currents (net long-term tidally averaged direction and volume of flow) along the north coast of Java are heavily influenced by the monsoon. In May to September, during the southeast monsoon, the residual ocean current is directed towards the west. In October to April, during and around the northwest monsoon, the residual ocean current is eastward. According to Winterwerp et al. (2014), the long-term average residual fine sediment transport is therefore likely to be towards the east, as the northern winds are stronger and persist longer than during the southeast monsoon.

According to Winterwerp et al. (2014) “Most coastal erosion is expected during the months December through February, when the NW-monsoon winds are strong, and waves are high and from the north. On the other hand, also fine sediments are carried by the rivers, and fines from the river bed are also expected to



4-49. Wave rose for Demak coastline for the years 2003-2009. © MMAF (2012), Winterwerp et al. (2014)



4-50. The Demak coastline showing the relatively stable area to the north, the reference coast of 11 km and the eroding area of 7.8 km to the south. © Wetlands International be mobilised in this season, enlarging the suspended sediment concentration in the coastal zone. Fortunately, large-scale circulations keep these sediments close to the shore, thus available for regeneration of the coast."

The northern 11 km of coastline (reference coast) is fairly stable, owing to a chain of sandbanks (cheniers) along the coast, formed from sand from the rivers, and the northerly transport of fine sediments eroded from the south. You may choose to use this part of the Demak coast as a reference for your design of a nature friendly solution to the severe erosion and consequent increased vulnerability to flooding in the south.

The southern 7.8 km of the coast of Demak can be divided into three characteristic sub-sections on the basis of their erosion patterns (see Winterwerp et al., 2014):

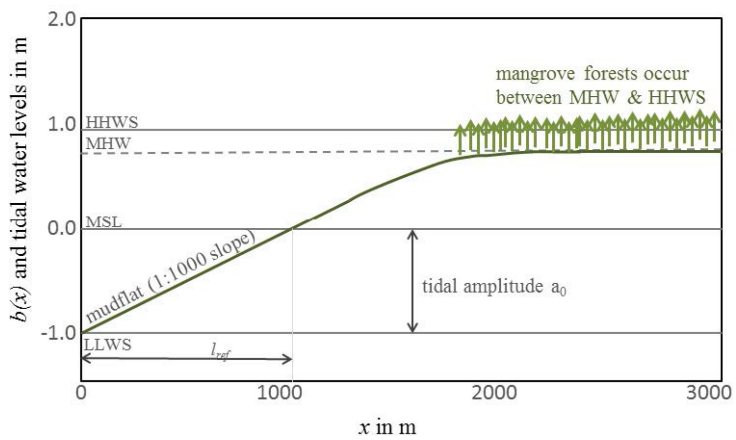
- Coast I: This stretch exhibits mild erosion with a fairly closed coastline,
- Coast II: This area is subject to severe erosion since 2003, that was induced by the breaching of aquaculture ponds. The landward extent of the erosion is limited by coastal roads,
- Coast III: Severe erosion induced by the breaching of aquaculture ponds and subsidence, that was already ongoing prior to 2003.

From 2000 to 2010, the Demak coast retreated a distance of between 100 m to 1 km, particularly in Coast I and Coast II, while Coast III had already experienced severe erosion.

At present, the muddy intertidal areas extend seaward for about 1 km and have bed slopes of about 1:1000. Further offshore, the bed has a steeper slope of about 1:500. Subsidence from deep and shallow groundwater extraction, land drainage, limited sediment input by rivers and sea level rise is a problem along the entire Demak coast. Sea level rise is estimated at 0.04 to 0.043 m per year for this coast, with even higher rates of 0.08 m per year near Semarang.

The equilibrium cross shore profile for intertidal mudflats under tidal currents (assuming the bed shear stress induced by the tidal currents is uniform across the mudflat) can be determined (Friedrich and Aubrey, 1996). The elevation of the bed level $b(x)$ for x the distance along the mudflat is then given by the following formula:

$$b(x) = \begin{cases} a_0\left({}^{x}/_{l_{ref}} - 1\right) & for\ x \leq l_{ref} \\ a_0 sin\left({}^{x}/_{l_{ref}} - 1\right) & for\ x \geq l_{ref} \end{cases}$$



4-51. *Mangroves located between mean high water (MHW) and high high water spring (HHWS) on a mudflat profile in cross-section. The equilibrium bed level $b(x)$ is indicated by the thick green line, and is calculated as a function of distance along the mudflat according to Friedrichs and Aubrey (1996). Here a tidal amplitude of 0.8 m at mean tide and an amplitude of 1 m at spring tide is assumed. © Jill Slinger, based on Winterwerp et al. (2013)*

where a_0 is the tidal amplitude, and l_{ref} is the reference length of the mudflat below mean sea level (MSL). For a coastline to be in equilibrium or to be accreting, the cross-shore profile below mean sea level extends a distance of l_{ref} off shore or further, and the upper profile is convex, rather than concave (see Figure 3). A concave profile usually indicates that wave-induced erosion is happening in the upper profile. So, your design will need to ensure that the supply of sediment to the coast is such that the equilibrium profile length is met or exceeded and the upper portion of the profile becomes convex in shape, allowing mangroves to establish. Mangroves then occur between mean high water (MHW) and high high water spring (HHWS).

Estimating the volume of fine sediment that needs to accrete to change the present concave sediment profile into a convex profile along the Demak coast can be undertaken using these formulae. But, this merely indicates the desired state and provides no guarantee that it can be achieved. Your challenge is to think up nature friendly ways in which you can ensure sufficient sediment in the nearshore water column, and sufficiently quiet waters, with wave penetration (for transporting sediments onshore), to ensure accretion. If this is achieved mangroves can become established and will help to ensure even more accretion.

You need to make a plan that takes the variation in erosion intensity and consequent vulnerability along the coast into account, perhaps by focussing on one area and monitoring effects on others, or by trying to tackle the full 7.8 km southern stretch. What will your strategy be? Enjoy using the information on the muddy substrate, the present extent of intertidal areas, average slopes, residual sediment transport, subsidence rates and different mangrove species to Build with Nature and solve these problems!

Hint

Remember to include monitoring of the northern Demak coastline in your monitoring programme, as its relative stability may change if sediment from the south is no longer supplied to this stretch of coast.

Consult the article by Winterwerp et al. (2013) for guidance on strategies to combat erosion along muddy mangrove coasts.

Acknowledgements

Source material was supplied by Building with Nature Indonesia. Building with Nature Indonesia is a programme by Wetlands International, Ecoshape, the Indonesian Ministry of Marine Affairs and Fisheries (MMAF), and the Ministry of Public Works and Housing (PU), supported by the Dutch Sustainable Water Fund and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). For more information: www.Indonesia.buildingwithnature.nl

Additional Knowledge Clips

Have a look at these videos on coastal systems and coastal interventions. These videos are part of the MOOC Water and Climate, also from Delft University of Technology. They will provide you with additional knowledge on river and coastal systems, and river and coastal interventions. You can apply this knowledge to design your own Building with Nature solution.

Video: Coastal Systems

Video: Coastal Engineering

Additional Sources

Please be aware that one of the solutions to this problem has already been implemented at Demak, Indonesia. We ask you to only consult this information, and the additional sources, after you have completed your own assignment. This will give you the opportunity to explore your own ideas while designing an original Building with Nature solution.

Building with Nature Indonesia

4.4 Detailed Case Material for Assignment 4

Case 7: Individual Cases

Information Requirements to Select Your Own Case in Assignment 4

In this document you will find a guide to the information that you need to collate in order to work with your own case in Assignment 4. Please note that as you work on the assignment, you might also need to look for additional information.

In the four pre-prepared cases, we supply **only** the information that is required to develop a design that addresses the specific problem presented.

1. Required information on the societal needs

- Main problem owner/direct client.
- Expressed need or required service that the infrastructure should satisfy.
- Stakeholders who react directly with the ecosystem and how they do this; e.g. local communities harvest fish, use mangroves or extract drinking water from the dunes.
- Interested and affected parties.
- Sources of ecosystem knowledge and expertise.

2. Information on the abiotic environment

Depending on the type of wetland that your problem is located in, you will need to collate the following information:

- Topographic or bathymetric chart, preferably digital
- Measurements and estimates of sediment grain sizes at different locations on the chart
- Average water depths
- Details of factors influencing the water depth. So, if a lake or reservoir system: inflows and outflows. If a river system: monthly or daily hydrological record, plus an indication of the percentage occurrence of different flows over time. If a marine or estuarine system: tidal variation and river discharges. If a dune system: potentially information on the groundwater level.

- Average current speeds (and variations upon these)
- For marine and coastal (estuary and dunes) systems, information on significant wave heights and directions, and estimates of wave period, height and direction under storm conditions.
- Wind directions and strengths
- Average air and water temperatures, and seasonal variations
- For lakes, estuaries and the nearshore zone, you may need information on the (thermal and/or haline) stratification in the water body over time.
- For estuaries, you will need information on the longitudinal variation in salinities, and the associated river discharges and depths in the inlet mouth.
- Additionally, information on changes in the bathymetry or topography over time or in response to specific events - **A morphological or hydrodynamic history. This need not only consist in measurements, but can be descriptive.**

3. Information on the biotic environment

Depending on the type of wetland that your problem is located in, you will need to collate the following information:

- Type of wetland
- Surrounding land use, this could vary from intensive agriculture with nutrient-rich run-offs, through urban use to protected nature area
- (Legal) Conservation status e.g. protected area, multiple use area, European Natura 2000 area, wetland with RAMSAR status, world heritage site
- Wetland habitat disturbance or fragmentation (compared to a reference condition)
- Endangered and threatened species, or populations
- Key processes and associated species; e.g. migration of fish or prawns from an estuarine environment to the sea for breeding purposes.
- Successionary processes and states; e.g. the formation and ecological succession of coastal dune systems from pioneer dunes to forested and stabilised dunes
- Naturally occurring zonation and the types of communities and species that would occur there; e.g. the lower intertidal zone of a sandy shore with more marine seaweeds compared with the upper intertidal zone with less seaweeds.
- A description of the trophic web present in these types of wetlands and an accompanying assessment of the relative health of the wetland that you are dealing with.

4. Linking the abiotic and the biotic information

Often, abiotic and biotic information derives from different data sources and are not linked to each other. If this is so for your wetland, you will need to link the abiotic and the biotic information that you have obtained. You can do this by providing a descrip-

tive explanation of the physical-chemical environment and the zones in the ecosystem, the physical-chemical process and inorganic cycles and explaining how they contribute to zone integrity and interact with the living environment.

5. Additional (non-required) information on the social environment

- Any legal requirements, regulations that apply directly to the locality or the types of activities that you will be undertaking (form constraints to actions, which you may choose to ignore in your BwN design, but which you should include in your risk assessment)
- Planning system and permissions
- Government system for your locality – who has what authority? For example, the province has authority over regional spatial planning, transport networks, but the local authority is responsible for water service provision.
- Local knowledge of the “unofficial” social system.

Time to continue

If you have chosen to work with an individual case and will have gathered the required background information, you can now move forward to Part 1 of Assignment 4.

We look forward to learning with you about potential Building with Nature applications worldwide!

4.5 Assignment 4: Building with Nature Design Assignment

Welcome to Assignment 4!

Over the last three chapters you have learnt about the Building with Nature philosophy, the Engineering Design process and Principles, the Ecological Design Principles and the Building with Nature Integrated Design process. Now you are ready to apply your knowledge to one Building with Nature case study.

In Assignment 4, you will analyse a particular problem, you will propose a conventional design and a Building with Nature design to address the issue. You will assess your own design in terms of the engineering and ecological design principles, and then will grade yourself as per the self assessment video and instruction text. Two or three example answers are provided for each of the six cases, so that you can compare your integrated design with selected answers of other students.

Good luck in completing this assignment!

Instructions Part 1

Go to the assignment form in Section 4.5 and complete the form by either:

- Recommended: Type the answers to the written questions, put an X in the right check boxes, and include your sketches by either:
    - drawing your sketches in another programme like Paint and inserting it as a picture in the form, or
    - drawing your sketches on real paper, then scanning or photographing them and inserting them.
- Print the form and write each question out by hand, before either scanning or photographing each page.

Once your form is complete, save your form. When filling in the checkboxes, please be explicit when you don't know how to fill in a certain item, but please limit these to sections where you truly don't know.

Part 2: Self review

For the self review, you are asked to examine your design by answering a series of questions and comparing with the designs of 2 or 3 examples from the same case. If you chose to do your own case, feel free to consult the example answers for any of the other cases to deepen your insight in integrated Building with Nature design.

Instruction Video: Sample Case

For more detailed instructions on how to complete this assignment, please re-watch the video from the sample case below.

In this video, Prof. Jill Slinger and Ir. Graciela del Carmen Nava Guerrero explain the structure underlying the assignment and provide an example of how to complete it, using the Sand Engine material.

At the beginning of the next chapter you'll find a grading rubric for the self review and an instruction video on how to assess your integrated Building with Nature design.

4.5 Assignment 4: Building with Nature Design Assignment

Assignment Form

Case Title & Location

Functional requirements (list at least 4)

-
-
-
-

Conventional solution (annotated):

Sketch

BwN design (annotated sketch, indicating anticipated changes over time):

Sketch

Consider the following principles, then rate (with an X in one of the five boxes) the extent to which you have taken this principle into account in your new design. Remember, this is an exercise in trade-offs, so you will not be able to meet every principle fully. Then explain why you have rated your design accordingly.

On this page you'll find the Engineering Principles, on the next the Ecological Principles.

Engineering Principles	Checkboxes *Minimum-maximum*	Explanation
1. Requisite standard	○ ○ ○ ○ ○	
2. Control variability	○ ○ ○ ○ ○	
3. Reasonable costs	○ ○ ○ ○ ○	
4. Structural integrity	○ ○ ○ ○ ○	
5. Reliability	○ ○ ○ ○ ○	
6. Implementability	○ ○ ○ ○ ○	
7. Adaptability	○ ○ ○ ○ ○	
8. Resilience	○ ○ ○ ○ ○	
9. Appropriate boundary conditions and loads	○ ○ ○ ○ ○	

Ecological Principles	Checkboxes *Minimum-maximum*	Explanation
1. Continuity	○ ○ ○ ○ ○	
2. No direct human disturbance	○ ○ ○ ○ ○	
3. Endogeneity	○ ○ ○ ○ ○	
4. Viability of populations	○ ○ ○ ○ ○	
5. Opportunity for threatened species	○ ○ ○ ○ ○	
6. Trophic web integrity	○ ○ ○ ○ ○	

4-206

Ecological Principles	Checkboxes *Minimum-maximum*	Explanation
7. Opportunity for ecological succession	○ ○ ○ ○ ○	
8. Zone integrity	○ ○ ○ ○ ○	
9. Characteristic (in) organic cycles	○ ○ ○ ○ ○	
10. Characteristic physi-cal-chemical water quality	○ ○ ○ ○ ○	
11. Resilience	○ ○ ○ ○ ○	

Monitoring and Risk assessment

In a short paragraph, discuss any future monitoring and risk assessment required for your Building with Nature design.

Trade-offs

Comment on any trade-offs you made in order to introduce more ecological principles. In other words, describe how your Building with Nature sketch differs from the conventional approach (max 200 words).

4.6 Bibliography

Literature

Aarninkhof, S.G.J., J.A. van Dalfsen, J.P.M. Mulder and D. Rijks, (2010), Sustainable development of nourished shorelines; Innovations in project design and realisation, Proc. PIANC MMX Congress Liverpool UK 2010

Bruens, A. et al., (2007), Globaal voorontwerp Zandmotor., WL| Delft Hydraulics report. Project nr Z4459 (in Dutch)

Bruun, P. (1954) Coast erosion and the development of beach profiles. Beach Erosion Board Technical Memorandum. No. 44. U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS.

Dean, R.G., Kriebel, D.L. and Walton, T.L. (2002). Cross-shore secdiment transport processes. Chapter 3 of Part III of the Coastal Engineering Manual, EM 1110-2-1100.

Deltares (2016). *Harbour Sedimentation Harlingen* – Delft3D Flexible Mesh pilot. Retrieved April 24, 2016, from Deltares: https://www.deltares.nl/en/projects/harbour-sedimentation-harlingen- pilot-delft3d-flexible-mesh/

Deltares/ Ecoshape (n.d.), *Sand nourishment - Sand Engine Delfland, North Sea, NL.* Retrieved February 2016 from https://www.ecoshape.org/en/sand-nourishment-sand-engine-delfland-north-sea-nl/

Eekelen, E. van, Baptist, M.J, Dankers, P.J.T., Grasmeijer, B., Van Kessel, T. and Van Maren, D.S. (2016) “Muddy waters and the Wadden Sea Harbours”. Proceedings of the Twenty-First World Dredging Congress, WODCON XXI, Miami, Florida, USA, June 13-17, 2016.

Eijk, A. van der, & Esselink, P. (2014). *It Fryske Gea*. Heerenveen: SMG Groep.

Eleftherakis, D., Amiri-Simkooei, A., Snellen, M., & Simons, D. G. (2012). Improving riverbed sediment classification using backscatter and depth residual features of multi-beam echo-sounder systems. The Journal of the Acoustical Society of America, 131(5), 3710-3725.

Fiselier, J. (2010), Projectnota MER Zandmotor Delflandse Kust, rapport DHV en H+N+S Amersfoort; dossier C 6158-01.001; 303 pp. (EIA-report; in Dutch)

Friedrichs, C. T., Aubrey D. G. (1996) Uniform bottom shear stress and equilibrium hypsometry of intertidal flats. In: Pattriaratchi C (ed) Mixing in estuaries and coastal seas. American Geophysical Union, Washington, pp 1061–1077.

Gemeente Harlingen (2016). Havens, diepte. http://www.harlingen.nl/inwoners/onderwerpen-a- z_42168/product/

havens-diepte_991.html. Consulted on: 24 April 2016.

Giardino, A., Santinelli, G., Bruens, A. (2012). The state of the coast. Case study: North-Holland. Deltares Report 1206171-003-ZKS-0001, Delft, Netherlands. 57 pp.

Grontmij (2008), Pilot Zandmotor Delflandse Kust, Startnotitie Milieu effect rapportage, Grontmij Nederland, Houten december 2008; 13/99088668/RJJ D2 (in Dutch)

Klijn, F. (2016). Personal communication

Loon-Steensma, J. van. (2015). *Salt marshes to adapt the flood defences along the Dutch Wadden Sea*. Wageningen: Wageningen University & Research Centre.

Mehta, A. J. (2002). Mudshore dynamics and controls. In: *Muddy Coasts of the World.* (ed.) Healy, T., Wang, Y., Healey, J-A. Proceedings in Marine Science 4, Elsevier. 19-60.

Mulder, J.P.M. , and J. van Dalfsen, (2011), Current Challenges in Coastal Management in the Netherlands: Examples of Pilot Projects, DOI: 10.1061/41190(422)88, ASCE Conference Proceedings , 1088 – 1101

Mulder, Jan P.M. and P.K. Tonnon, (2010), “Sand Engine”: Background and design of a mega nourishment pilot in the Netherlands, Proceedings Of The International Conference On Coastal Engineering, No. 32(2010), Shanghai,China. Paper #: management.35.

Mulder J.P.M. en M.J.F. Stive, (2011), Zandmotor maakt bouwen met de natuur mogelijk, Land + Water nr. 5 (mei 2011); 20-22 (in Dutch)

Projectbureau Noordwaard (2007) Design Vision Noordwaard May 2007 (in Dutch). Retrieved 10 February 2016 from www.ruimtevoorderivier.nl

Rijkswaterstaat RIKZ Haren (1998). Sedimentatlas Waddenzee. Amsterdam, Noord-Holland, Nederland.

RWS (2016a). Retrieved June 2016 from: http://getij.rws.nl/getij_resultaat.cfm?page=home&location=KORNWDZBTN&-timezone=MET_DST&refplane=NAP&from=20160315

RWS (2016b) Retrieved June 2016 from: http://www.deafsluitdijk.nl/projecten/pompen/waarom-is-het-er/

RWS, Province Zuid Holland et al. (2013), The Sand Motor; pilot project for coastal protection, Rijkswaterstaat, Provincie

Zuid Holland, Ecoshape, Kansen voor West, EFRO, STW Monitoring and Research Sand Motor Brochure 15 pp.

RWS, Province Zuid Holland et al. (2013), Infographic Sand Motor Monitoring, 1p

RWS, Province Zuid Holland et al. (2013), Monitoring Fact Sheet Zand Motor. April 2013, 2 pp.

RWS and Province Zuid Holland. (2012), Fact Sheet Sand Motor, June 2012, 2 pp.

Stive, M.J.F. (2004). How important is global warming for coastal erosion? *Climatic Change*. 64: 27 – 39.

Stive, Marcel, Matthieu de Schipper, Arjen Luijendijk, Roshanka Ranasinghe, Jaap van Thiel de Vries, Stefan Aarninkhof, Carola van Gelder-Maas, Sierd de Vries, Martijn Henriquez, Sarah Marx, (2013). The Sand Engine: a solution for vulnerable Deltas in the 21st century?, Proceedings Coastal Dynamics 2013, 1537 – 1545.

Tonnon, P.K. (ed.), L. van der Valk, H. Holzhauer, M.J. Baptist, J.W.M. Wijsman, C.T.M. Vertegaal, S.M. Arens, (2011), Uitvoeringsprogramma Monitoring en Evaluatie Zand Motor., Rapport 1203519-000-ZKS-0034 | C172/10, Deltares / Imares, 150 pp. (Monitoring and Evaluation Program – in Dutch)

Winterwerp, H. , Erftemeijer, P.L.A., Suryadiputra, N., van Eijk, P., Zhang, L. (2013). Defining eco-morphodynamic requirements for rehabilitating eroding mangrove-mud coasts. Wetands 33: 515-526. doi: 10.1007/s13157-013-0409-x

Winterwerp, H., van Wesenbeeck, B., van Dalfsen, J., Tonneijck, F., Astra, A., Verschure, S., van Eijk, P. (2014). A sustainable solution for massive coastal erosion in Central Java . Towards Regional Scale Application of Hybrid Engineering. Discussion paper. Jointly published by Deltares and Wetlands International.

Figures

4-1. 6 Case Studies: A. Noordwaard P1340188 by G. Lanting is licensed under CC BY 4.0, **B.** Zicht op Waalkade vanaf overkant Waal - Nijmegen - 20358130 - RCE by P. van Galen is licensed under CC BY-SA 4.0, **C.** Dutch motorway A7 (Rijksweg 7) - Afsluitdijk by W. Bulach is licensed under CC BY-SA 4.0, **D.** Hondsbossche En Pettemer Zeewering by Ceinturion is licensed under CC BY-SA 3.0, **E.** Harlingen, haven foto 1 by Michielverbeek is licensed under CC BY-SA 3.0, **F.** See Figure 4-46.

4-2. Implications for the design process: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-3. Conventional design process: from social values to functional requirements: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-4. Ecological design? From nature values to functional requirements: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-5. Building with Nature: integration using H-E-principles 1: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-6. Building with Nature: integration using H-E-principles 2: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-7. Building with Nature Design Process: Step 1: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-8. Building with Nature Design Process: Step 2: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-9. Building with Nature Design Process: Steps 3+4: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-10. Building with Nature Design Process: Step 5: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-11. Building with Nature Design Process: Step 7: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-12. Building with Nature Design Process: Step 6: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-13. The complete Building with Nature design process: This image by Jill Slinger is reworked by Martijn Vos and is licensed under CC BY-NC-SA 4.0

4-14. Building with Nature: a balancing act: This image by Jill Slinger is reworked by Martijn Vos and licensed under CC BY-NC-SA 4.0

4-15. Location of Sand Engine: This image is Copyright Protected. © Projectbureau Pilot Zandmotor. All Rights Reserved.

4-16. Alternative nourishment schemes: This image by Ecoshape is licensed under CC BY-NC-SA 4.0

4-17. Preferred alternative, Peninsula: This image by Ecoshape is licensed under CC BY-NC-SA 4.0

4-18. Impression of the predicted evolution of the Sand Engine: This image is Copyright Protected. © Projectbureau Pilot Zandmotor. All Rights Reserved.

4-19. Map of the Netherlands: Netherlands map large by Scipius is licensed under CC BY-SA.3.0

4-20. Noordwaard Polder location: This map was created by TU Delft, using imagery copyrighted by Google MyMaps. Retrieved from: https://www.google.com/maps/d/viewer?mid=1jwHVJQQpaDapDeHa1HXd8-NVuWo&usp=sharing

4-21. Predicted water levels in the Noordwaard and Biesbosch under the 1 in 2000 year flood (left) and the 1 in 100 year flood (right): Waterstand Overschrijdingsfrequentie 1/100 en 1/2000 jaar by Deltares was prepared for Ruimte voor de Rivier and is licensed under CC BY-NC-SA 4.0

4-22. Sketch of wind fetch: This image by Jill Slinger is licensed under CC BY-NC-SA 4.0

4-23. Sketch of wave height: This image by Jill Slinger is licensed under CC BY-NC-SA 4.0

4-24. Significant wave height - fetch relationship, for water depth 3.2 m and wind speed 30 m.s-1: This graph is in the Public Domain

4-25. Noordwaardpolder infographic 1: Depoldering the Noordwaard is Copyright protected. © Loek Weijts, Martijn Van Staveren and Ecoshape. All Rights Reserved

4-26. Noordwaardpolder infographic 2: Depoldering Noordwaard (flood plain) is Copyright protected. © Ruimte voor de Rivier. All Rights Reserved.

4-27. Location of Nijmegen and satellite image of the city: This map is using imagery copyrighted by Google. Retrieved from: https://www.google.com/maps

4-28. De Waal in Nijmegen: This image by Ruimte voor de Rivier is licensed under CC BY-NC-SA 4.0

4-29. Planning kit output for the River Waal: This image by Ruimte voor de Rivier is licensed under CC BY-NC-SA 4.0

4-30. Effect on water levels of different interventions on the River Waal (Klijn, 2016): This image by F. Klijn is licensed under CC BY-NC-SA 4.0

4-31. Schematic representation of the River Waal's cross-section: This cross section by Jill Slinger is based on information from Eleftherakis et al. (2012) and is licensed under CC BY-NC-SA 4.0

4-32. Location of the study area: This map is using imagery copyrighted by Google. Retrieved from: https://www.google.com/maps

4-33. Indicative semi-diurnal tidal variation in the Wadden Sea at Kornwerderzand: This graph by Rijkswaterstaat is in the Public Domain

4-34. Window for freshwater discharge from the IJssel Lake to the Wadden Sea: This graph by Rijkswaterstaat is in the Public Domain

4-35. Fish that will benefit from restoration of fresh-salt interfaces: "Vissoorten vismigratierivier" is Copyright protected. © Rijkswaterstaat. All Rights Reserved.

4-36. Coastal Protection location: This map was created by TU Delft, using imagery copyrighted by Google MyMaps. Retrieved from: https://www.google.com/maps/

4-37. Potential coastal protection solutions: This image by Jill Slinger is licensed under CC BY-NC-SA 4.0

4-38. Wind rose for 1995: Giardino, A., Santinelli, G., Bruens, A. (2012). Wind rose 1995. Retrieved from: http://edepot.wur.nl/368831

4-39. Natural dynamics of a cross-shore profile: "Seasonal beach adjustments" is in the Public Domain.

4-40. Plan view of the cross shore and longshore sediment transport processes operating on a seaward sandy extension in front of a dike: This image by Jill Slinger is licensed under CC BY-NC-SA 4.0

4-41. Location of Harlingen Harbour: This map was created by TU Delft, using imagery copyrighted by Google MyMaps. Retrieved from: https://www.google.com/maps/

4-42. Harlingen Harbour schematic overview: This image by Ana Colina Alonso is licensed under CC BY-NC-SA 4.0

4-43. Overview harbour specification: The data from this table is retrieved from http://www.harlingen.nl/inwoners/onderwerpen-a- z_42168/product/havens-diepte_991.html

4-44. Potential disposal locations: This image by Deltares is licensed under CC BY-NC-SA 4.0

4-45. Location of Demak Coast: This map was created by TU Delft, using imagery copyrighted by Google MyMaps. Retrieved from: https://www.google.com/maps/

4-46. Muddy Demak coast showing flooding of the mangrove areas (dark green) and the aquaculture ponds behind them: "Flooded Mangrove areas in Demak" by Wetlands International is licensed under CC BY-NC-SA 4.0

4-47. Solid structure along the Demak coast: This image by Wetlands International is licensed under CC BY-NC-SA 4.0

4-48. Failing sea wall along the Demak coast: This image by Wetlands International is licensed under CC BY-NC-SA 4.0

4-49. Wave rose for Demak coastline for the years 2003-2009: Wave rose for Demak 2003-2009 by Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia is licensed under CC BY-NC-SA 4.0

4-50. The Demak coastline: This image by Wetlands International is licensed under CC BY-NC-SA 4.0

4-51. Mangroves located between mean high water (MHW) and high high water spring (HHWS) on a mudflat profile in cross-section: This graph by Jill Slinger is based on Winterwerp, H. et al. (2013) and is licensed under CC BY-NC-SA 4.0

5-1: Mangrove Restoration in Timbul Sloko, Indonesia. © Wetlands International

Chapter 5 Assessing BwN Designs

5.1 Introduction

Congratulations on finishing Chapter 1 to 4 of this book! You have almost finished the first part!

In Chapter 5, we focus on two activities. First, you are required to conduct a self-review of your work (Part 2 of Assignment 4). Instructions on how to conduct the self-review are provided in the following pages. Depending on the case you selected, you are asked to also cross-compare your Integrated Building with Nature Design with some example answers. For those of you who selected your own case rather than one of the 6 pre-prepared cases, you are free to consult a number of the example answers.

After finalising Part 2 of Assignment 4, we ask you to move on to the second activity of Chapter 5, in Section 5.2. In this section you can read about a Building with Nature solution implemented in practice in each of the six pre-prepared cases.

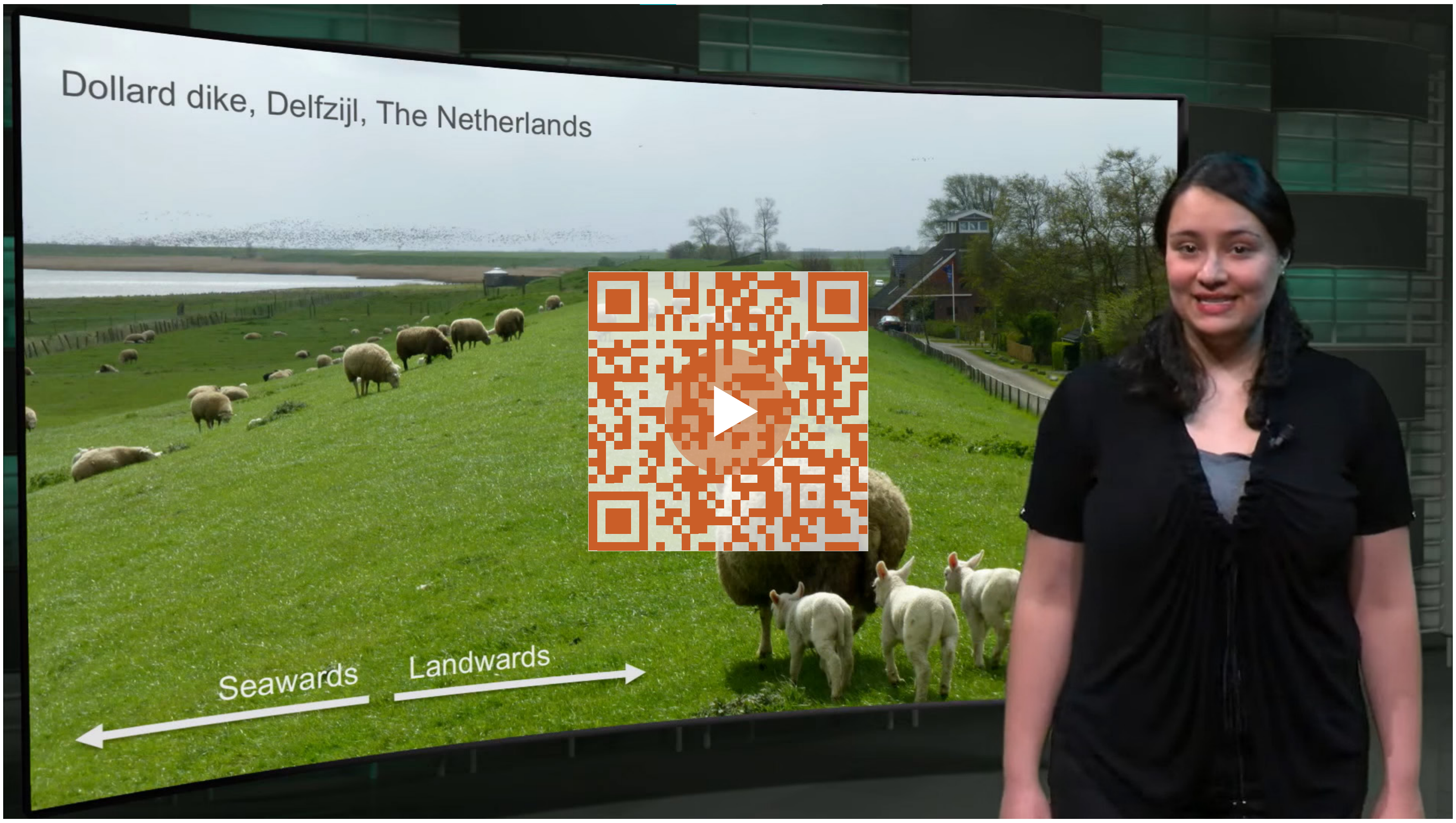
Remember to take the opportunity to discuss these, and other possible solutions, with your peers. Enjoy learning about a wide range of Building with Nature solutions!

Table: Self Review Grading Table

Components	Indicative questions (Criterion)	Options	Grade
Title and location	Are the title and location specified?	**No** **Yes**	**0** **3**
Functional requirements	Are at least 4 functional requirements included? Do these include both engineering and ecological requirements?	**Poor:** Less than 2 and these are both engineering or both ecological requirements. **Fair:** At least 3 functional requirements are listed and these consider both engineering and ecological requirements. **Good:** At least 4 are included and they consider both ecological and engineering requirements.	**0** **5** **10**
Sketches	Is an annotated sketch of a conventional design provided? Is an annotated sketch of a Building with Nature design provided?	**No:** The sketches are missing **Only 1:** Only 1 sketch is present (regardless of how good or bad they are). **Yes, both:** Both sketches are there (regardless of how good or bad they are).	**0** **7** **15**
Quality of sketches	Are at least 2 Building with Nature measures clearly specified? Is there any indication of how they will develop over time?	**Poor:** This sketch is unclear compared to the model answers. Can't distinguish between land and water and there are no hydraulic boundary conditions indicated . **Fair:** This sketch is understandable, but at least one of these components is missing: 1. boundary conditions, 2. the distinction between land and sea, and 3. indication of change over time. **Good:** This sketch is clear and all of these components are present: 1. boundary conditions (primary characteristics), 2. the distinction between land and sea, and 3. indication of change over time.	**0** **5** **10**
Engineering principles	Are at least 4 Engineering Design Principles ranked in the last two boxes? Is the Building with Nature design evaluated rather than the conventional solution? Are the explanations placed in the correct boxes? Do the explanations match the scoring of the principle? Is sufficient explanation provided for each choice?	**Poor:** No, less than 4 engineering principles have a high ranking (in the last 2 boxes), and/or no explanations are included. **Fair:** Yes, at least 4 engineering principles have a high ranking (in the last 2 boxes), and but 2 explanations are missing from those 4. **Good:** Yes, at least 4 engineering principles have a high/maximum ranking (in the last 2 boxes), and explanations are included for those 4 at least.	**0** **8** **16**

Table continues →

Components	Indicative questions (Criterion)	Options	Grade
Ecological principles	Are at least 5 Ecological Design Principles ranked in the last three boxes? Is the Building with Nature design evaluated rather than the conventional solution? Are the explanations placed in the correct boxes? Do the explanations match the scoring of the principle? Is sufficient explanation provided for each choice?	**Poor:** No, less than 3 ecological principles have a sufficient ranking (in the last 3 boxes), and/or explanations are included for more than 3. **Fair:** Yes, at least 4 ecological principles have a sufficient ranking (in the last 3 boxes), but not all 4 have explanations. **Good:** Yes, at least 5 ecological principles have a sufficient ranking (in the last 3 boxes), but not all 5 have explanations.	0 8 16
Monitoring and risk assessment	Is a monitoring and risk assessment strategy provided? Does this address the relevant aspects?	**Poor:** I have neither noted that the Building with Nature solution is associated with risks nor have I proposed solutions to manage. **Fair:** Yes, but either: 1. I noted that the Building with Nature solution is associated with risks and have proposed solutions to identify and manage those risks. But I have not noted monitoring is part of risk management in my answer, **or** 2. I mentioned monitoring as part of risk assessment, but have proposed other solutions to deal with risk management. **Good:** Yes, I noted that the Building with Nature solution is associated with risks and have proposed solutions to identify and manage those risks. I also noted that monitoring is part of risk management, and have included this in my answer.	0 5 10
Trade-offs	Are at least 2 trade-offs included, and described in terms of Engineering and Ecological Design Principles?	**Poor:** I have not identified any trade-offs nor have I described them. **Fair:** I have identified at least 1 trade-off and described this in terms of the engineering and ecological principles, or I have identified 2 but have not described these in terms of the engineering and ecological principles. **Good:** I have identified at least 2 trade-offs and described these in terms of the engineering and ecological principles.	0 5 10
Comparison with Example Answers	How does the overall quality of the design compare with that of the Example Answers?	**Weaker** **Partially stronger:** My design is: 1. equivalent to, **or** 2. substantially stronger on at least 1 component (i.e. sketches, engineer principles, trade-offs, etc.), but potentially weaker on other components for all 3 model answers, **or** 3. substantially stronger on 3 components of at least 1 model answer, but with a few weaker components. **Stronger:** My design is stronger on at least 3 components (i.e. sketches, ecological principles, trade-offs, etc.) for all 3 example answers for my chosen case.	0 5 10



Self Review Instruction Text and Video

In Chapter 5 you are required to assess your integrated design. You can become familiar with how to complete this second part of Assignment 4 by first watching the video presented by **engineer Graciela del Carmen Nava Guerrero** above. Then, you are encouraged to look carefully at the example answers provided and think how your design compares. You are guided in this comparison and through the grading by a series of questions on each of the components listed in the Self Review Table on the previous pages. You can cite the video as:

Nava Guerrero, G.d.C. (Graciela) (2016): *Engineering: Building with Nature 101x video #11 - Peer Review of the Building with Nature Design Assignment.* 4TU.ResearchData. Dataset. https://doi.org/10.4121/uuid:b9dbb185-0c94-46e1-af71-c51f860c8c2f

You can compare each of the criterion to example answers of the case you have chosen by clicking or scanning the following link/QR Code:

Download Comparison Answers from TU Delft Open Textbook Website

In addition, blank forms on which to complete assignments are provided as downloads on TU Delft Open, as is a set of example answers for use in the self-assessment of your Building with Nature Design Assignment from Chapter 4.

Before You Continue...

Discuss with your peers how your Building with Nature design is similar and/or different to the model designs. Please note that this is not a value judgement on whose is better, but merely an opportunity to reflect.

Building with Nature in Practice

5.2 Building with Nature in Practice

In the following pages you will find detailed information on the Building with Nature solutions that were implemented in The Netherlands and Indonesia, for each of the 6 pre-prepared cases.

As you will now know, the selected solution represents only one of a number of possible options.

Enjoy comparing your solution to the one that was actually implemented!

Case 1: Climate-proof Noordwaard

Introduction

The river Rhine runs through the Netherlands towards the North Sea. During very high discharges, which may occur more frequently in future owing to climate change, the floodwaters needs more space to spread out so as to prevent disastrous downstream flooding. There needs to be more *Room for the River*! This will be provided for the New Merwede branch of the Rhine by de-poldering the 4450 Ha Noordwaard **polder***, which is situated in the southwestern part of the Netherlands. De-poldering involves allowing water to stream through and over the Noordwaard polder when the river discharge is very high. By allowing flooding of the land that was previously protected by dikes, the predicted high water levels from river flooding will be reduced by 30 cm at the nearby town of Gorinchem.

Nevertheless, within this de-poldered area, there are location(s) that still have to be protected from flooding. For instance, in the northeast corner of the Noordwaard polder, there is a fortress called Fort Steurgat. This fortress has cultural and historical value. This corner is also home to eleven households.

In Assignment 4, course participants were required to design a nature friendly solution for this particular problem, possibly by building a dike. Rijkswaterstaat (RWS) required a design that delivered a protection level comparable to other dikes in this region (1 in 2000 years) while still achieving the overarching goals of the Room for the River programme.

In short, the primary problem owner or client is the Dutch Ministry of Infrastructure and Water Management, who is tasked with

* In the Netherlands, a polder is an area of low land that is protected from river or coastal floods by a ring of dikes.

ensuring that appropriate planning is undertaken to ensure the safety from flooding in the Netherlands. It is they who commission studies to determine the predicted flood levels, and they who then determine the desired reduction in flood level that must be achieved through actions like de-poldering.

The Noordwaard Polder is situated in the western part of the Netherlands, close to the cities of Dordrecht and Gorichem.

The picture below shows the implemented solution in action. The depoldered Noordwaard flooded for the first time in 2020.

5-2. *Flooded depoldered Noordwaard. ⓪ Rijkswaterstaat.*

Description of One Building with Nature Solution

The materials below provide you with a description of one Building with Nature solution to Case 1. This solution has already been implemented in the Netherlands.

1. Video: Depoldering Noordwaard

2. Video: Dutch Homeowners Move to Make Room for the River

3. Factsheet: Room for the River - The case of Noordwaard

4. Ecoshape: Wave attenuation with willow woodland

5. Key Aspects of This Solution to Case 1

By Prof. Jill Slinger and Ir. Graciela del Carmen Nava Guerrero

General Information on the solution

Title	Wave reducing Eco Dike
Abstract	Construction of willow forest on a new river dike, resulting in a lower dike height and added natural value and natural landscape.
Location	Noordwaard near Werkendam, The Netherlands
Date	2009 - 2015
Main problem owner	Dutch Ministry of Infrastructure and Water Management
Companies & partners	Deltares, WINN, Rijkswaterstaat Room for the River program, Project Bureau Noordwaard, Waterschap Rivierenland, Ecoshape
Costs	Lower construction costs as the crest height of the wave reducing Eco Dike is lower than a conventional dike. Maintenance costs are unknown, but will include regular trimming and care for the trees, as well as inspections of the dike and the willows.
Project details	The willow plantation is located on a low embankment with the lowest willow at an elevation of 70 cm above the surrounding floodplain so that the willows will not be inundated too frequently or for too long. The width of the willow stand is about 80 meter and it stretches before the dike of Fort Steurgat. The willows were planted in a staggered grid with a density of approximately 4 tree stems per m^2, resulting in hundreds of branches per m^2.
Safety level	1:2000 per year

Additional Information on the design problem

In an attempt to combat the risk of disease, it is wise to plant two species of indigenous willow *Salix alba* and *Salix viminalis* in the hope that when one is affected by disease, the other may not be. Maintenance of the willow stand, to ensure that the vegetation is not so thick that it forms a complete blockage to flow is essential. The willows need to protect against waves, but still allow water to flow through and around them. Accordingly, the lower stems need to be kept clear of too much vegetation whereas above 0.5 to 0.7 m they can be leafy and strongly branched as this will reduce wave effects.

Calculating the dike height without wave reduction due to willows.

The following elements are included in the calculation of the height that the dike would need to have had without a wave reducing foreshore of willows:

1. The **design water level** is the calculated flood level that we indicate that you may use as 3.2 m to chart datum (NAP). You may have used the anticipated water levels near Fort Steurgat which are 3.7 m. This is also fine, your answer will just be 0.5 m higher.
2. A **wave overtopping** value. If you consulted the graph, using a fetch of between 7 to 10 km, you will have obtained a value for significant wave height Hs of around 1 m. This you would then add to your design water level to get 4.2 m.
3. An **additional compensation** for settling of the dike, sea level rise effects till 2050 and to ensure it is robust, of 0.95 m in total.
4. So, adding this compensation to the previous calculations, you get **5.15 m dike height.**

This is the average height of the dike that would have had to be constructed if there had been no wave reducing foreshore of willows. The dike would also have had to be widened far more to accommodate the increase in height.

Case 2: City with Nature

Introduction

On its journey through the Netherlands, the Waal River passes the city of Nijmegen, in the eastern part of the country. To prevent dangerous situations similar to those of 1993 and 1995 when extreme river discharges occurred and major evacuations of people and animals had to be undertaken, more room has to be given to the river near Nijmegen.

Rijkswaterstaat (RWS), the operational arm of the Dutch Ministry of Infrastructure and Water Management, has planned to make Room for the River in the proximity of Nijmegen. The city of Nijmegen and the district waterboard Rivierenland are also involved in the plan.

In Assignment 4, course participants were required to design a nature friendly solution that makes Room for the River while maintaining the flood safety standard and improving the quality of the environment for urban dwellers.

Nijmegen is located in the eastern part of the Netherlands. The river Waal, a branch of the river Rhine, flows through the city.

In the image below an aerial photo of the implemented solution is shown.

5-3. Nijmegen and the river Waal after implementation of BwN solution. ⓒ Rijkswaterstaat.

Description of One Building with Nature Solution

The materials below provide you with a description of one Building with Nature solution to Case 2. This solution has already been implemented in the Netherlands.

1. Video: Nijmegen embraces the river Waal

2. Video: Construction works Room for the River Waal, Nijmegen & Lent

3. Factsheet: Room for the River - The case of Lent

4. Brochure: Room for the river Waal in Nijmegen and Lent

5. Key Aspects of This Solution to Case 2

By Prof. Jill Slinger and Ir. Graciela del Carmen Nava Guerrero

General Information on the solution

Title	Room for the river Waal in Nijmegen and Lent
Abstract	An ancillary channel was constructed to reduce high water levels during floods by increasing the discharge capacity. A dike had to be relocated to increase the floodplain of the river Waal.
Location	Nijmegen, The Netherlands
Date	2013 - 2015
Main problem owner	Dutch Ministry of Infrastructure and Water Management, City of Nijmegen, district waterboard Rivierenland are all involved in the plan.
Companies & partners	Royal Haskoning DHV, Antea and Stroming
Costs	351 million euro
Project details	A 3 km long ancillary channel 10 m below the crest height of the dike, with a total width of 200 m (150 m at normal water levels) was created in a new floodplain area by relocating the dike at Lent 350 m inland of its previous location. The upstream end of the channel is not connected directly to the River Waal so that it does not take too much water from the main channel. Water from the main channel can flow over the barrier separating the river and ancillary channel only at high water levels, increasing the discharge capacity of the river. At the downstream end of the ancillary channel, there is a permanent connection with the river, and the ancillary channel is filled with water, creating an island. The island offers excellent opportunities for the development of specific river biotopes. It can also be used for purposes other than nature development, namely: work and leisure activities.
Safety level	The dike at Lent is a primary flood defence

Additional Information on the design problem

Existing cross-section at Nijmegen:

- Depth ~ 6 m
- The river is 350 m wide
- Cross-sectional area is determined from the trapezium rule: ½depth(sum of the parallel sides) = ½(6 m)(350m+250m) = 1800 m^2

30% of 1800 m^2 = 540 m^2

- Depth 10 m below dike crest (dike height 6m), so channel depth is 4 m
- The channel is about 150 m wide
- Cross-sectional area: ½(4m)(150m+100m)=500 m^2

Case 3: Fish Manager

Introduction

One hundred years ago, a long dike was constructed in the north of the Netherlands to protect large tracts of land from flooding. This barrier dike transformed the Zuiderzee into a freshwater lake known as the IJsselmeer (IJssel Lake), and continues to separate the fresh IJssel Lake from the salt water of the Wadden Sea. Sluices in the barrier dike only allow freshwater to drain into the salty sea water, but do not allow salt water to penetrate into the freshwater lake. This means that at present fish cannot migrate from the sea into the lake or *vice versa.*

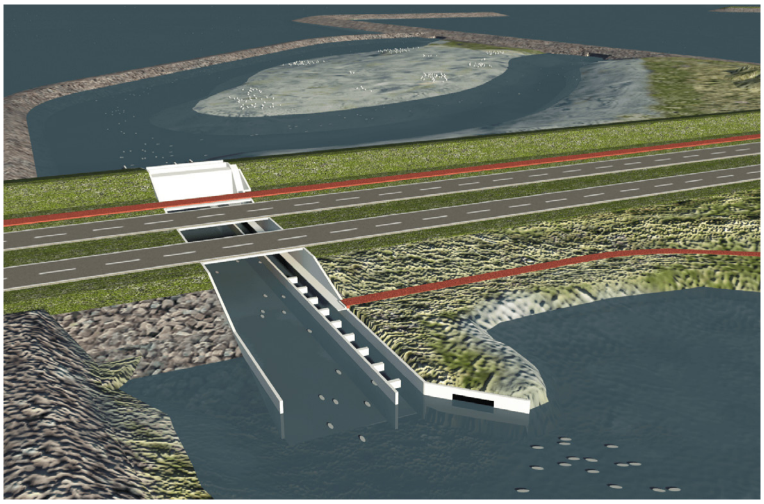
The Wadden Sea region is a highly valued nature area and various parties are concerned with the connection between the IJssel Lake and the Wadden Sea. Different levels of government (municipality, province and national government) and commercial fishing companies are highly interested in investigating solutions that would restore the connection between the two water bodies while maintaining the safety standard of the barrier.

In Assignment 4, course participants were required to design a nature friendly solution for this problem. Solutions must provide ecological opportunities for the Wadden Sea and IJssel Lake while maintaining the flood safety standard and ensuring that the IJssel Lake can still be used for freshwater supply.

The study area is situated in the northern part of the Netherlands, where the IJssel lake is separated from the Wadden Sea by a 30 km long barrier dam.

Description of One Building with Nature Solution

The materials below provide you with a description of one Building with Nature solution to Case 3. This solution has already been implemented in the Netherlands.



5-4. *Artist impression of the future Fish Migration River. © Rijkswaterstaat.*

1. Video: The Fish Migration River

2. Website: Official site of the project

4. Official Information on the Project

The interactive PDF of the Fish Migration River solution, available via this link or the QR code on the right provides official information on the project. Because this information is written in Dutch, below this text we provide you with an English translation.

Understanding the interactive PDF

This document is based on the *Vismigratierivier Afsluitdijk*, developed by 'Programma naar een Rijke Waddenzee' and the alliance 'de Nieuwe Afsluitdijk'. Because the original document is written in Dutch, this document provides an English translation.

In the original PDF document, you can click on the items in the legend (the red box in the top right corner of the document). This will make some boxes with text appear in the image. Because the original document is in Dutch, this document provides you with a translation for each of these boxes. The items from the checked legend option are labeled in the image (orange) and correspond to the numbered items in the text column next to the image.

Ontwerp = Design

1. In the future, the influence of tides in the Wadden Sea will enable a salt marsh landscape to become established.
2. A storm surge barrier can close off the channel opening. The storm surge barrier ensures safety from flooding.
3. Fish can cross the Afsluitdijk via an open channel. The primary channel of the migration route has strong currents and the secondary channel has weak currents. There is a walking path alongside the channel.
4. The Fish Migration River can be closed off at the southern side. This mechanism prevents salt water from flowing into the IJssel Lake.

Werking = Operation

1. The fish from the Wadden Sea are attracted by the fresh water signal in the discharge area. The fish can easily swim into the Fish Migration River via two openings.
2. Weak swimmers, like the eel and the flounder use the flood tide to move from the Wadden Sea to the IJssel Lake.
3. When it is ebb tide in the Wadden Sea, fresh water flows out of the IJssel Lake. Strong swimmers like the sea trout and the Atlantic salmon can easily swim against these flows.
4. Locks are located in both channels. The current speeds and salt intrusion can be controlled using these locks. The secondary channel is always open. In this stream vertical gates are placed to ensure that the current speeds remain low here.

Natuur = Nature

1. Between the two attractive fresh water streams lies a bird island where for example plover and terns can breed undisturbed.
2. The meandering transition zone between salt water and freshwater creates a dynamic area where new vegetation such as salt marsh bulrush and silt grassland can become established.
3. The migrating fish continue on their route to the IJssel Lake and further upstream, to mature and reproduce.
4. Towards the IJssel Lake the water will become progressively more fresh. Reeds can grow on the banks and higher on the dikes colourful vegetation and flowers can grow.

Beleving = Experience

1. In the Kazematten museum, you can find information about migratory fish species and their migration routes. Here you can experience the world of salt and fresh water!
2. It is possible to watch the migrating fish through a window. There will always be fish to see in this part.
3. The field with ‘Happy Fish’ is an art project of 300 fish silhouettes that turn with the tide.
4. The boating public can reach the Fish Migration River via a jetty.
5. A large part of the area is open to visitors. The new nature area can be discovered via walking paths.

5. Key Aspects of This Solution to Case 3

By Prof. Jill Slinger, Ir. Graciela del Carmen Nava Guerrero and engineer Ilse Caminada

General Information on the solution

Title	Fish Migration River
Abstract	The Fish Migration River is an innovative plan to make the barrier of the Afsluitdijk passable to fish by re-connecting the Wadden Sea and the IJssel Lake. This route will allow many migratory fish species to pass between the marine and riverine environments and so reach their spawning and living areas once again.
Location	Kornwerderzand on the Afsluitdijk, Friesland, The Netherlands
Date	Planned for medio 2020 (long delays experienced)
Main problem owner	Rijswaterstaat, Province of Friesland
Companies & Partners	De Nieuwe Afsluitdijk – a cooperation between the provinces of North-Holland, Friesland, Hollands Kroon, Súdwest-Fryslân and Harlingen.
Costs	Planning and preparation 4.6 million euro, Construction 60 to 75 million euro
Project details	The 3 kilometer long fish migration route connects the main channels in the Wadden Sea with the IJssel Lake. The direction of flow in this migratory route depends on the tide. On the ebb tide, fresh-water flows from the IJssel Lake into the Wadden Sea. On the flood tide, salt water flows from the Wadden Sea into the IJssel Lake. The length of the connecting stream, and the fact that both ends can be closed off, will prevent a high volume of salt water from flowing into the IJssel Lake. However, the intention is that the opening can be used by fish every day of the year. The dimensions of the opening in the Afsluitdijk will be: • Height: 10 meter • Width: 15 meter • Length: 100 meter (the width of the Afsluitdijk) • Water depth: 4 meters. The opening in the Afsluitdijk can be closed under storm surge conditions. The migratory route includes elements such as a soft sand bank and a straight stone dike. There will be a gradual transition from marine to brackish to freshwater to allow the fish to become accustomed to water of different salinity. It is estimated that 300 000 tons of stone, 1 million m³ of sand and 3000 wooden poles will be needed.
Safety level	1:10 000 per year

Case 4: Coastal Protection

Introduction

Regular assessments of the safety of a dike are undertaken in the Netherlands. During a recent long term assessment, the anticipated performance of the sea dikes and dunes subjected to a storm surge with an incidence of occurrence of 1 in 10 000 years (the Dutch flood protection standard) was tested.

The sea defence dike along the North-Holland coast near Petten was deemed not to be able to satisfy the safety requirements over the next 50 years. Accordingly, the coastal defences have to be upgraded. Several parties are concerned about this issue, including the water board *Hollands Noorderkwartier*, the Dutch Ministry of Infrastructure and Water Management, the Province of North-Holland, local municipalities and some nature organisations.

The dike along this stretch of coast is a hard, stone and concrete defence structure. **With the new insights on combating the erosion of the Dutch coast by sand nourishment and the experience of the Sand Engine in mind, this case required the course participants to design a nature friendly solution to this problem.**

The Hondsbossche Pettemer Zeewering is located in the province of North-Holland, as depicted in the map. The coastal defence used to be two separate dikes, but over time they have been upgraded to one contiguous sea defence structure. Click on the map to view it online or scan the QR code in the map.

5-5. *Hondsbossche Dunes near Petten. © Jan W.H. Werner*

Description of One Building with Nature Solution

The materials below provide you with a description of one Building with Nature solution to Case 4. This solution has already been implemented in the Netherlands.

1. Website: Ecoshape's explanation of the solution

2A. Website: Van Oord's explanation of the solution

2B. Website: Boskalis's explanation of the solution.

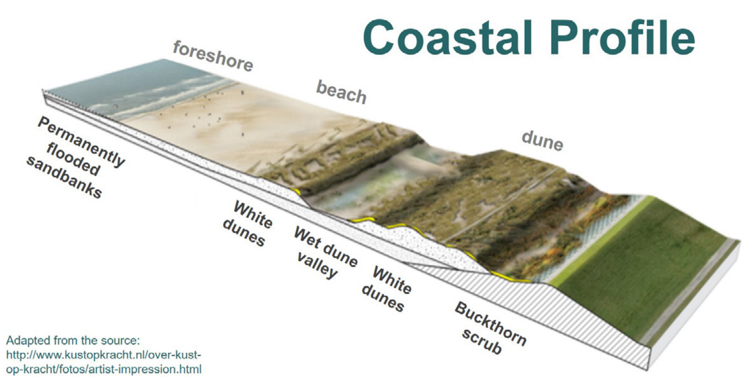
See also the infographic in Fig 5-6.

3. Video: Reinforcing the Dutch coastline

4. Video: Monitoring the New Coastline at the Hondsbossche Zeewering

5-6. *Infographic about Case 4 Solution. © Boskalis*

5. Artist impression of the new coastal profile.



5-7. *Coastal Profile. © Hoogheemraadschap Hollands Noorderkwartier*

6. Key Aspects of This Solution to Case 4

By Prof. Jill Slinger and engineer Ilse Caminada

General Information on the solution

Title	Kust op Kracht (in Dutch) – A Fortified Coast
Abstract	A broad seaward extension was selected as Building with Nature solution with nature and recreational features in addition to increased safety from flooding.
Location	Hondsbossche Pettermer Zeewering, North-Holland, The Netherlands
Date	Finished in 2015
Main problem owner	Dutch Ministry of Infrastructure and Water Management, their operational arm Rijkswaterstaat, and the district water board Hollands Noorderkwartier.
Companies & Partners	Van Oord (50%), Boskalis (50%), Ecoshape, Province of North-Holland
Costs	The project costs cover Design, Construct and Maintain for 20 years. The project costs amount to 230 million euros.
Project details	• 20 year maintenance phase (commenced January 2016) • 35.5 million m³ of sand nourishment • 9 km long project site, 7 km central section, 1 km on each side • 640 000 m² of marram grass planted • 3 km long nature reserve with a damp dune valley • 1.5 km of beach with a lagoon • 25 metre high panorama dune • Willow-slip sand drift screens http://www.vanoord.com/activities/reinforcing-dutch-coastline
Safety level	1:10 000 per year

Additional Information on the design problem

Calculations:

A. Broad seaward extension: 8 to 10 km @ 2500 m^3/m ~ 25 million m^3 sand in total

B. Cross shore losses: 8 to 10 km x 10 $m^3/m/yr$ ~ 0.1 million m^3 sand per yr

C. Longshore losses: 0.4 million m^3 sand per yr

D. Margin for sea level rise, uncertainty/storms: 5 million m^3 sand in total.

Requisite volume of sand over 10 years:

A + B.10 years + C.10 years + D = 25 million m^3 sand +(0.1 million m^3 sand per yr x 10yr)+(0.4 million m^3 sand per yr x 10 yr)+ 5 million m^3 sand = **35 million m^3 sand**

Sand buffers placed on the **foreshore**, beaches, and dunes, particularly on the sides of the seaward extension where the longshore transport gradients are highest.

Case 5: Harlingen Harbour

Introduction

The harbour of Harlingen is located in the north of the Netherlands, in the tidal basin of the Wadden Sea. The Wadden Sea is a large unbroken system of intertidal mudflats that is rich in species. It is considered one of the most important areas for migratory birds in the world.

Currently an average amount of 1.3 million m^3 of mainly fine sediments has to be dredged per year, as a result of high sedimentation rates in the harbour of Harlingen. A conventional dredging strategy in which the sediment is disposed in the vicinity of the harbour is increasingly undesirable, as it is expected that a large amount of the sediment will be returned to the harbour. Besides being economically inefficient, this may also lead to negative ecological effects due to the increased turbidity.

The problem is also likely to be exacerbated by sea level rise in future. Accordingly, **this case required the course participants to design a nature friendly solution to the dredging and disposal problem of Harlingen harbour for the next 5 to 15 years.** The solutions should maintain the required depth in the harbour, while providing ecological opportunities for the Wadden Sea.

The harbour of Harlingen is situated in the northern part of the Netherlands, on the coast of Friesland just east of the Afsluitdijk, as depicted on the map. The Wadden Sea coast stretches from Den Helder in the west, across the Aflsuitdijk separating the IJssel Lake from the Wadden Sea to the Eems/Dollard on the eastern border with Germany. The Dutch Wadden islands are located in the Wadden Sea to the northwest of the mainland coast. Click on the map to view it online or scan the QR code in the map.

5-8. *Harlingen Harbour. © Michiel Verbeek*

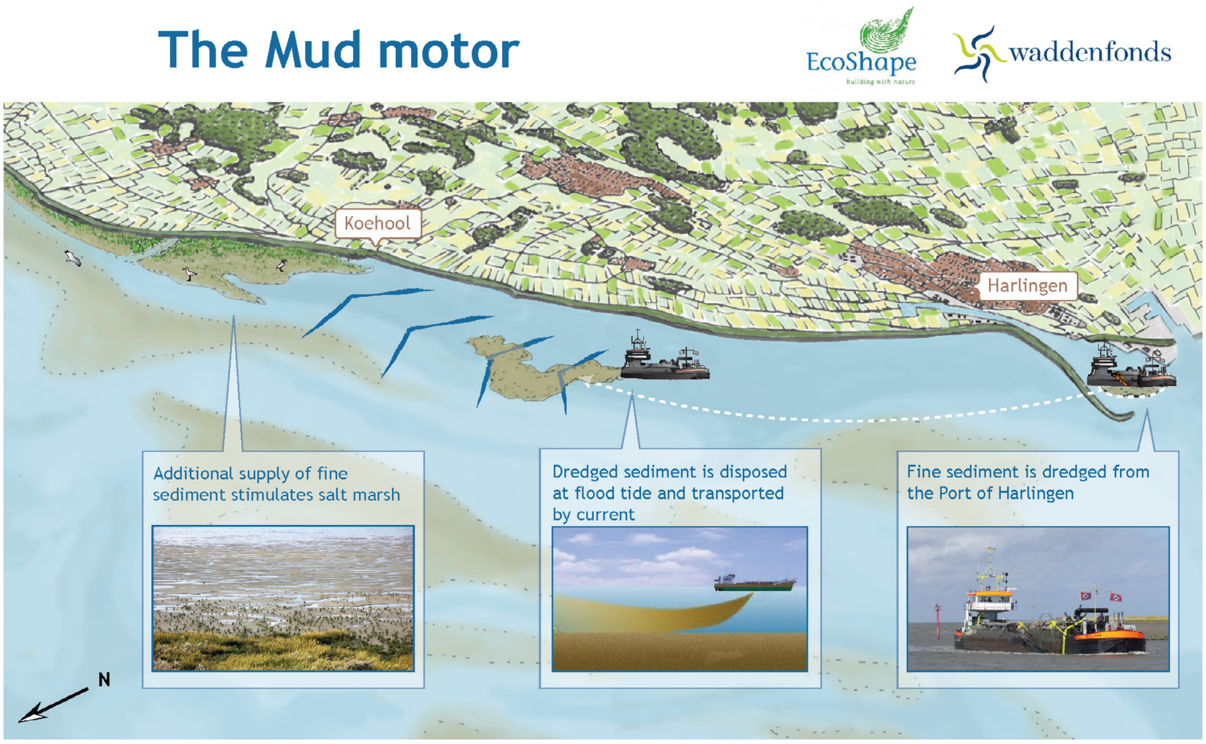
Description of one Building with Nature Solution

The materials below provide you with a description of one Building with Nature solution to Case 5. This solution has already been implemented in the Netherlands.

The paper below shows four pilot projects of the Wadden Sea harbours programme. This dredging case of the Harlingen harbour is based on the first project: the Koehoal Mudmotor.

1. Paper: Pilot cases in the Wadden Sea harbours

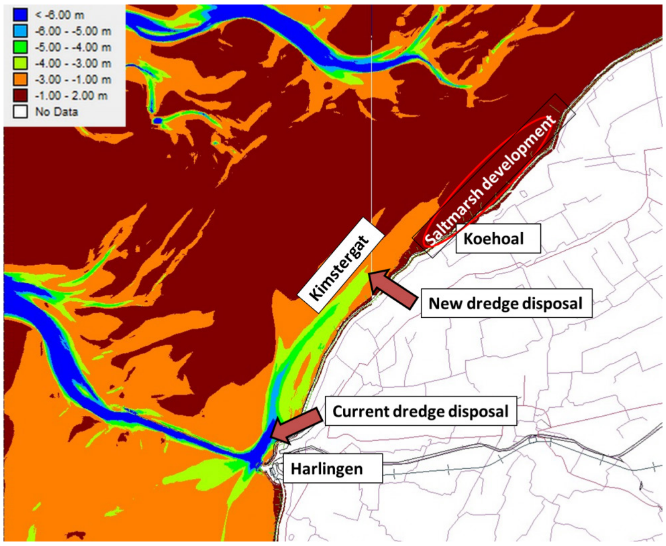
2. Website: Ecoshape/Deltares's explanation of the solution



5-9. *Infographic of the Mud Motor Solution. © Ecoshape / Waddenfonds*

6. Key Aspects of This Solution to Case 5

By engineer Ana Colina Alonso



5-10. Map of disposal location dredged sediment. 🅭 Martin Baptist

General Information on the solution

Title	The Mud Motor
Abstract	Dredged material from the harbour of Harlingen is disposed further north of Harlingen as a semi-continuous source of sediment: the mud motor. The sediment is expected to be transported by natural processes further into the area. The extra input of sediment is expected to lead to the formation and extension of salt marshes.
Location	Harlingen harbour and Koehoal, The Netherlands
Date	Project implementation started in September 2016. The first results were produced in 2017
Main problem owner	Rijkswaterstaat, the harbour authority and the Province of Friesland
Companies & Partners	Ecoshape, WUR, Deltares, Arcadis, Royal Haskoning DHV, van Oord, It Fryske Gea, NIOZ, IMARES
Project details	Within the EcoShape Building with Nature programme on Wadden Sea Harbours, an experiment is being done with disposal of dredged sediment (silt) from Harlingen harbour in the form of a multi-year semi-continuous mud nourishment nearby salt marshes. The aim of this application is to enlarge the sediment supply towards, and thereby stimulate growth of, salt marshes. This is expected to increase natural values and safety against flooding, as well as a decrease in dredged volumes from Harlingen harbour, leading to cost reduction. The project aims to develop the fundamental knowledge needed to understand and quantify the technological, physical and ecological aspects of such large-scale mud nourishments for further upscaling and exporting.
Safety level	Salt marshes can reduce wave energy and prevent coastal erosion.

Case 6: Flood-proof Indonesia

Introduction

In Indonesia, the northern coastline of the main island of Java faces the threats of land subsidence and severe coastal erosion. Frequent flooding, occurring during high tides, periods of excessive rainfall and storm surges, may threaten the lives and livelihoods of local communities. Historically, this area had been surrounded by mangrove forests, that act as natural flood defences. However, land conversion for urbanisation, agriculture and aquaculture practices and climate change threatens the continued existence and health of the mangrove areas.

Several parties are concerned about this issue, including the Indonesian Ministry of Marine Affairs and Fisheries, Indonesian Ministry of Public Works, and knowledge organisations such as Deltares and Wageningen Marine, the nature organisation Wetlands International (The Netherlands and Indonesia Offices) and consultants from Witteveen+Bos. These partners have been involved in recent flagship projects in northern Java that have focused on counteracting coastal erosion and reversing the trends of unsustainable economic development, particularly in the Demak district.

Using practical insights on combating erosion along muddy coasts and theoretical insights from the course, this case required the course participants to design a nature friendly solution to the ongoing erosion and flood protection issues.

Demak is a district located in the province of Central Java, Indonesia, and lies on the northern coast of the island. As can be seen from the map, the district has a ragged coastline of about 20 km, approximated by the dark blue line. Click on the map to view it online or scan the QR code in the map.

Description of One Building with Nature Solution

The materials below provide you with a description of one Building with Nature solution to Case 6. This solution has already been implemented in Demak by **Building with Nature Indonesia** which is a programme by Wetlands International, Ecoshape, the Indonesian Ministry of Marine Affairs and Fisheries (MMAF), and the Ministry of Public Works and Housing (PU), supported by the Dutch Sustainable Water Fund and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). For more information on the programme visit this website.

5-11. Mangrove restoration near Demak, December 2019. © Wetlands International

1. Description of the solution implemented by Building with Nature, Indonesia

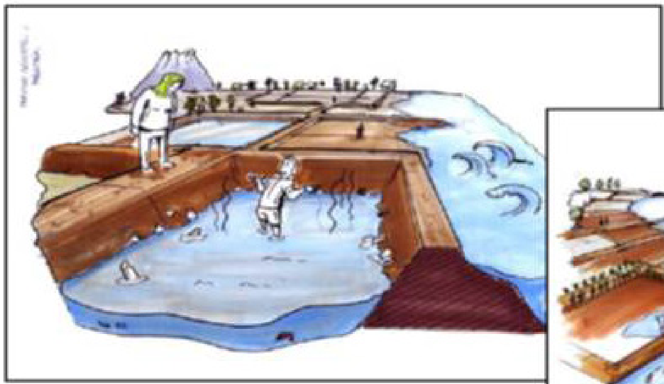
2. Video: Restoring mangroves with semi-permeable dams

This video by Witteveen+Bos was made for the Vernufteling award 2016, a prestigious Dutch engineering award, won by Building with Nature in Indonesia.

Video: Restoring mangroves with semi-permeable dams

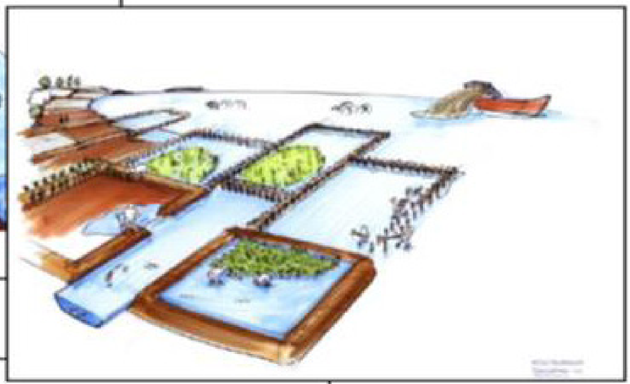
1. Current situation

Unsustainable aquaculture development, following mangrove conversion has rendered many coastal areas highly vulnerable: productivity has collapsed, carbon stocks are lost and coastal erosion and soil subsidence cause land loss, flooding and salt water intrusion.



2. Rehabilitation phase

By combining small-scale engineering works (establishment of semi-permeable groins, agitation dredging) and mangrove rehabilitation measures, coastal erosion is halted. Revival of mangrove services boosts productivity of the land.



3. End situation

A resilient mangrove-based economy has been created; people make optimal use of mangrove resources and are protected by a mangrove buffer zone. This buffer zone harbours rich biodiversity and stores substantial amounts of carbon. To avoid future mangrove losses, communities are supported to develop sustainable alternatives to harmful livelihood activities.

5-12. 4. Infographic of three phases in the hybrid engineering approach in Indonesia. © Deltares

5-13. 5. Scenarios Infographic. © Wetlands International, Indonesia

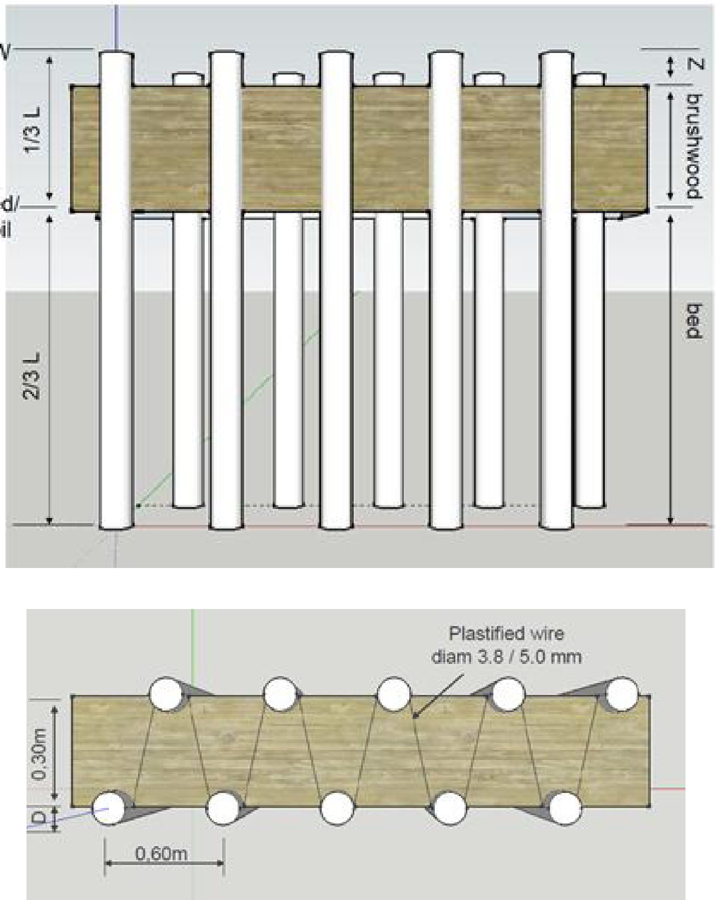
6. Key Aspects of This Solution to Case 6

By Prof. Jill Slinger, Dr. Heleen Vreugdenhil and Drs. Aashna Mittal

General Information on the solution

Title	Building with Nature Indonesia – Securing eroding delta coastlines
Abstract	The Building with Nature solution adopted an innovative approach that combines civil engineering with mangrove rehabilitation to build safe and adaptive coastlines, while simultaneously introducing sustainable land use.
Location	Indonesia, north coast of Java, Demak District
Date	Project completion date 2021
Main problem owner	Indonesian Ministry of Marine Affairs and Fisheries, Indonesian Ministry of Public Works
Companies & Partners	Wetlands International (Netherlands and Indonesia Office), Deltares, Indonesian Ministry of Marine Affairs and Fisheries (MMAF), Indonesian Ministry of Public Works and Housing (PU), Wageningen Marine Research, Witteveen+Bos, UNESCO-IHE, TU Delft, Blue Forests, Von Lieberman and Kota Kita, Diponegoro University, local communities.
Costs	8 million euros (bilateral funding and Ecoshape, excluding research and Indonesian Government funding)
Project details	To achieve coastal safety in Demak, the choice was made to implement a hybrid engineering approach in which a healthy mangrove ecosystem is restored in combination with smaller flood defences. The solutions differ according to the variation in erosion intensity experienced along the 7.8 km stretch of the southern Demak coast, and are specified per coastal stretch as described briefly below. More detail can be found in Winterwerp et al. (2014). **Coast I (mild erosion):** In the areas where erosion is still limited, the aquaculture ponds, channelisation and degradation of tidal creeks have impacted on the hydrology of the area. This hampers mangrove recovery and functioning. Here the focus lies on restoring the hydrology (river flows) and the sediment balance and no permeable dams or mud nourishment occurs. **Coast II (severe erosion) and Coast III (severe erosion and land subsidence):** In these severely eroding settings, the sediment balance will be restored using permeable dams (Figure 1) and mud nourishments. Once the erosion process has stopped and the shoreline has accreted to a sufficient elevation, mangroves will colonise naturally. The mangroves then dissipate the wave energy further, enhancing the capture of sediment in the sheltered waters behind the permeable dams. The mangroves will eventually take over the wave dissipation, sediment accretion and flood defence functions of these dams.

Project details (continued)



5-14. Permeable structure design (MHW = Mean High Water. Top image: side view. Bottom image: Top view. By Winterwerp et al. (2014). © Deltares

Safety level

The measures are expected to halt the 100 m per annum erosion rate, successfully preventing the loss of 6000 Ha of aquaculture ponds in the Demak district that are expected to flood by 2100 owing to sea level rise.

Additional Information on the design problem

The reasoning behind the choices made in the Indonesian case can be found via the link below in both English and Indonesian.

Document: Bilingual QA with Building with Nature Indonesia

Discussion Paper: Winterwerp et al. (2014). A sustainable solution for massive coastal erosion in Central Java.

5.3 Supplementary Material

Introduction to Value Sensitive Design

Have a look at the videos below. These videos are part of the MOOC: Responsible Innovation: Ethics, Safety and Technology, also from Delft University of Technology. They will provide you with additional knowledge on the concept of Value Sensitive Design. After learning about the principles and real-life application of Building with Nature, we encourage you to compare and contrast the two approaches.

Enjoy learning about **Value Sensitive Design!**

Introduction to VSD: Value Sensitive Design Part 1

Why use VSD? Value Sensitive Design Part 2

Applying Value Sensitive Design

Additional Sources

You can find additional information on Building with Nature, including practical examples, in the following website:

Ecoshape

5.4 Bibliography

Figures

5-1. Mangrove Restoration in Timbul Sloko, Indonesia: "Mangroveherstel Demak December 2019" by Wetlands International is licensed under CC-BY-NC-SA 4.0.

5-2. Flooded depoldered Noordwaard: This image by Rijkswaterstaat is in the Public Domain, CC0

5-3. Nijmegen and the river Waal after implementation of BwN solution: This image by Rijkswaterstaat is in the Public Domain, CC0

5-4. Artist impression of the future Fish Migration River: This image by Rijkswaterstaat is in the Public Domain, CC0

5-5. Hondsbossche Dunes near Petten: This image by Jan W.H. Werner is licensed under CC BY-SA 4.0

5-6. Infographic about Case 4 Solution: Hondsbossche Pettemer Zeewering: a unique beach and dune landscape by Boskalis is licensed under CC-BY-NC-SA 4.0.

5-7. Coastal Profile: Artist impression new situation 'Hondsbossche Dunes' by Hoogheemraadschap Hollands Noorderkwartier is adapted from: http://www.kustopkracht.nl/over-kust-op-kracht/fotos/artist-impression.html and licensed under CC BY-NC-SA.4.0

5-8. Harlingen Harbour: Harlingen, haven foto 1 by Michiel Verbeek is licensed under CC BY-SA 3.0

5-9. Infographic of the Mud Motor Solution: "Principle of the Mud Motor" by Ecoshape and Waddenfonds is licensed under CC-BY-NC-SA 4.0.

5-10. Map of disposal location dredged sediment: MUDMOTOR Sediment for salt marshes by Martin Baptist is licensed under CC-BY-NC-SA 4.0.

5-11. Mangrove restoration near Demak, December 2019: See 5-1

5-12. 4. Infographic of three phases in the hybrid engineering approach in Indonesia: Infographic of three phases in the hybrid engineering approach in Indonesia (2014) by Deltares is licensed under CC-BY-NC-SA 4.0.

5-13. 5. Scenarios Infographic: Infographic Mangrove Greenbelt by Wetlands International is licensed under CC-BY-NC-SA 4.0.

5-14. Permeable structure design (MHW = Mean High Water. Top image: side view. Bottom image: Top view: Permeable Structure Design (2014) is Copyright Protected. © Deltares. All Rights Reserved.

Part II -
Beyond Engineering: Building with Nature

6-1. BwN Indonesia Workshop. © Heleen Vreugdenhil

Chapter 6
Why Beyond Engineering?

6.1 Introduction

After completing Part I, you are now familiar with the need to integrate ecological and engineering knowledge in developing ecosystem friendly hydraulic infrastructure. You are familiar with the H-Principles (Engineering Design Principles) and the E-Principles (Ecological Design Principles). This chapter moves on to explore why it is necessary to move Beyond Engineering in Building with Nature towards the S-principles (Social Design Principles). It explores why and when it is necessary to consider the social context.

The chapter consists of the following videos:

- Why Beyond Engineering? - a video presented by Prof. Jill Slinger.
- Deltas and Ports of the Future - a video presented by Prof. (em.) Tiedo Vellinga about stakeholder inclusion in the expansion of the Port of Rotterdam in the Rhine-Meuse Delta, and
- Do you want to make a difference? - a video presented by Prof. Tally Palmer.

There are two assignments in which you apply the knowledge you have gained to analyse whether social engagement is appropriate in a particular situation or not, together with a reading on transdisciplinary learning.

Wishing you success in completing the sixth chapter!

6.2 Why consider the social context?

Video: Why Beyond Engineering?

This section contains a video presented and written by **Prof. Jill Slinger**. She will explore why the social context should be considered in the Building with Nature design process, drawing on examples from the Netherlands and South Africa.

You can cite this video as:

Slinger, J.H. (Jill). (2020). *Beyond Engineering: Building with Nature 2x video #01 – Why Beyond Engineering?* 4TU.Dataset. https://doi.org/10.4121/14910102

Video Transcript

6-2. *The Sand Engine. ⓔ De Zandmotor*

Presented by Prof. Jill Slinger

Why Beyond Engineering? Building with Nature is a comprehensive engineering approach that seeks to enhance the use of natural ecological processes to achieve efficient and sustainable hydraulic infrastructural designs. According to Dr. Ronald Waterman, it strives for a flexible integration of land in water and water in land using interactions and materials present in nature.

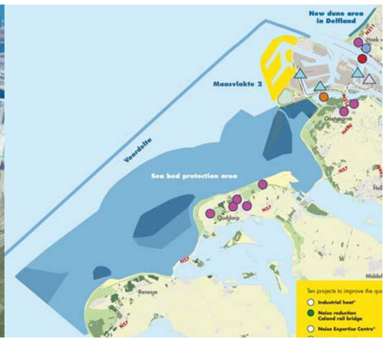
6-3. *Hondsbossche Dunes, North-Holland. ⓔ HWBP*

This ecosystem-based design concept has been applied in large infrastructural projects along the coast of the Netherlands and elsewhere.

Take the Sand Engine and the Hondsbossche Pettermer Zeewering (they are now called the Hondsbossche Dunes). They provide examples along the Dutch coast. Or even the Maasvlakte II extension. This is an extension to the Port of Rotterdam. Here the Maasvlakte II is the yellow area in the right hand picture, the last in a long line of extensions to Rotterdam harbour. Did you know that the breakwater protecting Europe's largest port is made up for 70% of dunes and only 30% is a conventional hydraulic structure? You can see this

in the left hand picture. And, did you realise that the marine protected area near the mouth of the harbour - the darker blue area - expanded to 25 thousand hectares to compensate for the 2 thousand hectares covered by the harbour extension? The liveability of the surrounding area also improved for the residents. Think of the air quality and recreational areas.

6-4. *Maasvlakte II. © Port of Rotterdam)*



6-5. *Maasvlakte II compensation. © Port of Rotterdam*

So, somehow this port development in the Rhine-Meuse delta managed to achieve benefits for the local people, the ecosystem and the harbour. But this didn't happen easily.

2005
- Appeal against Maasvlakte II expansion to Port of Rotterdam upheld
- Development stopped by high court

2009
- Maasvlakte II expansion approved by the high court
- Planned nature compensation approved

2013
- Maasvlakte II realised
- Agreements with stakeholders

6-6. *Problems with port expansion. 🅭 Jill Slinger*

On the contrary, the need to listen to stakeholders became painfully apparent when the proposed extension was halted by the Raad van State - the highest general administrative court in the Netherlands in January 2005. Following an appeal by environmentalists, fishermen, local residents and other stakeholders, the high court drew a line through the plans for land reclamation for port expansion. But then, how did the Maasvlakte II come to be?

Why Beyond Engineering?

Why consider the social context?

At the time, Tiedo Vellinga was appointed Head of the Environmental section of the Port of Rotterdam - the Harbour Authority. He took charge of the process. Instead of first undertaking more extensive environmental and social impact studies, he decided to start with the people. To talk to the people about their values, and so get the values - what people care about - on the table at the outset. By taking people seriously, and doing the required research, the Maasvlakte II expansion was approved by the high court in 2009, 4 years after the original prohibition, and the Maasvlakte II, now the red area, was realised by 2013.

Our learning on the importance of listening to stakeholders in designing and realising the extension to the Port of Rotterdam in the Rhine-Meuse Delta runs as a thread through the course in the hope that it will inspire you to undertake stakeholder-inclusive, nature-friendly design, just as it inspired us.

This course therefore explores why stakeholder-inclusive, ecosystem-based designs are needed in moving beyond standard hydraulic engineering. We draw on a number of international examples:

- from the Volta Delta and its nearest port city, Tema, in Ghana,

- to the Crocodile River,
- the Tsitsa Catchment, and
- the Great Brak Estuary in South Africa,
- to Sierra Leone,
- and Semarang in Indonesia.

All of these cases have in common that standard engineering designs do not realise the opportunities to be found by working with people and with nature. In this course we build on the previous Building with Nature MOOC, which distilled the Hydraulic Engineering and Ecological Design Principles - the H-E principles. In this course, the missing element of the Social Design Principles - the S principles - are developed and taught. So, this course moves from the HE - principles to the SHE – principles. It teaches you how to use Social Design Principles in developing more effective and sustainable hydraulic infrastructure, with an emphasis on delta, coastal and port environments.

6-7. Tema, Ghana. © Baukje Kothuis (left) / Jorrit van den Houten (right)

6-8. Crocodile River, South Africa. 🅭 Olga Ernst

6-9. Tsitsa Catchment, South Africa. 🅭 IWR, Rhodes University

6-10. Great Brak Estuary, South Africa. 🅭 CSIR

6-11. *Sierra Leone.* 🅭 *Witteveen+Bos*

6-12. *Semarang, Indonesia.* 🅭 *Witteveen+Bos*

6-13. *Moving from H-E to S-H-E in Building with Nature.* 🅭 *Jill Slinger*

Diagnostic Questions on Moving Beyond Engineering

When it is necessary to consider the social context and move beyond engineering? What are the characteristics of Building with Nature design problems that make this necessary? When is it sufficient to adopt a standard engineering design process and when not?

These issues lie at the heart of this course. In addressing them, we turn to a paper by de Bruijn and Porter (2004) in which they develop a situational analysis decision tree to determine whether and what type of a process to engage stakeholders is appropriate. They suggest that by answering five questions you can diagnose when more than traditional disciplinary science and engineering is required, that is when the involvement of a wider range of people and consideration for the social context is necessary. Here we use the adapted version of the questions proposed by Enserink et al. (2010), modified slightly to suit the Building with Nature application. Note that an actor is an individual or group with the power to act or make decisions in a Building with Nature problem situation.

The five diagnostic questions that you are encouraged to ask in each situation are:

1. Can the problem be solved and the solution decided upon essentially by one actor (i.e. authoritarian) or by a consensual process of multiple actors (i.e., network)?
2. Are the interests and objectives of the actors involved closely aligned?
3. Is there consensus on the scientific and engineering knowledge?
4. Is the issue considered vitally important to the people affected by the problem and potential solutions?
5. Is there agreement that the decision is urgent?

Why Beyond Engineering?

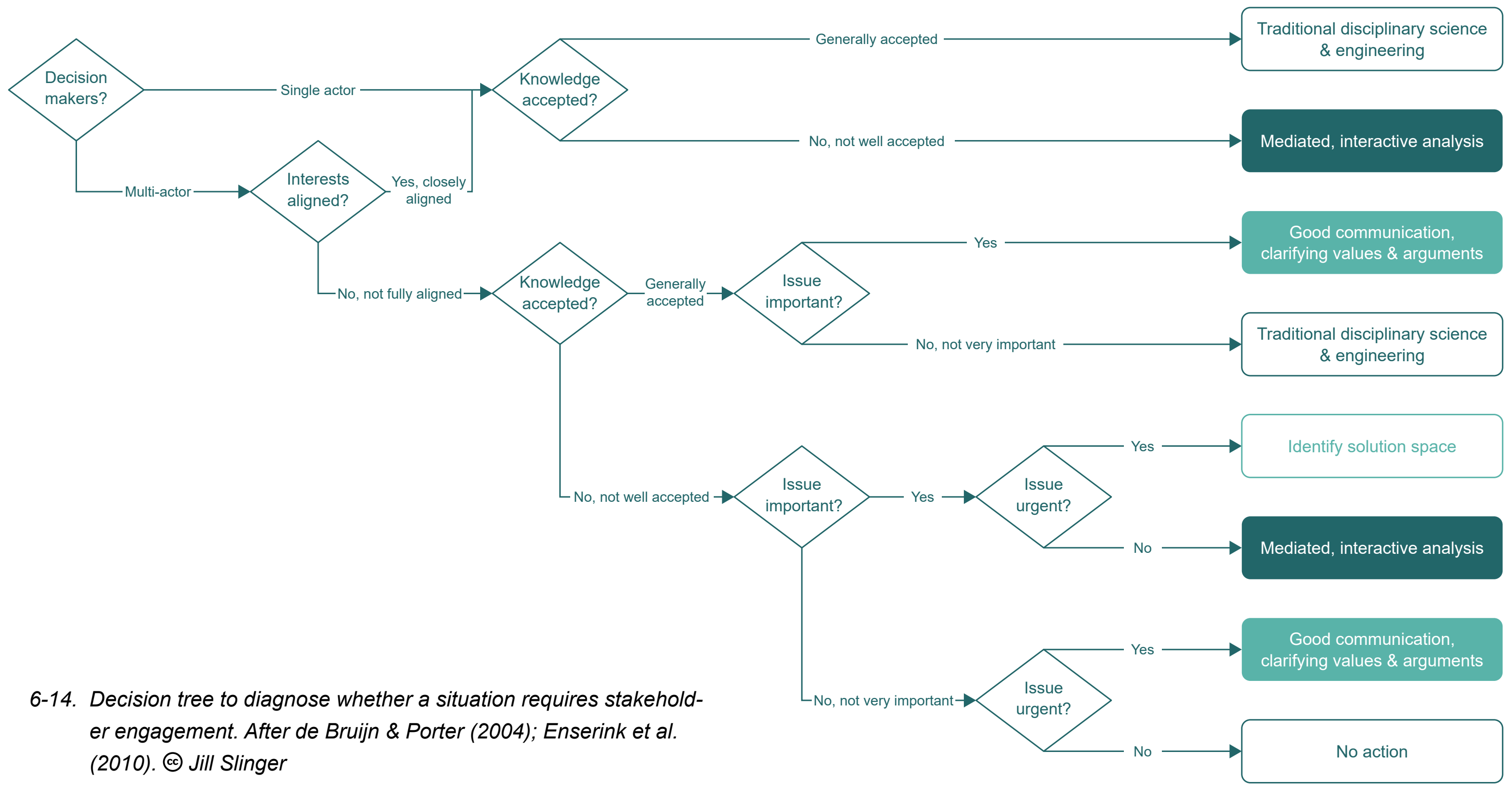
Why consider the social context?

These 5 questions can also be portrayed as the decision tree in Figure 6-14.

De Bruijn and Porter (2004) associated five generic strategies or approaches with the different situational diagnoses that could arise (potentially $2^5 = 32$ diagnoses). These include:

1. Undertake traditional disciplinary science or engineering to solve the problem and design solutions, in support of decision making.
2. Institute mediated, participatory interactive analysis to negotiate shared knowledge upon which the solutions can be based.
3. Initiate good communication, serving to clarify the values and arguments which the designed solutions are based and their knowledge basis.
4. Identify the solution space. This strategy is applied when the issue is important and urgent. There is no time for extensive interactive analysis. There are diverse knowledge sources and interests although not closely aligned must be taken into account. The only option is to collaboratively identify the potential solution space without closing off options too early.
5. No action is required, the issue is neither important nor urgent.

This analysis reveals the situations in which stakeholder engagement represents a sound strategy – represented by the shaded areas in Figure 6-14.



6-14. Decision tree to diagnose whether a situation requires stakeholder engagement. After de Bruijn & Porter (2004); Enserink et al. (2010). © Jill Slinger

6.3 Inspiration from the Maasvlakte 2 process

Video: Deltas and Ports of the Future

Hydraulic infrastructure is found where water and land meet - in deltas, coasts, ports and rivers, the areas where most people live and many economic activities are located. So, is it sufficient to consider only the bio-geophysical nature of the environment in designing infrastructures? Here we contend, that the social context is equally important in designing the deltas, coasts, rivers and ports of the future and ensuring their sustainability.

Prof. (em.) Tiedo Vellinga shares his experience with the Maasvlakte 2 expansion of the Port of Rotterdam in the following video. The video is a product of the Deltas, Infrastructures & Mobility Initiative of the Delft University of Technology. The port of Rotterdam is located in the Rhine-Meuse delta (Meuse = Maas in Dutch), one of the most urbanised coastal areas in the world.

This video and the following section on Inspiration from the Maasvlakte 2, reflect learning from the Maasvlakte 2 process on the necessity to move beyond engineering in striving for sustainable development. The natural and social environment also need to be integrated in the design process.

Video Transcript

By TU Delft - Infrastructures & Mobility Initiative and Prof. (em.) Tiedo Vellinga

[TEXT IN VIDEO] Prof. (em.) T. Vellinga: Professor Ports and Waterways / Hydraulic Engineering Section

You have to make rigorous improvements. Once you do that, you'll see that it works. That you not only create value for the port, but also for the stakeholders. When it comes to nature, to recreation, biodiversity, landscape and even archaeology. And that because of this, your project gains value.

[TEXT IN VIDEO] Vellinga was involved in the realisation of Maasvlakte 2, a large industrial area in the Maas estuary.

All of the value you create has little to do with your business case. Agreements are made with environmental protection agencies regarding cleaner air, with animal protection agencies regarding birds, space for birds, and with conservation agencies regarding how the effects on nature can be compensated for. New recreation areas are established. Not in your business case, but they are a major success factor.

So it's also important to consider the surrounding area. When it comes to Maasvlakte 2, I think one of the best concepts is that our work is grounded in a dual objective. In this case, a dual objective means that alongside the economy, you also want to improve liveability.

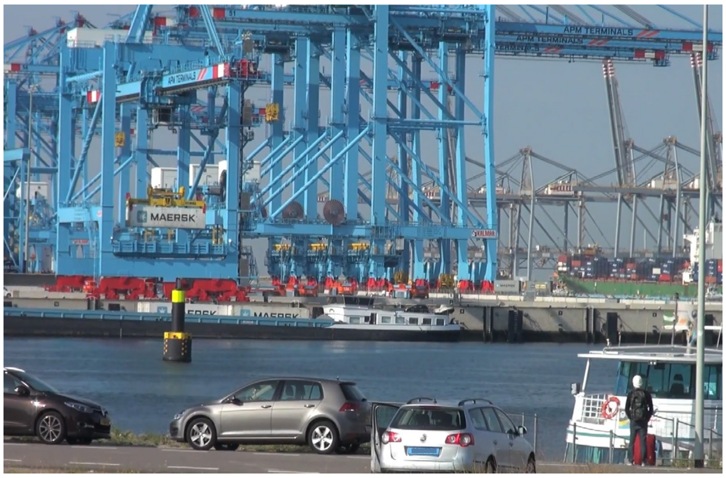
[TEXT IN VIDEO] Robots are increasingly used for transferring containers. It's efficient and sustainable.

Behind us you can see (Figure 6-15) what's of course a great example of robotisation. Over there is the new APM Terminals terminal, with fully automated cranes. Over at the back is a zero-emission terminal, they even use electricity generated by wind turbines. That's the height of sustainability and I think it's a means of integrally linking automation with sustainability.

And that leads me to the future, that we're working with a research consortium with a major role for TU Delft to further concretise the expertise we've already gained on the job. For example, that the value you create can be converted; perhaps

not into money, but into other values. Perhaps into positive image for the port.

Based on international demand alone, it has become clear to me that there's a great deal of interest in this way of thinking. You need to think integrally, to develop a solution that works both for the port and for nature. You need to co-create. And if I take people to visit Maasvlakte 2, I only have to show them the site and they're convinced. That's certainly a sign that we're on the right track.



6-15. APM Terminals terminal. 🅭 TU Delft / New Energy TV

Explore Additional Information on the Maasvlakte 2

In the last USGS Earth View of 2016 a Landsat satellite image of the expansion of the port of Rotterdam is presented.

Information from the Port of Rotterdam on the Maasvlakte 2 at present: New port area at sea

Here you can read a reflective interview with Prof. (em.) Tiedo Vellinga in Dredging Today.

Information from the Port of Rotterdam mapping and describing a number of port development initiatives.

Information from the Port of Rotterdam on the Mainport Development Project, the project for the development of the Maasvlakte 2.

6.4 Assignment 6.1

Introduction

In Assignment 6.1 you are asked to give your opinion regarding an appropriate stakeholder engagement process in a number of example situations. This is an assignment for which you will need to use the five diagnostic questions and the decision tree, applying your learning on when to move beyond engineering.

Before proceeding to the assignment make sure you have covered the material in 6.2 Why consider the Social Context and 6.3 Inspiration from the Maasvlakte 2.

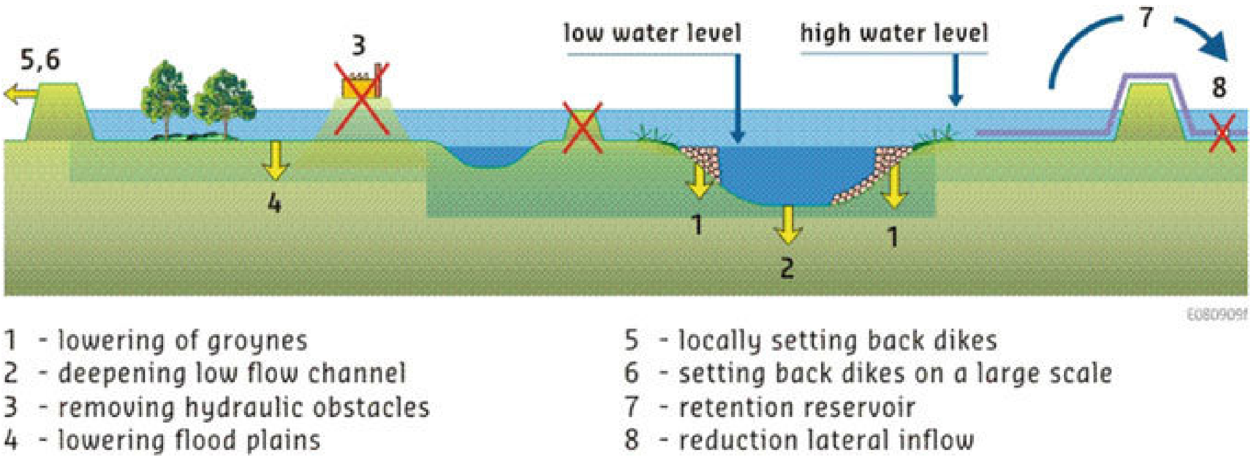
You are invited to consult the Feedback on Assignment 6.1 when you have completed the assignment.

1. Room for the River

Very high discharges in the Rhine River in the 1993 and 1995 meant that many people and animals were in danger of flooding and had to be evacuated. This lead to the realisation that instead of continuing to engineer the Rhine River for efficient navigation and trying to prevent flooding by raising dikes, a broader range of hydraulic interventions that could benefit nature and people was needed. The opportunities for Building with the Nature in the Netherlands were recognised.

This led to the Room for the River process. In Figure 6-16, you can see eight different types of measures that were considered in the Room for the River process. You can imagine that these measures would affect the form, function and character of the river where they were implemented, and the people living and working near the river.

In the Netherlands, Rijkswaterstaat is the national authority responsible for maintaining the rivers and water boards are responsible for regional water safety. There are environmental agencies responsible for nature conservation, and various other agencies and government departments responsible for agriculture, industry, spatial planning and so on. Moreover, many people live in the cities and rural areas along the rivers and many activities take place on the river and its floodplains. These include navigation, fishing, farming, nature conservation, industry, energy production, recreation, and habitation. Despite this complex social



6-16. Room for the River: plenty of possibilites. © Deltares / Rijkswaterstaat

context, the Room for the River process managed to design and implement interventions at 34 places along the Dutch rivers in the period from 2000 to 2019.

Would you like to know more about making 'Room for the River'?

Video: Corporate Clip
Room for the River

Before You Continue...

Room for the River poll

Based on the description above, which of the five strategies would you consider appropriate for the Room for the River process?

- ◯ Traditional disciplinary science and engineering
- ◯ Mediated, interactive analysis
- ◯ Good communication, clarifying values and arguments
- ◯ Identify solution space
- ◯ No action

You may wish to discuss this with your peers.

2. Maasvlakte 2 Port Expansion prior to Jan 2005

Consider the problem situation of the Maasvlakte 2 expansion of the Port of Rotterdam prior to 2005. From the point of view of the Port of Rotterdam, there is an evident need to expand the capacity of the port. Plans for this were initiated as early as May 1998 (start of the project MainPortdevelopment Rotterdam (PMR)). By 2003 a planning process to expand the Port of Rotterdam was well underway. Extensive environmental and social impact assessments were undertaken by experts. Simulation modelling studies of the effects of the planned expansion on nearby coastal hydrodynamics, sediments and ecosystems were undertaken, and stakeholders were informed of the results. However, in January 2005, an appeal against the expansion was upheld in the highest general administrative court in the Netherlands (Raad van State) and the expansion process halted!

You are asked to analyse this situation **retrospectively**.

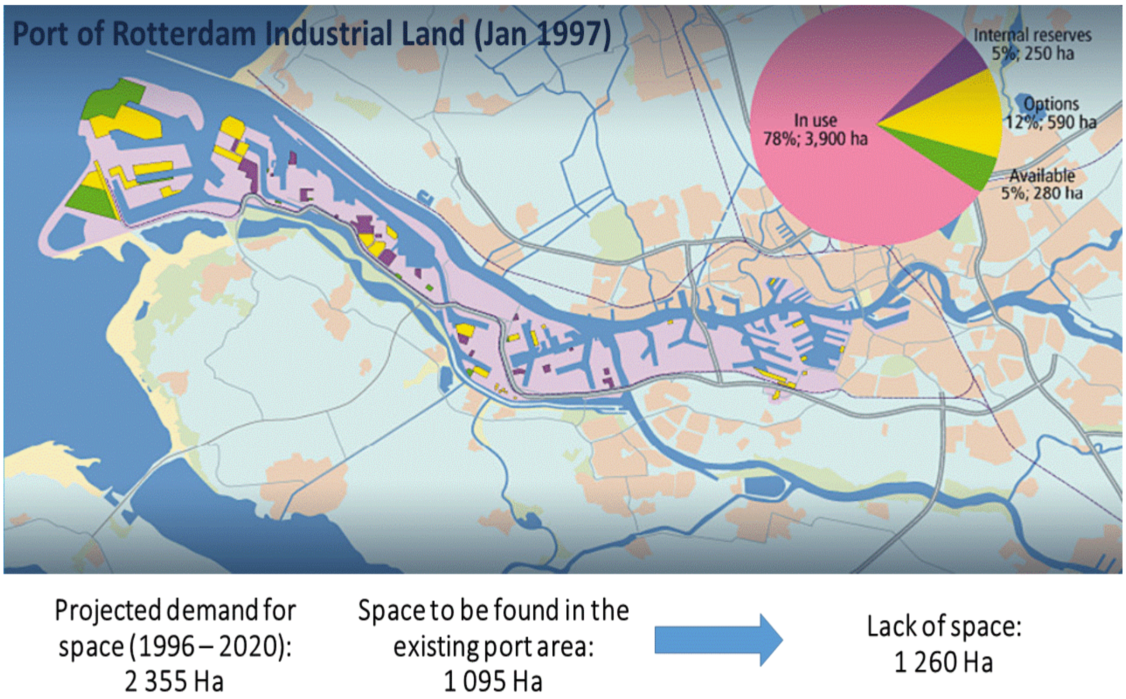
Before You Continue...

Maasvlakte 2 < Jan 2005 Poll

From the description above, which of the five strategies do you think the Port of Rotterdam applied prior to 2005?

- ◯ Traditional disciplinary science and engineering
- ◯ Mediated, interactive analysis
- ◯ Good communication, clarifying values and arguments
- ◯ Identify solution space
- ◯ No action

You may wish to discuss this with your peers.

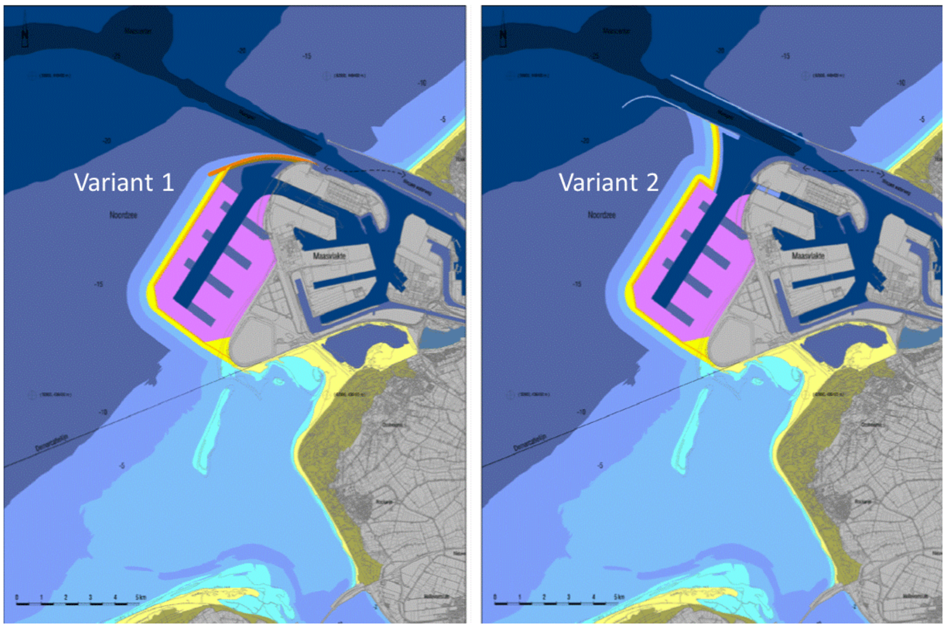


6-17. Port of Rotterdam Industrial Land, Jan 1997. Adapted from van Schuylenburg (2002). © Port of Rotterdam

2. Maasvlakte 2 Port Expansion After Jan 2005

Consider the problem situation of the Maasvlakte 2 expansion of the Port of Rotterdam after 2005. Although a planning process to expand the Port of Rotterdam was underway from 2003, and the expansion had been approved in principal by the Dutch parliament, the highest general administrative court in the Netherlands (Raad van State) upheld an appeal by concerned citizens and interest groups and the expansion process was halted in Jan 2005. The Port of Rotterdam was forced to reconsider their approach. As Prof. (em.) Tiedo Vellinga explains in the video "Deltas and Ports of the Future", the interests of diverse stakeholders had to be taken into account. After all, many people's lives and livelihoods are affected by the Port of Rotterdam. These include workers in the port and allied industries, people who live in the municipalities along the waterway and near the port, fisherman, transporters, environmental enthusiasts and many others. Furthermore, decision making on port expansion concerns many government authorities at both national and regional level. These include environmental agencies, spatial planners, agriculture and fisheries, trade and industry departments, customs and excise, as well as the national water authority. But, the stakeholders are not only confined to Dutch society, they extend to the international companies using and investing in the Port of Rotterdam. You can think of international terminal operators, the offshore industry, multi-national petroleum companies and many others. Similarly, the international implications of extending the Dutch coastline on the environmental health of the Wadden Sea, a UN world heritage site to the north, and on the North Sea required investigation.

Extensive environmental and social impact assessments had already been undertaken. Simulation modelling studies of the effects of the planned expansion on nearby coastal hydrodynamics, sediments and ecosystems had also been undertaken. A wide range of stakeholders had been informed of the results. But, stakeholders had not been involved in determining the questions to be addressed by all these research efforts. You are asked to analyse this situation retrospectively. Think about which stakeholder engagement process you would consider appropriate and what you think the Port of Rotterdam could do to achieve the Maasvlakte 2 expansion with the support of society.



6-18. Two variants of the proposed Maasvlakte 2 expansion of the Port of Rotterdam. Adapted from van Schuylenburg (2002). © Port of Rotterdam

Before You Continue...

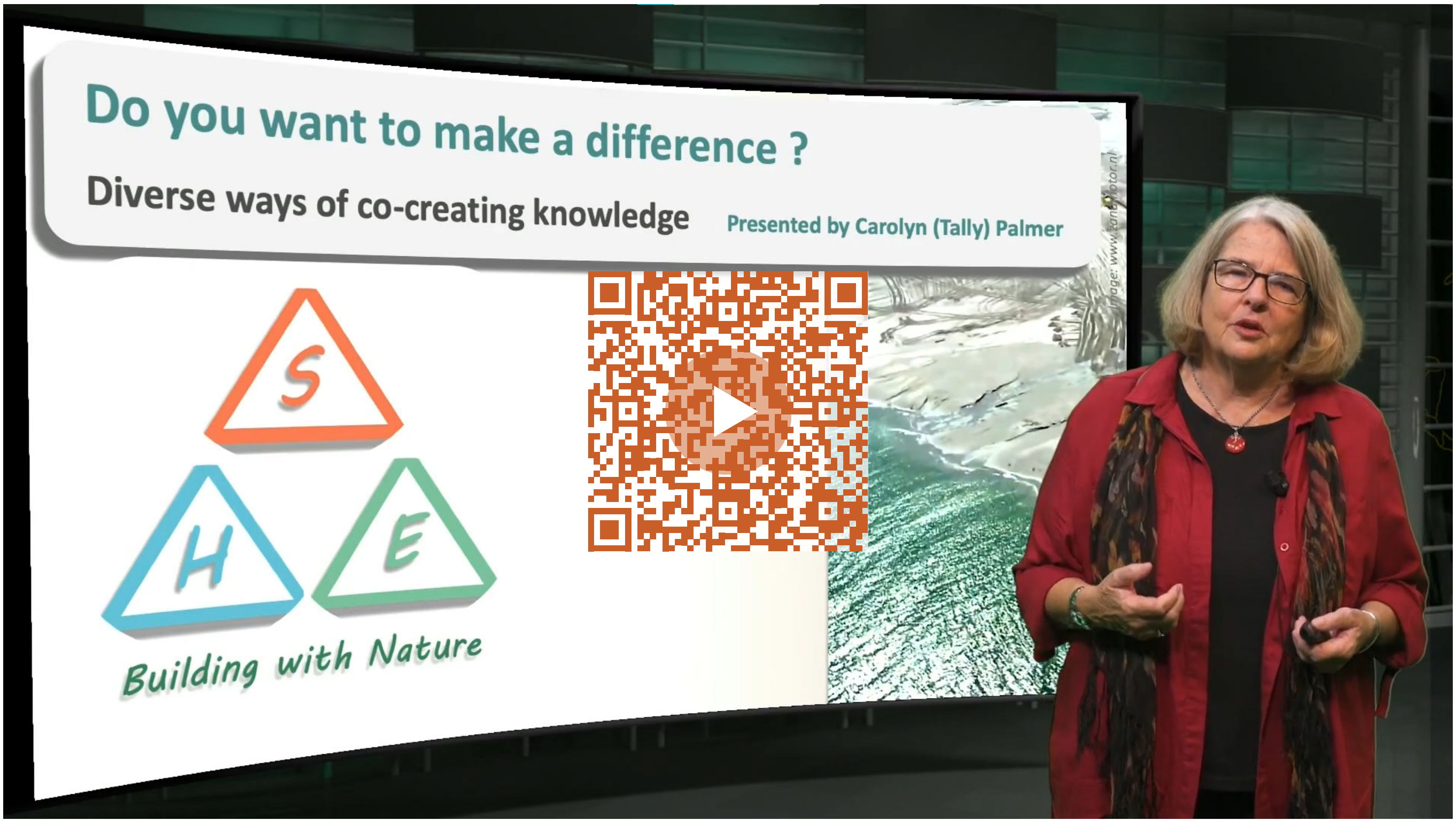
Maasvlakte 2 > Jan 2005 Poll

Based on the description above, which of the five strategies do you think the Port of Rotterdam applied after 2005?

- ◯ Traditional disciplinary science and engineering
- ◯ Mediated, interactive analysis
- ◯ Good communication, clarifying values and arguments
- ◯ Identify solution space
- ◯ No action

You may wish to discuss this with your peers.

6.5 Making a Difference?



Video: Do You Want to Make a Difference?

Prof. Tally Palmer shares her insights on engaging in complex problem situations, challenging you to join her in making a difference. This video is written by **Tally Palmer**, **Jill Slinger** and **Athina Copteros**.

The reading for Chapter 6 on transdisciplinary learning in complex coastal systems follows. You will need to watch the video and read the paper before moving on to Assignment 6.2.

You can cite the video as:

Palmer, C. (Tally), Slinger, J.H. (Jill), Copteros, A. (Athina) (2020). *Beyond Engineering: Building with Nature 2x video #02. Do you want to make a difference? Diverse ways of co-creating knowledge.* 4TU.Dataset. https://doi.org/10.4121/14910129

Video Transcript

Presented by Prof. Tally Palmer

Today I'm going to be asking you a really important question. Do you want to make a difference? And I'm going to suggest that if you do, that there are different ways of doing this. But importantly we want to co-create knowledge from diverse sources of knowledge and we call this commitment to drawing in different knowledges the transdisciplinary approach. The transdisciplinary approach is important because it locates us in the real world that we know. It's problem-focused. It is also importantly integrating different knowledge disciplines, our training and what we have learned to know. And fundamentally it is with and for society. It takes account of the fact that we live together on this planet. This planet of land and water. As we live we cause problems. We know we do. We know what those problems are. They include industrial and agricultural pollution, climate change, erosion.

We know that we are trained in academic knowledge. We learn to be ecologists. We learn to be anthropologists. We learn to be engineers and we also each of us - and we don't take account of this as much as we should - we each of us have a lived knowledge. We have a contextual knowledge of

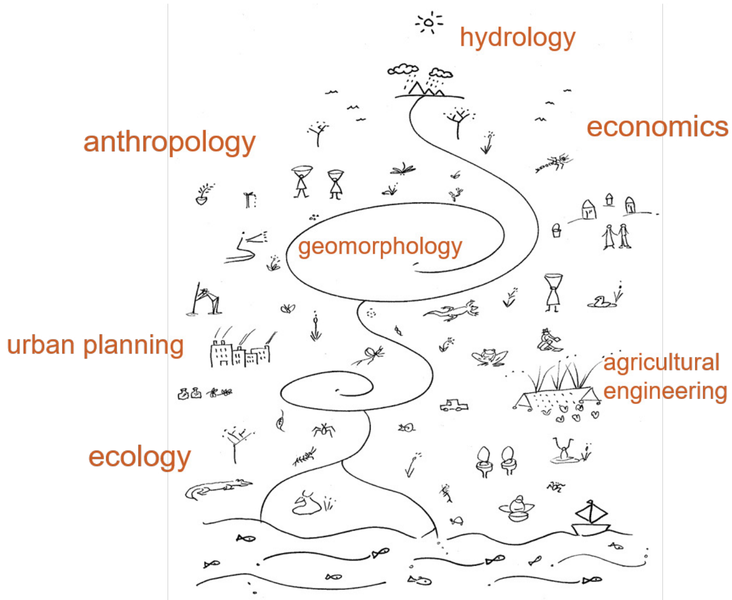
the places we live in, of the way they work of who knows to do what. But what we're trying to do in the transdisciplinary approach is pull all of these things together.

Now one of the first people who tried to do this formally was Max Neef and he looked at the foundations of knowledge, the empirical knowledge of what we know, mathematics, ecology, anthropology. The work that we do to get the knowledge. And then he said out of that knowledge that we have gathered we learn how to do things, we can do things like design and engineering.

And there are so many things that we learn what to do that we have to select them. We have to choose which of those applies to the particular problem we're working with. And so we have these selective knowledges - we learn how to plan, we learn strategic adaptive management.

But at the heart of it what do we actually do? How do we act?

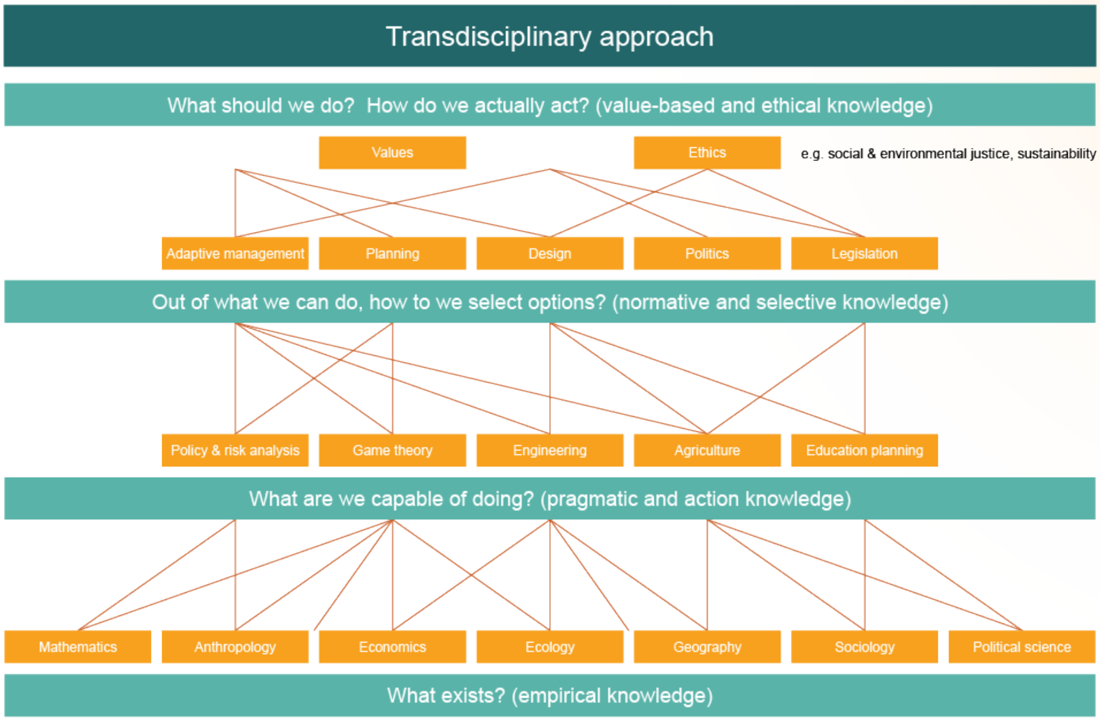
6-19. *We all live on this planet of land and water together and what we do causes problems.* © *IWR, Rhodes University*



6-20. *Academic disciplinary knowledge.* © *IWR, Rhodes University*

6-21. *Problems caused by us living in catchments.* © *IWR, Rhodes University*

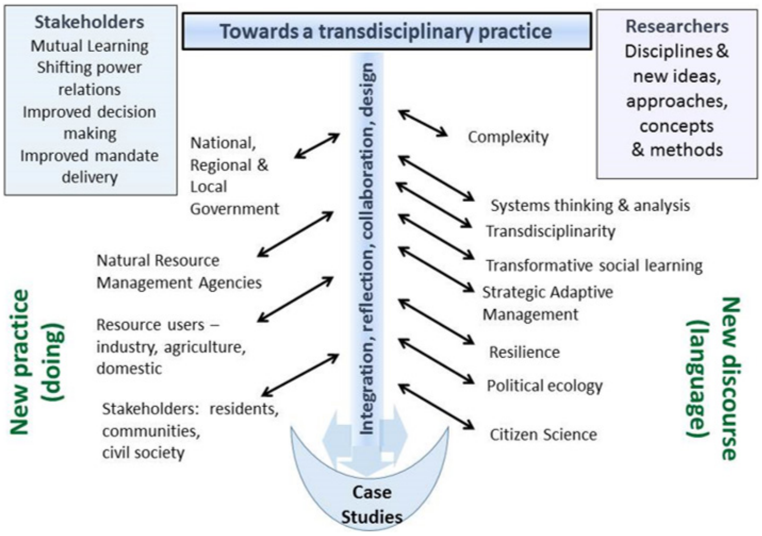
6-22. *Lived knowledge. People living together in society on this planet.* 🅭 *IWR, Rhodes University*



6-23. *Transdisciplinary approach.* 🅭 *Martijn Vos. Adapted from Wolff et al. (2019)*

And out of choosing what we do and what we actually do is driven by values by what we deeply value and what our ethical stance is.

Now out of this complicated way of arranging knowledge. We added some new and exciting ideas that helped pull things together. Things like complexity, resilience, social learning, transformative social learning. And by doing this we have created a new language, a new way of talking about problems. But in order to talk you have to talk to somebody. You also have to listen to them. You have to have conversations so who are you having conversations with? You're having conversations with government at all levels. You're having conversations with industry. You're having conversations with people who manage resources and also people who live in resources. And it's important then to think about the way in which you're having these conversations. You're consciously trying to integrate. You're taking time to reflect in those reflective spaces where you learn. You're learning how to collaborate and work with people that you never thought you might have to or be able to collaborate with. And out of all that you're paying attention to design, to the style, the shape of different interventions and you use case studies to do this. And out of all of this you build the transdisciplinary approach.

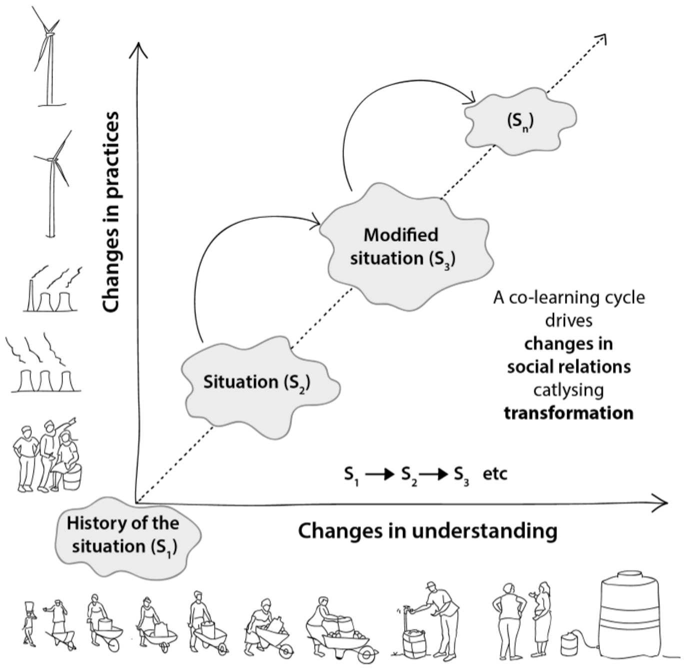


6-24. *Towards a transdisciplinary practice.* © *IWR, Rhodes University*

6-25. *Working in different spaces.* © *IWR, Rhodes University*

So fundamentally, we worked in many different spaces and they all had all of them had a different feel, from a city hall to a rural hut. Out of all of these experiences and all of these different contexts and all of these different knowledges we have to have ways of pulling things together.

And so, if I'm going to ask you the question 'Do you really want to make a difference?' I need to be able to give you some pathway some way of doing that and I'm going to suggest that this transformative pathway of pulling things together is through learning by doing. When we're faced with a problem we do something, we watch what happens and we learn from that and our learning changes our doing. And so we do something else and then we learn from that. And this learning by doing takes us along a transformative space, where the situation we started with with all of its history takes us to a new place and addresses the problems that we were trying to grapple with right in the beginning.



6-26. *Making a difference...Transformation...Emerges from learning by doing.* © *IWR, Rhodes University. Adapted from Steyaert and Jiggins (2007).*

Reading Material: Transdisciplinary Learning in Complex Coastal Systems

The reading for Chapter 6 is the introductory chapter of a book "Complex Coastal Systems. Transdisciplinary insights from international case studies". This chapter has been selected because it introduces the reader to fundamental concepts in the (complex) system sciences, integrated environmental assessment and management, and social-ecological systems. It draws on these fields to explain how transdisciplinary learning can occur when people with different disciplinary backgrounds and life experiences seek to learn with, and from each other, on coastal management.

You can purchase your own copy of the book via Delft Academic Press or via Amazon, or you can download the book from the TU Delft repository:

Complex Coastal Systems. Transdisciplinary insights from international case studies.

You can cite the book chapter as:

Slinger, J. H., Taljaard, S., D'Hont, F.M. (2020). Chapter 1. Introduction. In: (eds) Slinger, J. H., Taljaard, S., D'Hont, F.M. *Complex Coastal Systems. Transdisciplinary insights from international case studies.* Delft Academic Press, Delft, Netherlands. ISBN: 97890-6562-4437

6.6 Assignment 6.2

Introduction

This assignment is based on the introductory chapter of the book "Complex Coastal Systems. Transdisciplinary insights from international case studies". If you have not yet read this chapter then you are advised to return to the previous section before attempting Assignment 6.2.

There are 6 questions in Assignment 6.2 and two of the questions are slightly more complex.

Good luck in completing the assignment, and remember to consult the Feedback on Assignment 6.2 when you are finished.

Assignment 6.2

In this section you will find the questions as described in the introduction.

To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

To answer, check as many boxes as you consider appropriate.

Characteristics of ‘wicked’, ‘messy’ or ‘unstructured’ problems in coastal management include:

- ☐ nested spatial scales
- ☐ bio-geophysical dynamics
- ☐ predictable social dynamics
- ☐ consensus on which outcomes are desired
- ☐ diverse sources of knowledge

Show Answer

Question 2

To answer, check as many boxes as you consider appropriate.

Viewing a problem from a systems perspective means recognising:

- ☐ the interdependence of component parts of the problem
- ☐ the need to fully understand the behaviour of parts of the problem in isolation
- ☐ that exploring the implications of human interventions and decision making on the problem is necessary
- ☐ that properties can emerge that do not exist in the parts, but are found in the whole
- ☐ that the outcomes of proposed human interventions must be predicted before sound decisions can be made

Show Answer

Question 3

*To answer, check the **3 boxes** that you think are appropriate.*

The 3 cornerstones in realising participatory decision making in complex problem settings mentioned in the reading are:

- ☐ allowing all who wish to participate to have their say
- ☐ valid decision-relevant scientific knowledge
- ☐ consent by stakeholders to a process designed to achieve appropriate and information-based decision outcomes
- ☐ stable stakeholder participation that accounts for different roles and contributions
- ☐ preparing logically consistent choices for decision makers based on adequate information

Show Answer

Question 4

To answer, check only one answer.

The conviction that natural resources and the environment can be managed more effectively if the ecosystem is placed centrally underlies:

- ○ ecosystem-based management
- ○ adaptive management
- ○ objectives-based management
- ○ none of the above

Show Answer

Question 5

To answer, check only one answer.

Social-ecological theory recognises linked systems of people and nature in the world around us, viewing humans as:

- ◯ controlling nature
- ◯ separate from nature
- ◯ part of, not apart from, nature
- ◯ controlled by nature
- ◯ none of the above

Show Answer

Question 6

To answer, check as many boxes as you consider appropriate.

Transdisciplinarity is a scientific approach that:

- ☐ involves multiple disciplines
- ☐ ignores deep disciplinary knowledge in favour of integrated knowledge
- ☐ uses place-based knowledge
- ☐ involves scientists and society
- ☐ produces only site-specific knowledge
- ☐ focuses on learning and reflection

Show Answer

6.7 Feedback

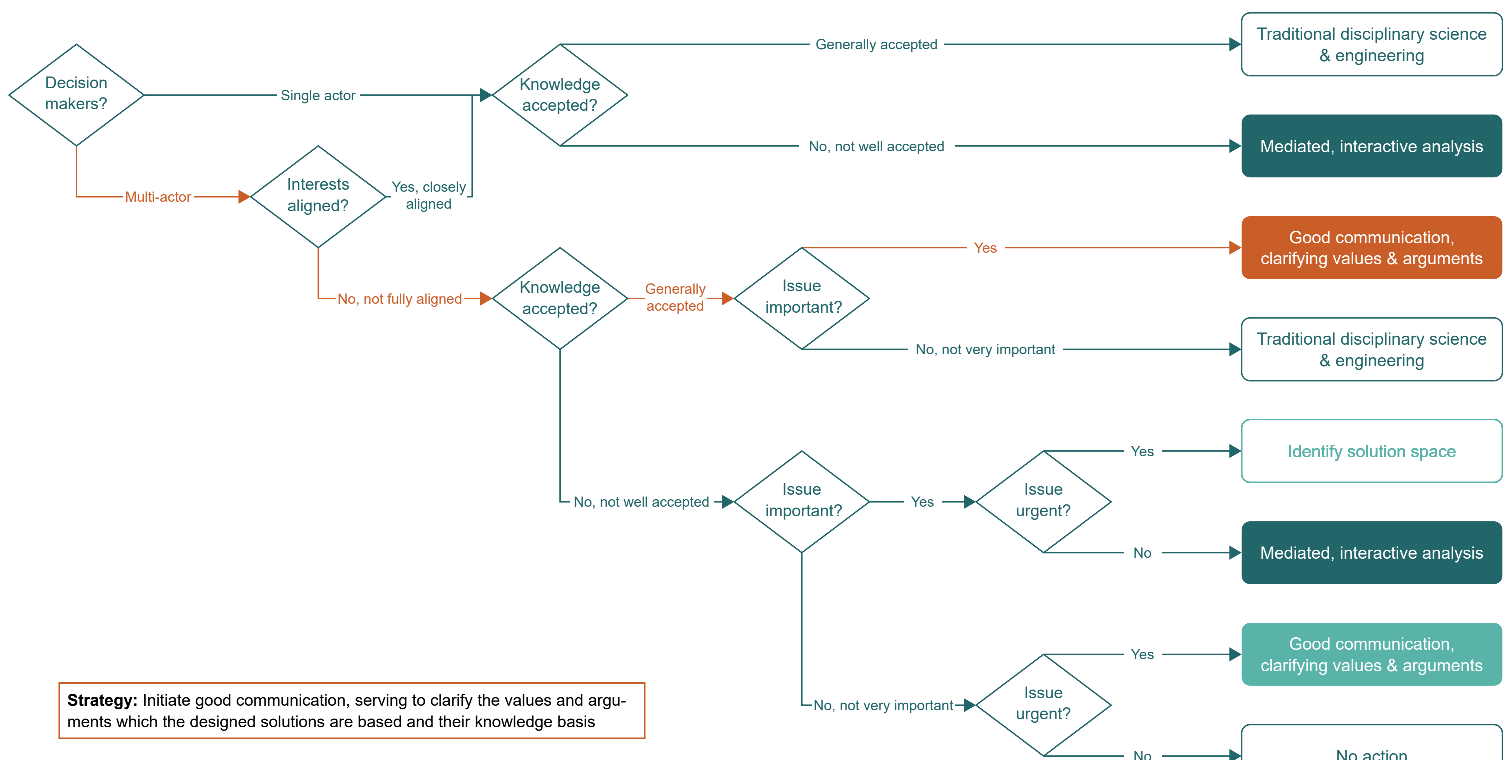
Feedback on Assignment 6.1

The five diagnostic questions are:

1. Can the problem be solved and the solution decided upon essentially by one actor (i.e. authoritarian) or by a consensual process of multiple actors (i.e., network)?
2. Are the interests and objectives of the actors involved closely aligned?
3. Is there consensus on the scientific and engineering knowledge?
4. Is the issue considered vitally important to the people affected by the problem and potential solutions?
5. Is there agreement that the decision is urgent?

1. Room for the River

	Diagnostic Question	Room for the River: 8 Potential Measures
1.	More than one decision maker?	**Yes,** the decisions cannot be taken unilaterally by the national water authority or even the water board (regional water authority), as such decisions can influence spatial planning, industry and agriculture.
2.	Interests aligned?	**No,** although the common interest of reducing the risk of flooding is aligned, the interests of ecology, recreation, water security, urban development, navigation are not necessarily aligned.
3.	Knowledge accepted?	**Yes,** because advanced modelling techniques are used to test the effects of the proposed infrastructure measures on anticipated flood levels. Ecologists, planners and other scientific disciplines contribute knowledge to the process.
4.	Issue important?	**Yes,** the people living alongside the rivers could be flooded more frequently in future if no measures are implemented. However, some of the measures could affect how they live, whether they have a view of the river, can experience nature nearby, and whether they may even have their property expropriated. It could affect their quality of life.
5.	Issue urgent?	**No,** the potential measures are not needed tomorrow. They are to ensure safety from flooding and more nature areas in future.

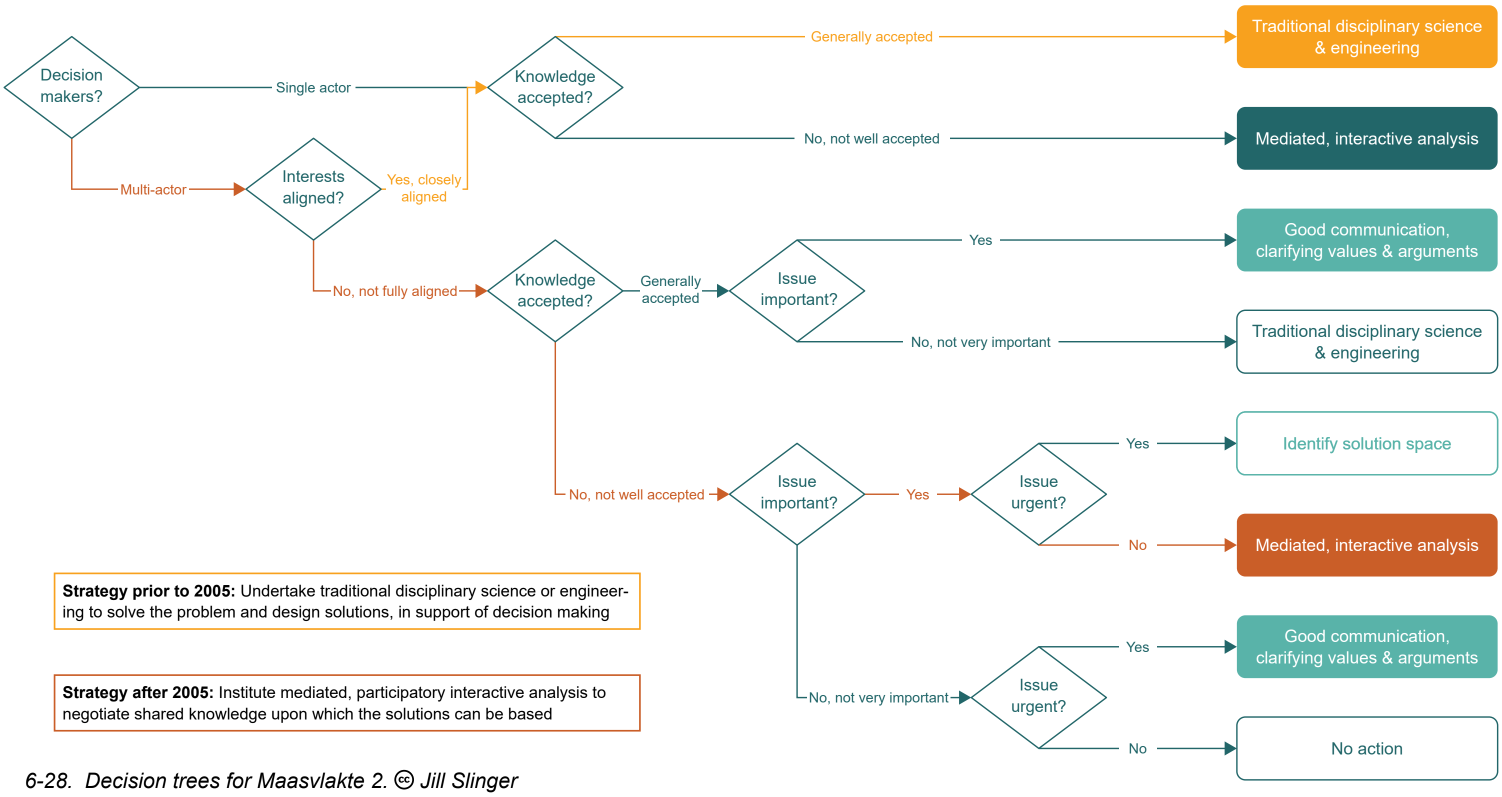


6-27. Decision tree for Room for the River. Ⓒ *Jill Slinger*

2. Maasvlakte 2

Here, we provide two different diagnoses of the Maasvlakte 2 expansion planning process. The viewpoint prior to 2005 (on the right) was challenged when the high court in The Netherlands upheld the appeal against the expansion. The viewpoint presented on the left predominated from 2005 onwards and led to a successful planning process and the realisation of the Maasvlakte 2 in 2013. But what, depending on your viewpoint, do the diagnostic questions indicate as an appropriate strategy?

	Diagnostic Question	Maasvlakte 2 (Viewpoint prior to 2005)	Maasvlakte 2 expansion (Viewpoint from 2005-2009 and beyond)
1.	More than one decision maker?	**Yes,** even though the Port of Rotterdam is very powerful, there are multiple stakeholders and even other authorities (e.g. surrounding municipalities) or environmental NGO's who have a role to play and at the least have the power to block the process.	**Yes,** the Port of Rotterdam is the biggest in Europe. Its expansion will benefit the economy and provide jobs. Moreover, environmental impacts are assessed and mitigated. So, the goal of port expansion should be achieved by following appropriate planning procedures.
2.	Interests aligned?	**No,** definitely not. Many of the actors have different objectives and they care about very different things. For instance, Rijkswaterstaat is the national authority responsible for maintaining the coast. They are concerned about extra sand nourishment costs and flooding safety. These concerns do not align one to one with those of the Port of Rotterdam.	**Yes,** everyone associated with the harbour recognises the need to expand, and that the port is the economic heart of Rotterdam.
3.	Knowledge accepted?	**No,** in regard to the engineering and technical aspects there is a high degree of consensus. In regard to the ecological aspects there is less consensus. And issues related to air pollution are highly disputed.	**Yes,** because advanced modelling techniques are used to test the engineering designs and to reduce the hydrodynamic and sedimentary effects.
4.	Issue important?	**Yes,** it will affect numerous aspects of the affected peoples' lives from economic prosperity, to air quality, recreational opportunities and the ecological health of the Dutch coast.	**Yes,** the affected people generally depend for their economic well-being on the port. Its expansion and continued prosperity is vitally important and will affect their livelihoods.
5.	Issue urgent?	**No,** some people do not think that the expansion needs to happen urgently. They consider that adequate environmental and social studies need to be completed first.	**Yes,** otherwise Rotterdam will no longer be able to cope with the demand, and might not be able to accommodate the largest container ships in the future.



6-28. Decision trees for Maasvlakte 2. © Jill Slinger

Feedback on Assignment 6.2

Question 1

Characteristics of ‘wicked’, ‘messy’ or ‘unstructured’ problems in coastal management include:

- ☑ nested spatial scales
- ☑ bio-geophysical dynamics
- ☐ predictable social dynamics
- ☐ consensus on which outcomes are desired
- ☑ diverse sources of knowledge

Comments on Question 1

According to Slinger et al. (2020, Section 1.1, 1st & 4th paragraphs) complex coastal management problems are characterised by nested spatial scales, bio-geophysical dynamics and diverse sources of knowledge (diversity in what is known). There is a lack of consensus on desirable outcomes, values differ, and the social dynamics are complex and variable.

Question 2

Viewing a problem from a systems perspective means recognising

- ☑ the interdependence of component parts of the problem
- ☐ the need to fully understand the behaviour of parts of the problem in isolation
- ☑ that exploring the implications of human interventions and decision making on the problem is necessary
- ☑ that properties can emerge that do not exist in the parts, but are found in the whole
- ☐ that the outcomes of proposed human interventions must be predicted before sound decisions can be made

(comments on next page)

Comments on Question 2

Viewing a problem as a system means recognising that there are interrelations between different elements of the problem i.e. interdependence between components. Because of the complex and often non-linear interactions of the parts within a system, properties can emerge from the whole that are not manifested in the parts. So exhaustively analysing and understanding the behavior of the parts in isolation is not enough. This also means that the implications of human interventions need to be explored, but cannot be predicted entirely. So decision making occurs through explorative assessment and analysis rather than through absolute prediction. Sensible decisions can sometimes also be taken without knowing all possible behaviours, but by taking such uncertainties over outcomes into account. See Section 1.2.1 of Slinger et al. (2020).

Question 3

The 3 cornerstones in realising participatory decision making in complex problem settings mentioned in the reading are:

- [ ] allowing all who wish to participate to have their say
- [x] valid decision-relevant scientific knowledge
- [x] consent by stakeholders to a process designed to achieve appropriate and information-based decision outcomes
- [x] stable stakeholder participation that accounts for different roles and contributions
- [ ] preparing logically consistent choices for decision makers based on adequate information

Comments on Question 3

The three cornerstones are listed in Section 1.2.2 of Slinger et al. (2020, pg 16, 2nd paragraph). They do not include allowing all who wish to participate to have their say, nor preparing logically consistent choices for decision makers based on adequate information.

Question 4

The conviction that natural resources and the environment can be managed more effectively if the ecosystem is placed centrally underlies:

- (●) ecosystem-based management
- ( ) adaptive management
- ( ) objectives-based management
- ( ) none of the above

Comments on Question 4

This is the conviction underpinning ecosystem-based management (Slinger et al. 2020, Section 1.2.3, pg 19, last paragraph).

Question 5

Social-ecological theory recognises linked systems of people and nature in the world around us, viewing humans as:

- ( ) controlling nature
- ( ) separate from nature
- (●) part of, not apart from, nature
- ( ) controlled by nature
- ( ) none of the above

Comments on Question 5

Social-ecological theory is a co-evolutionary theory, recognising humans as a part of, and not apart from, nature (Berkes & Folke, 1998), as stated in Section 1.2.4 (Slinger et al. 2020, pg 19).

Question 6

Transdisciplinarity is a scientific approach that:

- ☑ involves multiple disciplines
- ☐ ignores deep disciplinary knowledge in favour of integrated knowledge
- ☑ uses place-based knowledge
- ☑ involves scientists and society
- ☐ produces only site-specific knowledge
- ☑ focuses on learning and reflection

Comments on Question 6

Transdisciplinary science does not ignore deep disciplinary science in favour of integrated knowledge. It values deep disciplinary science, seeking to learn from it and integrate it with other disciplinary knowledge to produce new transdisciplinary knowledge. So it involves multiple disciplines, and focuses on learning and reflection. In addition, it seeks to use place-based knowledge and involves science and society in knowledge generation and learning.Despite a place-based focus it doesn't only generate site-specific knowledge. For example, the learning and reflection process reported in Slinger et al. (2020, Sections 1.2.4 & 1.2.5) enables learning across case study sites.

6.8 Bibliography

Literature

Berkes, F., & Folke, C. (1998). *Linking social and ecological systems for resilience and sustainability. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*, 1–25.

De Bruijn, H., Porter, A.L. (2004). The education of a technology policy analist – to process management. *Technology Analysis & Strategic Management 16(2):* 261-274.

Enserink, B, Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., Bots, P. (2010). *Policy Analysis of Multi-Actor Systems.* Lemma, The Hague, Netherlands. ISBN 978-90-5931-538-9

Slinger, J. H., Taljaard, S., D'Hont, F.M. (2020). Chapter 1. Introduction. In: (eds) Slinger, J. H., Taljaard, S., D'Hont, F.M. *Complex Coastal Systems. Transdisciplinary insights from international case studies.* Delft Academic Press, Delft, Netherlands. ISBN: 97890-6562-4437

van Schuylenburg, M. (2002). Timing of the second Maasvlakte, presentation Port of Rotterdam, 17 January 2002.

Steyaert, P., & Jiggins, J. (2007). Governance of complex environmental situations through social learning: A synthesis of SLIM's lessons for research, policy and practice. *Environmental Science & Policy, 10*, 575–586

Wolff, M. G., J. J. Cockburn, C. De Wet, J. C. Bezerra, M. J. T. Weaver, A. Finca, A. De Vos, M. M. Ralekhetla, N. Libala, Q. B.Mkabile, O. N. Odume, and C. G. Palmer. 2019. Exploring and expanding transdisciplinary research for sustainable and just natural resource management. *Ecology and Society 24(4)*:14. http://dx.doi.org/10.5751/ES-11077-240414

Figures

6-1. **BwN Indonesia Workshop:** This image by Heleen Vreugdenhil is licensed under CC-BY-NC-SA 4.0.

6-2. **The Sand Engine:** This image by De Zandmotor is in the Public Domain, CC0.

6-3. **Hondsbossche Dunes, North-Holland:** This image by Hoogwater Beschermings Programma HwBP is in the Public Domain, CC0.

6-4. **Maasvlakte II:** This image is Copyright protected. © Port of Rotterdam. All Rights Reserved.

6-5. **Maasvlakte II compensation:** This image is Copyright protected. © Port of Rotterdam. All Rights Reserved.

6-6. **Problems with port expansion:** This image by Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

6-7. **Tema, Ghana:** These images are Copyright protected. © Baukje Kothuis / Jorrit van den Houten. All Rights Reserved.

6-8. **Crocodile River, South Africa:** This image by Olga Ernst is licensed under CC BY-SA 4.0.

6-9. **Tsitsa Catchment, South Africa:** This image by IWR, Rhodes University is licensed under CC-BY-NC-SA 4.0.

6-10. **Great Brak Estuary, South Africa:** This image by CSIR is licensed under CC-BY-NC-SA 4.0.

6-11. **Sierra Leone:** This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

6-12. **Semarang, Indonesia:** This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

6-13. **Moving from H-E to S-H-E in Building with Nature:** This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0.

6-14. **Decision tree to diagnose whether a situation requires stakeholder engagement. After de Bruijn & Porter (2004); Enserink et al. (2010):** This image by Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

6-15. **APM Terminals terminal:** This image by TU Delft / New Energy TV is licensed under CC-BY-NC-SA 4.0.

6-16. **Room for the River: plenty of possibilites:** This image by Deltares / Rijkswaterstaat is licensed under CC-BY-NC-ND 4.0.

6-17. **Port of Rotterdam Industrial Land, Jan 1997. Adapted from van Schuylenburg (2002):** This image is Copyright protected. © Port of Rotterdam. All Rights Reserved.

6-18. **Two variants of the proposed Maasvlakte 2 expansion of the Port of Rotterdam. Adapted from van Schuylenburg (2002):** This image is Copyright protected. © Port of Rotterdam. All Rights Reserved.

6-19. **We all live on this planet of land and water together and what we do causes problems:** This image by IWR, Rhodes University is licensed under CC-BY-NC-SA 4.0.

6-20. **Academic disciplinary knowledge:** This image by IWR, Rhodes University is licensed under CC-BY-NC-SA 4.0.

6-21. **Problems caused by us living in catchments:** This image by IWR, Rhodes University is licensed under CC-BY-NC-SA 4.0.

6-22. **Lived knowledge:** This image by IWR, Rhodes University is licensed under CC-BY-NC-SA 4.0.

6-23. **Transdisciplinary approach:** This image by Martijn Vos is adapted from Wolff et al. (2019) and licensed under CC-BY-NC-SA 4.0.

6-24. **Towards a transdisciplinary practice:** This image by IWR, Rhodes University is licensed under CC-BY-NC-SA 4.0.

6-25. **Working in different spaces:** This image by IWR, Rhodes University is licensed under CC-BY-NC-SA 4.0.

6-26. **Making a difference...Transformation...Emerges from learning by doing:** This image by IWR, Rhodes University is adapted from Steyaert, P., & Jiggins, J. (2007) and is licensed under CC-BY-NC-SA 4.0.

6-27. **Decision tree for Room for the River:** This image by Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

6-28. **Decision trees for Maasvlakte 2:** This image by Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

7-1. Maasvlakte 2. © Martijn Vos

Chapter 7
Stakeholder Analysis & Mapping

7.1 Introduction

In Chapter 6 you learned to diagnose when stakeholder engagement is necessary in a complex problem situation. In Chapter 7 you will learn how to identify relevant stakeholders, map them on a power interest grid, and identify their mutual dependencies.

The chapter consists of the following videos:

- Stakeholder analysis and the power interest grid - a video by Dr. Alexander de Haan
- The value of working with stakeholders - a video by Prof. Tally Palmer in which she shares experiences from the Crocodile River in South Africa.
- Issues of scale - a video by Prof. Jill Slinger (and Heleen Vreugdenhil) on the influence of scale perceptions in the design and decision making regarding Building with Nature interventions.

There are two assignments. In the first assignment you apply the knowledge you have gained to identify stakeholders based on material from the Maasvlakte 2, and you explore the mutual dependencies between actors in the Maasvlakte 2 decision making process. You explore how these techniques can be applied to situations with which you are familiar. A reading on scale issues forms the basis of the second assignment.

Enjoy learning how to identify relevant stakeholders, map their interdependencies and consider issues of scale.

7.2 Stakeholder Analysis & Mapping

7-270

Video: Stakeholders and the Power-Interest Grid

Dr. Alexander de Haan starts this video by explaining why we need to include and listen to stakeholders in complex problem solving. He then moves on to describe briefly how you identify stakeholders and what a power interest grid is.

You can cite this video as:

de Haan, A. (2013). *Introduction video Stakeholders and PI-grid. Massive Open Online Course Solving Complex Problems.* TUDelft, Netherlands.

Video Transcript

Presented by Dr. Alexander de Haan

The most elementary characteristic of a complex situation is that there is no way to find ‘the best answer’, ‘the single right solution’, or ‘the correct way to do it’.

In our analytical approach to dealing with these kinds of complex situations, one of the first things we do is using the perspective of many different stakeholders involved in your complex situation. Their ideas and experiences within that complex situation help us as they enrich our ideas of that situation. Also, their ideas for changes, system interventions or solutions to existing problems in that situation help us to consider a variety of options rather than focusing on one only.

That last thing, focusing on one idea to change the situation or one particular solution for a complex problem is very natural to people in general. As soon as we want to change something we focus on the first idea that seems to be good enough. And from that moment on we selectively collect arguments why our idea is so good. We even defend our idea against the ideas of others.

Well, that is clear what happens then. A lot of discussion. Delay in decision making. Maybe the strongest person puts his idea through. Or the person that shouts the loudest. Or the one that knows best how to influence colleagues in a company or influence public opinion in society.

Just as it is very useful to know how these kind of power and influence mechanisms work, it is also very useful to have the advantages of a systematic approach, which is what we do, as it gives you a good overview and it structures the situation. By applying it, chances increase that you take better decisions and get more support for that decision from the stakeholders involved.

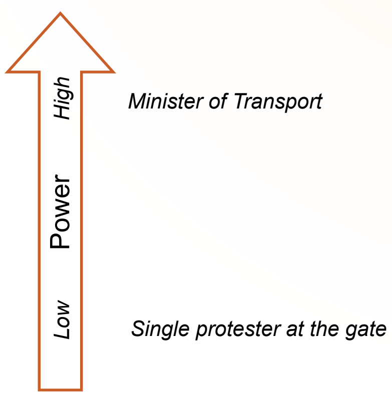
I will help you now with the identification of those stakeholders in your complex situation that, so to say, ‘matter’. And from these stakeholders we more clearly can identify what the situation looks like using the dilemmatic perspective on the complex situation. Only after, we focus on what our own role is in the situation and whom we need in order to either change our situation or solve our problem.

But first, the stakeholders. You already might have given the perspectives of some people some thought, but let’s do it more elaborate here. First try to enlarge your list of possible stakeholders and make it as long as you can. Include persons, but also organised groups such as departments, teams, pressure groups, and also include whole organisations, governmental institutions and so on. Try to make them as clear as possible. Things like ‘the government’ or ‘society’ are far too vague. Whom are you going to talk to if you want to know what ‘society thinks of it’? So, mention a clear group in society that has explicit ideas. Mention directors at a ministry, or even the minister herself.

Then, give each of these stakeholders a place in the following grid.

The vertical axis is the amount of power these stakeholders have in your complex situation. That is, to what extent are they capable of making changes, making system interventions, in that complex situation? It is much more likely that a minister can influence the expansion ideas of an airport than that a single protester at the gate of that airport shouts ‘no expansions because I can’t sleep at night anymore due to the noise’. This doesn’t say anything about who is right or wrong (if anyone is), but about the level of influence certain stakeholders have.

The horizontal axis is about the level of interest these stakeholders have in the complex situation. If they don’t care about



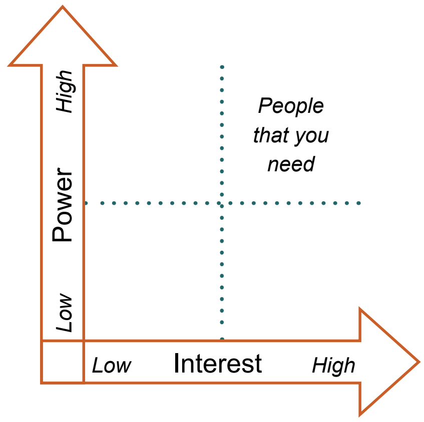
7-2. *Vertical Axis of Power-Interest grid.* © *Alexander de Haan*

Stakeholder Analysis & Mapping

it, they can have a lot of power in that situation, but still nothing will happen.

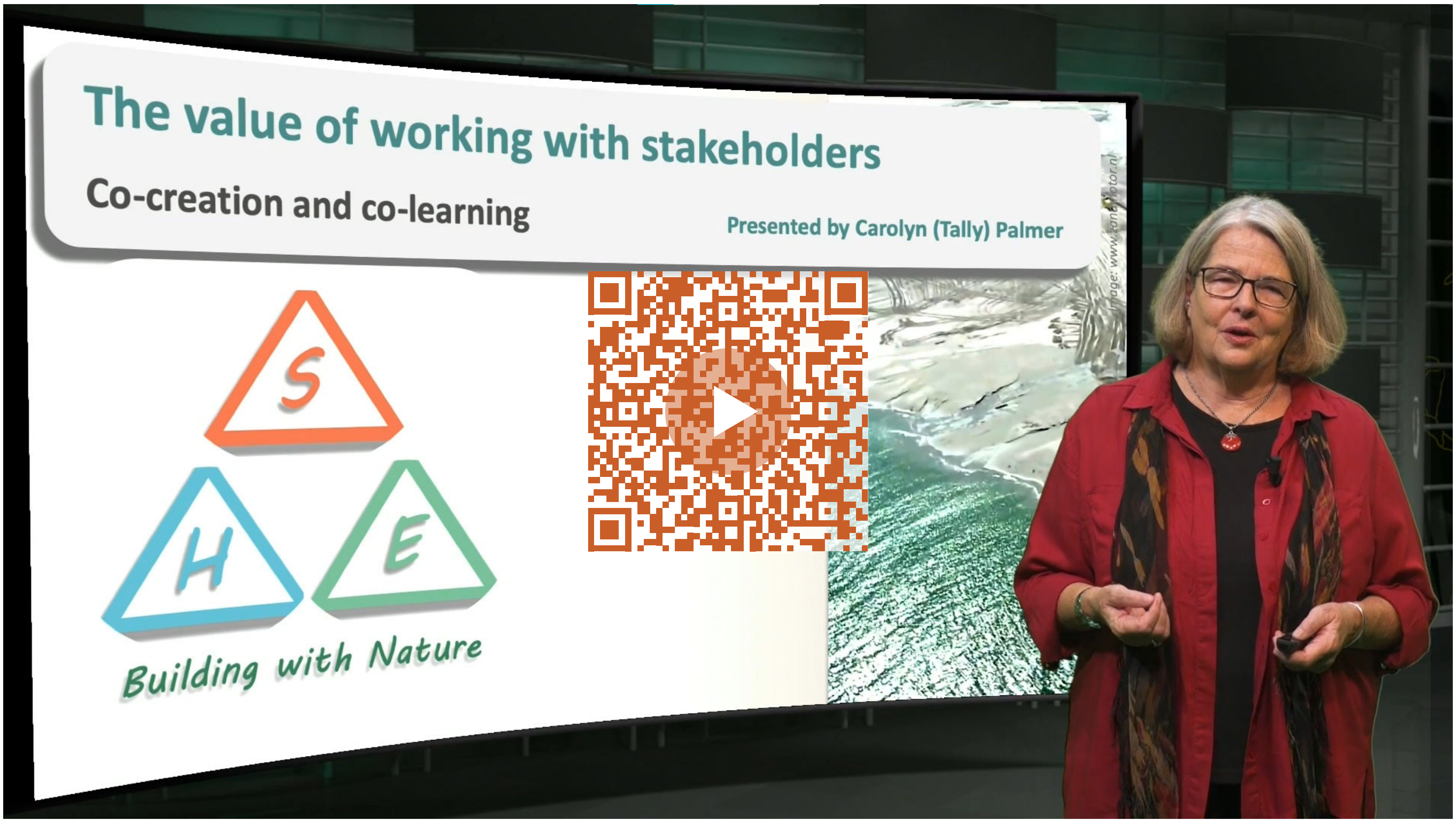
The people that you need are the people in the right upper corner: stakeholder who have both power and interest. They can make system interventions and they are motivated to do so.

Now, where do you put yourself? That is an interesting question. If you are in the right upper corner, you can consider yourself to 'own' to a certain extent, your complex problem. You have the power to change it. And you have the interest. If you, however, did not put yourself in the upper right corner but still want to change the current complex situation that you are facing, you need to think about bonding with stakeholders in that corner.



7-3. Stakeholders in the Power-Interest grid. © Alexander de Haan

Stakeholder Analysis & Mapping



Video: The Value of Working with Stakeholders

Here **Prof. Tally Palmer** will share with you her experience in working with a wide range of stakeholders in the Crocodile River catchment, South Africa. This video is written by **Tally Palmer**, **Jill Slinger** and **Athina Copteros**.

You can cite this video as:

Palmer, C. (Tally), Slinger, J.H. (Jill), Copteros, A. (Athina) (2020). *Beyond Engineering: Building with Nature 2x video #03. The value of working with stakeholders. Co-creation and co-learning.* 4TU.Dataset. https://doi.org/10.4121/14910237

Stakeholder Analysis & Mapping

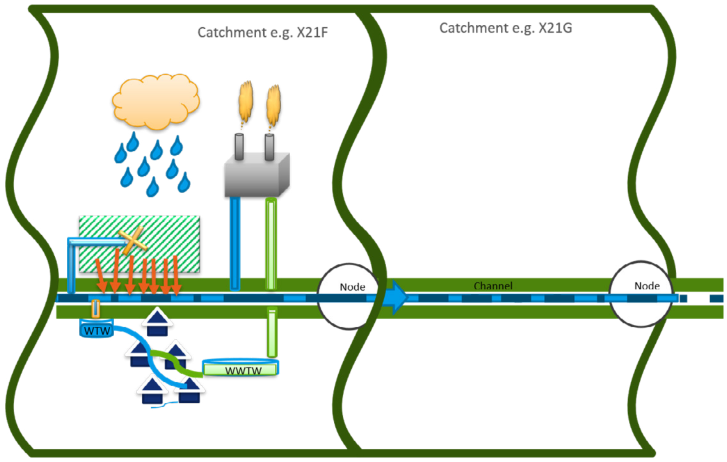
Video Transcript

Presented by Prof. Tally Palmer

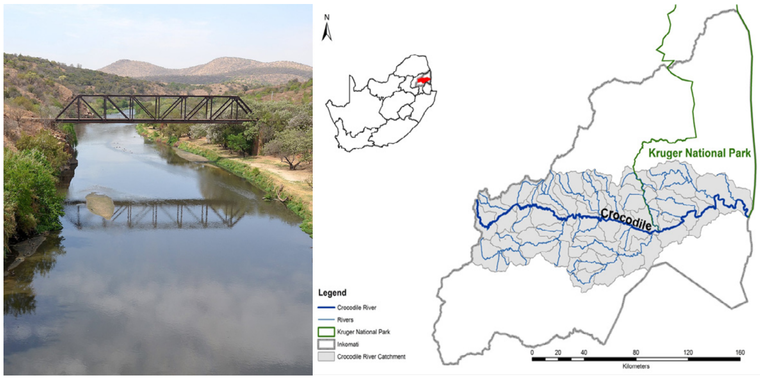
Today we're going to be talking about working with stakeholders and the value of working with stakeholders. We're going to be talking about what it means to co-create knowledge and to learn together in wide groups of people who have different ways of knowing. We're going to be talking about the Crocodile River in South Africa which like many rivers in southern Africa arise in highly industrialised areas with many urban areas and agriculture around them but also people discharging sewage. There are two main water-quality impacts in this kind of a catchment. The water quality impacts come from salts which come mainly from the industries, and also from irrigated agriculture. And, also increased nutrients coming from fertilised agricultural fields and from Wastewater Treatment Works that maybe aren't working as well as they should, bringing sewage enrichment into the system.

So let's look at how this might work. Here are two catchments. One sub catchment is upstream and one downstream which is the way rivers work. And you have rainfall. Rainfall falling on agricultural fields that have abstracted water in order to irrigate, and there are return flows with salts and fertilisers.

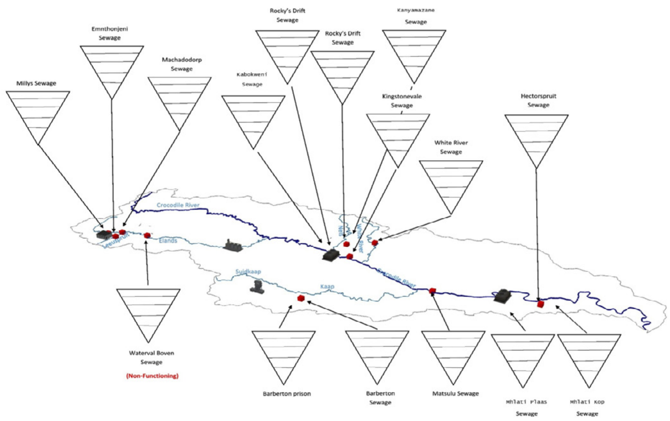
You also have industries abstracting water for their processes and releasing wastewater in the same kind of place you have urban living areas taking water from Water Treatment Works (WTW) but also discharging sewage into Wastewater Treatment Works (WTWW) which then release their outfall into the river. And it all flows downstream into the next sub catchment which then needs to take account of the upstream impacts. Here we have the Crocodile river. In some places so beautiful and in some places quite polluted and it's flowing as you see downstream into the Kruger National Park, which is our most prestigious national park and a protected area. So obviously we are wanting to improve water quality to maintain the kinds of things you want to happen in a national park. So we came in as a transdisciplinary team. I was the team leader. I got trained as an ecologist. I then became interested in water quality and then had the opportunity in South Africa to work on an emerging water law and policy and out of that varied experience I've become a transdisciplinarian. And in this case I worked with two bright energetic students one of whom



7-4. *Water quality problems in the Crocodile River. © Hugo Retief*



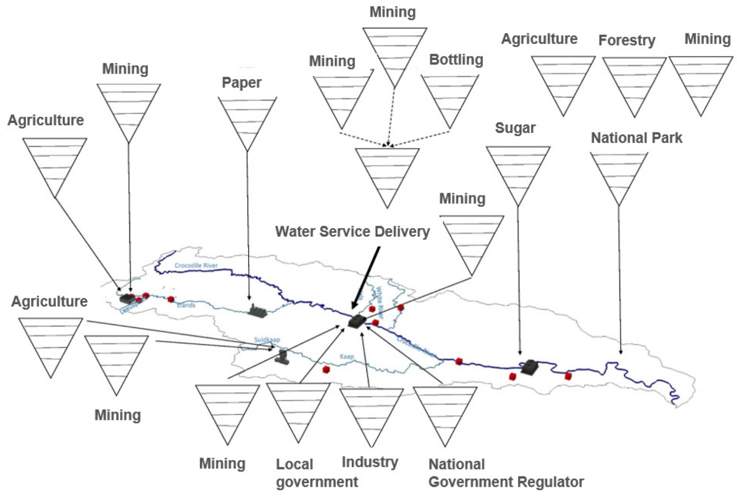
7-5. *Crocodile River view and location. © Olga Ernst (left) and Hugo Retief (right)*



7-6. *Waste-water treatment works. © Hugo Retief*

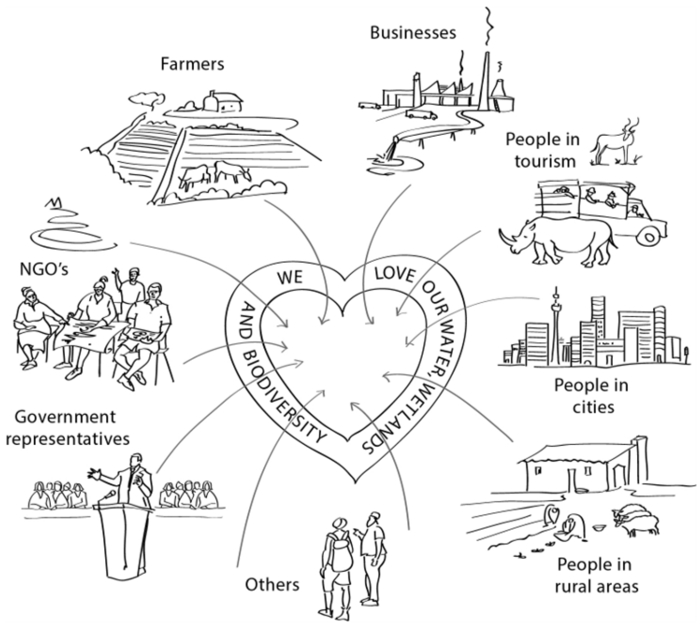
7-7. *Quarterly meetings with scientific data feedback. © IWR, Rhodes University*

Stakeholder Analysis & Mapping



7-8. *Working with industry stakeholders.* © *Hugo Retief*

7-9. *The Kruger National Park.* © *Tally Palmer*



7-10. *With stakeholders, we created a space for the possibility of water quality improvement.* © *IWR, Rhodes University*

worked in modelling. Putting the flow and the water quality together and the other of whom was working in learning and co-learning particularly with the sugar industry. And I was supported by two social scientists, one a political ecologist who was interested in the kinds of conflicts that arise when people are grappling with pollution and the other of whom was interested in collective action. And together we embarked on this engagement with stakeholders.

The first intervention was led by the political ecologist and he was working with those people who were managing wastewater treatment works in a government program called the Green Drop program which incentivised better performance of waste water treatment works. And he was able to listen to the very many challenges that are faced by people trying to manage wastewater treatment works in a developing country. And then we worked with the big boys. The people in industry, the sugar farmers, the people who ran pulp and paper industries and we gathered them together quarterly to listen to the science. To listen to this energetic student talking about the integration of flow and water quality and how these worked together and how you can't improve water quality if you also abstract all the water out of the river. The Kruger Park, this completely astonishing wilderness with all its wonderful animals, after three years the Kruger Park showed an improvement in

many of the indicators that we were worried about. The chemistry of the water, the kinds of monitoring that you do for flow and for those for the water quality indicators, also for biotic indicators. Now we can't claim that we were the influence that changed that scenario, nor that solved the problem of water quality, but that showed the trajectory towards the possibility of improvement. What we can do and what we are doing to encourage you is to say that this transdisciplinary work created a space, created the possibility of improving water quality.

Stakeholder Analysis & Mapping

7.3 Assignment 7.1

Introduction

Assignment 7.1 is an exercise that forms essential preparation for Assignment 10.1.

In this assignment you are asked to:

- identify the stakeholders relevant to the Maasvlakte 2 port expansion problem (after Jan 2005),
- categorise them according to their power and interest in the problem, and
- map their interdependencies with an eye to coalition forming.

You will need to read the information section ‘Stakeholders for the Maasvlakte 2 Expansion of the Port of Rotterdam’ by Vellinga and Slinger (2020) starting below, before continuing to the form that will take you through the analysis step by step. When you have completed your analysis, you are encouraged to consult the Feedback on Assignment 7.1 before undertaking the last part of the assignment, the self assessment.

The self assessment also has a number of steps, teaching you to critically evaluate your own work and so identify areas for improvement.

Stakeholders for the Maasvlakte 2 Expansion of the Port of Rotterdam

By Prof. (em.) Tiedo Vellinga and Prof. Jill Slinger

Large-scale infrastructure development projects such as port expansions can have significant impacts on nature, nearby cities and the hinterland. The Port of Rotterdam is located in the Rhine-Meuze delta and is an ecologically important waterway for migratory fish and birds. About 1 million people live in the vicinity of the port. With an average population density of 1317 per km², this highly urbanised area is also one of the most densely populated areas in the world. Accordingly, there are many stakeholders concerned with the expansion of the port.

Consider the nineteen stakeholder groups concerned about the Maasvlakte 2 expansion of the Port of Rotterdam listed below. Note that this list does not include all stakeholder groups, as international interests such as those of trading partners in Germany are omitted for the purposes of this assignment as are departments like customs and excise.

Port of Rotterdam Harbor Authority (PoR)

The Port of Rotterdam was concerned about a future lack of space in the port required to meet the predicted transport and industry demands (see the predicted need for space in Assignment 1.1). They were concerned that expansion of the harbor should be achieved timeously to maintain growth and their international competitive position as the largest European harbor and the 2nd largest harbor in the world. They considered that they represent the interests of the harbor and its associated industries in this drive for expansion, as well as the region of South-Holland in continuing to ensure employment. The Port of Rotterdam is the managing authority for the harbor, and has significant economic influence in the Netherlands.

Harbor and Associated Industry Employees (HIEMP)

The people employed in the harbor and its associated industries are directly affected by expansion plans. They want to retain their jobs and have a thriving region, but not at the risk of worker safety and health. They are also concerned about the effects of automation on low skilled job opportunities. They have little to no decision making power, but can act to boycott or protest when they do not agree with specific developments.

Associated Transport and Logistics Services (TLS)

The transport and logistics companies, and their employees, are generally in favour of harbor expansion as it will increase their throughput. However, harbor expansion needs to be accompanied by appropriate transport planning. This includes rail, road and inland water transport. Issues such as the modal split, congestion on the roads, sufficient rail and inland transport capacity, and the degree of automation to be applied are of concern to this group of stakeholders, who together contribute to the high cargo throughput achieved by the port.

Organised Local Industry

This is an alliance of local industries concerned about traffic congestion, availability of labour and the side effects of the proposed port expansion that might affect them negatively.

International Terminal Operators (TO)

The potential availability of space for terminal operations, able to accommodate the largest seagoing vessels, is of interest to the international terminal operators. They are concerned with how the expansion would be phased, when the land would become available, what facilities would be provided by the harbor authority, what leasing arrangements could be made, and how competition between rival companies would be handled. In short, they are interested in the economic exploitation of the potential new land, and have financial resources and influence at national and international level.

Dutch Ministry of Transport, Public Works and Water Management (MoT, RWS)

The then Ministry of Transport, Public Works and Water Management had multiple responsibilities in regard to the Maasvlakte 2 expansion of the Port of Rotterdam. First, as the ministry responsible for Transport and Public Works, it was concerned with meeting transport needs and ensuring that infrastructure of sufficient capacity is in place to meet these needs sustainably in future. It is the regulatory authority for large scale infrastructural projects. Second, it is responsible for water management policy. In particular, the executive branch of this ministry **Rijkswaterstaat (RWS)** is concerned with the flooding safety of the Netherlands and needed to ensure that hydrodynamic and sedimentary

effects would not negatively influence the stability of the Dutch coast, nor ongoing coastal management strategies, nor impact the freshwater salt water balance unduly. Reconciling these sometimes conflicting aims and its role as regulatory authority was a challenging task for the Ministry.

Ministry of Housing, Spatial Planning and the Environment (MoE)

During the time of the preparation phase of the Maasvlakte 2 port expansion, the environment portfolio fell under the Ministry of Housing, Spatial Planning and the Environment. Now the environment portfolio falls under the Ministry of Infrastructure and Water Management (together with transport, public works and water management). MoE was tasked with protecting the environment of the Netherlands, and ensuring its long term sustainability. As the regulatory authority for environment and spatial planning, the MoE is responsible for strategic planning policy in the Netherlands and sets the conditions for environmental impact assessments. The MoE is also responsible for air quality, and ultimately for emission management throughout the Netherlands. The MoE must also ensure that the environmental regulation of the European Union is carried out in the Netherlands.

Ministry of Economic Affairs (MoEA)

The Ministry of Economic Affairs is concerned with the health of the Dutch economy, employment opportunities, and internal and international trade and industry. It is also concerned with the international competitive position of the Netherlands. The proposed expansion of the Port of Rotterdam aligns strongly with the interests of this powerful ministry.

Province of South-Holland (Prov)

The Province is responsible for developing a strategic planning vision for South-Holland in line with national policy. So, in broad lines, the province determines where roads, rail, shipping routes, residential and industrial areas are located, where agriculture occurs, the extent of nature areas and which recreational facilities are available. This strategic planning vision then forms the framework with which municipalities and cities in the province must comply in their more detailed planning. The Province of South-Holland recognised and accommodated the need to expand the port of Rotterdam in their strategic planning vision, but were concerned about the effects on nature, recreation and liveability of the region.

District Water Boards (WB)

In the Netherlands, Rijkswaterstaat (RWS) and the district water boards are charged with water management. District water boards are responsible for regional waters, such as canals and local waterways. For example, they ensure that the water is clean in order to keep fish stocks up to par. The district water boards also protect the country from flooding and ensure that farmers have sufficient water for their crops. Furthermore, they are responsible for wastewater purification. In the case of the Maasvlakte 2, their interests are well represented by RWS.

City Of Rotterdam (CoR)

The City of Rotterdam has multiple interests in the proposed expansion of the Port of Rotterdam. There are increased employment opportunities which can benefit her citizens, and increased trade and industry opportunities which are also generally beneficial. However, there are many potentially negative effects. Depending on which industries are located on the new land, there are potential negative effects on air quality, noise levels, and road congestion, as well as impacts on the natural environment and the aesthetic and recreational value of the Rotterdam region. Although the new land does not lie within the City of Rotterdam, the potential negative effects, mean that the liveability of Rotterdam could be affected. As the 2^{nd} largest city in the Netherlands, Rotterdam has a greta deal of influence on political opinion.

Rotterdam Region (RR)

The Rotterdam Region is an alliance of small municipalities on the north bank of the Nieuw Waterweg (the exit channel to sea from the PoR). These municipalities have similar concerns to the City of Rotterdam. They have citizens who may benefit from new employment opportunities, but also many concerns regarding reduced liveability of the Rotterdam region. This alliance has no direct influence on the Port of Rotterdam, but can be significantly affected by decisions made regarding the expansion of the port.

Federation For Environment And Nature (N&M - Natuur en Milieufederatie)

The Federation for Environment and Nature is concerned about the quality and health of the natural environment, also in urban areas. They are interested in ecosystem protection, but also in targeted species protection, and in sustainable recreation. They considered that the proposed extension of the port should not be

at the cost of ecosystem quality, nor at the cost of human health and enjoyment of the natural environment. They can raise their concerns in response to the expansion plans and together with other environmental organisations are prepared to launch court cases against the expansion should their concerns not be researched nor taken seriously.

Concerned Citizens of Voorne (VBV - Verontruste Burgers van Voorne)

This is an alliance of residents of a small town just south of the proposed expansion. The citizens are interested in maintaining or improving the liveability of their town and surrounding area. They are deeply concerned about traffic congestion, increased air and noise pollution and reduced natural areas with concomitant effects on the natural environment e.g. reduced bird numbers. They are prepared to launch court cases against the expansion should their concerns not be researched nor taken seriously.

South-Holland Landscape Foundation (ZHL - Zuid-Hollands Landschap)

This is an environmental organisation concerned with the natural environment, its biodiversity and cultural integrity. So, they are interested in conserving and enhancing the extent, connectedness, and authentic regional character of the natural environment as well as preserving the cultural heritage of the South-Holland region. They are prepared to negotiate about the character of new land, but are also concerned about the archeological heritage. They have knowledge and influential members and could launch court cases against the expansion should their concerns not be taken into account.

Foundation for Dune Protection (SD - Stichting Duinbehoud)

Dunes occur naturally on the sandy Dutch coast, forming a smooth transition between sea and land that is ecologically beneficial. The Foundation for Dune Protection is active along the Dutch coast, seeking to protect dune landscapes. Because dunes are exposed to high nitrogen dioxide levels (pollution from industry and traffic), they experience higher density vegetation growth than would occur naturally. This tends to fix the sand in place, and reduce the incidence of young, pioneer dunes. The Foundation for Dune Protection is concerned with maintaining naturalness in dune landscapes, and their characteristic ecosystems. They also educate people about dunes, and seek to increase the area of dunes along the coast. They support sustainable recreation in dune landscapes.

Friends of the Earth NL (MD - Milieudefensie)

The Friends of the Earth are an ecological pressure group striving to maintain and improve environmental quality. They are particularly interested in air quality emissions from the harbour and its industries and concerned to achieve reductions in emissions. They consider the proposed location of a coal-fired power station on the Maasvlakte 2 an anathema. They are prepared to fund their own scientific studies, contest current monitoring of air pollution, and can mobilise public opinion to oppose the port expansion should the environmental issues not be addressed comprehensively.

Non-Governmental Fisheries Organisation (FO)

This is an alliance of fishermen whose livelihoods would be affected by the proposed port expansion. They would lose fishing grounds for which they had trawl fishing permits. They are interested in direct monetary compensation for their loss of income, but also in arrangements for the future so that they could fish sustainably in the area. They are also interested in fishing innovations. They could have recourse to the European Union should their concerns not be addressed well.

The Fauna Conservation Foundation (DF - De Faunabescherming)

The Fauna Conservation Foundation is interested in the habitat loss to birds, fish and reptiles owing to the proposed expansion. They are also interested in active protection of fauna within the existing harbour area. So, they are concerned to achieve an integrated conservation plan for fauna in the harbour. This foundation requires that adequate studies are undertaken and that action and monitoring of the status of animals in the port should occur. They could also have recourse to the courts should nature conservation and conservation of threatened species not be taken seriously.

Assignment 7.1

You can find the form that will take you through the analysis step by step in the next section. Once you have completed the analysis you can assess Assignment 7.1.

Enjoy completing the assignment.

Assignment 7.1: Identifying and Mapping Stakeholders

By Prof. Jill Slinger and Prof. (em.) Tiedo Vellinga

Introduction

In this assignment you will first identify the stakeholders relevant to your Building with Nature design problem, then categorise them according to their power and interest in the problem, and finally identify the interdependencies of stakeholders with an eye to coalition forming.

The first step in a stakeholder analysis involves generating a list of people or organisations that in some way relate to the complex problem. Perhaps no individual or organisation has the required means to solve the complex problem and hence they need to be aware of the interests and objectives of other stakeholders who are involved with the problem, have some of the means to solve the problem, or are affected by the solutions adopted (Enserink, Hermans, Kwakkel, Thissen, Koppenjan & Bots, 2010).

You would normally begin by identifying at least 10 stakeholders and noting them down in a list. You would include individuals, teams, groups, departments, organisations, ministers, directors, or local communities that have an interest in the problem, or its solution.

Because the majority of participants are unfamiliar with the Dutch system of governance, for this assignment we have made a long list of 19 stakeholders for you. You can read about the interests, responsibilities and resources of the stakeholders in the section entitled 'Stakeholders for the Maasvlakte 2 Expansion of the Port of Rotterdam' by Vellinga and Slinger (2020).

Now, assume that it is after January 2005 and the objections to the proposed Maasvlakte 2 expansion of the Port of Rotterdam, already approved by the Dutch parliament, have been upheld in court. It is **your task to identify and map stakeholders that you consider relevant in re-starting the planning process,** given the diagnosis undertaken in Assignment 6.1 (Question 3) that the strategy 'Institute mediated, participatory interactive analysis to negotiate shared knowledge upon which the solutions can be based' is required.

Step 1 – Determining Key Stakeholders

Which are the key stakeholders? In other words, identify who you consider needs to be included and listened to in the new process?

Choose between 8 and 12 stakeholders from the long list of 19 stakeholders as your initial list of key stakeholders and write them in the left hand column of Table 7-11. Now, consider clustering stakeholders with very similar objectives. For instance, if you have named three non-governmental organisations (NGO's) active in environmental protection, consider clustering them into one stakeholder group - Environmental NGO's. Finally, shortlist 6 to 8 stakeholders or stakeholder groups that you consider most relevant to the problem situation in the right hand column of Table 7-11. You can indicate the members of stakeholder groups in brackets after the group name using their abbreviations e.g. Flood safety (RWS, WB). This is then your preliminary list of key stakeholders.

In a real situation, you would consult documents, interview key people and ask each of the contact people of your preliminary list of key stakeholders who they consider should be included. You repeat this question with all key stakeholders, and those they suggest inviting until you get no new suggestions. This process is called snowballing and provides an effective means of identifying potential stakeholders.

In this case, you cannot conduct such a review of your preliminary list. Instead, you are asked to reread the stakeholder document and check that you are satisfied with your selection of key stakeholders, before moving on to Step 2.

Initial List of Key Stakeholders	Key Stakeholders
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

7-11. Table for Step 1: Key Stakeholders

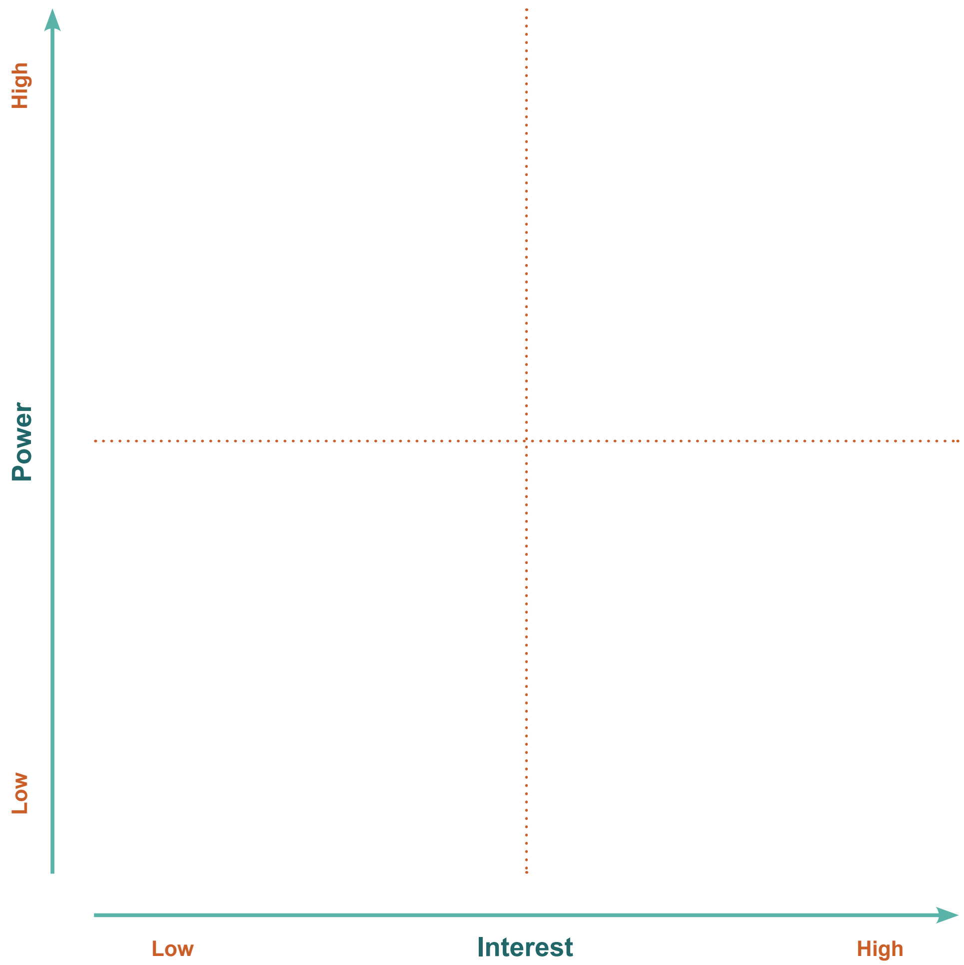
Step 2 – Power-Interest Grid

Which of the stakeholders are highly interested in the situation and have the power to influence it? Alternatively, who has a great deal of interest, but no power or influence? And, who has power, but no interest in the situation? The answer to these questions is depicted in a Power-Interest grid.

You will need to have watched the introductory video by Dr. Alexander de Haan in 7.2. Stakeholders and the Power-Interest Grid before attempting to complete Step 2. He explains how to categorise stakeholders based on their power and interest in the problem situation.

Now, take your key stakeholders from Step 1, and position them one by one in the Power-Interest grid in figure 7-12 by considering their 'power' and 'interest'. The vertical axis is the power axis. The higher up the axis, the more power you consider the stakeholder to have in regard to your complex situation. The horizontal axis is the 'interest' axis. The more to the right, the more interest you consider the stakeholder to have regarding the problem. Position each of your stakeholders in the quadrants depending on their Power and Interest.

Notice that the stakeholders located in the upper right quadrant are committed – they have high interest and high power. They are key players. Stakeholders with high interest and little power (lower right quadrant) are termed subjects – decisions are made that affect them, but they often have little influence on decision making. This is in contrast to the stakeholders in the upper left quadrant who have high power and influence, but who have little direct interest in the problem situation. They are termed the context setters. The stakeholders in the lower left quadrant are termed the crowd.



7-12. Step 2: Power-Interest Grid

Step 3 – Identifying Actor Resources

What does it mean to have power and influence? What are the resources that stakeholders possess?

Resources are the formal and informal means that are available to stakeholders to attain their objectives (Enserink et al., 2010). For example, formal resources can be authority (power of decision, licensing) and instruments (money, subsidies, or taxes) while informal resources can include information, local knowledge, manpower, organisation (ability to mobilise people or resources), and so on.

Now list the resources associated with the key stakeholders you identified in Step 1, and positioned on the PI-grid in Step 2. Consider whether important resources (such as funding for a potential solution or the authority to issue permits) are omitted. If so, you may want to modify your list of key stakeholders to include the stakeholders who control those resources in table 7-13 (and on the PI-diagram). Note that all the stakeholders having high power and interest (the key players) should be in your final list of key stakeholders.

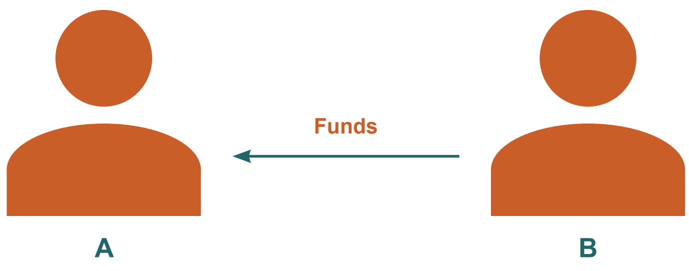
Key Stakeholder	Important Resources
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

7-13. Table for Step 3: Resources of Key Stakeholders

Step 4 – Visualising Resource Dependencies

What are the interdependencies amongst stakeholders?

A stakeholder A is said to be resource dependent on stakeholder B, if B through their actions can enable (or prohibit) A to achieve objectives. The figure below shows that A is resource dependent on B for funds since the resources flow from B to A.



For Step 4, map the flow of resources (identified in Step 1) among stakeholders in the box provided below. Please make sure to label both the stakeholder and the resource (on the arrows) as in the example.

Now identify the stakeholder(s) who are the least resource dependent (only, or the most outgoing arrows) and those who are the most resource dependent (only, or the most incoming arrows). This gives you an insight into which stakeholders hold key resources to either solve or block the problem solution. Also consider groups of stakeholders who are mutually dependent on each other, or who by sharing resources could increase their power and influence in the problem.

These insights are a first step in exploring options for coalition forming.

7-14. *Step 4: Visualising Resource Dependencies*

References

Enserink, B., Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., & Bots, P. (2010). *Policy Analysis of Multi-Actor Systems.* Lemma.

Self-Assessment

When you have finished the assignment, we advise you to consult Feedback on Assignment 7.1 in Section 7.6 immediately before undertaking the self assessment (Part 2 of this Assignment).

In this feedback section you can view the model answer. Then compare your answer to ours, bearing in mind that there is no one correct answer, and check:

Step 1: Determining key Stakeholders

Have you considered and ranked at least 6 key stakeholders in the right hand column of Table 1 in the Form for Identifying and Mapping Stakeholders?

Poor: **Less** than 6 key stakeholders are identified, and/or they are not key to the start of the new process for Maasvlakte 2 port expansion.
Fair: **At least** 6 key stakeholders have been identified, but they are not grouped sensibly, and/or they do not span the interests at stake in starting the new process for the Maasvlakte 2 port expansion, and/or the overlap with the model answer is minimal.
Good: **6 to 8** key stakeholders are identified, and are grouped sensibly e.g. Environmental NGO's, Port Expansion Coalition, and/or are similar to the model answer

Step 2: Power-Interest Grid

Have you positioned your key stakeholders appropriately on the Power-Interest grid?

Poor: **Not all** key stakeholders identified in Step 1 are positioned on the Power-Interest grid, and/or the Port of Rotterdam is **not** in the upper right quadrant, and/or there are **less** than 3 key stakeholders in the upper right quadrant, and/or there are **no** key stakeholders in the lower right quadrant.
Fair: **All** key stakeholders identified in Step 1 are positioned on the Power-Interest grid, and the Port of Rotterdam is located in the upper right quadrant, and/or there are at **at least** 3 key stakeholders in the upper right quadrant, and/or there is **at least** 1 key stakeholder in the lower right quadrant.
Good: **All** key stakeholders identified in Step 1 are positioned on the Power-Interest grid, and the Port of Rotterdam is located in the upper right quadrant, and there are 4 key stakeholders in the upper right quadrant, and there is **at least** 1 key stakeholders in the lower right quadrant.

Steps 3 & 4: Mapping stakeholder interdependencies

Have you listed some of the resources of the key stakeholders in Table 7-13 and then mapped their resource-dependence appropriately in a diagram?

Poor: The resources of **only some** of the key stakeholders identified in Step 1 are listed in Table 7-13, and/or not all key stakeholders appear in the diagram, and/or the arrows are not labelled, and/or the arrows go in the wrong direction.
Fair: The resources of **most** of the key stakeholders identified in Step 1 are listed in Table 7-13, and **all** key stakeholders appear in the diagram, and /or **most** of the arrows are labelled, and/or **most** of the arrows go in the correct direction.
Good: The resources of **all** of the key stakeholders identified in Step 1 are listed in Table 7-13, and **all** key stakeholders appear in the diagram, and the arrows are labelled, and the arrows go in the correct direction.

7.4 Issues of Scale

Video: Issues of Scale

In this video, presented by **Prof. Jill Slinger**, she will introduce the issue of scale in designing and implementing Building with Nature innovations. The video is written by **Jill Slinger** and **Heleen Vreugdenhil** and was produced for use in a standard teaching course within Delft University of Technology, and she therefore addresses the viewer as “an engineer”. For this book, the term engineer can be understood to be all of you - course participants interested in nature based engineering and planning.

In the video, she uses an example from Dutch coastal policy and management to illustrate how the disciplinary background and tasks of actors can influence their scale preferences, and explains the Analytical Scale Hierarchy for Sandy Coasts (Vreugdenhil et al., 2010).

You can cite the video as:

(Adapted from) Slinger, J.H. (Jill); Vreugdenhil, H.S.I. (Heleen) (2015) Building with Nature video #12 - Issues of Scale in Building with Nature @ TU Delft 2015. 4TU.Dataset. http://dx.doi.org/10.4121/uuid:6209da77-4774-46fc-83a5-9fbe11fba1b6

Video Transcript

Presented by Prof. Jill Slinger

In this knowledge clip, we'll focus on issues of scale. But why is scale so important? Because you always face choices on scale. In this clip we offer you an analytical tool that can help to clarify scale preferences of members of a multidisciplinary design team or even of your client.

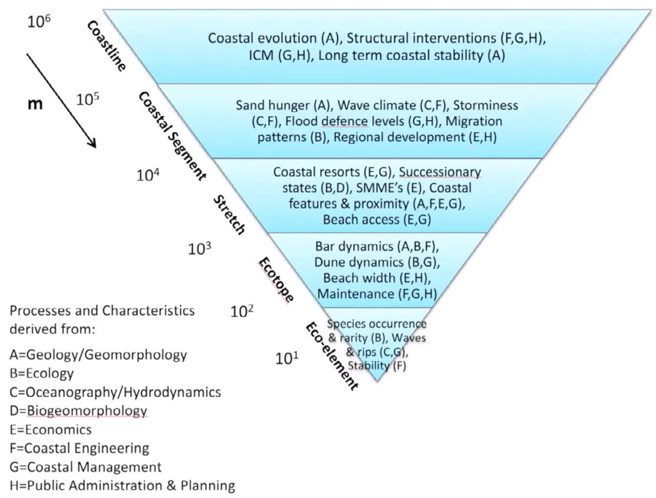
An infrastructural design project is typically presented at a particular scale usually the scale of the client or problem owner. For instance, the dredging of silt from a harbor is often presented as a problem at the local scale of the harbor and of its immediate environment. Or the construction of a small dam for agricultural water is seen as only having a local effect. But a little farm dam, together with other small dams can have a big impact - at the river base in scale. It can contribute to urban water shortages and even have an impact on the natural environment downstream. This is happening in the Great Brak River in South Africa and in many such examples in South Africa, Australia and in California.

So, although it's very tempting to solve problems at the scale at which they're presented, it's the task of the engineer to sometimes broaden the scale and at other times to zoom in on the problem. To be a good engineer, it's essential to know when to zoom in or to zoom out, and this means that you know exactly at which scale you have to build your design. Since we're following the Building with Nature philosophy, this means that the materials we're going to use or the opportunities that we're going to provide for nature often require a scale different from the scale of the problem owner.

So, for instance Heleen Vreugdenhil studied the application of a Building with Nature concept called Cyclic Floodplain Rejuvenation along the River Waal in the Netherlands. She found, that the personal scale preferences of the stakeholders determined where the morphological intervention was implemented. Basically, a secondary channel was dug, on the floodplain near Beuningen, in an effort to rejuvenate the vegetation and to reduce the danger of flooding. Another place that could have worked to reduce the danger of flooding wasn't even considered seriously, owing to issues of scale. You can read more about this in the prescribed literature.

In another example I analysed the scale preferences of a range of stakeholders involved in implementing the 1990 Dutch coastal policy. This policy seeks to prevent the structural erosion of the Dutch coast by dynamically maintaining the coast at the 1990 position. This is done primarily through sand nourishments. Now I want you to have a close look at this diagram, the Integrated Scale Hierarchy for Sandy Coasts.

7-15. *Cyclic Floodplain Rejuvenation, Beuningen, Netherlands. © Stichting Ark*

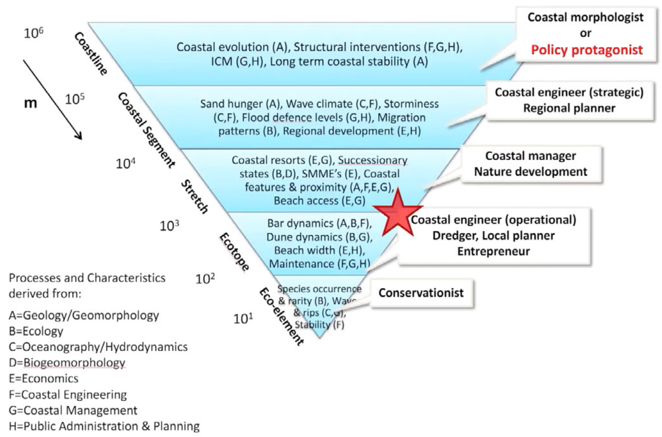


7-16. *Integrated Scale Hierarchy for Sandy Coasts. Ⓒ Jill Slinger*

On the left-hand side you can see the spatial and timescales associated with a biogeomorphology of the coast, within the different layers of the diagram the processes and the characteristics deriving from different disciplines are listed and are signified by letters. The Integrated Scale Hierarchy for Sandy Coasts is an instrument that shows you on the one hand, the bigeomorphological scale for the coast and on the other hand the different scales adopted by the different actors. So, for instance a geologist characteristically considers longer timescales and more extensive spatial scales than most other disciplines. They see factors like Coastal Evolution, Sand hunger, Bar dynamics but they don't necessarily see waves and rips.

I found that it is the combination of people's disciplinary training and their tasks in coastal management that determine the scale at which they prefer to focus. The tasks in coastal management and policy implementation of the people that I interviewed are shown in the boxes on the right-hand side (Fig 7-17).

This analysis, reveals that the coastal policy was designed with a geomorphological scale perspective in mind. Have a look at the place of the red coastal protagonists at the top - at a very high scale level. But when it came to implementation, people with different, more local or regional perspectives were involved, indicated by the red star. This resulted in local adaptations to the policy and to regional differences in implementation. Using the Integrated Scale Hierarchy for Sandy coasts, you can show this. Let me be clear here, I consider



7-17. Integrated Scale Hierarchy for Sandy Coasts with actors. © Jill Slinger

this modification a strength of the policy implementation process. It's exactly this fine tuning - that makes the policy implementable. If you stick to the letter of the policy rather than the spirit, it's difficult to implement well, especially together with all the local and regional authorities.

So, in the example from Beuningen and from the Dutch coastal policy, we encountered differences in stakeholders opinions. These differences arise not only from the disciplinary training but also from the tasks such as being a river manager or nature manager. So, two ecologists can have very different opinions on

the desirability of a natural intervention, and for instance two engineers can completely disagree on the desirability of sand nourishments. In working with nature, we have found that it is the combination of actors tasks and disciplinary backgrounds that either gives them an affinity for the Building with Nature concept or not.

But what does this mean for you as a hydraulic engineer? Well, to be a good hydraulic engineer you need to know when to zoom in and when to zoom out, the Integrated Scale Hierarchy helps you to choose an appropriate scale for your design. It's also an excellent instrument for comparing the different views of different actors.

The Influence of Scale Preferences on the Design of a Water Innovation: A Case in Dutch River Management

In the previous video, **Prof. Jill Slinger** illustrated the issue of scale in designing and implementing Building with Nature innovations in Dutch coastal policy and management. She mentioned the work of **Dr. Heleen Vreugdenhil**, who found that the personal scale preferences of the actors involved in the design of a nature-based innovation along a Dutch River influenced the decisions made.

You can read about how this happened via the link or QR code on this page, which takes you to the journal publication. You learn that the disciplinary background and assigned tasks of people influence which designs they prefer. Central to the analysis is the understanding that the nature-based measures - here termed Cyclic Floodplain Rejuvenation - are themselves associated with a bio-geomorphological disciplinary view and often have a preferred scale of application.

Read about the development of the Integrated Scale Hierarchy for Rivers below, before applying it to diagnose potential scale mismatches in Assignment 7.2.

You can cite the paper as:

Vreugdenhil, H., Slinger, J.H., Kater, E. (2010). The influence of scale preferences on the design of a water innovation: A case in Dutch river management. *Environmental Management* 46(1): 29-43. URL : http://dx.doi.org/10.1007/s00267-010-9565-4

7.5 Assignment 7.2

This assignment is based on the journal paper ‘The influence of scale preferences on the design of a water innovation: A case in Dutch river management’ by Vreugdenhil et al. (2010). If you have not yet read this article then you are advised to return to the previous section before attempting Assignment 7.2.

There are 6 questions in Assignment 7.2, and four of the questions are more complex.

Good luck in completing the assignment, and remember to consult the Feedback on Assignment 7.2 when you are finished.

Assignment 7.2

In this section you will find the questions as described in the introduction.

To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

To answer, check as many boxes as you consider appropriate.

When moving from a lower to a higher scale level (scaling up) in an environmental system:

- ☐ more information on the context becomes available
- ☐ spatial patterns and relationships become less obvious
- ☐ more detailed information becomes available
- ☐ the relevant time scales become longer

Show Answer

Question 2

To answer, check as many boxes as you consider appropriate.

Vreugdenhil et al. (2010) distinguish eight disciplinary and managerial scale perspectives on rivers. Which of the following statements are **true** regarding these scale perspectives?

- ☐ the geological, ecological, hydrological and bio-geomorphological scale perspectives are universally applicable
- ☐ the geological, ecological and hydrological scale perspectives are universally applicable, but the geo-morphological perspective is specific to the Netherlands
- ☐ the managerial scale perspectives are generally applicable
- ☐ the river engineering perspective is generally applicable, but the other managerial perspectives are country-specific
- ☐ all of the disciplinary and managerial perspectives are generally applicable

Show Answer

Question 3

Check only one answer.

The operational river managers in the Beuningen/Ewijk pilot study had a preference for:

- ○ the river basin or catchment scale
- ○ the river segment scale
- ○ the river reach scale
- ○ the ecotope (e.g. floodplain) scale
- ○ the eco-element scale

Show Answer

Question 4

Check only one answer.

In the Beuningen/Ewijk pilot study, which of the following actors held a scale perspective matching well with the bio-geomorphologic scale underlying the cyclic floodplain rejuvenation (CFR) concept?

- ○ River basin planner
- ○ Regional planners e.g. the Province of Gelderland
- ○ Entrepreneur e.g. a sand mining company
- ○ Conservationists e.g. the forestry authority
- ○ Local planners e.g. the Municipality of Beuningen
- ○ None of the above

Show Answer

Question 5

To answer, check as many boxes as you consider appropriate.

Mismatches in the scale preferences of the actors in the Beuningen/Ewijk pilot project impacted the design of potential interventions by:

- [ ] constraining the size of the potential intervention to prevent effects on navigation
- [ ] avoiding complexity by limiting the number of actors involved
- [ ] connecting the intervention to similar actions elsewhere
- [ ] considering interventions on nearby or downstream floodplains
- [ ] limiting the location to the floodplain at Beuningen/Ewijk

Show Answer

Question 6

To answer, check as many boxes as you consider appropriate.

The Integrated Scale Hierarchy for Rivers has a bio-geomorphological scale on the left hand side, with the major processes and characteristics of interest from the different disciplinary and management perspectives indicated at each of the levels. By projecting the scale perspective of actors onto the right hand side of the diagram you can:

- [ ] portray the scale requirements associated with an innovative bio-geomorphic concept (e.g. a proposed Building with Nature innovation)
- [ ] contrast the perspective of a specific actor with the scale perspectives of other actors
- [ ] identify the best scale perspective for designing and implementing the innovation
- [ ] identify whether the scale preference of a specific actor fits with the scale perspective required by the innovation
- [ ] explore potential changes in scale perspective on the part of actors to improve the fit with the innovative concept

Show Answer

7.6 Feedback

Feedback on Assignment 7.1

The feedback on Assignment 7.1 is provided in 2 parts:

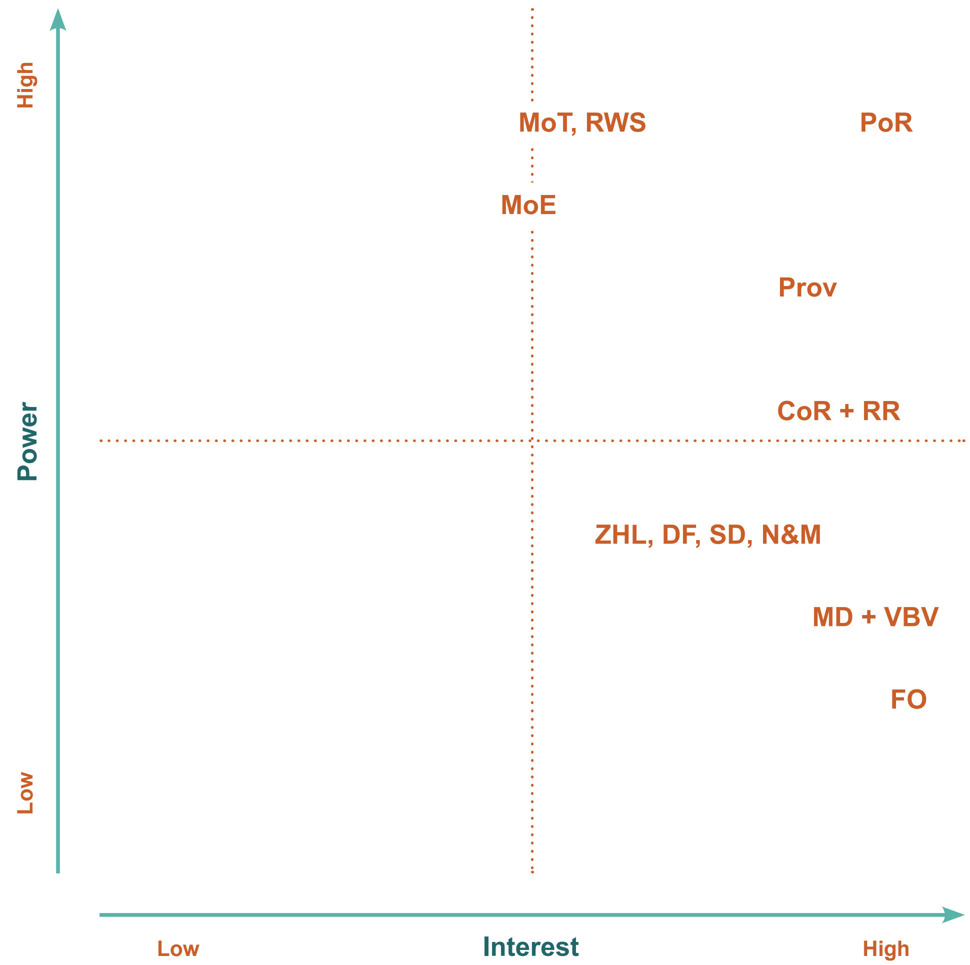
1. The 1st section is a model answer that you need to consult for the self assessment.
2. The 2nd section is a description of the actual agreements made with stakeholders for the Maasvlakte 2 port expansion.

Model answer for Assignment 7.1

Step 1: Determining key stakeholders

	Initial List of Key Stakeholders	Key Stakeholders
1.	Port of Rotterdam harbor authority (PoR) / Ministry of Economic Affairs (MoEA) / Associated transport and logistic services (TLS)	Port of Rotterdam harbor authority (PoR **+ MoEA, TLS**) – focussed on economic interests associated with port expansion
2.	Dutch Ministry of Transport, Public Works and Water Management (MoT, RWS) / District Water Boards (WB)	Dutch Ministry of Transport, Public Works and Water Management (MoT, RWS **+ WB**)
3.	Ministry of Housing, Spatial Planning and the Environment (MoE)	Ministry of Housing, Spatial Planning and the Environment (MoE)
4.	Province of South-Holland (Prov)	Province of South-Holland (Prov)
5.	City of Rotterdam (CoR)	Rotterdam City & Region (**CoR + RR**) – focussed on liveability & employment
6.	Rotterdam Region (RR)	Environmental NGO's (**ZHL, DF, SD, N&M**) – focussed on conservation, nature development & sustainable recreation
7.	South-Holland Landscape Foundation (ZHL) / Foundation for Dune Protection (SD)	Air Quality Alliance (**MD + VBV**) – focussed on reducing emissions, improving environmental quality
8.	The Fauna Conservation Foundation (DF)	Non-Governmental Fisheries Organisation (FO)
9.	Friends of the Earth NL (MD)	
10.	Federation for Environment and Nature (N&M)	
11.	Non-Governmental Fisheries Organisation (FO)	
12.	Concerned Citizens of Voorne (VBV)	

Step 2: Power-Interest Grid



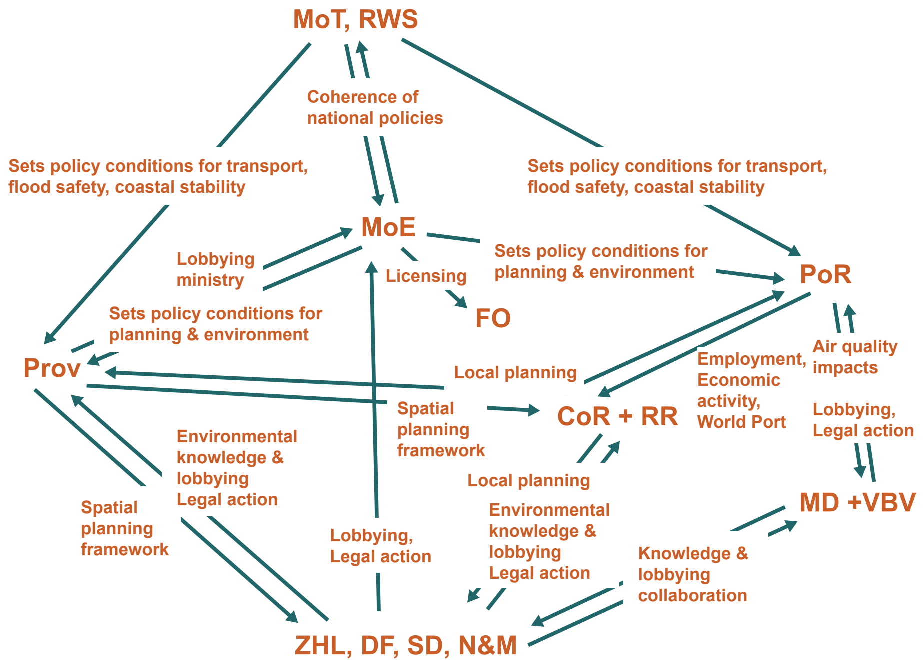
Step 3: Identifying actor resources

	Key Stakeholder	Important Resources
1.	Port of Rotterdam harbor authority (PoR **+ MoE, TLS**) – focussed on economic interests associated with port expansion	• Financial Resources, Major regional employer • Influence at highest government level • Represents a broad alliance of harbour, industry and associated services • Impose environmental conditions on harbour users and industry, World port
2.	Dutch Ministry of Transport, Public Works and Water Management (MoT, RWS +**WB**)	Set policy conditions for transport, flood safety, coastal stability
3.	Ministry of Housing, Spatial Planning and the Environment (MoE)	Set policy conditions for spatial planning and environmental management
4.	Province of South-Holland (Prov)	Set spatial planning framework in accord with policy to ensure liveability in the province

Table continues on next page

	Key Stakeholder	Important Resources
5.	Rotterdam City & Region (**CoR + RR**) – focussed on liveability & employment	Impose local level environmental, recreational, transport and industrial conditions in accord with provincial and national policy, Influential city
6.	Environmental NGO's (**ZHL, DF, SD, N&M**) – focussed on conservation, nature development & sustainable recreation	Environmental knowledge, Local knowledge, Committed members, Lobbying, Influence public opinion/ Protest, Formulate environmental and recreational design elements, Recourse to court
7.	Air Quality Alliance (**MD + VBV**) – focussed on reducing emissions, improving environmental quality	Environmental knowledge, Local members, Influence Public opinion, Recourse to court, Lobbying, Emissions monitoring experience
8.	Non-Governmental Fisheries Organisation (FO)	Existing fishing licenses, Recourse to court, Recourse to EU

Step 4: Visualising resource dependencies



What Happened in Reality? Maasvlakte 2 Agreements with Stakeholders

By Prof. (em.) Tiedo Vellinga, Dr. Poonam Taneja and Prof. Jill Slinger

After January 2005, a new process for the Maasvlakte 2 port expansion was initiated in which stakeholders and their values were placed centrally, as described in the video 'Deltas and Ports of the Future' by Tiedo Vellinga. This process led to a number of agreements with stakeholders, which are described hereafter in chronological order in terms of: (i) the parties, (ii) the aims, and (iii) the contents of the agreements. You will notice that most of the parties to the agreements are contained in the long list of 19 stakeholders provided to you in Assignment 7.1. In Assignment 7.1, you were asked to identify and map the stakeholders relevant to re-instigating the Maasvlakte 2 port expansion process after the January 2005 court ruling. In reality, this aspect of the process culminated in the Vision and Trust agreement signed by a broad range of stakeholders in January 2008. The agreements on the Sustainable Voordelta, Sustainable Maasvlakte, and Sea Birds Maasvlakte 2 deal with specific issues alongside the broader value-based Vision and Trust agreement. Following the construction of the Maasvlakte 2, agreements were also been made with the international terminal operators and other exploiters of the new land regarding the level of automation employed, the modal split and the carbon neutrality of the Maasvlakte 2. The set of stakeholders involved in these exploitation agreements differs from the stakeholders involved in the Vision and Trust agreement.

Another aspect worth noting is the scale of the stakeholder analysis and mapping undertaken on the Massvlakte 2 port expansion. We chose to focus at the scale of the Rotterdam region and its significance to the Dutch economy. This means that effects at the international scale e.g. trade with Germany, competition with the harbor of Antwerp, and potential ecological effects on the Wadden Sea or the Belgian coast have not been considered. In reality, these effects were taken into account in the actual decision making, demonstrating that innovative Building with Nature infrastructures will always require analysis and decision making at multiple nested scales.

1. Vision and Trust Agreement (Jan 2008)

Parties

- Dutch Ministry of Transport, Public Works and Water Management
- Ministry of Housing, Spatial Planning and the Environment

(Now the environment falls under the Ministry of Infrastructure and Water Management)
- Ministry of Economic Affairs
- City of Rotterdam
- Province South-Holland
- Rotterdam Region (alliance of smaller municipalities in the Rotterdam region)
- Federation for Environment and Nature (Natuur en Milieufederatie)
- South-Holland Landscape Foundation (Zuid-Hollands Landschap)
- Foundation for Dune Protection (Stichting Duinbehoud)
- Organised Local Industry
- Port of Rotterdam (harbour authority).

Aim

The purpose of this agreement was to monitor and control the sustainability concept which combines improvement of the liveability with the port expansion.

Agreement

The agreement comprised 35 detailed commitments between the stakeholders / parties to the agreement. The commitments concerned the following:

- Sustainable construction and exploitation
- Efficient use of space with stepping stones for nature and dedicated space for extensive and intensive beach recreation.
- Modal split: a maximum of 35 % transport by road from the new port area to the hinterland
- Strict emission control: no net increase in noise and air quality pollutants.
- Compensation of the effects on nature caused by the Maasvlakte 2: realisation of a dedicated marine protection area, ten times the area of the port expansion, in which trawl fishing is prohibited and there are bird islands.
- Compensation of the effects on nature caused by the use of the new port area through the creation of 35 hectares of new dunes.

- Creation of 750 hectares of additional public green space for recreation (and nature) close to the city of Rotterdam, to improve the liveability of the region.
- A number of projects to intensify the use of the existing port area and to improve its environmental quality and the liveability of the surrounding areas.
- Yearly reporting on the monitoring and evaluation of the outcomes to the Assurance Committee (Tafel van de Borging) with its representatives from the signatories of the signing parties and an independent chair.

Participating objecting parties agreed to refrain from further legal procedures against the plans and the realisation of the Maasvlakte 2.

2. Sustainable Voordelta Agreement (Jan 2009)

Parties

- Dutch Ministry of Transport, Public Works and Water Management
- Ministry of Housing, Spatial Planning and the Environment (Now the environment falls under the Ministry of Infrastructure and Water Management)
- Ministry of Economic Affairs
- Non-Governmental Fisheries organisation
- A Nature Conservation Organisation
- Port of Rotterdam harbor authority.

Aim

To compensate the fishing industry for the loss of fishing area due to the realisation of the new port area and the banning of trawl fishing in an area ten times that of the port expansion and to balance ongoing fishing activities and nature conservation objectives.

Agreement

Detailed arrangements for the full financial compensation of the fishermen who could provide proof of loss of income. The fishing activities still allowed within and outside the bird migration season and a fund to develop technology for sustainable fishing.
The fishing industry agreed to withdraw their appeal in court against the planned port expansion and instead to cooperate in the realisation of the plans, provided the agreed detailed arrangements were carried out.

3. Sustainable Maasvlakte Agreement (March 2009)

Parties

Friends of the Earth NL (Milieudefensie) and Port of Rotterdam Authority.

Aim

Air quality improvement and emissions reduction.

Agreement

Joint research on further air quality improvement towards a 10% lower target for the emission ceiling and the commitment of the Port of Rotterdam harbour authority to act to realise the identified and mutually agreed additional measures. Friends of the Earth NL agreed to withdraw their appeal in court against the plans and instead agreed to cooperate in the realisation of the plans.

The complicating situation preceding this agreement was that it started with a negative relationship between parties. Friends of the Earth NL had started an advertising campaign to fund the legal costs of protesting against the port expansion plans (Figure 1). To bring the opposing parties together, an independent mediating party was engaged.


Press release FOE Netherlands 2008

Rotterdam AD

Milieudefensie wil megazaak tegen Maasvlakte

ROTTERDAM
Milieudefensie vraagt duizenden Rotterdammers mee te procederen tegen de aanleg van de Tweede Maasvlakte. Rotterdammers die dit steunen, moeten geld doneren aan de milieubeweging om de proceskosten te betalen.

FOE Netherlands wants mega courtcase against Maasvlakte 2

It asks thousands of Rotterdam citizens to join a legal procedure against the construction of the port expansion Maasvlakte 2 and asks them to donate money to FOE Netherlands to pay for the cost of the legal procedure

7-18. Report that Friends of the Earth (FOE) were seeking to fund legal proceedings against the port expansion.

4. Sea Birds Maasvlakte 2 Agreement (May 2009)

Parties

The Fauna Conservation Foundation (De Faunabescherming) and Port of Rotterdam Authority.

Aim

To curtail the series of court cases about protected birds in the port area and to make lasting arrangements for the conservation of a substantial population of protected bird species (e.g. black-backed gull and tern) that would lose natural habitat through the port expansion.

Agreement

Arranging for the co-existence of port activities and bird resting and nesting areas for a population of protected birds (a population of 10 000 or so). The Port Authority committed themselves to making 100 hectares of dedicated bird habitat available on a yearly basis. This habitat can change location over time – the arrangement is flexible, but the quality and size of the habitat is not. They also committed to investing in physical and knowledge infrastructure for bird management. The Fauna Conservation Foundation agreed to withdraw their court appeal against the expansion plans and instead to cooperate in the realisation of the plans, and the accompanying agreements on sea bird habitats and population numbers.

5. A Non-realised Agreement

Extensive negotiations took place between Port of Rotterdam Authority and the Concerned Citizens of Voorne (Verontruste Burgers van Voorne). The citizens resident in an urban area neighbouring the port did not agree with the final expansion plans and proceeded to appeal the expansion in court. Their main reason for continuing to protest the expansion was concern regarding the effects on local noise levels and the increased traffic volumes on local roads. No agreement was reached. However, the appeal of the Concerned Citizens of Voorne was dismissed in court and the Maasvlakte 2 expansion of the Port of Rotterdam went ahead.

Feedback on Assignment 7.2

Question 1

When moving from a lower to a higher scale level (scaling up) in an environmental system:

- [x] more information on the context becomes available
- [ ] spatial patterns and relationships become less obvious
- [ ] more detailed information becomes available
- [x] the relevant time scales become longer

Comments on Question 1

Vreugdenhil et al. (2010, pg 30, last paragraph) follow Jewitt (1998) in stating that when moving from a lower to a higher level (scaling up), less detail and more information on the context becomes available. In moving from a higher to a lower level (scaling down), more detailed information becomes available and patterns and relationships become less obvious.

Question 2

Vreugdenhil et al. (2010) distinguish eight disciplinary and managerial scale perspectives on rivers. Which of the following statements are **true** regarding these scale perspectives?

- [x] the geological, ecological, hydrological and bio-geomorphological scale perspectives are universally applicable
- [ ] the geological, ecological and hydrological scale perspectives are universally applicable, but the geo-morphological perspective is specific to the Netherlands
- [ ] the managerial scale perspectives are generally applicable
- [ ] the river engineering perspective is generally applicable, but the other managerial perspectives are country-specific
- [ ] all of the disciplinary and managerial perspectives are generally applicable

Comments on Question 2

Vreugdenhil and others (2008) distinguish four biophysical scale perspectives that derive from the geological, ecological, hydrological and bio-geomorphological disciplines and four scale perspectives that derive from the practice of managing a river. Whereas the managerial scale perspectives are grounded in Dutch river management, the disciplinary scale perspectives are generically applicable.

Question 3

The operational river managers in the Beuningen/Ewijk pilot study had a preference for:

- ○ the river basin or catchment scale
- ○ the river segment scale
- ○ the river reach scale
- ● the ecotope (e.g. floodplain) scale
- ○ the eco-element scale

Comments on Question 3

In the Beuningen/Ewijk case study the operational river managers exhibited a strong preference for the ecotope or floodplain scale. They offered multiple arguments, such as navigational stability, hydraulic effectiveness, legal responsibilities and managerial complexity, for using this level as the basis for designing the CFR measures.

Question 4

In the Beuningen/Ewijk pilot study, which of the following actors held a scale perspective matching well with the bio-geomorphologic scale underlying the cyclic floodplain rejuvenation (CFR) concept?

- ○ River basin planner
- ◉ Regional planners e.g. the Province of Gelderland
- ○ Entrepreneur e.g. a sand mining company
- ○ Conservationists e.g. the forestry authority
- ○ Local planners e.g. the Municipality of Beuningen
- ○ None of the above

Comments on Question 4

In the Beuningen/Ewijk case only the regional planners from the Province of Gelderland shared the river reach scale perspective with the CFR protaganists.

Question 5

Mismatches in the scale preferences of the actors in the Beuningen/Ewijk pilot project impacted the design of potential interventions by:

- [x] constraining the size of the potential intervention to prevent effects on navigation
- [x] avoiding complexity by limiting the number of actors involved
- [ ] connecting the intervention to similar actions elsewhere
- [ ] considering interventions on nearby or downstream floodplains
- [x] limiting the location to the floodplain at Beuningen/Ewijk

Comments on Question 5

Limitations were indeed placed upon the design in a number of ways. According to Vreugdenhil et al. (2010), first the location was limited to Beuningen/Ewijk, which meant that potential interventions on nearby or downstream floodplains were not considered. The size of the intervention was limited by concerns about navigability and the required grazing access, excluding the possibility of a permanent island or a channel across the entire floodplain. Secondly, although the cyclic character of the intervention was addressed by resetting some of the stands of uniform vegetation to pioneer stages, for the intervention to become part of a cyclic strategy, similar measures would need to be designed and implemented within the same river reach in the future. At the time, the design and implementation process occurred in isolation.

Question 6

The Integrated Scale Hierarchy for Rivers has a bio-geomorphological scale on the left hand side, with the major processes and characteristics of interest from the different disciplinary and management perspectives indicated at each of the levels. By projecting the scale perspective of actors onto the right hand side of the diagram you can:

- [x] portray the scale requirements associated with an innovative bio-geomorphic concept (e.g. a proposed Building with Nature innovation)
- [x] contrast the perspective of a specific actor with the scale perspectives of other actors
- [ ] identify the best scale perspective for designing and implementing the innovation
- [x] identify whether the scale preference of a specific actor fits with the scale perspective required by the innovation
- [x] explore potential changes in scale perspective on the part of actors to improve the fit with the innovative concept

Comments on Question 6

Vreugdenhil et al. (2010) use the Integrated Scale Hierarchy for Rivers as an analytical framework to assess the scale preferences of different actors and to contrast their perspectives with that of the underlying innovative concept and the perspectives of other actors. So, by projecting the scale perspectives of different types of actors from a particular case study onto the right hand side of the diagram, you can identify the degree of fit between the scale preferences of the involved actors and the scale requirements of the underlying bio-geomorphological concept. Inherent differences in scale perspective of different actors are accepted. They arise from differences in disciplinary training and their present role and dominant tasks. Accordingly, there is no ‘best' scale perspective, but flexibility in scale perspective and potential changes in actors' scale perspectives can be explored using the Integrated Scale Hierarchy.

7.7 Bibliography

Literature

Enserink, B., Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., & Bots, P. (2010). *Policy Analysis of Multi-Actor Systems.* Lemma.

Jewitt GPW (1998) *Resolution of scale issues in an integrated catchment information system for the rivers of the Kruger national park.* University of Stellenbosch, Stellenbosch

Vreugdenhil H., Slinger J.H., Kater E. (2008). Adapting scale use for successful implementation of cyclic floodplain rejuvenation in the Netherlands. In: Pahl-Wostl C., Kabat P., Moeltgen J. (eds) *Adaptive and integrated water management.* Springer, Berlin.

Vreugdenhil, H., Slinger, J.H., Kater, E. (2010). The influence of scale preferences on the design of a water innovation: A case in Dutch river management. *Environmental Management* 46(1): 29-43. URL : http://dx.doi.org/10.1007/s00267-010-9565-4

Figures

7-1. Maasvlakte 2: This image by Martijn Vos is licensed under CC-BY-NC-SA 4.0.

7-2. Vertical Axis of Power-Interest grid: This image by Alexander de Haan is in the Public Domain.

7-3. Stakeholders in the Power-Interest grid: This image by Alexander de Haan is in the Public Domain.

7-4. Water quality problems in the Crocodile River: This image by Hugo Retief from 2014 is licensed under CC-BY-NC-SA 4.0.

7-5. Crocodile River view and location: This image by Olga Ernst is licensed under CC BY-SA 4.0. The image by Hugo Retief from 2014 is licensed under CC-BY-NC-SA 4.0.

7-6. Waste-water treatment works: The right image by Hugo Retief from 2014 is licensed under CC-BY-NC-SA 4.0.

7-7. Quarterly meetings with scientific data feedback: This image by IWR, Rhodes University from 2014 is licensed under CC-BY-NC-SA 4.0.

7-8. Working with industry stakeholders: This image by Hugo Retief from 2014 is licensed under CC-BY-NC-SA 4.0.

7-9. The Kruger National Park: These images by Tally Palmer are licensed under CC-BY-NC-SA 4.0.

7-10. With stakeholders, we created a space for the possibility of water quality improvement: This image by IWR, Rhodes University from 2014 is licensed under CC-BY-NC-SA 4.0.

7-15. Cyclic Floodplain Rejuvenation, Beuningen, Netherlands: These images are Copyright protected. © Stichting Ark. All Rights Reserved.

7-16. Integrated Scale Hierarchy for Sandy Coasts: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0.

7-17. Integrated Scale Hierarchy for Sandy Coasts with actors: This image by IWR, Rhodes University from 2014 is licensed under CC-BY-NC-SA 4.0.

8-1. *Playing Games in Tema, Ghana. © Baukje Kothuis*

Chapter 8
Cooperative Game Theory

8.1 Introduction

In Chapter 6 you learned to diagnose when stakeholder engagement is necessary in a complex problem situation, and in Chapter 7 you learned how to identify and map relevant stakeholders and about issues of scale. In Chapter 8 you will learn the basics of cooperative game theory and its application in analysing coalition building in Building with Nature examples.

The chapter consists of the following videos:

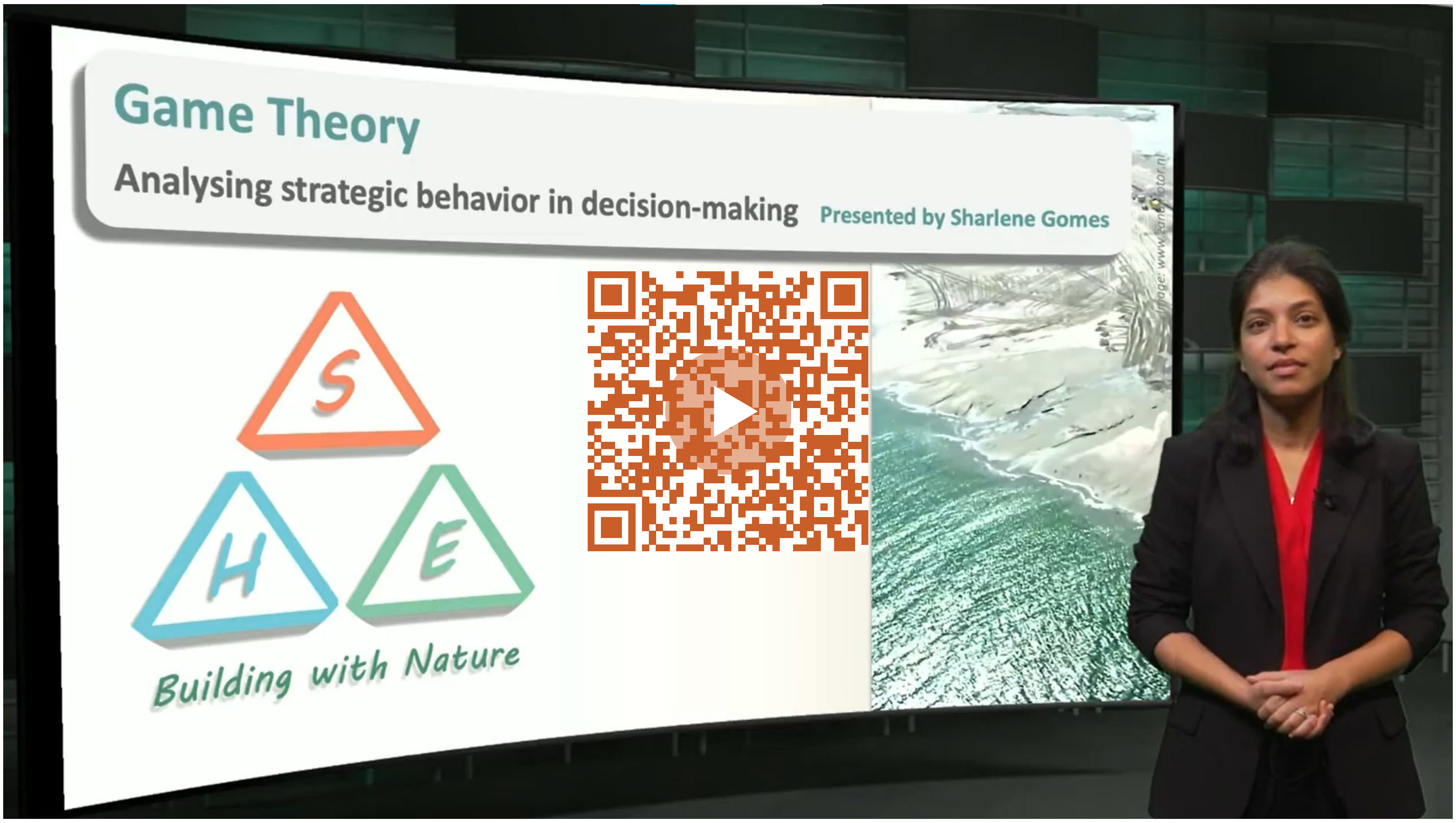
- Game Theory - a video by Dr. Sharlene Gomes
- Game Theory and Coalition Building - a video by Prof. Susan Taljaard in which she explains the application of cooperative game theory to the management of the Great Brak Estuary in South Africa.
- Innovating in the IJssel River - a video by Dr. Heleen Vreugdenhil on coalition building in innovative river management pilot projects in the Netherlands.

The **first assignment** focuses on concepts from game theory, and is primarily based on the first video. The **second assignment** involves the application of cooperative game theory to the Maasvlakte 2 Port Development and draws upon the second video.

A reading entitled “The usefulness of game theory as a method for policy evaluation” by Hermans et al. (2014) is offered as supplementary material.

Enjoy learning about cooperative game theory and its application in strategic decision making and coalition building.

8.2 Game Theory Fundamentals



8-304

Video: Game Theory: Analysing strategic behaviour in decision making

This section contains a video presented by **Dr. Sharlene Gomes** and written by **Sharlene Gomes, Leon Hermans** and **Jill Slinger**. She will explain the fundamentals of game theory very briefly, concentrating on cooperative game theory and illustrating her explanation with an example from Bangladesh.

You can cite this video as:

Gomes, S. (Sharlene), Hermans, L. (Leon), Slinger, J.H. (Jill). (2020). *Beyond Engineering: Building with Nature 2x video #04. Game Theory. Analysing strategic behavior in decision making.* 4TU.Dataset. https://doi.org/10.4121/14910387

Video Transcript

Presented by Dr. Sharlene Gomes

In my research in water management in South Asia, I've used game theory models to analyse strategic behavior in stakeholder decision making. I'm going to explain the basics of this method. So, lets go through the foundations of game theory and how it can be applied to real-world problems.

What is Game theory? Osborne and Rubinstein (1994) say it is **a tool to help understand the phenomena of when decision-makers interact.**
It isn't a new method. Modern game theory has been around for over 80 years (von Neumann and Morgenstern, 1944).

When is game theory useful? Well, we use it when we want to study strategic behavior and the outcomes of decision-making. And what is important when using game theory, is to think about situations as a 'game' with players, actions, outcomes, and payoffs (Rasmusen, 2007).

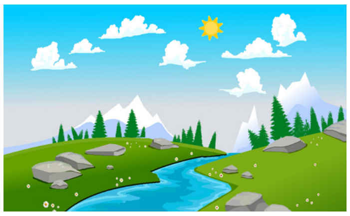
So why should we learn game theory? Game theory offers a structured way to think about real-world decision making and actor interactions. It is a tool to analyse people's strategies in a given problem situation. What is nice about game theory is that it requires few inputs, making it easy to apply even when you have very little data. It helps examine very complex situations by focusing on actor interactions and capturing these in a simple model.

Here, we define an actor as a social entity; an individual or organisation with an ability to directly or indirectly influence the system in which it has an interest (Enserink et al., 2010).

When can you use game theory? When we:

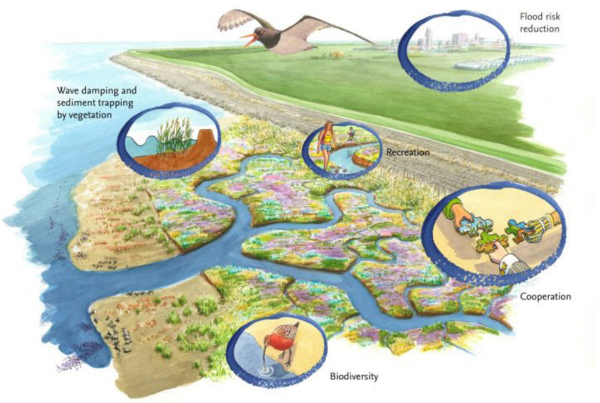
1. Need strategic insights into complex, multi-actor problems.
2. When the goal is to understand why certain outcomes exist, or are likely to occur in society.
3. Need to explore alternate solutions in multi-actor situations, or identify promising coalitions.

Game theory should not be used in predicting a way forward but it can deepen our understanding of a complex problem.



8-2. *Coastal or River Basin Management. ⓪ NA*

8-3. *Drinking Water Management. ⓒ Christine Daniloff / MIT*



8-4. *Nature-based Flood Defences. ⓒ Deltares*

What kinds of multi-actor 'games' exist in the real world, particularly in the water sector?
Games can be found in coastal or river basin management, for example games between upstream and downstream water users. In drinking water management: for example in the supply of water between rural and urban areas. And in funding arrangements in implementing nature-based flood defences, rather than just choosing standard infrastructure solutions. We have provided references to some examples of game theory applications on each of these topics.

Now, lets explore some basics about game theory. The main inputs in constructing a game theory model include: Actors, Action, Resources and Values from the real-world.
In the model: actors become players in the game, actions and resources define the moves in the game, and actor's values are used to calculate payoffs (or utility) associated with the different outcomes in the game.

There are two ways to model multi-actor games: one is through a non-cooperative game theory model in which actors compete for their preferred outcomes. The non-cooperative model is used in situations in which actors are unwilling to cooperate in a fixed set of rules and make decisions to benefit themselves. These games are often represented using a decision-tree like this (Figure 8-6).

The second way is through a cooperative game theory model. This type of model explores cooperative solutions where actors are willing to communicate, coordinate, and potentially pool resources to collectively find a solution.

Take for example this 3 player game (Figure 8-7). Here we have 3 actors who can make decisions either individually or together. The cooperative model helps us explore the payoffs of outcomes where all 3 actors act individually, vs. bi-lateral or multi-lateral coalitions. In this video, we will focus on cooperative game theory.

Next, lets explore some solution concepts in a cooperative game. I'll use the example of groundwater monitoring in Bangladesh to explain this.

Groundwater is an essential source of water in Bangladesh, yet aquifer data is scarce and spread across different actors.

There are three main actors who monitor groundwater: Engineers (E) who conduct groundwater assessment when installing tube wells for drinking water supply, the Monitoring agency (M) who is the Environmental department, and Residents (R) who also keep track of changes in groundwater quality and quantity over time.

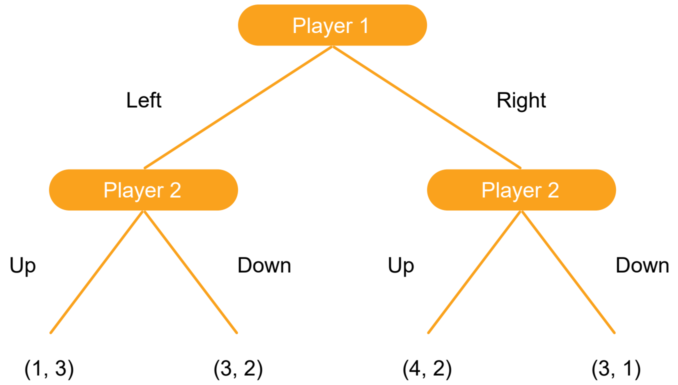
A cooperative model of this problem represents the different outcomes in this game. Outcomes are the different forms of collaboration that are possible between the actors like actors monitoring groundwater individually versus together.

Based on this model, we can go on to explore 3 solution possibilities. Each solutions represents what each player can expect to receive in the game. Let's understand these solution concepts.

This triangle figure is known as a ternary plot. It is used to plot the solutions in a cooperative game. The solutions from the

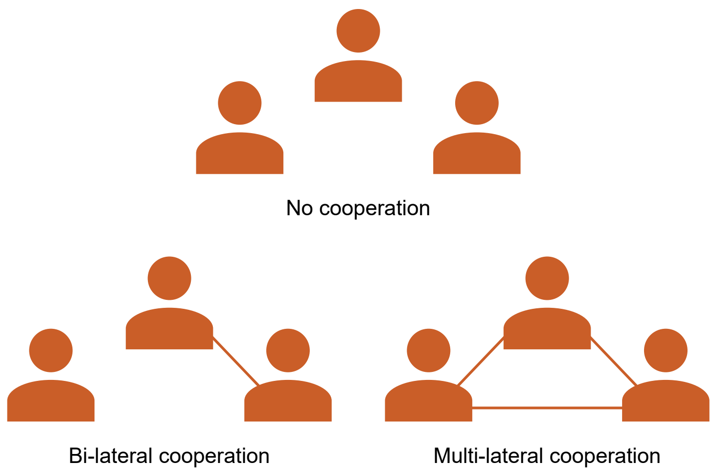
Real-world	Model
Actors	Players
Actions & Resources	Moves & Outcomes
Values	Payoffs

8-5. *Elements of a Game Theory Model*

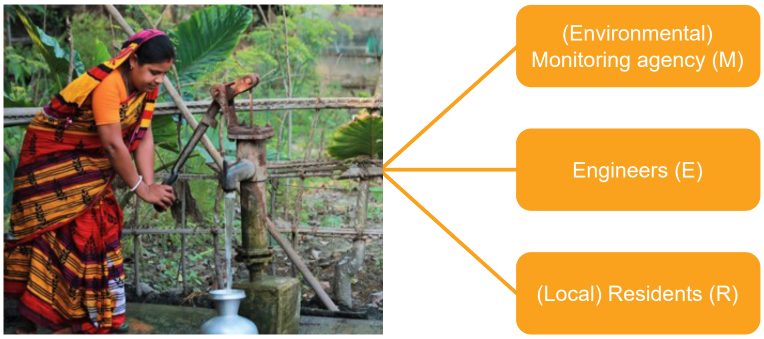


8-6. *Non-cooperative Game Theory. © Sharlene Gomes and Jill Slinger*

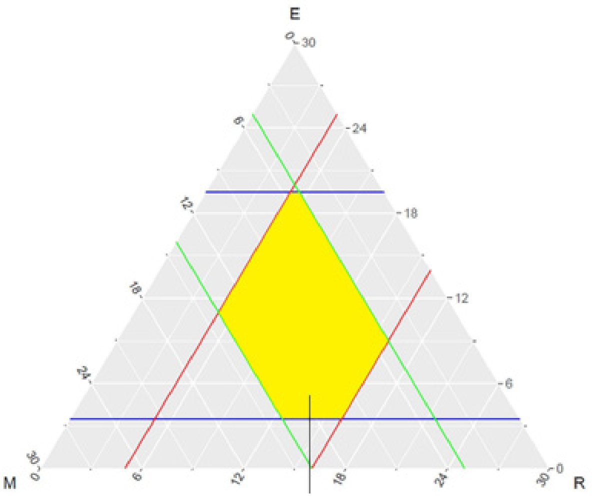
Outcome	Moves	Outcome type
1	-	Null Coalition
2	A	Individual Action
3	B	Individual Action
4	C	Individual Action
5	AB	2-Player Coalition
6	BC	2-Player Coalition
7	AC	2-Player Coalition
8	ABC	Grand Coalition



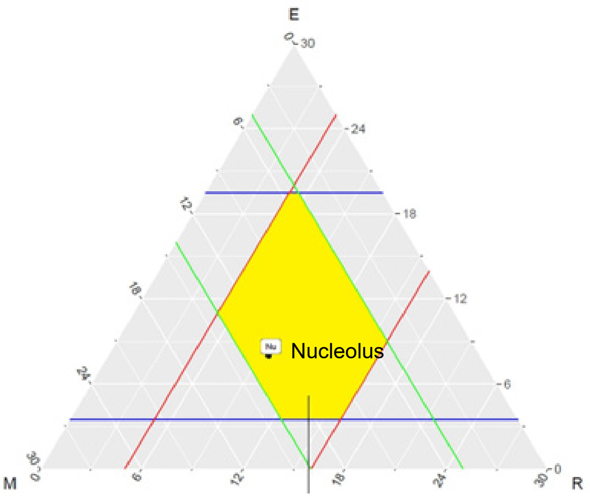
8-7. *Cooperative Game Theory. © Sharlene Gomes*



8-8. *Groundwater monitoring in Bangladesh. © Jagrata Juba Shangha*



8-9. *Ternary Plot: Core. © Sharlene Gomes. Adapted from Gomes (2019)*



8-10. *Ternary Plot: Nucleolus. © Sharlene Gomes. Adapted from Gomes (2019)*

groundwater monitoring game were calculated and plotted using the software R.

The first solution that we will discuss is the Core. In this figure, the core is marked in yellow. The core is the space where actors can enter voluntarily into cooperative agreements with other actors. In the core, the three actors can expect to receive at least as much payoff as they would from acting individually. So there is a benefit from cooperating. In the core, there can exist numerous possible cooperative solutions. The core is not a specific solution to the monitoring problem, but more a depiction of the voluntary solution space.

The second, more specific solution concept that we calculate is called the Nucleolus. In this solution, all players are considered equal. The Nucleolus is the solution that makes the most unhappy coalition less unhappy without negatively affecting the other coalitions. So here, we offer the most unhappy actor some utility to stay in the coalition without hurting the others.

In this game, the Nucleolus falls is located within the core, which means an egalitarian solution is possible through voluntary cooperation by the players. If the Nucleolus fell outside the core, this means an egalitarian solution is not possible without incentivising the actors.

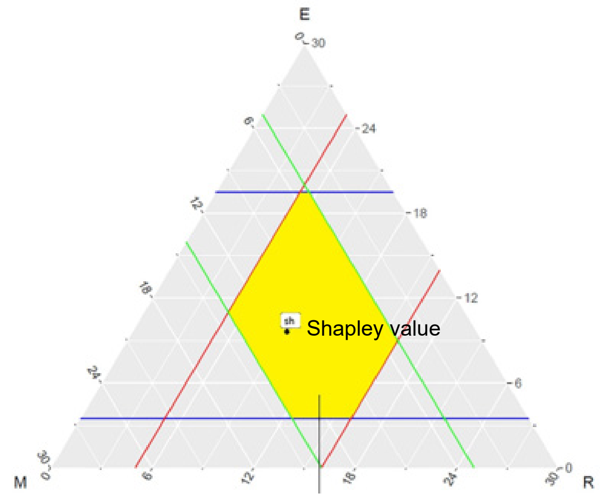
The Shapley value is the 3rd solution concept. This solution is representative of a 'fair' solution. This solution may be pursued if the actors hold fairness as an important normative value in the problem solving process. Here, payoffs are distributed in a coalition based on what each actor brings to the table and how the coalition is formed. Given our understanding of this method, lets think about what it offers to Building with Nature.

Game theory can serve as a starting point for exploring cooperative potential in Building with Nature. For instance,

- Who are the actors in the project?
- What do they care about in the potential Building with Nature projects and designs?
- What added value do they bring if involved?
- How can the actors cooperate?
- Which coalitions are feasible?
- How beneficial is cooperation?

So cooperative game theory can be applied in Building with Nature. The method works best with a limited number of players, typically between 2 to 4. But this simplified decision-making context offers insights into actors in the design and implementation of Building with Nature projects.

If you want to learn more about game theory or its application methods, you may want to refer to these resources.



8-11. Ternary Plot: Shapley Value. © Sharlene Gomes. Adapted from Gomes (2019)

Further Reading

Application

Gomes, S. (2019). *An Institutional Approach to Peri-Urban Water Problems: Supporting community problem solving in the peri-urban Ganges Delta.* Delft, NL. https://doi.org/10.4233/uuid:4e2900cd-1fa1-4bce-b0f5-c99f23a13c6c

Hermans, LM., Cunningham, S., & Slinger, JH. (2013). Adaptive co-management and learning: Developments in coastal management in the Netherlands from 1985 to 2010. In VI. Grover, & G. Krantzberg (Eds.), *Water co-management* (pp. 266-291). Enfield, New Hampshire: CRC Press. https://doi.org/10.1201/b14591-14

Janssen, S., Vreugdenhil, H., Hermans, L., & Slinger, J. (2020). On the nature based flood defence dilemma and its Resolution: A game theory based analysis. *Science of the Total Environment, 705*, 135359. https://doi.org/10.1016/j.scitotenv.2019.135359

Video Tutorials on Game Theory Fundamentals

https://www.youtube.com/playlist?list=PLKI1h_nAkaQoDzI4xDIXzx6U2ergFmedo

Theory

Osborne, M. J., & Rubinstein, A. (1994). Introduction. In *A Course in Game Theory* (pp. 1–8). Cambridge: The MIT Press.

Rasmusen, E. (2007). The Rules of the Game. In *Games and Information: An Introduction to Game Theory* (Fourth, pp. 11–33). Malden, MA: Blackwell Publishing.

Straffin, P. D. (1993). *Game Theory and Strategy*. Washington D.C., USA: The Mathematical Association of America.

Hermans, L. M., & Cunningham, S. W. (2013). Actor Models for Policy Analysis. In *International Series in Operations Research & Management Science. Public Policy Analysis: New Developments* (pp. 185–214). New York: Springer.

8.3 Assignment 8.1

Introduction

Assignment 8.1 is an ungraded assignment aimed at reinforcing the understanding of game theory concepts deriving from the video 'Game Theory. Analysing strategic behavior in decision making.' presented by Dr. Sharlene Gomes.

This assignment comprises 6 multiple choice questions. There is only one correct answer per question.

Once you have completed the assignment, you are encouraged to consult the Feedback on Assignment 8.1 at the end of this chapter. On the next pages you will find the questions.

To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

In the video entitled 'Game Theory. Analysing strategic behavior in decision making.' Dr. Gomes defines an actor as:

- ○ all the stakeholders involved in strategic decision making on the system of interest
- ○ a stakeholder or a group of stakeholders whose interest(s) are affected by decision making on the system of interest
- ○ a participant in a theatre performance
- ○ a social entity, an individual or organisation with the ability to directly or indirectly influence the system in which it has an interest

Show Answer

Question 2

In game theory models, real world actions, values and actors are represented by:

- ○ strategies, pay-offs and players
- ○ moves, pay-offs and players
- ○ strategies, outcomes and players
- ○ strategies, outcomes and stakeholders
- ○ moves, outcomes and players

Show Answer

Question 3

When is it appropriate to apply cooperative game theory rather than non-cooperative game theory?

- ○ Actors are willing to follow a fixed set of rules
- ○ Actors are willing to communicate, coordinate and collectively act towards a solution
- ○ Actors are committed to pursuing their own interest
- ○ None of the above

Show Answer

Question 4

The outcomes of a cooperative game are:

- ○ what each player (actor) can expect to receive
- ○ what each player can expect to receive in different forms of collaboration between players (actors)
- ○ the different forms of collaboration that are possible between players (actors)
- ○ the potential space of collaborative agreements

Show Answer

Question 5

The solution concepts in cooperative game theory have different names. The Core depicts:

- ○ the potential space of voluntary collaborative agreements
- ○ the space where each player will get more pay-off than they would alone
- ○ the space that makes the most unhappy actor less unhappy without affecting the others
- ○ all of the above

Show Answer

Question 6

The solution concept that distributes pay-offs equitably according to what each player brings in and takes into account how the coalition was formed is called:

- ○ the Core
- ○ the Nucleolus
- ○ the Shapley value
- ○ the Coalition
- ○ none of the above

Show Answer

8.4 Applying Cooperative Game Theory

Video: Game Theory and Coalition Building - the Story of the Great Brak Estuary

This section contains a video presented by **Prof. Susan Taljaard** and written by **Susan Taljaard**, **Jill Slinger** and **Lara van Niekerk**. She explains the application of cooperative game theory to the case of the Great Brak Estuary in South Africa.

You can cite this video as:

Taljaard, S. (Susan), Slinger, J.H. (Jill), van Niekerk, L. (Lara) (2020). *Beyond Engineering: Building with Nature 2x video. Game Theory and coalition building. The story of the Great Brak Estuary.* 4TU.Dataset. https://doi.org/10.4121/14910405

Video Transcript

Presented by Prof. Susan Taljaard

Today I want to tell you about a game-based analysis that was used to unravel the interactions amongst various stakeholders - or role players - following a decision by the South African national government to build a new dam just upstream of a small estuary.

The playing field was the Great Brak Estuary, a relatively small system situated along South Africa's warm temperate south coast. The mouth of this estuary closes from time to time due to strong wave action, and requires river flow to open again. The area is also a popular holiday destination, where many of the houses and commercial properties lie within the floodplain, making them vulnerable to flooding. To meet the water demands of a strategically important petroleum refinery in the area, the government decided to build the Wolwedans dam about 7 km upstream of this estuary.

So, the playing field comprised an estuary of which the mouth closed from time to time, needing river flow to open, a popular holiday destination where low-lying developments were vulnerable to flooding, and then came the decision to build a

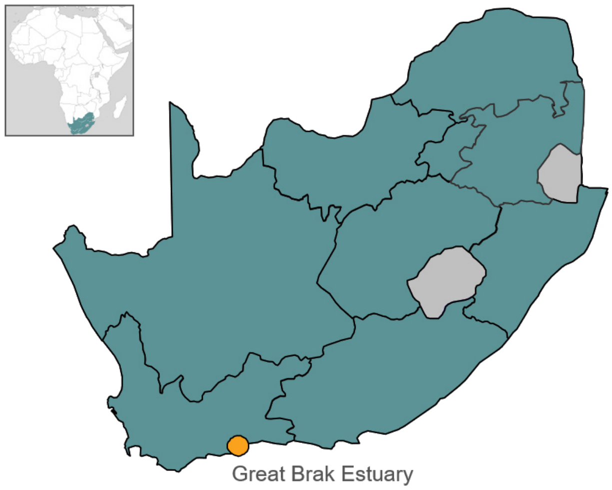
8-312

dam that would affect both river flow and flooding.

Who were then were the role players? First, those who were in favour of building the dam, including both the national and regional authorities responsible for water planning, the petroleum industry that needed the water, and also local farmers that could benefit from the dam during droughts.

These role players formed what we can refer to as the Water Security coalition, with secure water supply as their main goal. They also had the power and financial resources to build the dam and so realise their goal.

Then, there were the local role players comprising the residents of the town, the local municipality and smaller industries situated on the floodplain, for example small shops and a shoe factory. They formed the Local Citizen coalition that had the health and safety of the community at heart. As many of them were living in the area for years, they had local knowl-

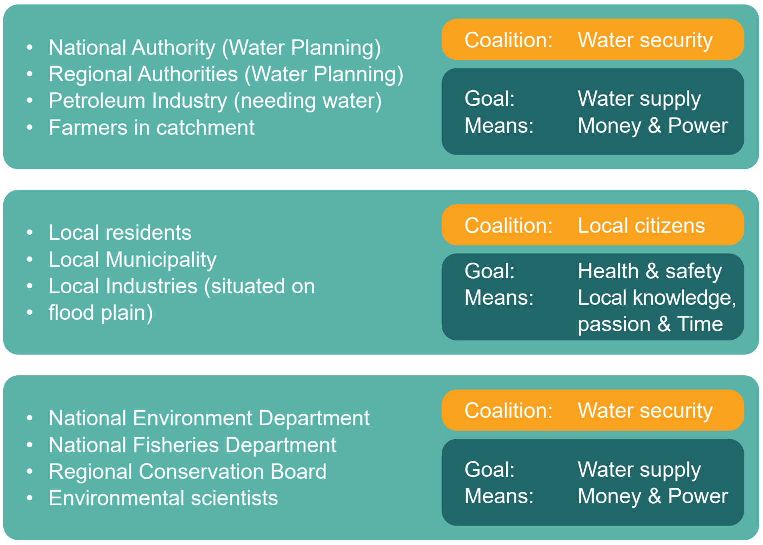


8-12. Great Brak Estuary. © *Susan Taljaard*

8-13. Great Brak Estuary Mouth. © *CSIR*

8-14. Low lying developments in Great Brak flood plain. © *CSIR*

8-15. Wolwedans Dam. ⓒ Louis / Alida van der Walt



8-16. The Players . ⓒ Susan Taljaard and Jill Slinger

8-17. The Games. ⓒ Susan Taljaard and Jill Slinger

edge and were passionate about the natural beauty of their estuary. Many of the local residents were also retirees so they had the time to devote to this issue and could voice their wishes and concerns.

The last set of role players comprised national environmental and fisheries authorities, the regional conservation body, and a group of environmental scientists. Their common goal was biodiversity protection and long term environmental sustainability, so they became the Environment coalition. This coalition's strength lay in their scientific knowledge on estuarine processes, which was critical to understand the environmental implications of the new dam.

So, now that we understand the playing field and the players, let's explore how the game unfolded over the years that followed. In the early 1980s, the national water authority made a bureaucratic decision to build the Wolwedans Dam to secure water for the petroleum industry. When the news reached the local community, they were outraged as they feared for their safety from flooding and had concerns about environmental damage. Their protests were so intense that the national government had no choice but to call for an environmental impact assessment – even before this became a legal requirement in South Africa.

Then, in the early 1990s, after construction of the dam, good rains filled the dam faster than expected and we entered a period where there was enough water for all – for industry and the estuary and her people. In accordance with the environmental requirements, monitoring had to be conducted to improve understanding of the estuary's response to changes in river flow. Increasingly, the local citizens, authorities and the scientists started working and learning together about functions and processes in the estuary.

Towards the mid-2000s, the improved scientific understanding indicated that the estuary actually needed more water than was originally allocated. On top of this, a severe drought affected the area during this period placing severe stress on water availability. So much so, that the authorities stopped releasing water to the estuary. As you can imagine, mutual trust, co-management arrangements and collaboration took a dive!

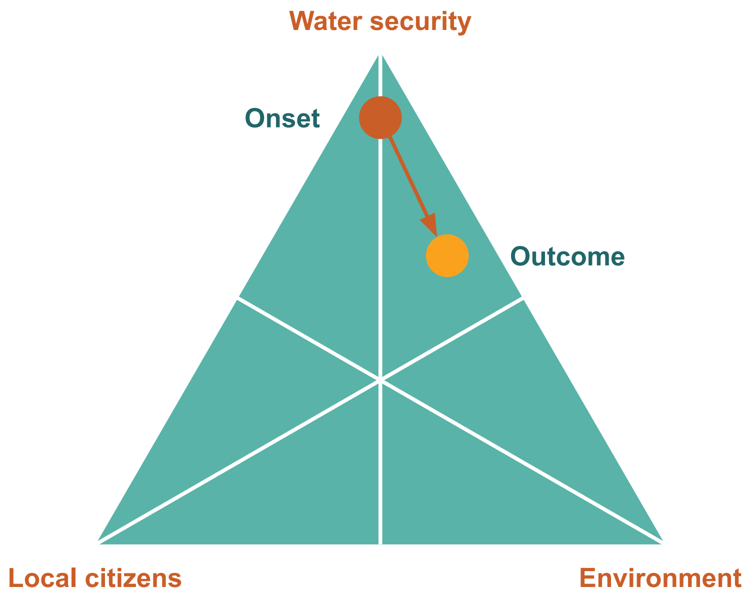
All in all, we can distinguish three games. The first one happened during the early stages in the 1980's, characterised by conflict and distrust. So we named this "Defiance".

Then followed the good times when there was enough water for all, trust was built and everyone worked together. So we called this game "Co-managing the estuary".

This was followed by a bleak period with drought, water was scarce and conflicts surfaced again. So we call this game "The Drought".

Let's now analyse the dynamics amongst the various role players and their coalitions during each of the games. We schematise the corners of a triangle as representing the stakeholder (or actor) coalitions and their goals. So, any position in the triangle reflects the degree to which one or more of the coalitions has dominated the game. The closer to a corner, the more that coalition's goals were achieved. The closer to the center, the more balanced the outcome.

At the onset of Game 1, Water Security dominated the game because the authorities in this coalition unilaterally decided to build the dam. Major conflict with the local citizens resulted. Even the scientists that entered the game as part of the en-

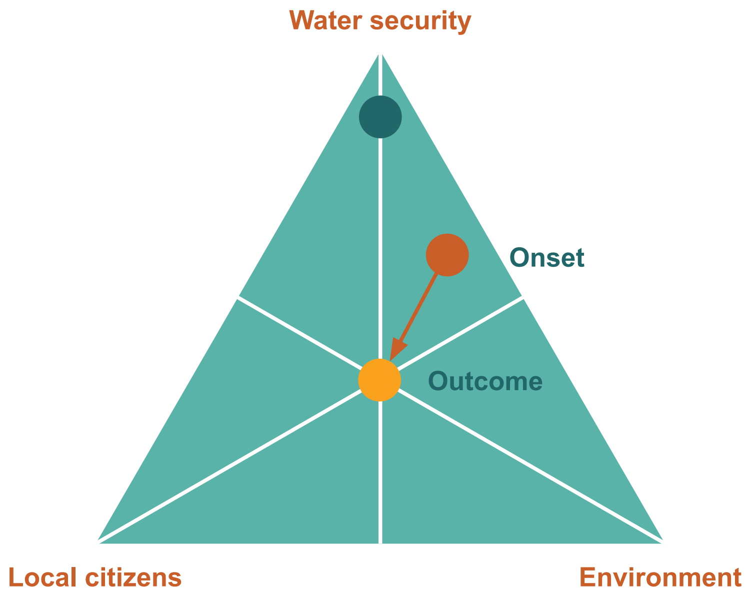


8-18. Game 1: "Defiance" (1980-1990). © Susan Taljaard and Jill Slinger

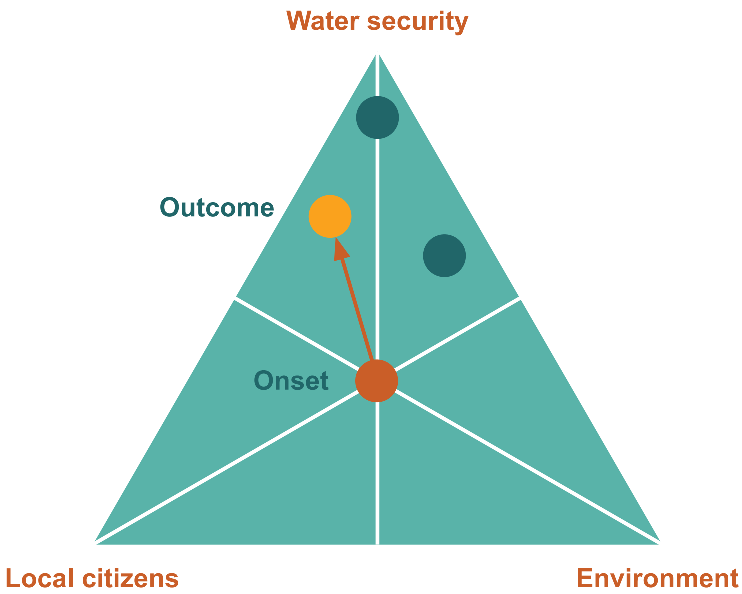
vironmental assessment were distrusted by the locals. They were seen as being in cahoots with the authorities!

Then the game unfolds. Committed engagement and regular communication starts to occur between the authorities and scientists. Despite heated discussions at times, a dedicated environmental committee was established that also included local representatives. The outcome of this game was the adoption of the first environmental management plan in 1990. So the Environment coalition gains influence during this game.

With the Environment coalition gaining influence in Game 1, they started gaining the trust of the Local Citizens coalition. They shared their scientific knowledge with the local community and so all learned together. A hugely important factor during Game 2 was enough rain filled the dam fast so there was plenty of water for all.



8-19. Game 2: "Co-Managing Estuary" (1990-2004). © Susan Taljaard and Jill Slinger



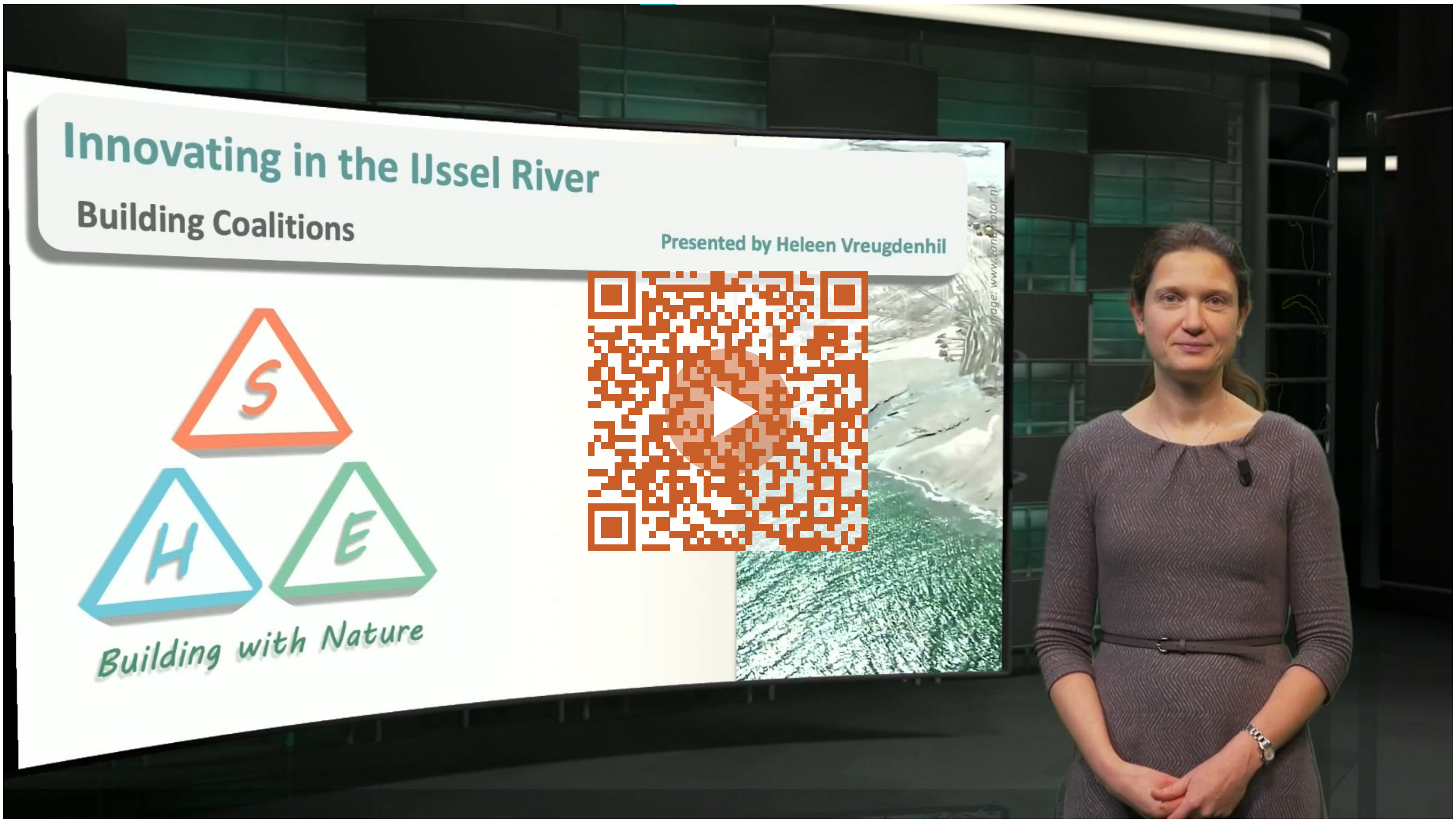
8-20. Game 3: "The Drought" (2004-2011). ⓒ Susan Taljaard

So during Game 2, trust was built among the coalitions and they viewed themselves as co-managers of the estuary. The outcome of this game was a revised environmental management plan in 2004. The plan adopted the newly gained scientific knowledge and so they had learned by doing. The influence of the local citizens increased towards the end of this game, reaching almost the perfect co-management balance!

But then in Game 3, the tables turn! First, new scientific knowledge reveals that the minimum water requirements of the system were much higher than initially estimated, and on top of this, a severe unanticipated drought hits the area. The Water Security coalition feared that they could not meet their commitment to industry to guarantee water supply. So they chose the route of least resistance, or so they thought, cutting the water supply to the estuary.

So this game reveals an almost complete breakdown of collaboration amongst the coalitions. The local citizens even threatened with legal action. This game ends with much unhappiness and an estuary without freshwater! To date collaboration in the Great Brak still has not returned to its heyday in the 2000's, mainly due to instability within the coalitions, and uncertainty in the implementation of government water policies.

So, we have applied game theory, using concepts like a playing field, role-players, their goals, coalitions and the decision outcomes to explore a real-life situation. But, what does this example teach us? We learn that game theory is a useful tool to apply in understanding decision making on complex environmental issues, especially where a diversity of stakeholders are involved. It allows us to distinguish value-based actor coalitions and to explore how influences in decision making shift over time - showing us who is dominant when. So, how can game theory and coalition building contribute to sustainable nature based design?



Video: Innovation on the IJssel River

This section contains a video presented by **Dr. Heleen Vreugdenhil** and written by **Heleen Vreugdenhil** and **Jill Slinger**. She explains coalition building in innovative pilot projects on the IJssel River in the Netherlands, illustrating the interdependencies amongst actors.

You can cite this video as:

Vreugdenhil, H. (Heleen), Slinger, J.H. (Jill) (2020). *Beyond Engineering: Building with Nature 2x video #06. Innovating in the IJssel River. Building coalitions.* 4TU.Dataset. https://doi.org/10.4121/14910462

8-21. River IJssel (Green) and Twente Canal (Yellow).
© Heleen Vreugdenhil

8-22. The river IJssel in Deventer. Beeldbank.rws.nl, Rijkswaterstaat

8-23. Twente Canal. © Ger Boedeltje

Video Transcript

Presented by Dr. Heleen Vreugdenhil

I'm going to talk to you about coalition building in the river IJssel. In the Netherlands, the maintenance of rivers is the task of Rijkswaterstaat. This means, for example, maintaining the navigation channel and ensuring that vegetation does not block the view. Rijkswaterstaat enters into 5-year contracts to execute the work. However, Rijkswaterstaat is facing several challenges. They need to maintain large areas with lower budgets and it needs to become more sustainable.

So, in 2011, some people in Rijkswaterstaat took the initiative to start a new program called Self Supporting River System, or SSRS. The idea was that the natural capital and dynamics of the river could be used much better by all sorts of societal actors. The river is not for Rijkswaterstaat alone. Instead, innovations in use and management could lead to a reduction in costs and generate benefits, so that the river could support itself.

In 2015, a new maintenance contract had to be agreed for the IJssel River and the Twente canals, in the east of the Netherlands. The SSRS initiators took the opportunity to include

an appendix in the contract stating that an Innovation Team had to be established. This meant that the IJssel River became available as an experimental space. The Twente canals also became available as experimental space. So, innovation teams, or coalitions, had to be built and generate and facilitate innovations in river and canal maintenance.

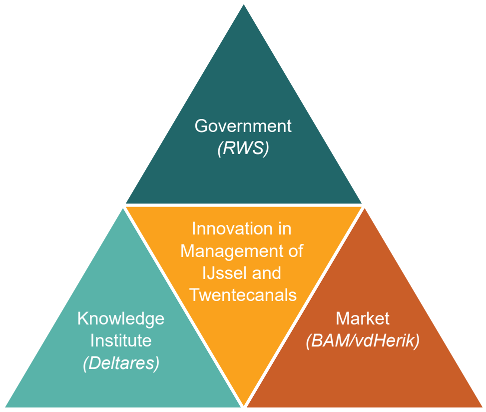
This is unusual. Normally, there is very little incentive for innovation. Here the river contractor 'has to', because of the contract conditions. Moreover, the areas under maintenance contracts are usually closed to other contractors and entrepreneurs. But with this appendix to the contract the area became open for experimentation. Quite revolutionary, don't you agree?

So, what is this Innovation Team? It's based on principles of cooperation, in what we call, the golden triangle. Representatives from governmental authorities, Rijkswaterstaat in this case, the market, or private sector, the contractor in this case, and a knowledge institute, or university, work together. The actors jointly develop initiatives and cooperate to innovate. They work as a single project team and so dare to share risks, knowledge and initiatives, rather than keeping it for themselves.

And how does it work in practice? When a new team with new people is installed they first need to get to know each other. and agree on the rules of how they wish to work together. So, for example, they visit each other's organisations, the river area, and develop a common work plan. But most importantly, ideas were generated and collected in several collaborative sessions to stimulate innovation.

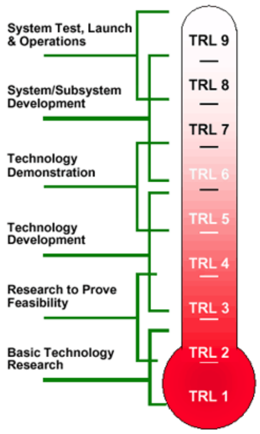
Then, the ideas were assessed. One way this was done, was by identifying the maturity of the innovation. Not only technologically, but also from a stakeholder perspective. Are stakeholders ready to adopt the innovation? And if not, what still needs to be done? Knowing this, a plan was then made of how to take the idea further. This often involves knowledge development, connecting people together and improving the innovation by increasing its benefits and reducing the costs. Pilot projects are a powerful instrument to facilitate such a process. So the Innovation Team initiated and organised several pilot projects.

Here you see some examples of the pilot projects. First there is the idea of the flexible groynes, that promise easier maintenance, use less material and above all reduce erosion. Second, we introduced herded sheep to keep the vegetation sufficiently low instead of having to mow using machines. Using sheep in this way, is part of the cultural heritage of the Netherlands, and could potentially boost the biodiversity. Here you see a bubble barrier designed to divert plastic onto the river bank so that the plastic can be removed. Here it's being tested. With regular river maintenance, a lot of tree trunks are collected from forests along the river. Instead of having to dispose of these, they can be used in the area itself. Here, three wooden screens have been constructed that reduce the impacts of waves on the banks and so prevent bank erosion. Another innovation is the semi-autonomous aquatic drone that can be used for monitoring the river. It has also been used for monitoring at the other pilot project sites.



8-24. Principles of the Innovation Team. cc Heleen Vreugdenhil

8-25. SRL, adapted from Rijkswaterstaat. Rijkswaterstaat



8-26. Technology Readyness level. NASA

8-27. Flexible Groynes. cc SSRS Innovation Team

8-28. Sheep herding instead of machine mowing. cc SSRS Innovation Team

8-29. *Bubble screen to remove plastic from rivers.*
© 3 Images: The Great Bubble Barrier

8-30. *Wooden screens to prevent bank erosion. © BAM / Van den Herik*

8-31. *Aquatic drones' Phoenix 1.5, used for monitoring purpopes.*
© AquaticDrones.eu

You can see that this is a diverse range of innovations. But, how is this arranged? How have the coalitions been formed to make this possible? Cooperation in the golden triangle formed the starting point. However, the Innovation Team is an open platform. On the one hand, other external actors can also bring their innovations to the table. On the other hand, particular innovations affect other actors as well and they should, or could be, included in the process. This can include other governmental bodies such as municipalities or ministries, diverse market parties, for example, the organisations that developed the aquatic drone or the bubble barrier, and diverse knowledge partners that can contribute specific knowledge or studies.

But above all, societal actors also became part of the process. These can be nature organisations, cooperatives of shepherds or even local scouts. So the triangle is no longer just a triangle.

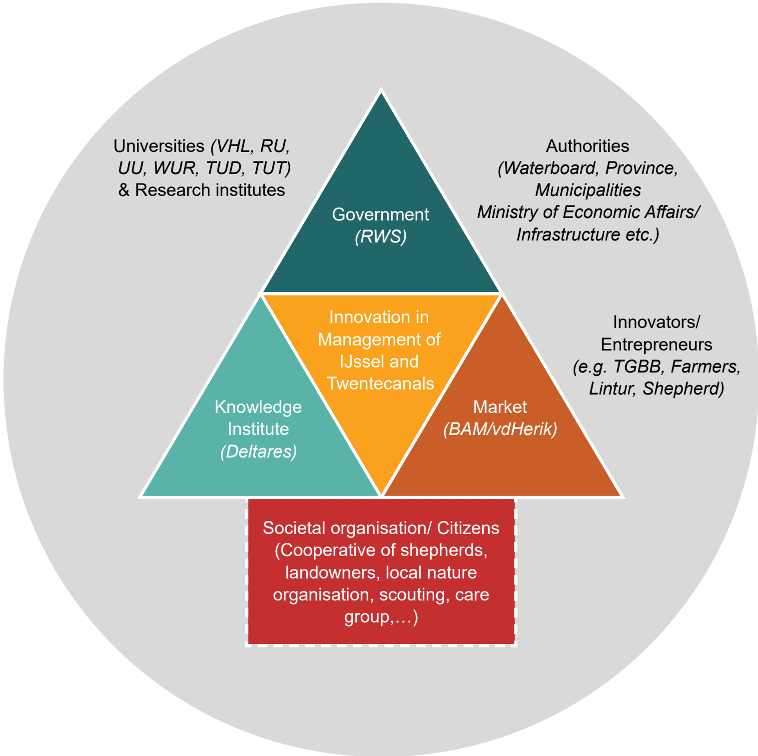
Now, what conditions contribute to innovation in coalitions? First, different knowledge sources are accessed. And diverse facilities are brought together. Second, equal or egalitarian relationships are required. So that means letting go of the traditional roles of client and contractor, for example, which increases creativity and support. Third, taking the full life time of

infrastructure or innovations into account makes working on a long lasting innovation process possible. Fourth, the presence of the experimental space. Fifth, the focus on shared interests, so that there is something for all parties. Sixth, well-organised interaction between the coalition partners and the actors around them, including those from the same organisation. This is particularly important for large governmental bodies where there are different departments, each having partially overlapping interests. Seventh, an innovation budget that helps to kick-start an innovation process, and in its turn, it can also help to find other additional resources. And eighth, the broader implementation needs to be prepared. What is the potential of the innovation? And what changes, technical or organisational, are needed?

Now, what did an Innovation Team achieve? Well, new coalitions emerged with the Innovation Team as the basis. This soon extended into broader coalition, depending on the needs of the particular innovation. For the participants in the pilot projects, it also means that they are at the forefront of the innovation. And, many ideas were collected, generated and advanced. Some went from small laboratory tests to full scale pilot projects. Without an innovation team, this team structure, this would not have happened. Alone, the actors would not have invested time, effort and money. Furthermore, the team created added value for the innovations. For example, by connecting activities into the pilot projects, such as waste collection, or creating work opportunities for people at a distance to the labour market. When an innovation creates more value, its chance of success increases.

Of course, an Innovation Team needs to deal with many challenges. Apart from critical conditions in any coalition, like trust, and finding a good working mode, it is necessary to find and keep the intrinsic motivation to participate. Participants need to be able and willing to look beyond the benefits of a single innovation. One innovation might be more interesting than another, but the cumulative value of long-term cooperation, finding new partnerships and being at the forefront of innovation should provide ongoing motivation to participate.

Second, innovation always comes with uncertainties. Clear insight in costs and benefits is not always available, which makes participants hesitant to invest. But without investment,



8-32. Coalition Building. © Heleen Vreugdenhil

the knowledge gaps cannot be addressed, so there is the risk of a chicken-and-egg situation. The third risk is the absence of active leadership. This is necessary for innovation.

But what does the future hold for the Innovation Team? First, some of the pilots I showed you will continue after the contract period. This is even the case when another contractor is active in the area. Second, the concept of an Innovation Team has been fully accepted by Rijkswaterstaat as a realistic option for new maintenance contracts. This has even been applied already in some new contracts. At least two will become active in the coming year. The potential of an Innovation Team also has been recognised by the European Agency on Public Procurement.

8-33. Runner up in European Public Procurement Innovation (PPI) Award 2015. © Heleen Vreugdenhil

Supplementary Reading

A supplementary reading for Chapter 8 is the journal paper "The usefulness of game theory as a method for policy evaluation" by Hermans et al. (2014). This paper has been selected because it reviews and discusses the use of game theory in public policy evaluation. It also presents an application of cooperative game theory to the evaluation of Dutch coastal policy implementation. When policy implementation depends on several interdependent actors, the results suggest that game theory helps in opening up the 'black-box' of policy implementation by adding structure and rigour to the study of social processes.

You can cite the journal paper as:

Hermans, L., Cunningham, S., Slinger, J. (2014). The usefulness of game theory as a method for policy evaluation. *Evaluation 20*(1): 10-25. DOI: 10.1177/1356389013516052

8.5 Assignment 8.2

Introduction

In this assignment you are asked to apply cooperative game theory to the Maasvlakte 2 port development process by answering a series of questions. The assignment builds on the previous Assignments 6.1 and 7.1 and draws upon the video 'Game Theory and coalition building. The story of the Great Brak estuary' presented by Prof. Susan Taljaard. If you have not yet watched this video then you are advised to return to the previous section before attempting Assignment 8.2.

There are 5 questions in Assignment 8.2.

Good luck in completing the assignment, and remember to consult the Feedback on Assignment 8.2 when you are finished.

On the next pages you will find the questions.

To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Assignment 8.2

The players

The first step involves identifying the players. Although game theory only requires the identification of the players, by considering the playing field as well you can take scale issues into account from the beginning, selecting the scale at which the game is construed.

Consider the initial list of key stakeholders on the right and Power-Interest Grid from Assignment 7.1 below, and consider the red, orange and green shapes in the Power-Interest Grid.

Initial List of Key Stakeholders

1.	Port of Rotterdam harbor authority (PoR) / Ministry of Economic Affairs (MoEA) / Associated transport and logistic services (TLS)
2.	Dutch Ministry of Transport, Public Works and Water Management (MoT, RWS) / District Water Boards (WB)
3.	Ministry of Housing, Spatial Planning and the Environment (MoE)
4.	Province of South-Holland (Prov)
5.	City of Rotterdam (CoR)
6.	Rotterdam Region (RR)
7.	South-Holland Landscape Foundation (ZHL) / Foundation for Dune Protection (SD)
8.	The Fauna Conservation Foundation (DF)
9.	Friends of the Earth NL (MD)
10.	Federation for Environment and Nature (N&M)
11.	Non-Governmental Fisheries Organisation (FO)
12.	Concerned Citizens of Voorne (VBV)

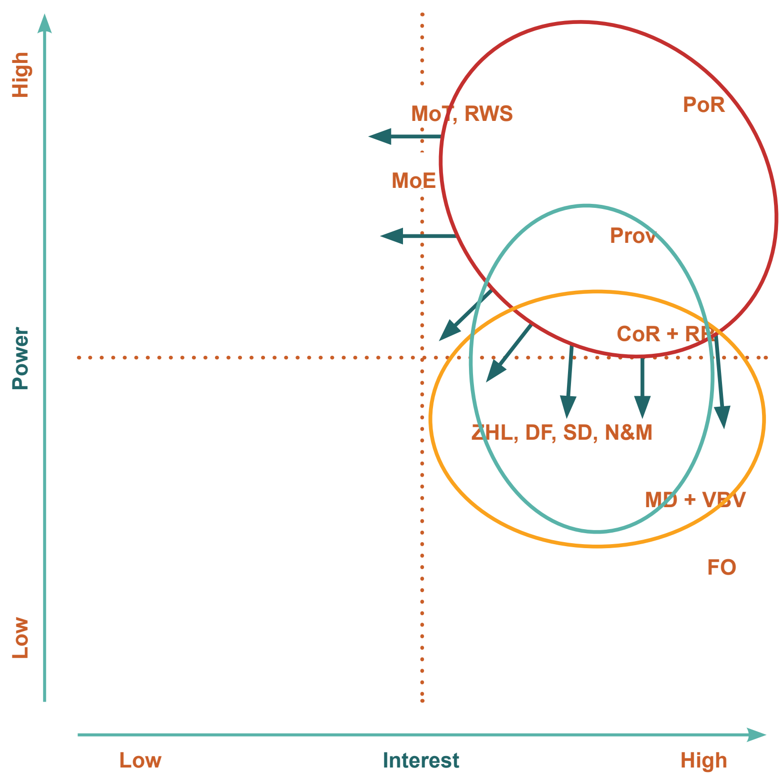
Question 1

To answer, check as many boxes as you consider appropriate.

Which of the following statements are true?

- [ ] The red circle is indicative of the player 'port development', who prior to January 2005 considered the scale of the game to be focused on the Maasvlakte 2 area
- [ ] The orange circle is indicative of the player 'local citizens' who is concerned about the effects of the Maasvlakte 2 port expansion on quality of life
- [ ] The green circle is indicative of the player 'environment' who is primarily concerned about ecological health and nature conservation

Show Answer



The Games

The second step involves identifying the games. The end of a game round is marked by a decision or event such as the appeal that was upheld in court in January 2005.

Consider the timeline below of the Maasvlakte 2 port development process.

1991
2002
2003
- Planning for future expansion of Port of Rotterdam starts (1991)
- Strategic environmental assessment and information provision
- Decision by parliament to support port expansion in principle (2002)
- Start of legal appeal by local citizens and environmental actors (2003)
- Appeal upheld in court and Maasvlakte 2 put on hold

2005
2008
2009
- Start of new Maasvlakte 2 planning process after appeal upheld in court
- Values of stakeholders taken into account from the outset
- Dual goals of Port Development and Liveability
- Agreements with stakeholders (Vision & Trust; Sea Birds etc.) [2008/2009]

2013
- Construction of the Maasvlakte 2 port expansion
- Start with liveability projects (e.g. recreation, conservation, air quality)
- Monitoring & evaluation of environmental indicators

Question 2

Check only one answer.

Which of the following statements is false?

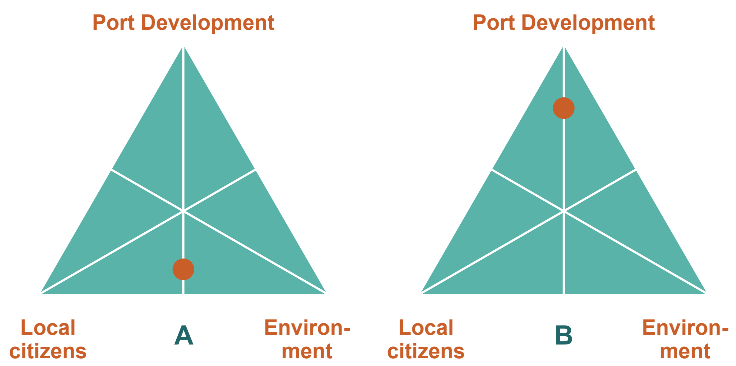
- ◯ The 1st phase (before January 2005) involved local citizens and environment players appealing against the Maasvlakte 2 port expansion in court
- ◯ The 1st phase can be characterised as the game ‘Recourse to Court’
- ◯ The 2nd phase involved negotiation between environment, local citizens and port development players about the objectives of the game
- ◯ The 2nd phase can be characterised as the game ‘ Dual Goals’
- ◯ The 3rd phase, involving the realisation of the Maasvlakte 2 port development and negotiation about monitoring of the effects, is not a game as it is ongoing
- ◯ The 3rd phase can be characterised as the game ‘Realisation and Monitoring’

Show Answer

Construction and interpreting the games

The next step involves constructing the games and analyzing the outcomes. Consider the diagrams on the right:

‘Recourse to Court’ (<Jan 2005)



Question 3

Check only one answer.

In the 1st game ‘Recourse to Court’ the solution favoured the port development player. Which of the following statements is true?

- ◯ Diagram A represents this situation because the red circle indicating the pay-offs is near maximum for the port development player
- ◯ Diagram B represents this situation because the red circle indicating the pay-offs is near maximum for the port development player
- ◯ Diagram A represents this situation because the red circle indicating the outcome is near maximum for the port development player
- ◯ Diagram B represents this situation because the red circle indicating the outcome is near maximum for the port development player

Show Answer

Construction and interpreting the games

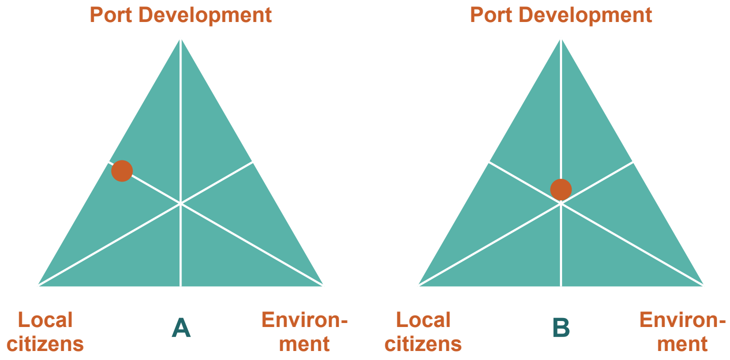
Now, consider the diagrams on the right:

Question 4

To answer, check as many boxes as you consider appropriate.

In the 2nd game ‘Dual Goals’, the two goals of port development **and** liveability were adopted. Which of the following statements are true?

‘Dual Goals’ (Jan 2005-2009)



- ☐ The outcome of the 2nd game ‘Dual Goals’ is a coalition between the port development player and the local citizens player
- ☐ A is representative of the 2nd game ‘Dual Goals’ because the red circle is in the middle between the port development player and the local citizens
- ☐ The outcome of the 2nd game ‘Dual Goals’ is a coalition between the port development player, the local citizens player and the environment player
- ☐ B is representative of the 2nd game ‘Dual Goals’ because liveability includes the environment and the red circle is almost equally distant from all players

Show Answer

Question 5

To answer, check as many boxes as you consider appropriate.

If we were to analyse the planning and design of the layout and harbor infrastructure of the Maasvlakte 2 as a game, then which of the following statements do you consider false?

- ☐ The same actors would form the players in the game of laying out the Maasvlakte 2 harbour area
- ☐ Non-cooperative game theory would probably provide a better representation of the competition between port stakeholders regarding facilities, position and pricing
- ☐ The companies wanting to utilise the new Maasvlakte 2 would have to adhere to the environmental monitoring conditions agreed within the broad coalition on port development and liveability, so the moves of players in the new game are in some sense constrained by the previous game(s)

Show Answer

8.6 Feedback

Feedback on Assignment 8.1

By Prof. Jill Slinger and Dr. Sharlene Gomes

Question 1

In the video entitled 'Game Theory. Analysing strategic behavior in decision making.' Dr. Gomes defines an actor as:

- ○ all the stakeholders involved in strategic decision making on the system of interest
- ○ a stakeholder or a group of stakeholders whose interest(s) are affected by decision making on the system of interest
- ○ a participant in a theatre performance
- ◉ a social entity, an individual or organisation with the ability to directly or indirectly influence the system in which it has an interest

Comments on Question 1

In policy analysis and game theory the term actor has a special meaning beyond that of a film star or theatre performer. Dr Gomes defines an actor as a social entity, an individual or organisation with the ability to directly or indirectly influence the system in which it has an interest. So, a stakeholder or a group of stakeholders whose interest(s) **are affected** by decision making on the system of interest is not necessarily an actor because they may not be able to exert influence directly or indirectly. Also, it can be useful to categorise or group stakeholders with similar interests or power. This means that **all** stakeholders involved in decision making may not feature as individual actors in a game theory analysis. In summary, an actor is a construct used in analysing a strategic decision making situation and so the relevant actors can differ per problem situation. An actor can be a single influential stakeholder or a group of like-minded stakeholders with direct/indirect influence on the system.

Question 2

In game theory models, real world actions, values and actors are represented by:

- ○ strategies, pay-offs and players
- ◉ moves, pay-offs and players
- ○ strategies, outcomes and players
- ○ strategies, outcomes and stakeholders
- ○ moves, outcomes and players

Comments on Question 2

The representation of the real world in game theory models is given in the table below.

Real-world	Model
Actors	Players
Actions & Resources	Moves & Outcomes
Values	Payoffs

Question 3

When is it appropriate to apply cooperative game theory rather than non-cooperative game theory?

- ○ Actors are willing to follow a fixed set of rules
- ◉ Actors are willing to communicate, coordinate and collectively act towards a solution
- ○ Actors are committed to pursuing their own interest
- ○ None of the above

Comments on Question 3

Cooperative game theory is only appropriate when actors are willing to communicate, coordinate and potentially pool resources to collectively find a solution. Non-cooperative game theory is appropriate when actors are willing to follow a fixed set of rules and are committed to pursuing their own interest. They are then in competition with one another for the best outcomes.

Question 4

The outcomes of a cooperative game are:

- ○ what each player (actor) can expect to receive
- ○ what each player can expect to receive in different forms of collaboration between players (actors)
- ◉ the different forms of collaboration that are possible between players (actors)
- ○ the potential space of collaborative agreements

Comments on Question 4

The outcomes of a cooperative game are the different forms of collaboration that are possible between players of the game and the actors in real life. See the example of a 3 player game and its eight outcomes in the table below. The solutions are what each player can expect to receive, and the solution concept of the core is the potential space of collaborative agreements.

Outcome	Moves	Outcome type
1	-	Null Coalition
2	A	Individual Action
3	B	Individual Action
4	C	Individual Action
5	AB	2-Player Coalition
6	BC	2-Player Coalition
7	AC	2-Player Coalition
8	ABC	Grand Coalition

Question 5

The solution concepts in cooperative game theory have different names. The Core depicts:

- ◉ the potential space of voluntary collaborative agreements
- ○ the space where each player will get more pay-off than they would alone
- ○ the space that makes the most unhappy actor less unhappy without affecting the others
- ○ all of the above

Comments on Question 5

The core depicts the potential space of voluntary collaborative agreements where each player will get **as much** (not necessarily **more**) pay-off than they would individually. The Nucleolus is the point that makes the most unhappy actor less unhappy without affecting the others. It is not necessarily located within the core.

Question 6

The solution concept that distributes pay-offs equitably according to what each player brings in and takes into account how the coalition was formed is called:

- ○ the Core
- ○ the Nucleolus
- ◉ the Shapley value
- ○ the Coalition
- ○ none of the above

Comments on Question 6

The solution concept that distributes pay-offs equitably/fairly according to what each player brings in and takes into account how the coalition was formed is called the Shapley value. The core depicts the potential space of voluntary collaborative agreements, while the solution concept treating each player as if they are of equal value i.e. in an egalitarian fashion, is the Nucleolus. A coalition is the form of collaborative arrangement (outcome) agreed by the actors (players).

Feedback on Assignment 8.2

The Feedback on Assignment 8.2 comprises:

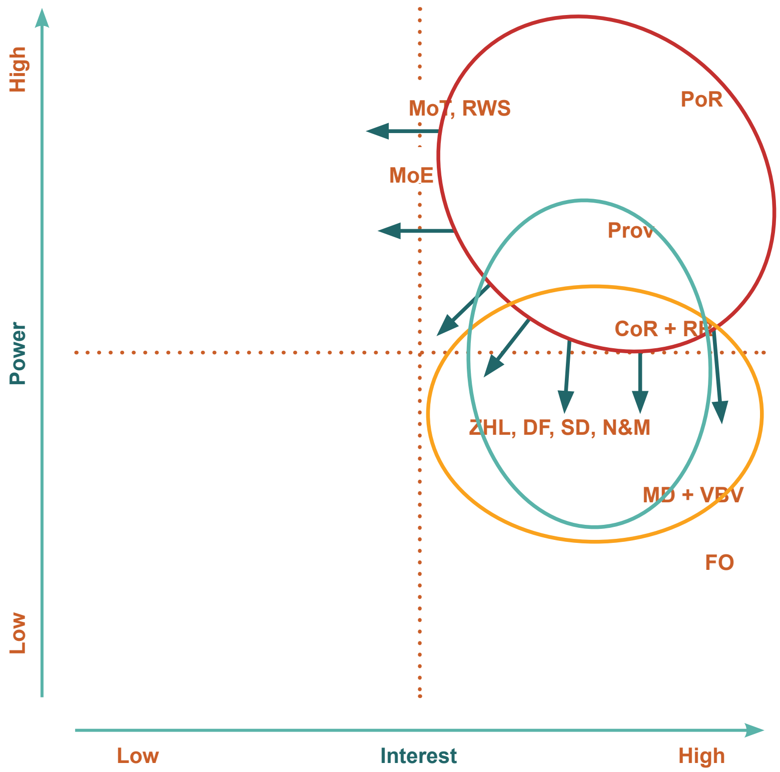
1. Comments on each of the questions in the document directly below, and
2. A slide presentation on '**A Cooperative Game Theory Application - Maasvlakte 2 Port Development**' by **Prof. Jill Slinger** afterwards.

Initial List of Key Stakeholders

1.	Port of Rotterdam harbor authority (PoR) / Ministry of Economic Affairs (MoEA) / Associated transport and logistic services (TLS)
2.	Dutch Ministry of Transport, Public Works and Water Management (MoT, RWS) / District Water Boards (WB)
3.	Ministry of Housing, Spatial Planning and the Environment (MoE)
4.	Province of South-Holland (Prov)
5.	City of Rotterdam (CoR)
6.	Rotterdam Region (RR)
7.	South-Holland Landscape Foundation (ZHL) / Foundation for Dune Protection (SD)
8.	The Fauna Conservation Foundation (DF)
9.	Friends of the Earth NL (MD)
10.	Federation for Environment and Nature (N&M)
11.	Non-Governmental Fisheries Organisation (FO)
12.	Concerned Citizens of Voorne (VBV)

Question 1 introduction

Consider the initial list of key stakeholders on the right and Power-Interest Grid from Assignment 7.1 on the next page, and consider the red, orange and green shapes in the Power-Interest Grid.



Question 1

Which of the following statements are true?

- ☑ The red circle is indicative of the player 'port development', who prior to January 2005 considered the scale of the game to be focused on the Maasvlakte 2 area
- ☑ The orange circle is indicative of the player 'local citizens' who is concerned about the effects of the Maasvlakte 2 port expansion on quality of life
- ☑ The green circle is indicative of the player 'environment' who is primarily concerned about ecological health and nature conservation

Comments on Question 1

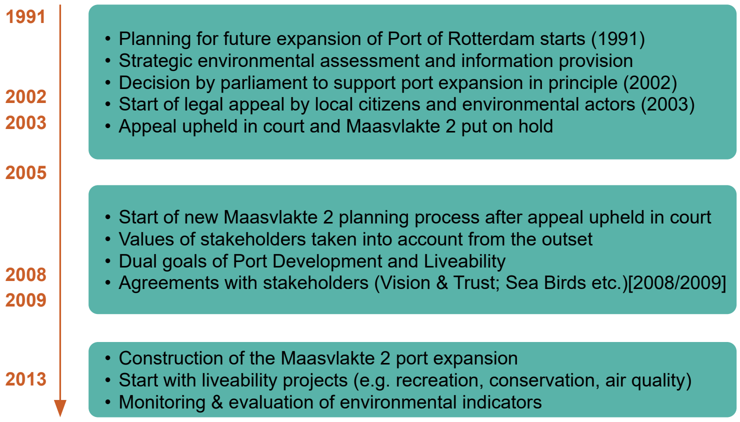
There is no false statement. See the slides 'A Cooperative Game Theory Application - Maasvlakte 2 Port Development' by Prof. Jill Slinger for the step by step depiction of the games.

Consider the timeline on the right of the Maasvlakte 2 port development process.

Question 2

Which of the following statements is false?

- ◯ The 1st phase (before January 2005) involved local citizens and environment players appealing against the Maasvlakte 2 port expansion in court
- ◯ The 1st phase can be characterised as the game ‘Recourse to Court’
- ◯ The 2nd phase involved negotiation between environment, local citizens and port development players about the objectives of the game
- ◯ The 2nd phase can be characterised as the game ‘Dual Goals’
- ◉ The 3rd phase, involving the realisation of the Maasvlakte 2 port development and negotiation about monitoring of the effects, is not a game as it is ongoing
- ◯ The 3rd phase can be characterised as the game ‘Realisation and Monitoring’



Comments on Question 2

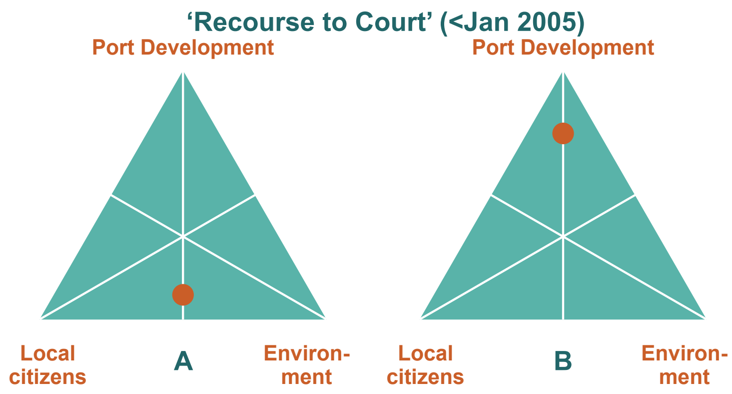
The statement that the 3rd phase, involving the realisation of the Maasvlakte 2 port development and negotiation about monitoring of the effects, is not a game as it is ongoing, is false. It can be characterised as a game Realisation and Monitoring’ that has not yet ended.

Consider the diagrams on the right:

Question 3

In the 1st game ‘Recourse to Court’ the solution favoured the port development player. Which of the following statements is true?

- ◯ Diagram A represents this situation because the red circle indicating the pay-offs is near maximum for the port development player
- ◉ Diagram B represents this situation because the red circle indicating the pay-offs is near maximum for the port development player
- ◯ Diagram A represents this situation because the red circle indicating the outcome is near maximum for the port development player
- ◯ Diagram B represents this situation because the red circle indicating the outcome is near maximum for the port development player



Comments on Question 3

Diagram B represents this situation because the red circle indicating the pay-offs is near maximum (nearest to the node) for the port development player. The outcome of a game is the arrangement that is formed by the players, so each for themselves, bilateral or multilateral coalitions.

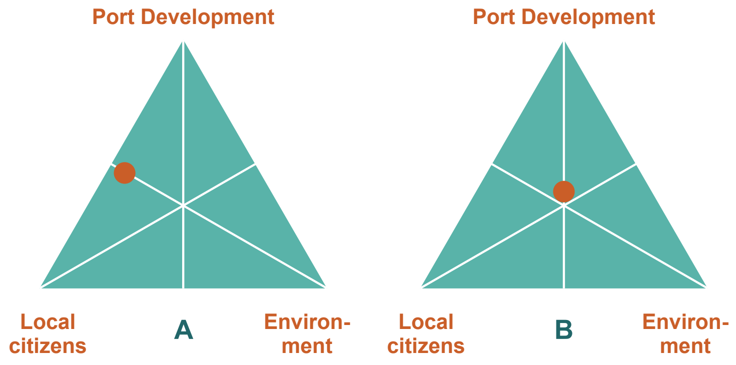
Now, consider the diagrams on the right:

Question 4

In the 2nd game 'Dual Goals', the two goals of port development **and** liveability were adopted. Which of the following statements are true?

- ☐ The outcome of the 2nd game 'Dual Goals' is a coalition between the port development player and the local citizens player
- ☐ **A** is representative of the 2nd game 'Dual Goals' because the red circle is in the middle between the port development player and the local citizens
- ☑ The outcome of the 2nd game 'Dual Goals' is a coalition between the port development player, the local citizens player and the environment player
- ☑ **B** is representative of the 2nd game 'Dual Goals' be cause liveability includes the environ-ment and the red circle is almost equally distant from all players

'Dual Goals' (Jan 2005-2009)



Comments on Question 4

The outcome of the 2nd game 'Dual Goals' is a coalition between the port development player, the local citizens player and the environment player. This is represented by **B** because liveability includes the environment and the red circle is almost equally distant from all players.

Question 5

If we were to analyse the planning and design of the layout and harbor infrastructure of the Maasvlakte 2 as a game, then which of the following statements do you consider false?

- ☑ The same actors would form the players in the game of laying out the Maasvlakte 2 harbour area
- ☐ Non-cooperative game theory would probably provide a better representation of the compe-tition between port stakeholders regarding faci-lities, position and pricing
- ☐ The companies wanting to utilise the new Maas-vlakte 2 would have to adhere to the environmental monitoring conditions agreed within the broad coa-lition on port development and liveability, so the moves of players in the new game are in some sense constrained by the previous game(s)

Comments on Question 5

The stakeholders concerned with the planning and design of the layout and harbour infrastructure include port industries, international terminal operators, pilots, transport and logistics organisations, the offshore industry, the Port of Rotterdam, harbour engineers and even energy companies, amongst others. Some of these stakeholders are in competition with each other for a prime location or good financial terms, so non-cooperative game theory is likely to offer a sound representation of the situation. And, yes, the environmental monitoring conditions agreed in the wider stakeholder consultation process form boundary conditions for the exploiters of the Maasvlakte 2, so previous games can infuence the moves available to players in subsequent games.

Feedback Slides: A Cooperative Game Theory Application - Maasvlakte 2 Port Development

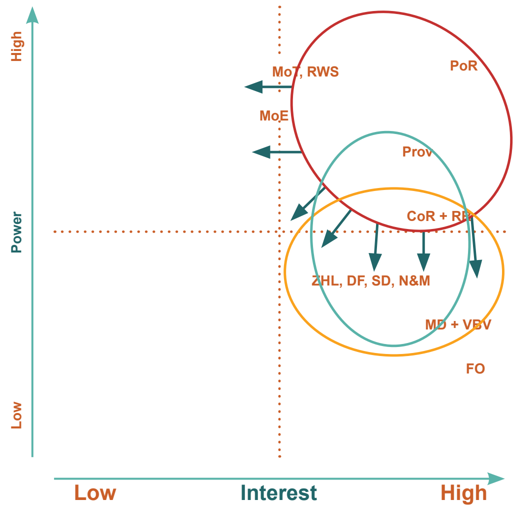
1. The Playing field...

8-34. The port of Rotterdam. © Port of Rotterdam

2. The Players

- **Port Development**
- **Local Citizens**
- **Environment**

Here we see the key players in the 1st game (red) and that the playing field widens in 2nd and subsequent games to include less influential, yet highly interested actors who can block the process



3. The Timeline

1991
- Planning for future expansion of Port of Rotterdam starts (1991)
- Strategic environmental assessment and information provision
- Decision by parliament to support port expansion in principle (2002)

2002
- Start of legal appeal by local citizens and environmental actors (2003)

2003
- Appeal upheld in court and Maasvlakte 2 put on hold

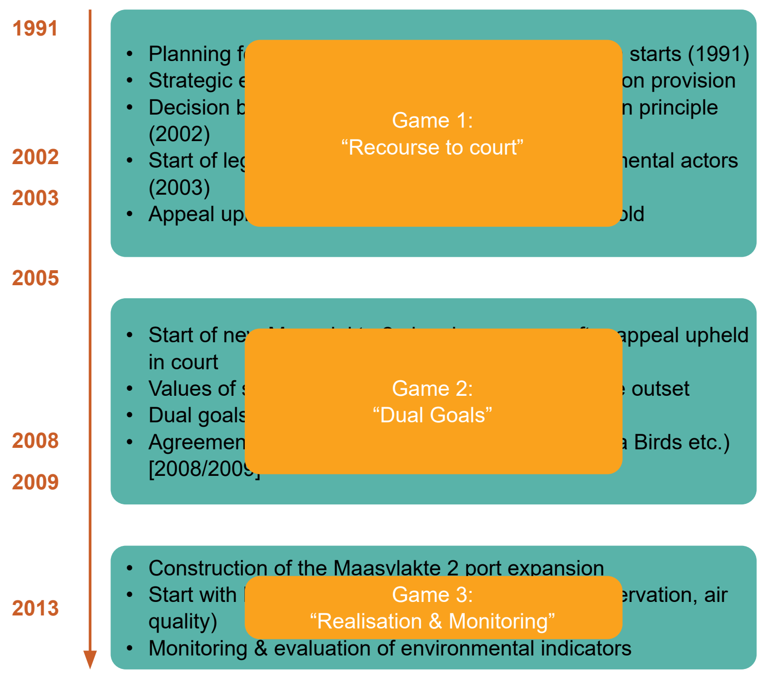
2005
- Start of new Maasvlakte 2 planning process after appeal upheld in court
- Values of stakeholders taken into account from the outset
- Dual goals of Port Development and Liveability

2008
- Agreements with stakeholders (Vision & Trust; Sea Birds etc.) [2008/2009]

2009

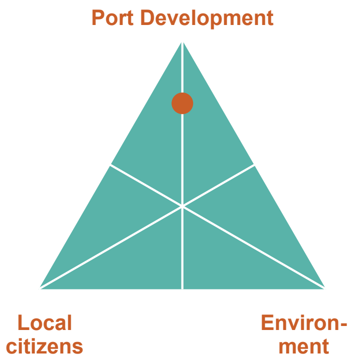
2013
- Construction of the Maasvlakte 2 port expansion
- Start with liveability projects (e.g. recreation, conservation, air quality)
- Monitoring & evaluation of environmental indicators

4. The Games



5. Game 1: 'Recourse to Court' (2002 – Jan 2005)

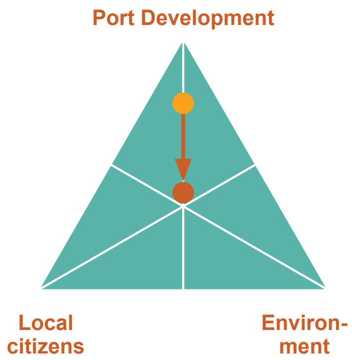
- 'Port development' influential economic actor
- Port expansion planning process underway from 1991, approved in principle in parliament in spring 2002
- Start of appeals against the expansion
- Conflict of interests between 'Port development', 'Local citizens' and 'Environmental' actors



Culminated in court ruling against port expansion in Jan 2005

6. Game 2: 'Dual Goals' (Jan 2005 – 2009)

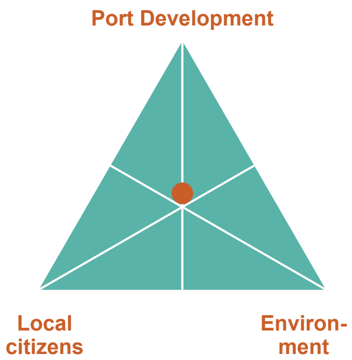
- Broad **liveability coalition** formed between **Local citizen**s and **Environmental actors**
- Commitment to dual goals of **Expansion & Liveability** throughout the planning process
- Agreements made with most stakeholders to formalise project commitments and avoid delays through legal action
- Final VBV appeal against the expansion



Culminated in court ruling for port expansion in Jan 2009

7. Game 3: 'Realisation & Monitoring' (< 2009)

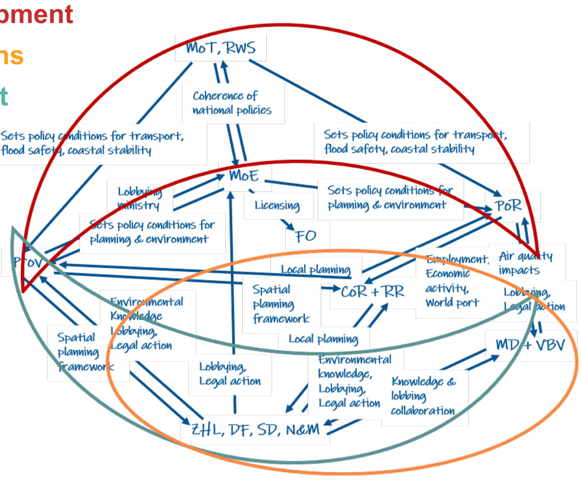
- Broad **liveability coalition** between **Local citizens** and **Environmental actors** maintained
- Maasvlakte 2 port expansion underway
- Multiple liveability and nature compensation projects underway
- Attention shifts to monitoring air quality, birds, recreation & appropriate modal split
- Improvements in air quality, high number of visitors to Maasvlakte 2



Port expansion realised in 2013, monitoring ongoing

8. Coalition Forming

Port Development
Local Citizens
Environment



Here we see **Environment** + **Local Citizens** naturally form a **Liveability** coalition.

When PoR + **Port development** actors agree to dual goals, the grand coalition is formed. The only actors potentially excluded are FO &VBV

9. Insights

- Game theory was useful in re-construing what happened during the Maasvlakte 2 port expansion planning process. It showed:
    - Game 1 was played with a focus on the port and its needs. The less powerful stakeholders had recourse to the court to block the process
    - Game 2 captured the formation of a broad **Liveability coalition**
    - Game 3 captures the ongoing monitoring of the Maasvlakte 2 after its realisation in 2013
- The need to widen the scope to include less influential yet highly interested stakeholders i.e. to scale up geographically and in multi-actor diversity was also evident from the PI-grid of Assignment 7.1 (see slide 2)
- The broad coalition was already potentially evident from the interdependence analysis of Assignment 7.1. (see slide 8)
- Stakeholder analysis & mapping is a necessary precursor to game theory, that in turn structures insights on coalition building

8.7 Bibliography

Literature

Enserink, B., Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., & Bots, P. (2010). *Policy Analysis of Multi-Actor Systems.* Lemma.

Gomes, S. (2019). *An Institutional Approach to Peri-Urban Water Problems: Supporting community problem solving in the peri-urban Ganges Delta*. PhD dissertation, Delft University of Technology, Delft, Netherlands

Hermans, L., Cunningham, S., Slinger, J.H. (2014). The usefulness of game theory as a method for policy evaluation. *Evaluation 20*(1): 10-25. DOI: 10.1177/1356389013516052

Osborne, M. J., & Rubinstein, A. (1994). Introduction. In *A Course in Game Theory* (pp. 1–8). Cambridge: The MIT Press.

Rasmusen, E. (2007). The Rules of the Game. In *Games and Information: An Introduction to Game Theory* (Fourth, pp. 11–33). Malden, MA: Blackwell Publishing.

Von Neumann, J., & Morgenstern, O. (1944). *Theory of games and economic behavior*. Princeton University Press.

Figures

8-1. Playing Games in Tema, Ghana: This image is Copyright protected.

8-2. Coastal or River Basin Management: This image is in the Public Domain, CC0

8-3. Drinking Water Management: This image by Christine Daniloff / MIT is licensed under CC BY-NC-ND 4.0

8-4. Nature-based Flood Defences: This image by Deltares is licensed under CC-BY-NC-SA 4.0.

8-5. Elements of a Game Theory Model: This table by Sharlene Gomes and Jill Slinger is licensed under CC-BY-NC-SA 4.0.

8-6. Non-cooperative Game Theory: This image by Sharlene Gomes and Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-7. Cooperative Game Theory: This image by Sharlene Gomes is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-8. Groundwater monitoring in Bangladesh: This image is adapted by Sharlene Gomes from Jagrata Juba Shangha (2016) and is licensed under CC-BY-NC-SA 4.0.

8-9. Ternary Plot: Core: This image by Sharlene Gomes is adapted from Gomes (2019) and is licensed under CC-BY-NC-SA 4.0.

8-10. Ternary Plot: Nucleolus: This image by Sharlene Gomes is adapted from Gomes (2019) and is licensed under CC-BY-NC-SA 4.0.

8-11. Ternary Plot: Shapley Value: This image by Sharlene Gomes is adapted from Gomes (2019) and is licensed under CC-BY-NC-SA 4.0.

8-12. Great Brak Estuary: This image by Susan Taljaard is licensed under CC-BY-NC-SA 4.0.

8-13. Great Brak Estuary Mouth: This image by CSIR is licensed under CC-BY-NC-SA 4.0.

8-14. Low lying developments in Great Brak flood plain: This image by CSIR is licensed under CC-BY-NC-SA 4.0.

8-15. Wolwedans Dam: Wolwedans dam, South Africa by Louis and Alida van der Walt is licensed under the CC BY-SA 3.0

8-16. The Players: This image by Susan Taljaard and Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-17. The Games: This image by Susan Taljaard and Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-18. Game 1: "Defiance" (1980-1990): This image by Susan Taljaard and Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-19. Game 2: "Co-Managing Estuary" (1990-2004): This image by Susan Taljaard and Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-20. Game 3: "The Drought" (2004-2011): This image by Susan Taljaard and Jill Slinger is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-21. River IJssel (Green) and Twente Canal (Yellow): This image by Heleen Vreugdenhil is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-22. The river IJssel in Deventer: Luchtfoto Deventer, 9-7-2014. by Rijkswaterstaat / Ruimte voor de Rivier. Retrieved from https://beeldbank.rws.nl/MediaObject/Details/497468

8-23. Twente Canal: "Glanshavervegetatie weer in de berm tussen de Ehzerbrug en Lochem" is Copyright protected. © 2018 Ger Boedeltje. All Rights Reserved.

8-24. Principles of the Innovation Team: This image by Heleen Vreugdenhil is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-25. SRL, adapted from Rijkswaterstaat: This adapted image by Rijkswaterstaat is in the Public Domain, CC0.

8-26. Technology Readyness level: This image by NASA / Airspace Systems is in the Public Domain

8-27. Flexible Groynes: This image by SSRS Innovation Team is licensed under CC-BY-NC-SA 4.0.

8-28. Sheep herding instead of machine mowing: This image by Deltares is licensed under CC-BY-NC-SA 4.0.

8-29. Bubble screen to remove plastic from rivers: These images are Copyright protected. © The Great Bubble Barrier. All Rights Reserved.

8-30. Wooden screens to prevent bank erosion: This image is Copyright protected. © BAM / Van den Herik. All Rights Reserved.

8-31. Aquatic drones' Phoenix 1.5, used for monitoring purpopes: "Aquatic Drones' Phoenix 1.5, IJssel bij Kampen" is Copyright protected. © www.AquaticDrones.eu. All Rights Reserved.

8-32. Coalition Building: This image by Heleen Vreugdenhil is reworked by Martijn Vos and licensed under CC-BY-NC-SA 4.0.

8-33. Runner up in European Public Procurement Innovation (PPI) Award 2015: This image by Heleen Vreugdenhil is licensed under CC-BY-NC-SA 4.0.

8-34. The port of Rotterdam: These images are Copyright protected. © Port of Rotterdam. All Rights Reserved.

9-1. Workshop with Stakeholders. © Baukje Kothuis

Chapter 9
Social Design Principles

9.1 Introduction

In Chapter 9 you will learn about Social Design Principles (S-principles). The idea is that by applying the Social Design Principles (S-principles) along with the Engineering Design Principles (H-principles) and the Ecological Design Principles (E-principles) you can take the social context into account and **move beyond engineering** in practising Building with Nature.

At this stage, you have learned to diagnose when stakeholder engagement is necessary in a complex problem situation (Chapter 6), and how to identify and map relevant stakeholders (Chapter 7). You are also familiar with the basics of cooperative game theory and its application in analyzing various Building with Nature examples (Chapter 8). Now, you will learn about Social Design Principles - the principles by which you can craft an engagement process and its substantive content to address the social context.

First, you will learn from experts in transdisciplinary stakeholder engagement and social impact assessment in the following videos:

- Principles for the process of engagement - a video presented by Prof. Tally Palmer and Dr. Athina Copteros in which they share insights from South Africa
- Eight themes for assessing social impact - a video presented by Drs. Abel Knipping in which he draws on an Indonesian example.

Then there is an **assignment** centered on an example from Sierra Leone. The information that you will need to complete the assignment is supplied in the video 'Small hydropower in Sierra Leone - Feasibility Study. Part 1' presented by Drs. Jacobiene Ritsema, a social impact assessment expert. Once you have completed the assignment, another video 'Small hydropower in Sierra Leone - Feasibility Study. Part 2' supplies information on what happened in the real situation.

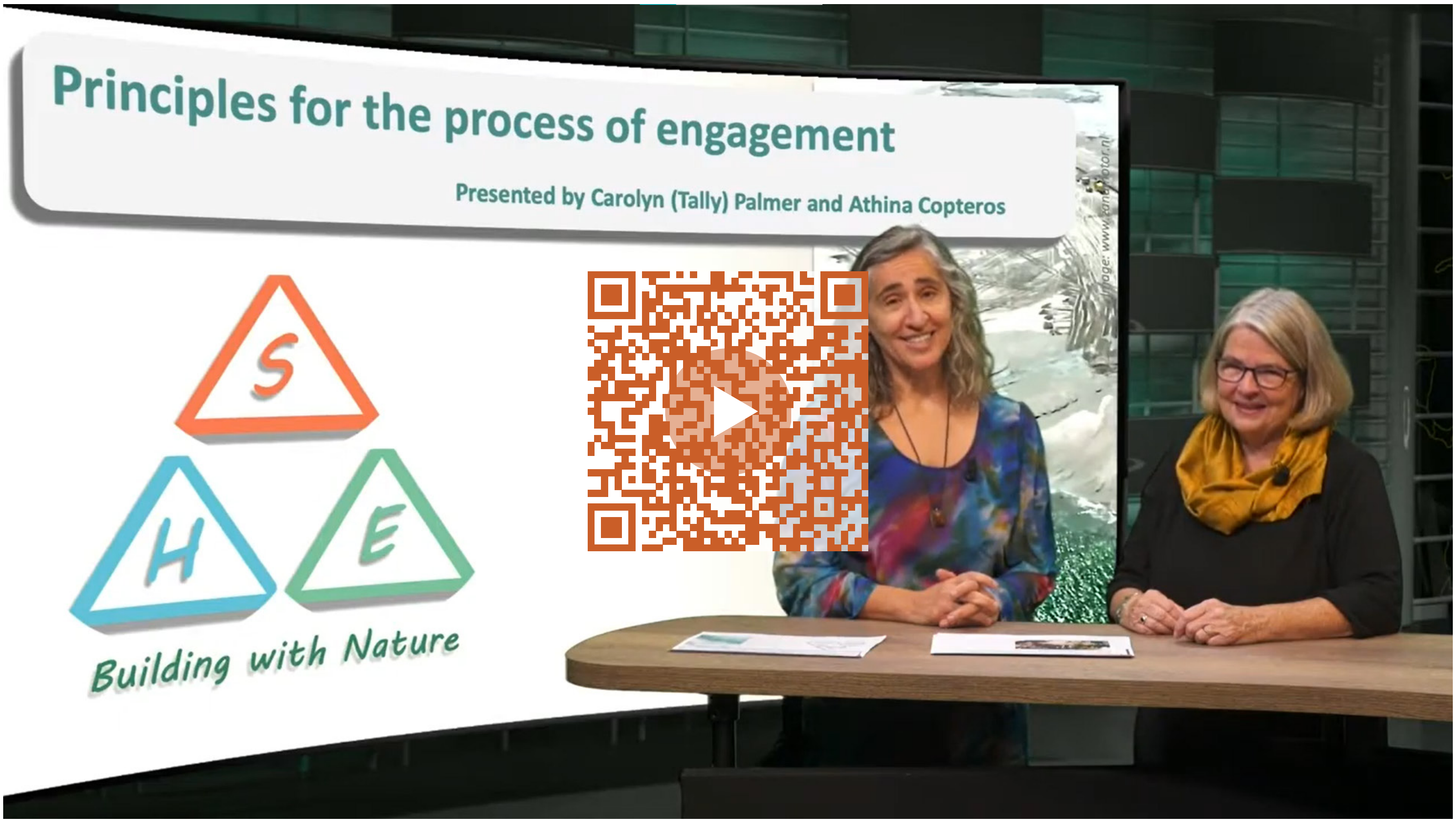
Next, drawing on the earlier videos, Prof. Jill Slinger will expound a set of Social Design Principles (S-principles) for use in Building with Nature design processes. She includes normative principles, principles for the engagement process and substantive principles.

You will be applying the Social Design Principles (S-principles) to material from Tema, Ghana, in the final course assignment in Chapter 10. Information on environmental and Building with Nature aspects considered in the recent development of the port of Tema is included in the supplementary readings after the video on the S-principles.

Remember that we do not focus on assessing **all** the potential impacts of the infrastructure on the social system. Nor, do we evaluate **all** the goods and services deriving to humans from the ecosystem. Instead, we focus on learning **how to engage with stakeholders and build coalitions so that the infrastructural designs fit well with the character and functioning of the social system.**

Enjoy learning about the Social Design Principles!

9.2 Principles for the Transdisciplinary Engagement process



Video: Principles for the Process of Engagement

As an experienced practitioner and leading academic in transdisciplinary science, **Prof. Tally Palmer** shares her insights on how to engage with stakeholders in participatory environmental and water management. She has distilled her experiences into 'Principles for the process of engagement' as she and **Dr. Athina Copteros** explain in the following video. This video was written by **Tally Palmer**, **Athina Copteros** and **Jill Slinger**.

You can cite the video as:

Palmer, C. (Tally), Copteros, A. (Athina), Slinger, J.H. (Jill) (2020). *Beyond Engineering: Building with Nature 2x video #07. Principles for the process of engagement.* 4TU.Dataset. https://doi.org/10.4121/14912409

Video Transcript

Presented by Prof. Tally Palmer and Dr. Athina Copteros

A: We are speaking with Tally Palmer today. She is a transdisciplinary researcher with a lot of experience of working within complex systems, and underlying complex systems are certain fundamental principles that have emerged through practice that she will be sharing with us today. Tally, let's start with the first principle around tolerating discomfort and unresolved tensions and how these are a gateway to a new level of knowledge.

T: We don't like everybody and not everybody likes us and it's uncomfortable. But in the moments of discomfort there are little cues for yourself to learn to allow the discomfort to open up something new for yourself.

A: And speaking of something new there are the 'aha' moments speak to us about those.

T: That's the fun bit! We all know what happens when we suddenly click and again being conscious of those and being generous in sharing what happened in your head as you went 'aha' is a really helpful thing.

A: And inherent to that I would think is also this principle of generosity that you have.

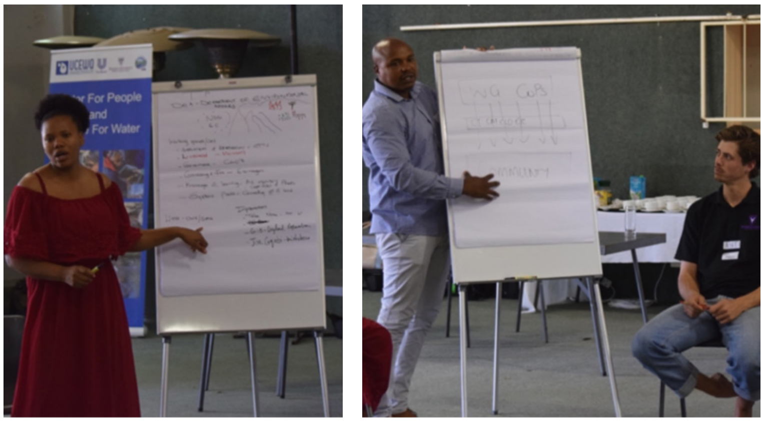
T: You see there are people like me who talk a lot and who don't find it difficult to intervene and say something that's in their head. There are also those people who are very quiet. And this notion of a balanced generosity is to cue yourself in to both listening and to speaking and sharing when you have something valuable to share.

A: And in order for people to be comfortable to share there has to be a certain level of trust.

T: Trust and building trust is the foundation and the glue of these processes. And trust comes from tolerance, people experience you tolerating kindly and listening, and the trust that builds out of that is really important.

9-2. *Principle 1. Tolerate discomfort and unresolved tensions as they are often a gateway to a new level of knowledge, understanding and trust. ⓒ IWR, Rhodes University*

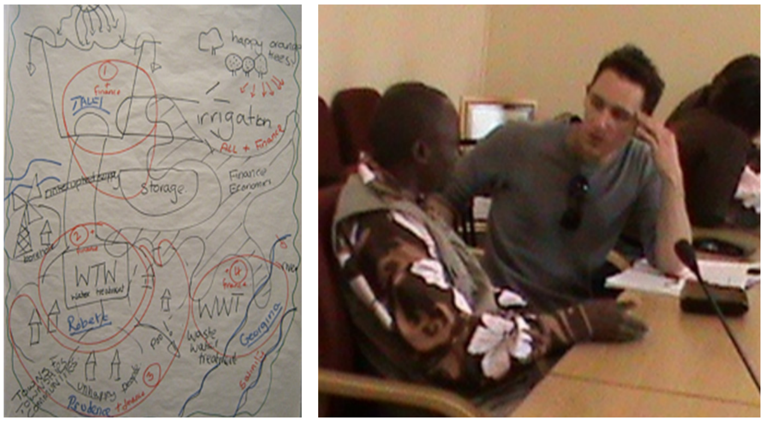
9-3. *Principle 2. Be sensitive to "Aha!" moments of insights. ⓒ IWR, Rhodes University*



9-4. *Principle 3. Engage with balanced generosity: enquiring, listening and sharing. Managing contribution and constraint is closely linked to listening. ⓒ IWR, Rhodes University*

9-5. Principle 4. Practise tolerance, build integrity and mutual trust. 🅭 IWR, Rhodes University

9-6. Principle 5. Create and use reflective opportunities. 🅭 IWR, Rhodes University



9-7. Principle 6. Be sensitive to the 'arrivals' of both people and ideas. 🅭 IWR, Rhodes University

9-8. Principle 7. Manage discontinuities, people come and go and arrangements change suddenly. 🅭 IWR, Rhodes University

A: And then reflection as part of building relationship.

T: We live in an extremely busy world. We rush from one thing to another and we think that business is efficiency. And it's really important to create far more places to think, to reflect and to reflect together.

A: And then being sensitive to the arrivals of ideas and people.

T: Arrivals are not always convenient. That takes us back to the discomfort. But arrivals bring richness and opportunity. So as they happen, whether they're a person walking into the door or the new idea, be sensitive to that.

A: And part of the arrivals is also that some people then will leave as well. And one has to also manage all sorts of discontinuities.

T: I think this principle has been the heart and the anchor of my practice because things change all the time. Meetings are cancelled. A new person replaces another one and you're not sure if they know where you've got to. And so knowing that this is going to happen helps you very much in just going forward. Even though there are these discontinuities.

A: And needing to sustain inquiry when there are very tough experiences that happen when there's a certain element of chaos.

T: The image that you have here is of a municipal building burning. And this happened when people were so frustrated with the lack of service delivery in terms of water that they burned the municipal buildings. And it happened in the middle of a doctoral thesis. Now that's an extreme event and the need to persevere often happens in a much less dramatic way. But there are times when you want to give up and the importance of persevering is one of these fundamental principles.

A: And then finally the fact that each person is a whole person who comes from many different experiences and is very much multi-dimensional.

T: We are used to discounting lots of things. I got trained as an ecologist in a science discipline but I also love poetry and I write poetry. And it's important for our whole beings and the way we are and our need to move and to be still and what we know of our local contexts to be part of this engagement. It's part of that generosity we talked about.

A: Tally, thank you for sharing those principles and for embodying those principles. And thank you to you!

9-9. Principle 8. Sustain enquiry (keep going when it is tough).

9-10. Principle 9. Be conscious that everyone involved is a whole, multi-dimensional person, with the potential to engage with their whole self and with many ways of knowing. IWR, Rhodes University

9.3 Themes for Assessing the Social Context

Video: 8 Themes for Assessing Social Impact

This section contains a video presented by **Drs. Abel Knipping** and written by **Abel Knipping**, **Jacobiene Ritsema**, **Cyntha Nijmeijer** and **Jill Slinger.** He explains the use of 8 themes for assessing the implications of an infrastructural intervention in a particular social context, drawing on an example from Semarang in Indonesia. The design for the canal in the last slide was made by Kuiper Compagnons.

You can cite this video as:

Knipping, A. (Abel), Ritsema, J. (Jacobiene), Nijmeijer, C. (Cyntha), Slinger, J.H. (Jill) (2020). *Beyond Engineering: Building with Nature 2x video #08. Eight themes for assessing social impact.* 4TU.Dataset. https://doi.org/10.4121/14912424

Video Transcript

Presented by Drs. Abel Knipping

Is the only function of a canal the transfer and capture of water? Is its value only expressible in the number of floods it prevents or the number of boats that use it?

We are in a paradigm shift. Projects with a singular 100% technical focus are getting smaller in number. Instead you see the focus is shifting from functional and financial aspects to societal aspects, added value and chances that arise besides the project's main goal.

Integral projects also take the social aspects of infrastructural development into consideration. They provide an opportunity for the local community to participate, discuss and contribute ideas. But an infrastructure can have many effects on society as well, some positive and some being negative.

Assessing these impacts of an infrastructure project on the natural environment has been researched, institutionalised, regulated and explained in text books for years. But how do we assess an infrastructure project's impact on the social environment?

Well that's difficult. Because social structures are fluid, subjective and hard to grasp. Frank Vanclay identified 8 themes which we use to describe the social context. By assessing each of these themes and speaking to local stakeholders about the potential impact of an infrastructure project on these themes, we are able to assess potential social impacts in the early stages of a project. I will explain these themes through the example of a water as leverage project in Semarang Indonesia. Water as leverage proposed the rechannelling of parts of the city in order to increase its climate resilience.

1. Theme 1 - Way of Life. Assessing the impact on this theme involves asking questions like: How do you spend your day? How do you earn your money? And do you see economic opportunities when this infrastructure development takes place? In Indonesia people replied with 'I sell rice on the market' to the second question. Others identified a preferred new market structure instead.

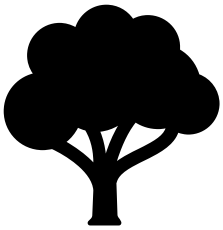
9-11. Local community engagement. © Witteveen+Bos

9-12. Theme 1: Way of life. © Witteveen+Bos

9-13. Theme 2: Culture. © Witteveen+Bos

9-14. Theme 3: Community. © Witteveen+Bos

9-15. *Theme 4: Political systems. © Witteveen+Bos*



9-16. *Theme 5: Environment. © Witteveen+Bos*

9-17. *Theme 6: Health and wellbeing. © Witteveen+Bos*

9-18. *Theme 7: Personal and property rights. © Witteveen+Bos*

2. The theme Culture. Questions are similar to what are important cultural expressions for you? In Semarang, the Wajang puppet theatre is an important cultural asset, providing a means of addressing social issues.

3. Community - do people in the community help each other? Who are the most vulnerable people in your community? How will the project impact your community? Well, this market was an important place for the community of Semarang to meet and enjoy the leisure time they have. People also identified a shortage of proper public spaces to meet each other.

4. Political systems - do you participate in decision-making? Do you trust politicians? In Semarang, many people were not confident that the local authorities could solve the problems they had.

5. Environment - what are the main environmental issues in your community? We found that waste was disposed in this canal and that the market's toilets flush into the canal as well, causing environmental pollution issues.

6. The theme - Health and wellbeing - we asked ques-

tions like - how is the health system organised? Who is your doctor? How near is the nearest hospital? One of our interviewees indicated the importance and benefits of the Kelurahan, meaning the community health care programme.

7. Personal & property rights - how are the land rights divided? Are you concerned that you will be negatively economically affected by this intervention? People in Semarang indeed feared that they would suffer loss of income after a potental relocation of this market. Others saw opportunities for a shift in the market's organisation.

8. For the theme - Fears & aspiration. What future do you see for your children in your community? The main aspirations the people in Semarang had were to increase security, sanitation, waste management, and harmony in their community.

And so we see that talking to people and gathering 'subjective' information on these 8 themes about community structure, helps in identifying potential opportunities for our infrastructure design - and these potential opportunities include local people, they help to avoid threats that are easily missed or disregarded when designing infrastructure only from behind our desk.

Let us take this example of Semarang Indonesia. In the city we conducted interviews with local people. They told us they missed a communal area in their neighbourhood, a proper public place to meet.

So instead of merely creating a big and broad canal that fulfils the need to drain flood waters rapidly, we designed the canal to also have space and facilities for this community to meet each other when the water level is low.

So we see that a canal is more than just a functional flood drainage system. It can be a catalyst for social wellbeing, even a catalyst for a city's attractiveness!

9-19. Theme 8. Fears and aspirations. © Witteveen+Bos

9-20. Canal in Semarang, Indonesia. © Witteveen+Bos

9-21. Artist impression of redesigned canal in Semarang, Indonesia. © Witteveen+Bos

Supplementary Reading

In the preceding video 'Eight themes for assessing social impact' Drs. Abel Knipping refers to Vanclay et al. (2015). This document on social impact assessment is published by the International Association for Impact Assessment. You can download the document by clicking the link or scanning the QR Code below.

You can cite the document as:

Vanclay, F., Esteves, A.M., Aucamp, I. & Franks, D. (2015). Social Impact Assessment: Guidance for assessing and managing the social impacts of projects. Fargo ND: International Association for Impact Assessment.

Social Impact Assessment: Guidance for assessing and managing the social impacts of projects.

9.4 Assignment 9.1

Introduction

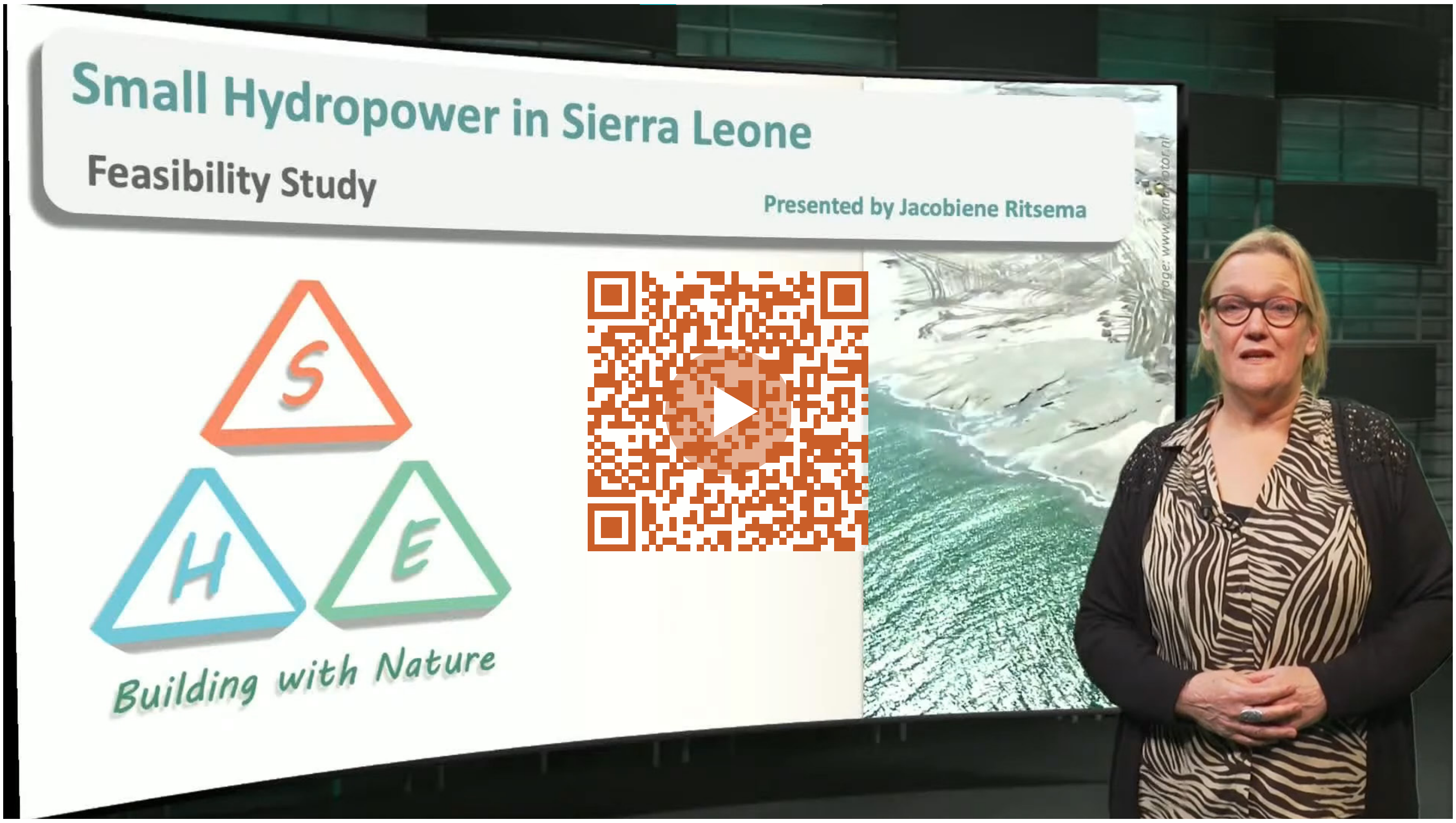
This assignment involves the application of the themes for assessing social impact, as explained in the video by Drs. Abel Knipping in the previous section.

The specific information that you need to complete this assignment is supplied in the following video:

- 'Small hydropower in Sierra Leone - Feasibility Study' presented by Drs. Jacobiene Ritsema, a social impact assessment expert.

Assignment 9.1 contains 6 questions. Once you have completed the assignment, you are encouraged to view what happened in the real situation in the next video, and consult the Feedback on Assignment 9.1.

Enjoy applying the themes to the situation in Sierra Leone!

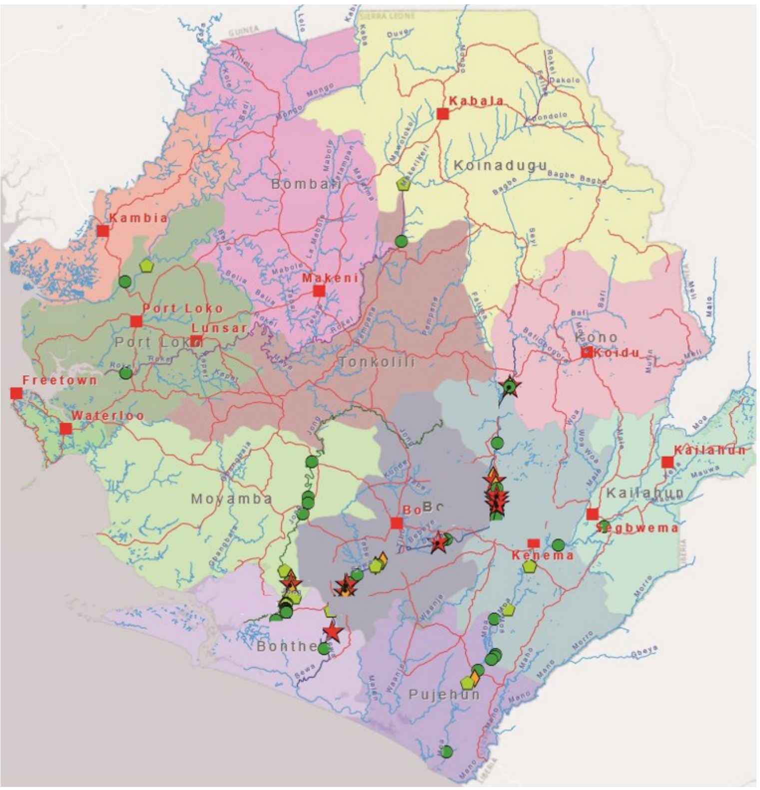


Video: 'Small hydropower in Sierra Leone - Feasibility Study

This video presented by **Drs. Jacobiene Ritsema**, a social impact assessment expert, provides the specific information that you need to complete Assignment 9.1. This video is written by **Jacobiene Ritsema**, **Cyntha Nijmeijer** and **Jill Slinger**.

You can cite this video as:

Ritsema, J. (Jacobiene), Nijmeijer, C. (Cyntha), Slinger, J.H. (Jill) (2021). *Beyond Engineering: Building with Nature 2x video #09. Small hydropower in Sierra Leone - Feasibility Study.* 4TU.Dataset. https://doi.org/10.4121/14912448



9-22. Potential locations for hydropower. ⓒ Witteveen+Bos

9-23. One of the locations during the wet season. ⓒ Witteveen+Bos

9-24. One of the locations during the dry season. ⓒ Witteveen+Bos

Video Transcript

Presented by Drs. Jacobiene Ritsema

So, I'll be telling you about a feasibility study on small hydropower in Sierra Leone This is a map of Sierra Leone and its rivers.

The potential locations for hydropower were identified based on a desk study and the best locations are indicated by symbols, such as the green dots and the red stars, along the rivers.

Sierra Leone is significantly short of power generation capacity, now as well as in the short and medium term. So, a Dutch company intends to install hydro power infrastructure in 2 initial locations with a targeted power production of 3 Mega Watt each or, if possible, 1 initial location with a targeted power production of 6 Mega Watt. Subsequently, more locations will be implemented to achieve a target power production of 75 Mega Watt or more.

So, each of the six potential power station locations has been studied by a team of biologists, ecologists, fisheries experts, land use planners and social scientists. The surveys and analysis have all been conducted in accordance with performance standards of the International Finance Corporation, the IFC,

the Equator Principles and Environmental Impact assessment requirements of the Environment Protection Agency in Sierra Leone.

And a first field visit revealed that the pre-selected locations are promising in terms of potential power generation.

Very promising! However, the first field visit was during the rainy season. So, during the second field visit, in the dry season, all locations were assessed as providing too little power given the current design.

Very little flow indeed… But, what does this mean for the proposed infrastructure?

Stakeholder identification revealed that there is:

1. A designated protected area, rich in biodiversity. This is the gallery forest along the river, that provides corridors for the movement of large mammals: antelopes, deer and bush pigs and habitat for birds and butterflies. And they were also visited by groups of primates including, on occasion, chimpanzees.
2. And - there is also a surrounding population and housing near the river.
3. There is river use for laundry and sanitation purposes.
4. There is sand mining
5. And there is diamond and gold mining.
6. Furthermore there is fishing.
7. And there is farming.

So, what we did - we performed modelling to identify the risk of flooding.

And what happens upstream if you construct a weir of 3 meters or 6 or 9 meters high?

And you can see from the shaded areas that there is flooding. And - our Impact assessment results showed that there are many consequences for people and their living environment. So, the red areas indicate potential major negative impacts for fish migration, fish stock, and community safety.

9-348

And, the impact assessment further shows that there is a major negative impact on the important gallery forest and a loss of livelihood for sand, diamond and gold miners. The full implications of the anticipated changes are explored with stakeholders to establish both the consequences, potential opportunities, and possible mitigation measures for the hydropower infrastructure.

9-25. Shortage of power generation. © Witteveen+Bos

9-26. The power station study team. © Witteveen+Bos

9-27. Gallery forest along the river. © Witteveen+Bos

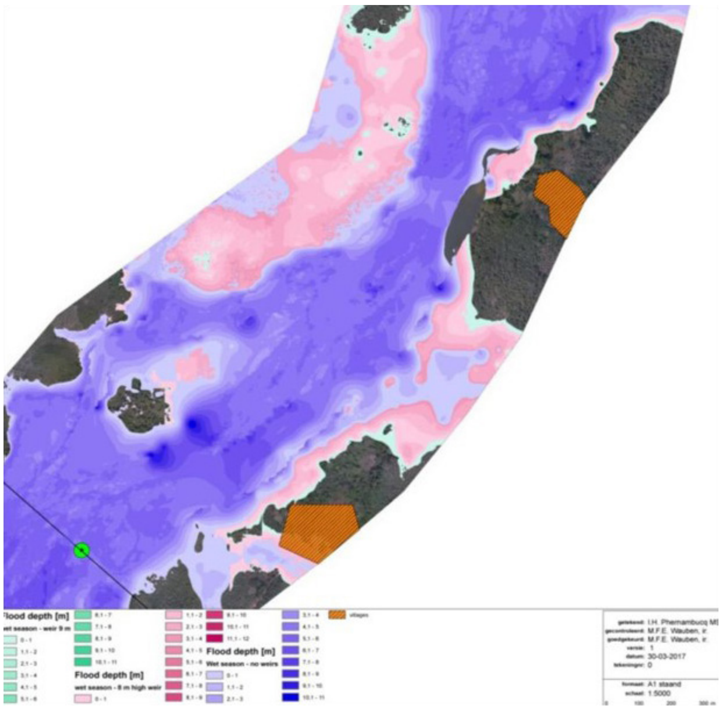
9-28. River use for sanitation and laundry purposes. © Witteveen+Bos

9-29. Sand mining. © Witteveen+Bos

9-31. Fishing. © Witteveen+Bos

9-30. Gold and diamond mining. © Witteveen+Bos

9-32. Farming. © Witteveen+Bos



9-33. Water level plotting for various weir heights. © Witteveen+Bos

9-34. Flooding assessment. © Witteveen+Bos

Adverse impacts during the operational phase

Project Component	Env/Social aspect	Impact	Impact severity site 1&2		Impact severity site 3, 4, 5		Impact severity site 6	
			Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Weir	Fish	Obstacle for fish migration						
	Fisheries/trade/ social interaction	Decreased upstream-downstream navigation possibilities						
	Community safety	Risk of accidents						
Intake channel	Community safety	Risk of accidents						
Turbine house & generating plant	Fish	Loss of fish stock						
	Community safety	Risk of accidents						
Supply network	Community safety	Risk of accidents						
Upstream water body	Terrestrial flora and fauna	Destruction of terrestrial vegetation						
		Loss of gallery forest corridors, significant riparian lands, wetlands, marshes or other wildlife habitats						
	Livelihoods	Obstruction of local sand mining						
		Obstruction of local diamond mining						
	Community safety	Flooding of inhabited area						
Fencing, access gate and security post	Land use	Loss of crops or farm land						

9-350

9-35. Impact assessment results [Red areas indicate potential major negative impacts. © Witteveen+Bos

Assignment 9.1

On the next pages you will find the questions for assignment 9.1.
To check your answer click on the button **Show Answer**. You can click **Hide Answer** if you would like to repeat the question at a later stage.

Question 1

To answer, check as many boxes as you consider appropriate.

Based on the information contained in the video 'Small hydropower in Sierra Leone – Feasibility Study. Part 1', the stakeholder engagement process may be characterised as:

- [ ] adhering to international performance standards for environmental and social appraisal
- [ ] meeting the legal requirements of the Environmental Protection Agency of Sierra Leone
- [ ] employing diverse sources of knowledge e.g. involving multiple disciplines and place-based knowledge
- [ ] interacting with the potentially affected community

Show Answer

Question 2

To answer, check as many boxes as you consider appropriate.

At present the communities living along the river in Sierra Leone are dependent on its resources for:

- [ ] fishing
- [ ] transport
- [ ] hydropower production
- [ ] mining for sand, diamonds and gold
- [ ] laundry and sanitation
- [ ] farming near the river
- [ ] housing located near the river

Show Answer

Question 3

To answer, check as many boxes as you consider appropriate.

Consider the theme 'Way of life'. Which of the following statements do you consider false?

- [ ] Subsistence fishing is a legitimate activity in tune with the ecosystem, and the impacts on such activities should be considered in assessing the theme 'Way of life'
- [ ] Sand mining is harmful to the ecosystem, so impacts on such activities should not be considered in assessing the theme 'Way of life'
- [ ] Most diamond and gold mining occurs illegally, so impacts on such activities should not be considered in assessing the theme 'Way of life'

Show Answer

Question 4

Check only one answer.

Consider the themes 'Environment' and 'Way of life'. Which of the following statements do you consider false?

- ○ effects on the nearby gallery forest, which is a protected ecosystem, should be considered in assessing the theme 'Environment'
- ○ effects on fish migration and fish stocks should be considered in the theme 'Environment' and the consequent effects on fishermen and their fishing activities should be considered in 'Way of life'
- ○ effects on farming (e.g. less land available for crop production) should be considered in the theme 'Environment', but not in 'Way of Life'

Show Answer

Question 5

Check only one answer.

For sites 1 and 2, simulation modelling reveals that locating a hydropower weir across the river will increase the severity of flooding, threatening productivity, property and potentially lives. Now consider the themes ‘Health and wellbeing’ and ‘Fears and aspirations’. Which of the following statements do you consider false?

- ◯ the ‘Health and wellbeing’ of community members is definitely affected, because they could suffer property losses if their houses are flooded’
- ◯ the ‘Health and wellbeing’ of community members is definitely affected, because their lives may be in danger from flooding’
- ◯ the ‘Fears and aspirations’ of community members are definitely affected by the potential property loss and loss of life from flooding

Show Answer

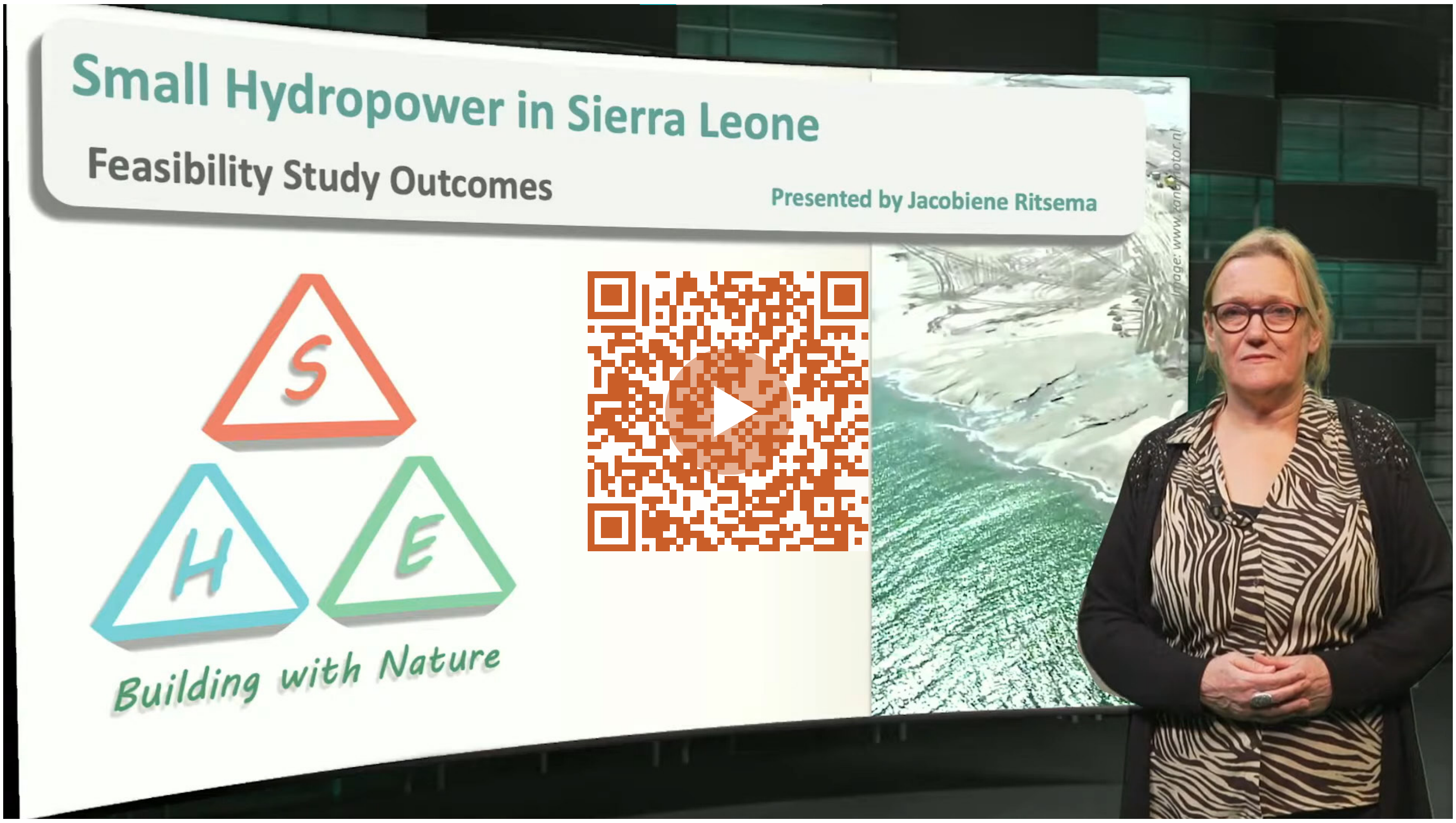
Question 6

Check only one answer.

Which of the following statements is true regarding cumulative effects and opportunities?

- ◯ cumulative effects need not be considered, because the most appropriate sites will be selected following a thorough and respectful stakeholder engagement process
- ◯ cumulative effects need not be considered in the feasibility study, because they are only relevant when you scale up
- ◯ cumulative effects need to be considered even in the feasibility study, because up to six sites might be exploited for hydropower

Show Answer



Video: Small hydropower in Sierra Leone - Feasibility Study Outcomes

Findings on Social Impacts of Hydropower - Sierra Leone

You can see what happened in the real feasibility study in the next video presented by **Drs. Jacobiene Ritsema** and written by **Jacobiene Ritsema**, **Cyntha Nijmeijer** and **Jill Slinger**.

You are also invited to consult the Feedback on Assignment 9.1 in the feedback section.

You can cite this video as:

Ritsema, J. (Jacobiene), Nijmeijer, C. (Cyntha), Slinger, J.H. (Jill) (2021). *Beyond Engineering: Building with Nature 2x video #10. Small hydropower in Sierra Leone - Feasibility Study. Part 2.* 4TU.Dataset. https://doi.org/10.4121/14912463

Video Transcript

Presented by Drs. Jacobiene Ritsema

Once the full implications of the anticipated changes are explored with stakeholders, a number of mitigation measures were proposed.

For instance, building fish-friendly turbines or restricting the design to acceptable weir heights so that upstream water levels are acceptable. This is not an easy decision: a lower weir height means less profit for the investor!

Even with such mitigation measures in place, some of the effects on the community still remain severe and would imply resettlement.

The overall conclusions of the Environmental and Social Impact Assessment indicate that some sites are suitable for hydropower infrastructure development and others are less suitable or not suitable at all.

So, by involving the community in the assessment at the feasibility stage, the construction of infrastructure that is unfriendly to people and nature is avoided, minimised or mitigated.

And this is one of the ways how we support the Sustainable Development Goals.

9-36. Exploration with stakeholders. © Witteveen+Bos

9-37. Sierra Leone's Sustainable Development goals. © Witteveen+Bos

Adverse impacts during the operational phase, after mitigation

Project Component	Env/Social aspect	Impact	Impact significance site 1&2		Impact significance site 3, 4, 5		Impact significance site 6		Mitigation measure
			Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	
Weir	Fish	Obstacle for fish migration							Construct fish ladders/ passes to enable fish migration; • Detailed before and after surveys of fish species and abundance of fish • Specific management proposals for enhancing fish stocks
Intake channel	Community safety	Risk of accidents							Install floating booms upstream of the intake
Turbine house & generating plant	Fish	Loss of fish stock							Build fish-friendly turbines
	Community safety	Risk of accidents							Ban public access to all areas with safety issues; information campaign in the villages; fence the most dangerous territories

Table continues →

Adverse impacts during the operational phase, after mitigation

Project Component	Env/Social aspect	Impact	Impact significance site 1&2	Impact significance site 3, 4, 5	Impact significance site 6	Mitigation measure
Upstream water body	Terrestrial flora and fauna	Destruction of terrestrial vegetation				Restrict the design to acceptable weir heights/ upstream water level
		Loss of gallery forest corridors, significant riparian lands, wetlands, marshes or other wildlife habitats				New planting of gallery forest species to re-establish continuous forest cover through all affected areas. • Prevention of hunting and trapping of mammals within the protected zone.
	Livelihoods	Obstruction of local sand mining				Implement Resettlement and Compensation plan according to international standards
		Obstruction of local diamond mining				Implement Resettlement and Compensation plan according to international standards
	Community safety	Flooding of inhabited area				Implement Resettlement and Compensation plan according to international standards; Conduct flood risk awareness campaigns
Fencing, access gate and security post	Land use	Loss of crops or farm land				Implement Resettlement and Compensation plan according to international standards

9-38. Impact assessment mitigation measures. © Witteveen+Bos

locations assessed ESHIA conclusions	Adverse impacts
Site 1	loss of livelihoods (sand & diamond mining) flooding of inhabited areas cost of compensation/resettlement
Site 2	no overriding Environmental Health and Safety (EHS) issues
Site 3	loss of livelihoods (sand mining) cost of compensation/resettlement
Site 4	affecting gallery forest with rich biodiversity mitigation and compensation needed
Site 5	loss of livelihoods (sand mining, vegetable production Sumbuya residents) compensation necessary, but feasible
Site 6	suitable for natural flow turbines little adverse EHS impacts
Site 7	affecting fragile ecology, thin patch of gallery forest affecting cultural and aesthetic values mitigation through controlled deforestation and human presence (continuous management of surrounding area)
Overall positive impacts:	Reliable and affordable electrical power will boost economic and social development capacity Huge benefits for local communities in case of local mini-grid construction

9-39. Overall conclusions of the Environmental and Social Impact Assessment. © Witteveen+Bos

9.5 Distilling Social Design Principles

Video: Distilling Social Design Principles

In this section, **Prof. Jill Slinger** draws on her experience to synthesise insights regarding the process of stakeholder engagement and the substantive themes for analysing the social context into a number of Social Design Principles. She includes five normative design principles and a scale-related substantive principle to reflect the choice for stakeholder-inclusive, value-based and ecosystem-friendly approaches to underpin moving beyond engineering in Building with Nature. This video is written by **Jill Slinger**, **Heleen Vreugdenhil**, **Tally Palmer**, **Jacobiene Ritsema** and **Floortje d'Hont**.

You can cite this video as:

Slinger, J.H. (Jill), Vreugdenhil, H. (Heleen), Palmer, C. (Tally), Ritsema, J. (Jacobiene), d'Hont, F. (Floortje) (2021). *Beyond Engineering: Building with Nature 2x video #11. Distilling Social Design Principles.* 4TU.Dataset. https://doi.org/10.4121/14912508

Video Transcript

Presented by Prof. Jill Slinger

In this video, I'm going to capture Social Design Principles for Building with Nature. These principles derive from my experience in working in a transdisciplinary fashion with engineers, ecologists, planners, public authorities and local residents to promote ecosystem-based water and coastal management on three continents - in Africa, Europe and North America.

9-40. Social Design Principles? 🅭 Martijn Vos and Jill Slinger

I have adopted a complex systems perspective from the outset. Complex systems are characterised by:

- non-linear processes, feedbacks, and
- the influence of scale, time and space.
- Small changes can induce large effects and vice versa.
- Many system components and interactions.
- They can exhibit emergent behavior, and
- Context and history matter.
- They are adaptive, and
- Change starts from within.

They give rise to 'Wicked' (Rittel & Webber, 1973) or 'messy' (Ackhoff, 1974) problems. These type of problems can also be called unstructured or multi-actor system problems.

In my career have been privileged to work with pioneers in stakeholder engagement, and multidisciplinary environmental science, as well as eminent hydraulic engineers. Consider Professor Tally Palmer who shared her insights on principles for transdisciplinary engagement processes. She has applied these in South Africa with remarkable and ongoing success. Consider also the experiences of Jacobiene Ritsema and Abel Knipping. They undertake environmental and social impact assessment for infrastructural development all over the world. They have shared with you the eight principles that they use in determining, together with local people, the substantive social changes that will occur as a result of infrastructure development. Consider also emeritus Prof. Tiedo Vellinga who has shared his stakeholder-inclusive approach to port development with you. He recognises the importance of taking people's values into account at the very beginning of an infrastructure design process. I will be sharing with you the additional social design principles that have been tested together with a team of scientists from the Netherlands and

9-41. Social Design word cloud. 🅭 WordItOut and Jill Slinger

Ghana in a "Sustainable Ports in Africa" project. You have encountered or will encounter some of these scientists. Prof. Kwasi Appeaning Addo and Dr. Edem Mahu on the Ghana case study and Dr. Heleen Vreugdenhil on the issue of scales and innovation along the IJssel River.

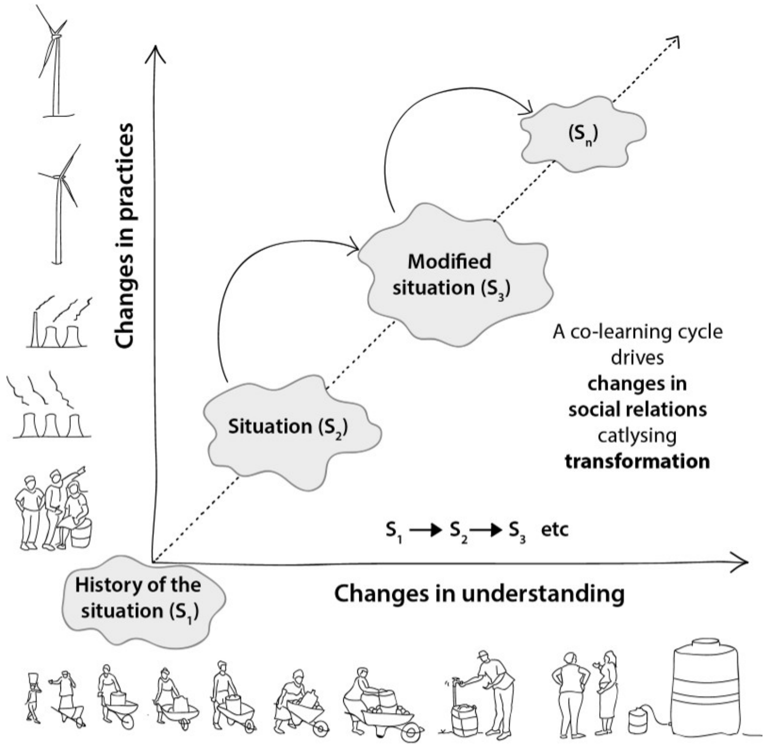
So, we can distinguish three kinds of social design principles:

- The principles that deal with the substantive content of the social environment – the fabric or local social context of the infrastructure development.
- The principles that deal with the stakeholder engagement process.
- The normative principles matching with the Building with Nature concept.

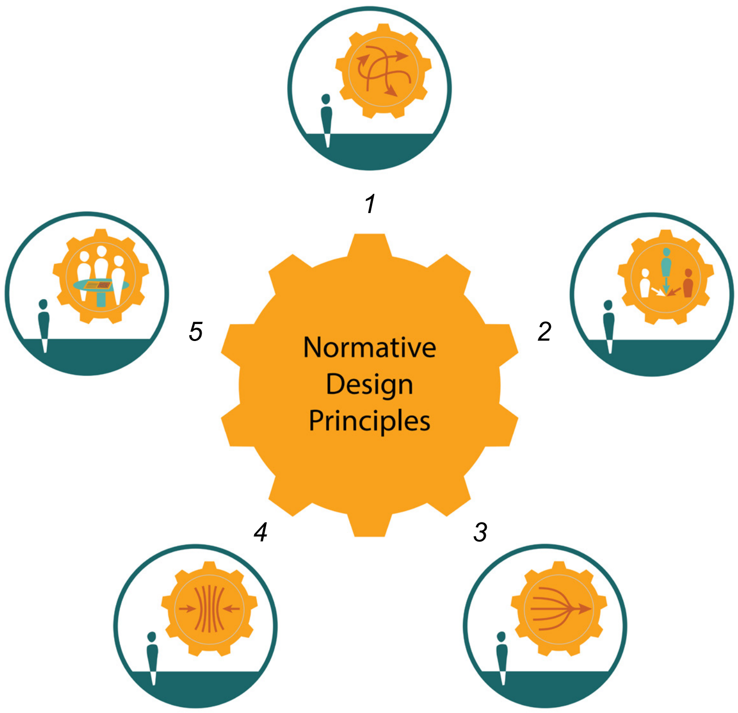
We will begin by distilling the normative Social Design Principles. These derive from a systems approach – a complexity-informed stance that acknowledges intrinsic uncertainties in dealing with multiple stakeholders and a dynamic wetland environment. We embrace the notion of multiple perspectives and partial solutions along an ever-evolving development path. For a particular locality, with its local stakeholders, a Building with Nature infrastructure design becomes a place-based intervention (see de Boer et al. 2019 for additional insight on this).

This means that the normative Social Design Principles include:

1. Adopt a complexity-informed stance, a complex multi-actor systems view, recognising both multi-actor complexity and dynamic natural systems complexity and their interactions and feedbacks at many scales.
2. Adopt a stakeholder-inclusive approach, acknowledging diverse knowledge sources, from disciplinary knowledge, public administrative knowledge to lived experiences.
3. Adopt a value-based approach to infrastructure design, recognising value differences from the outset.
4. Realise that uncertainty is inherent and adopt an adaptive approach.
5. Recognising that the Building with Nature concept is ecosystem-based and that infrastructure development has place-based effects on both the natural and social environments, engage in co-creation, co-learning and co-design to build coalitions for nature-friendly design.



9-42. Partial solutions along an ever-evolving development path. © IWR, Rhodes University, adapted from Steyaert and Jiggins (2007)



9-43. Five Normative Design Principles. © Martijn Vos and Jill Slinger

9-44. *Collaborative process of engaging with stakeholders.* © *Jill Slinger*

9-45. *Nine Design Principles for transdisciplinary engagement.* © *Martijn Vos and Jill Slinger*

The five principles set the scene, determining the framework within which a respectful and collaborative process of engaging with the people concerned with infrastructure development in a particular ecological and social environment can be given form.

Because of the place-based nature and long lifetimes of Building with Nature infrastructures, let's move on to consider the principles of such an engagement process. Clearly this needs to take the form of transdisciplinary engagement – after all there are diverse knowledge sources, different values, complex and dynamic social and ecological systems that will require adaptive decision making in the future.

The Social Design Principles for transdisciplinary engagement include:

1. Tolerate discomfort and unresolved tensions - they are often a gateway to a new level of knowledge, understanding and trust.
2. Be sensitive to "Aha!" moments of insights.
3. Engage with balanced generosity: enquiring, listening and sharing. Managing contribution and constraint is closely linked to listening.
4. Practise tolerance, build integrity and mutual trust.

5. Create and use reflective opportunities.
6. Be sensitive to the 'arrivals' of both people and ideas.
7. Manage discontinuities, people come and go and arrangements change suddenly.
8. Sustain enquiry - keep going when it is tough.
9. Be conscious that everyone involved is a whole, multi-dimensional person, with the potential to engage with their whole self and with many ways of knowing.

It is evident that these principles do not tell you what to do, but guide you in how to engage with a wide range of stakeholders productively and sincerely over time. I have conducted many co-design workshops or activities within such overarching transdisciplinary engagement processes. There is more than one way to do this successfully, but is all cases it is important to ensure that people and their knowledge and values are treated respectfully and that creative designs are sought that take the complexity of the social and natural environments into account. We know from McEvoy et al. (2020) that such workshop activities can have positive learning effects on the overarching engagement process up to 1.5 years later!

Finally, we come to the substantive Social Design Principles. Here we will use the eight Vanclay et al. (2015) principles elaborated by Abel Knipping for the local social context. They are:

1. Way of Life.
2. Culture.
3. Community.
4. Political system.
5. Environment.
6. Health and wellbeing.
7. Personal & property rights.
8. Fears & aspirations.

We add another substantive Social Design Principle to accommodate the issue of scale and to take account of cumulative effects or opportunities that extend beyond the local context. So the ninth principle is:

9. Identify cumulative effects and opportunities

This completes the distillation of the Social Design Principles for Building with Nature. I am quite aware that these principles are not complete, nor necessarily universal. They derive from co-design, co-creation and co-learning activities in countries with western democracies, although there were often very high power differences between stakeholders.

I encourage you to apply and test these principles in your Building with Nature practice to establish their degree of applicability more widely.

9-46. *Engaging with a wide range of stakeholders productively and sincerely. © IWR, Rhodes University*

9-47. *Nine Substantive Design Principles. © Martijn Vos and Jill Slinger*

Supplementary Reading

In the preceding video 'Distilling Social Design Principles' Prof. Jill Slinger mentions three references. The first is a journal article by de Boer et al. (2019), the second is a journal article by McEvoy et al. (2020), and the third is the document on social impact assessment by Vanclay et al. (2015) provided at the end of Section 9.3. The journal article by de Boer et al. (2019) is focused on the port of Tema, Ghana. The authors of the journal article establish that workshop activities can have positive learning effects on an overarching stakeholder engagement process for up to 1.5 years.

Both articles are available for download by clicking the links or scanning the QR-Codes below.

Identifying Ecosystem-Based Alternatives for the Design of a Seaport's Marine Infrastructure: The Case of Tema Port Expansion in Ghana

You can cite the two papers as:

de Boer, W., Slinger, J., Kangeri, A., Vreugdenhil, H., Taneja, P., Addo Appeaning, K., Vellinga, T.(2019). Identifying ecosystem-based alternatives for the design of a seaport's marine infrastructure: The case of Tema Port Expansion in Ghana. Sustainability 11, 6633; doi:10.3390/su11236633

McEvoy, S., van de Ven, F. H. M., Brolsma, R., Slinger, J. H. (2020). Evaluating a Planning Support System's Use and Effects in Urban Adaptation: An Exploratory Case Study from Berlin, Germany. Sustainability, 12, 173; doi:10.3390/su12010173

Evaluating a Planning Support System's Use and Effects in Urban Adaptation: An Exploratory Case Study from Berlin, Germany

9.6 Feedback

Introduction

If you have not yet done so, you are also encouraged to view Part 2 of the video presented by Drs. Jacobiene Ritsema in which she explains what happened in Sierra Leone in real-life. The severity of the anticipated social impacts at sites 1 and 2 meant that the river community would have had to undergo resettlement if a hydropower weir were built there. The socially and ecosystem-friendly decision taken was **not** to build a hydropower weir at either of these sites.

Feedback on the Assignment 9.1 questions is provided on the next pages.

Feedback on Assignment 9.1

Question 1

Based on the information contained in the video 'Small hydropower in Sierra Leone – Feasibility Study. Part 1', the stakeholder engagement process may be characterised as:

- [x] adhering to international performance standards for environmental and social appraisal
- [x] meeting the legal requirements of the Environmental Protection Agency of Sierra Leone
- [x] employing diverse sources of knowledge e.g. involving multiple disciplines and place-based knowledge
- [x] interacting with the potentially affected community

Comments on Question 1

According to the information supplied by Drs. Jacobiene Ritsema all of the above are true. The international standards adhered to include those of the International Finance Corporation and the Equator Principles. She also explicitly mentions meeting the standards of the Environmental Protection Agency of Sierra Leone. Moreover, the team of scientists included six disciplines from environmental scientist, engineer to social scientists and simulation modeller. The assessment included field trips, but went far beyond this in engaging with local people to establish the livelihood, environmental and health effects of the potential hydropower infrastructure.

No mention is made of cultural integrity and community effects (besides resettlement!), so the extent to which the process of engagement included these aspects cannot be evaluated.

Question 2

At present the communities living along the river in Sierra Leone are dependent on its resources for:

- [x] fishing
- [ ] transport
- [ ] hydropower production
- [x] mining for sand, diamonds and gold
- [x] laundry and sanitation
- [x] farming near the river
- [x] housing located near the river

Comments on Question 2

These subsistence communities are highly dependent for their livelihoods on riverine resources. Fishing, mining, laundry and

sanitation as well as the use of land near the river for farming and housing are all mentioned in the video. Hydropower production is not yet a use of the river, nor is mention made of use for transportation.

Other potential resource-dependencies on the river are also not mentioned. These can include hunting, or wood collection from forests, or the place of the river in spiritual beliefs and community ceremonies.

Question 3

Consider the theme 'Way of life'. Which of the following statements do you consider false?

- [ ] Subsistence fishing is a legitimate activity in tune with the ecosystem, and the impacts on such activities should be considered in assessing the theme 'Way of life'
- [x] Sand mining is harmful to the ecosystem, so impacts on such activities should not be considered in assessing the theme 'Way of life'
- [x] Most diamond and gold mining occurs illegally, so impacts on such activities should not be considered in assessing the theme 'Way of life'

Comments on Question 3

All of the effects on the 'Way of life' of the river community need to be considered in assessing the implications of an infrastructural intervention. It is not the place of the assessment or social engagement team to sit in judgement on the river community and so exclude issues that they consider illegal or ecologically damaging. In fact, this raises an important consideration in social engagement which is "Do no harm!". Sensitivity is required in dealing with information obtained during social engagement that if revealed could harm community members. However, the issue of ethics in social engagement is beyond the scope of this course.

Question 4

Consider the themes 'Environment' and 'Way of life'. Which of the following statements do you consider false?

- ○ effects on the nearby gallery forest, which is a protected ecosystem, should be considered in assessing the theme 'Environment'
- ○ effects on fish migration and fish stocks should be considered in the theme 'Environment' and the consequent effects on fishermen and their fishing activities should be considered in 'Way of life'
- ◉ effects on farming (e.g. less land available for crop production) should be considered in the theme 'Environment', but not in 'Way of Life'

Comments on Question 4

The direct and indirect effects of an infrastructure on the use of the environment by the community and the opportunities it offers should always be considered under the theme 'Environment'. Whether these are significant or not, should then be assessed by scientists and the stakeholders concerned. The consequent implications for the 'Way of life' of the river community can then also be assessed. An effect on fish migration, may or may not translate into a significant effect on fish stocks and this may or may not translate into a significant effect on the fishermen's 'Way of life'. Similarly for farming. The use of the riverine environment (land and water) for farming and the effects of farming on the environment should be assessed in the theme 'Environment', but the associated effects on farmers and their farming activities – their 'Way of life' may or may not be significant. This needs to be assessed under the 'Way of life' theme.

Question 5

For sites 1 and 2, simulation modelling reveals that locating a hydropower weir across the river will increase the severity of flooding, threatening productivity, property and potentially lives. Now consider the themes 'Health and wellbeing' and 'Fears and aspirations'. Which of the following statements do you consider false?

- ○ the 'Health and wellbeing' of community members is definitely affected, because they could suffer property losses if their houses are flooded'
- ○ the 'Health and wellbeing' of community members is definitely affected, because their lives may be in danger from flooding'
- ◉ the 'Fears and aspirations' of community members are definitely affected by the potential property loss and loss of life from flooding

Comments on Question 5

The 'Health and wellbeing' of community members' is definitely affected, because they could suffer property losses if their houses are flooded and their lives may be in danger from flooding. Whether this causes the people involved to suffer anxiety and fear of the potential property loss or loss of life is something that the stakeholders would have to be asked. It may not necessarily i.e **definitely**, translated into such fears, although it probably would.

Question 6

Which of the following statements is true regarding cumulative effects and opportunities?

- ○ cumulative effects need not be considered, because the most appropriate sites will be selected following a thorough and respectful stakeholder engagement process
- ○ cumulative effects need not be considered in the feasibility study, because they are only relevant when you scale up
- ◉ cumulative effects need to be considered even in the feasibility study, because up to six sites might be exploited for hydropower

Comments on Question 6

Cumulative effects need to be considered from the outset. Drs. Jacobiene Ritsema mentions at the start of the video that although we are focusing on one or two sites here, there are as many as six potential sites that need to be assessed. So, even though each of the sites is assessed individually, there also needs to be an assessment of the combined or cumulative effects. After all, these cumulative effects may make the infrastructure development non-feasible. So, it is not a good idea to only scale up later, nor is it valid to think that a careful process at individual sites can fully account for cumulative effects.

9.7 Bibliography

Literature

de Boer, W., Slinger, J., Kangeri, A., Vreugdenhil, H., Taneja, P., Addo Appeaning, K., Vellinga, T.(2019). Identifying ecosystem-based alternatives for the design of a seaport's marine infrastructure: The case of Tema Port Expansion in Ghana. Sustainability 11, 6633; doi:10.3390/su11236633

McEvoy, S., van de Ven, F. H. M., Brolsma, R., Slinger, J. H. (2020). Evaluating a Planning Support System's Use and Effects in Urban Adaptation: An Exploratory Case Study from Berlin, Germany. Sustainability, 12, 173; doi:10.3390/su12010173

Steyaert, P., Jiggins, J. (2007). Governance of complex environmental situations through social learning: a synthesis of SLIM's lessons for research, policy and practice, *Environmental Science & Policy, (10)6*, 575-586. https://doi.org/10.1016/j.envsci.2007.01.011

Vanclay, F., Esteves, A.M., Aucamp, I. & Franks, D. (2015). *Social Impact Assessment: Guidance for assessing and managing the social impacts of projects.* Fargo ND: International Association for Impact Assessment.

Figures

9-1. Workshop with Stakeholders: This image is Copyright protected. © 2017 Baukje Kothuis. All Rights Reserved.

9-2. Principle 1. Tolerate discomfort and unresolved tensions as they are often a gateway to a new level of knowledge, understanding and trust: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0.

9-3. Principle 2. Be sensitive to "Aha!" moments of insights: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0.

9-4. Principle 3. Engage with balanced generosity: enquiring, listening and sharing. Managing contribution and constraint is closely linked to listening: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0

9-5. Principle 4. Practise tolerance, build integrity and mutual trust: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0.

9-6. Principle 5. Create and use reflective opportunities: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0.

9-7. Principle 6. Be sensitive to the 'arrivals' of both people and ideas: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0.

9-8. Principle 7. Manage discontinuities, people come and go and arrangements change suddenly: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0.

9-9. Principle 8. Sustain enquiry (keep going when it is tough): This image is in the Public Domain.

9-10. Principle 9. Be conscious that everyone involved is a whole, multi-dimensional person, with the potential to engage with their whole self and with many ways of knowing: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0.

9-11. Local community engagement: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-12. Theme 1: Way of life: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-13. Theme 2: Culture: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-14. Theme 3: Community: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-15. Theme 4: Political systems: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-16. Theme 5: Environment: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-17. Theme 6: Health and wellbeing: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-18. Theme 7: Personal and property rights: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-19. Theme 8. Fears and aspirations: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-20. Canal in Semarang, Indonesia: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-21. Artist impression of redesigned canal in Semarang, Indonesia: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-22. Potential locations for hydropower: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-23. One of the locations during the wet season: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-24. One of the locations during the dry season: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-25. Shortage of power generation: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-26. The power station study team: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-27. Gallery forest along the river: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-28. River use for sanitation and laundry purposes: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-29. Sand mining: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-30. Gold and diamond mining: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-31. Fishing: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-32. Farming: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-33. Water level plotting for various weir heights: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-34. Flooding assessment: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-35. Impact assessment results [Red areas indicate potential major negative impacts: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-36. Exploration with stakeholders: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-37. Sierra Leone's Sustainable Development goals: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-38. Impact assessment mitigation measures: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-39. Overall conclusions of the Environmental and Social Impact Assessment: This image by Witteveen+Bos is licensed under CC-BY-NC-SA 4.0.

9-40. Social Design Principles?: This image by Martijn Vos and Jill Slinger is licensed under CC-BY-NC-SA 4.0.

9-41. Social Design word cloud: This image by WordItOut and Jill Slinger is licensed under CC-BY-NC-SA 4.0.

9-42. Partial solutions along an ever-evolving development path: This image by IWR, Rhodes University is adapted from Steyaert & Jiggins (2007) and is licensed under CC-BY-NC-SA 4.0.

9-43. Five Normative Design Principles: This image by Martijn Vos and Jill Slinger is licensed under CC-BY-NC-SA 4.0.

9-44. Collaborative process of engaging with stakeholders: This image by Martijn Vos and Jill Slinger is licensed under CC-BY-NC-SA 4.0.

9-45. Nine Design Principles for transdisciplinary engagement: This image by Martijn Vos and Jill Slinger is licensed under CC-BY-NC-SA 4.0.

9-46. Engaging with a wide range of stakeholders productively and sincerely: This image by IWR & Rhodes University is licensed under CC-BY-NC-SA 4.0.

9-47. Nine Substantive Design Principles: This image by Martijn Vos and Jill Slinger is licensed under CC-BY-NC-SA 4.0.

10-1. Fishing Harbour, Tema Ghana. © Baukje Kothuis

Chapter 10 Towards Coalition Building

10.1 Introduction

You now have all the knowledge you need to set about formulating your own strategy for stakeholder engagement in Building with Nature, and this is the focus of Chapter 10!

The case of port development in Tema, Ghana, is central to Chapter 10. First, you will meet Prof. Kwasi Appeaning Addo and Dr. Edem Mahu from the University of Ghana and Dr. Barnabas Akurigo Amisigo from CSIR in Ghana. Then you will be introduced to the issue of port development in Tema, the nearest large city to the Volta Delta, and acquire information on potential Building with Nature interventions. Next, you will read interviews from a wide variety of stakeholders from Tema. Finally, in the **assignment**, you are asked to apply the knowledge you have gained in the preceding weeks to design your own stakeholder-inclusive, ecosystem-friendly strategy for coalition building.

Once you have finished the assignment you can look at the strategy that the project 'Sustainable Ports in Africa' took in engaging with stakeholders regarding port development in Tema.

After the assignment there are 2 inspiring videos:

- Inspiring Interview - presented by Prof. Tally Palmer and Dr. Athina Copteros
- Aligning Building with Nature and Environmental Assessment - Port development and planning - presented by Prof. Susan Taljaard.

Enjoy Towards Coalition Building!

10.2 Tema Port Development, Ghana

Meet the Ghanaian Researchers

First, you will meet the Ghanaian researchers, **Prof. Kwasi Appeaning Addo**, **Dr. Edem Mahu** and **Dr. Barnabas Akurigo Amisigo**.

Then information on the issue of port development in Tema, Ghana, is supplied so that you can familiarise yourself with the Building with Nature opportunities and the wide range of stakeholders. The information includes:

- A video by Prof. Kwasi Appeaning Addo and Dr. Edem Mahu on Tema port and its social and ecological environment
- A video by Meridian Port Services, the international company expanding Tema Port
- The wider coastal environment of Tema and Building with Nature opportunities
- Meet the Port and Industry stakeholders
- Meet the Tema Residents
- Meet the Fishing Folk
- Meet the Community Leaders and Planning Authority
- Meet the Delta Alliance and Strategic Network Partners

Enjoy exploring Tema!

All of the interview information derives from:

Kothuis, B., Slinger, J. (2018). *Voices on sustainable ports in Africa. Stories from Tema Port, Ghana*. Delft University Publishers, Delft, Netherlands. ISBN 978 94-6186-945-6. 76pp.

Kwasi Appeaning Addo

Marine and Fisheries Sciences
University of Ghana, Legon

10-2. Kwasi Appeaning Addo. © Ascha Simons

Who are you?
My name is Kwasi Appeaning Addo, professor of Marine and Fisheries Sciences, University of Ghana. In the Sustainable Ports in Africa project, I am co-ordinating research activities, administration and science in Ghana, and connecting the project to people within Ghana.

How did you come to be involved with Tema Port and this project?
The Netherlands African Business Council called me about potentially collaborating in an interesting project that involved marine science. I started talking with other interested Ghanaian and Dutch parties and contributed to the research proposal. Finally we won the project, so here we are now.

What do you like about the project? Why are you interested in participating?

I like the collaboration. Although shipping and ports are not my direct area of expertise, I see it as an opportunity to learn about this aspect within the coastal system, to grow my understanding and participate in discussions. I like the openness, the collaboration, the discussions, and I like the methodology that we apply, involving stakeholders from the beginning and people buying into the project. So this will go a long way to helping me in future projects and activities.

What do you think of Sustainable Ports? How have you changed your idea about a Sustainable Port?

My ideas have changed a lot. Previously I thought a port was all about engineering - the design of engineering structures - and trade. This project has taught me that a port goes beyond this. A sustainable port involves the environment, ecology and people in a cohesive and interactive way. This is not something that I was used to. Through this project, I have seen how these systems interact, and sustain economic and operational functions within a port setting.

What is your particular learning?

I have learned about all the systems that operate within a port to enable it to function and to become sustainable. Also, as a scientist I have learned how to develop stakeholder meetings. I think the approach that is used in this project, this way of doing it, involving people in thinking about their futures, is a unique method. I am a natural scientist by training and have never been a moderator of these kinds of processes before. But, moving forward, I realise that the approach in engaging stakeholders is something that I have really learned, and it is becoming more and more part of me. Going around and gathering the information, the right type of information from stakeholders is the right way for me.

Edem Mahu

Marine Geochemistry
University of Ghana, Legon

Who are you?

My name is Edem Mahu. I am a lecturer in the Department of Marine and Fisheries Sciences at the University of Ghana. My research focuses on sediment dynamics, pollution in marine systems and the cycling of metals and nutrients in the coastal marine environment.

How did you come to be involved with Tema Port and this project?

Professor Appeaning Addo, contacted me to ask if I was interested in a potential position in a project on Sustainable Ports in Africa. I was very interested and my name was included in the proposal. My focus lies on the sediment dynamics of the Ghana coast, especially the project area of Tema. I collaborate in the ge-

10-3. Edem Mahu. © Ascha Simons

ochemical aspects of the project such as the water quality of the Sakumono Lagoon, trying to understand the biophysical functioning of the system.

What do you think of Sustainable Ports?

I think a sustainable port is a port whose design has taken multiple aspects into consideration, such as social aspects, economics, the environment in addition to engineering aspects. These aspects interact, and a port cannot be considered in isolation. As such, a sustainable port doesn't only focus on money, but considers the environment and the livelihoods of the people that the port interacts with or affects. Such a port looks into the future, while considering the short-term benefits, so that both present and future generations can all enjoy the economic, ecological, social and cultural benefits that come with this.

How does this differ from present practice?

The Sustainable Ports concept is different from how things are done in Ghana. It strives to involve stakeholders from scratch. It is the other way here and in most of Africa. Typically, engineering infrastructures and buildings are completed without any input from key stakeholders. When the very people who are supposed to benefit start receiving negative impacts due to system failure, then we start thinking of what actions to take. Our planners do not anticipate how many people a port development will attract, for example. Maybe these people cannot be accommodated by the environmental system. It could collapse. This is not just true for ports, it is even happening with other major projects in the country. Key questions to ask include whether or not possible environmental consequences of such projects have been duly considered. We need to conduct good environmental impact assessments, particularly with state-owned projects. The private sector is mostly obliged to comply with environmental protocols. A colleague at the Environmental Protection Agency confirmed that most state-owned projects are rolled out without duly assessing environmental impacts. So, the project is initiated, the problems start and then we start trying to find solutions. We need to change the way we do things.

What is your particular learning?

I've learned that every development requires a systems approach. I applaud this project, because it began by talking to stakeholders. In the past we would have ignored stakeholders, even though we know that problems can arise by ignoring them. In this project, we talked to them from the beginning, exploring ways in which the port development might benefit them, trying to design a green port for what they need.

10-370

Barnabas Akurigo Amisigo

Climate and hydrological modelling

CSIR Water Research Institute

Who are you?

My name is Barnabas Akurigo Amisigo and I am a hydrologist with a government agency, the CSIR Water Research Institute. CSIR stands for the Council for Scientific and Industrial Research.

How did you come to be involved with Tema Port and this project?

I am involved in climate modelling, hydrological modelling, and work with Professor Appeaning Addo on coastal modelling through the DECCMA project. Through him I heard about the SMART ports project, the Sustainable Ports. This was a little new to me, as I am not used to ports. It is an interesting new development, involving systems thinking and modelling; not just looking

10-4. Barnabas Akurigo Amisigo. © Barnabas Akurigo Amisigo at what they do in the port itself, but also linking to the upstream aspects both biophysically and socially.

What do you think of the idea of Sustainable Ports?

The concept of sustainable ports means not treating the port as an isolated entity, but taking the concerns and dreams of various stakeholders into account. So, people who are not normally associated with ports, can help to support the port to grow. I think it is a very good idea. In fact it brings to mind my hydrological modelling where I take not only the physical processes and environment into account, but also the livelihoods and concerns of people living in the catchment. The systems approach of the sustainable ports projects resonates very well with me.

How does the Sustainable Ports project differ from a more traditional view?

This Sustainable Ports approach brings into play a number of components: the ecosystem, economics and cultural issues. It links people that are located away from the port itself. This is quite new for me. I am used to just thinking of the catchment. It is an integrated way of looking at various interests and identifying them up-front – not when the port construction is finished and problems come. From the outset, you are looking at compatible and non-compatible interests and trying to marry them.

What is your particular learning?

My learning point is how this port is going to link up with upstream issues. So, connecting the issues of the lagoons in the area with their catchments. Are we just going to tick a box – as in: we have a lagoon here that will be impacted by the port, and an eye must be kept on it. Or are we really going to look at the catchment, and also how the lagoon affects the port and the port the lagoon?

Expansion of Tema Port by Meridian Port Services

The expansion of the Port of Tema is undertaken by Meridian Port Services Limited (MPS).

MPS is a joint venture between Ghana Ports and Harbours Authority and Meridian Port Holdings Limited, which is itself a joint venture with international companies Bolloré Transport and Logistics and APM Terminals. MPS was incorporated under the laws of the Republic of Ghana in December 2002.

MPS seeks to provide world-class container terminal services to contribute to Ghana’s trade, provide connectivity to new markets and so to increase the throughput volume of Tema Port.

A link to a video by MPS on the expansion of Tema Port is provided on the right. The focus lies on the port as a trade and transport node, with attention for the construction of the port infrastructure, and some attention for the sourcing of local content and the employment of Ghanaians.

You can move to the next section for information on the wider coastal context and Building with Nature opportunities.

Promotional Video -
Meridian Port Services Tema Port Expansion

10-372

Video: Tema Port Development

In this section, **Prof. Kwasi Appeaning Addo** and **Dr. Edem Mahu** introduce you to the environment of Tema and her port. The issues of coastal erosion and lagoon health associated with the port expansion, well as the traffic situation on the coastal road servicing the port become evident.

You can cite this video as:

Appeaning Addo, K. (Kwasi), Mahu, E. (Edem), Slinger, J.H. (Jill). (2021). *Beyond Engineering: Building with Nature 2x video #14. Tema in Ghana - Coastal erosion and effects of port expansion.* 4TU.Dataset. https://doi.org/10.4121/14912661

Building with Nature in the Coastal Environment of Tema

Introduction

To orientate you to the **city of Tema** and the **locations** mentioned in the stakeholder interviews, a **satellite image** is provided below.

This is followed by a list of **potential Building with Nature interventions within Tema Port and the surrounding area**. To help you in understanding why these interventions and not others were selected, a slide presentation by Prof Kwasi Appeaning Addo and engineer Wiebe de Boer follows. They explain the **structural erosion** that has been occurring along the Ghanaian coast near Tema. This means that sand is in short supply, eliminating as an option the large scale sandy options applied along the coast of Holland, like the Sand Engine.

The list of Building with Nature options is not meant to be exhaustive. It is designed to give you the idea that an ecosystem-based approach requires you to think beyond the scale of the port itself and consider its situation in the wider coastal system.

This thinking is demonstrated by the journal paper by de Boer et al. (2019) which follows. **Here, a framework that structures environment considerations in decision making on port development through all phases of port developmen**t is presented and applied to the Tema port expansion case.

Enjoy learning about more environmentally friendly options for the wider coastal area of Tema.

The city of Tema

'The city of Tema is home to the largest port of Ghana. Situated near Accra on the Gulf of Guinea, Tema was developed specifically to support its port, which was opened in 1962. The presence of the port attracted industries dependent on the port, and the Port of Tema became a catalyst for urban development. Indeed, Tema was envisioned to become the industrial center of the country.... Tema's port is the biggest of the country, serving both Accra and the Volta Delta. The port is currently undergoing a 1.5 billion dollar expansion, more than tripling its container handling capacity from 1 million to 3.5 million TEU ....' (van den Houten, 2017).

Owing to coastal erosion and increased salt intrusion with concomitant loss of livelihood, people are continually migrating from the nearby Volta Delta. Many of these people settle in Tema,

10-5. Map of Tema. © Jill Slinger

seeking a better future. The population of Tema is growing steadily, and this effect will strengthen with the expansion of the harbour.

A 2018 map of Tema is provided here. The following locations are indicated: Tema City, the original Tema Port, the new port development area, the crowded fishing harbour, Sakumono Village, the

Sakumono Lagoon, and Church Village. Tema New Town, which is where the original inhabitants were relocated when the port was built in 1962, is located east of the Tema Fishing Harbour.

Potential Building with Nature interventions within Tema Port and the surrounding area

Restoring the connection of the Sakumono Lagoon with the sea.

This lagoon is a RAMSAR wetland - a wetland of international significance for migratory and resident birds. The coastal road connecting Tema to Accra was built across the mouth of the Sakumono Lagoon. Two large culverts now allow water to flow out of the lagoon, but the inflow of seawater is limited to a small volume under high wave conditions. This has meant that the fish stocks in the lagoon have declined and the type of fish living there has changed to species that are tolerant of brackish water. The vegetation has also changed and the mud flats are covered in coastal scrub, while thick reed beds extend to within a kilometer of the mouth and choke the upper channels. The constrained connection with the sea has caused the character and functioning of the lagoon to change. A degree of restoration could be achieved by increasing the size and number of culverts at the mouth, and decreasing the water level at which exchange becomes possible (deepening the culverts).

Reducing the risk of flooding, near Church village

By dredging the channel of the Sakumono Lagoon, and removing some of the reeds in the channel itself, the high waters from the river can drain more quickly towards the mouth. However, the water can only drain effectively through the mouth if there are more and deeper culverts at the mouth.

Fully rehabilitating the Sakumono Lagoon

This is by far the most beneficial option for the ecosystem, and for those dependent on its resources e.g. the fisherman of Sakumono Village. It would involve designing a bridge over the estuary mouth and fully opening the lagoon to the sea. As there are plans to widen and repair the coastal road within the next 5 to 10 years, this option of a bridge is feasible. Such an option would have to be carefully designed and there would need to be a mouth management and monitoring programme. For small, wave dominated lagoons such as those occurring along the Ghanaian coast, seawater can serve to improve the water quality of the lagoon and to restore biodiversity.

Building with Nature measures within the harbour or along the breakwaters

According to de Boer et al. (2019) below, potential measures include:

- Breakwaters functioning as artificial reefs;

- Biological concrete for quay walls;
- Artificial habitat creation within the port;
- Novel resurfacing materials;
- Hanging ropes from poles or pontoons to enhance attachment of marine organisms.

Sand nourishment along the shoreline at Tema New Town

Tema New Town is on the leeward side of the harbour in terms of sand transport and the shoreline experiences ongoing erosion. Nourishment of the beaches with sand, would serve to address this ongoing problem and would restore the sandy beach and dune habitat.

Concerted effort to deal with plastic pollution along the coast

Volumes of plastic are found along the shoreline of Ghana, carried downstream from where it is thrown by the rivers and accumulating on the beaches. This is considered a problem by fishermen, and other users of the coast and beaches.

Presentation: Tema coastal system by Prof. Kwasi Appeaning-Addo and engineer Wiebe de Boer

Paper: Identifying Ecosystem-Based Alternatives for the Design of a Seaport's Marine Infrastructure: The Case of Tema Port Expansion in Ghana

Meet Port and Industry Stakeholders

Here you will meet **Mr. Edward Kofi Osei**, Director of Tema Port from 2017 to 2019, as well as a range of port and industry stakeholders. These include:

- **Mr. Kwabena Ofosu-Appiah**, **Mr. Joseph Agbaga** and **Mr. Robert Baffo Dapaah** representatives of the Ghana Institute of Freight Forwarders;
- **Mr. Bas de Vaal**, managing director of a shipping agency and logistics company;
- **Mr. Azonko Simpi**, an advocate of tourism and a cruise terminal at Tema port; and
- **Mr. Barnabas Apom**, a consultant for the water sector.

Note that from 1 March 2019, **Mrs. Sandra Opuku** became the new acting director of Tema Port, following the retirement of Mr. Edward Kofi Osei.

The interview information derives from:

Kothuis, B., Slinger, J. (2018). *Voices on sustainable ports in Africa. Stories from Tema Port, Ghana*. Delft University Publishers, Delft, Netherlands. ISBN 978 94-6186-945-6. 76pp.

Edward Kofi Osei

Ghana ports & harbour authority: Tema port
Tema Port

10-6. Edward Kofi Osei. © Edward Kofi Osei.

Who are you and what is your professional background?
I am Edward Kofi Osei, a man of diverse background with a diverse education ranging from business to law, and international relations. I have six degrees and have lived in Ghana and abroad, spending most of my working life in the United States.

How are you involved with Tema Port / this project?
In March 2017, I was appointed Director of Tema Port by the President (Nana Akufo Addo). I was asked to come back to Ghana for this position. It has been quite an adjustment.

What do you think of Sustainable Ports?
It is a very interesting concept in the sense of how do you define sustainability. Is sustainability dealing with the main functions of

a port or does it refer to both the main functions of a port and its impact on its immediate environment? I think of the examples of like the Port of Camden (in the United States), which is a 'shithole' dump, but the port exists and functions even though the neighbourhood around it is 'dead'. In contrast there is New York Port, which has vibrant city life around it and port functions. So, is sustainability ensuring that the port continues to function or considering the immediate environment? For me it means that sustainability is both continuing port functions and taking the impact on the immediate environment into account, because in the long run for a port to attract cargo and workers it has to exert an impact on its environment. Take congestion, for example. If a port is a first class port, but the road networks are congested the importers and exporters will refuse to use the port. The port itself suffers. A sustainable port means that the port impacts its immediate environment, but that the linkages between the port and the economies around it need to be sustained.

How does the Sustainable Ports project differ from a more traditional view?

I'm excited about the project. We can take this thinking and make it part of long term strategic planning. In strategy meetings, instead of talking about building another berth, we can also think about road networks, housing for workers and others, and education, so that it is attractive to the workforce. We can bring this to bear in planning any port.

What is your particular learning?

Awareness – I have gained awareness of these issues that one naturally doesn't think about when planning a port – dealing with environmental impact issues.

Kwabena Ofosu-Appiah, Joseph Agbaga & Robert Baffo Dapaah

Ghana Institute of Freight Forwarders
Tema Port

Who are you and what is your background?

In the middle in the picture is Mr. Kwabena Ofosu-Appiah, current president of Ghana Institute of Freight Forwarders (GIFF) in Tema; to his left is Mr. Joseph Agbaga, immediate past president of the GIFF, and to his right is Mr. Robert Baffo Dapaah, forwarding practioner and former Head of Education and Training at GIFF, in their offices in Tema.

What is your task?

The Ghana Institute of Freight Forwarders is an umbrella body, an association of about 300 commercial entities engaged in freight forwarding, customs brokerage and transport and allied services.

10-7. Kwabena Ofosu-Appiah, Joseph Agbaga & Robert Baffo Dapaah. © Baukje Kothuis

One of the key corporate objectives is capacity building for both existing and prospective members of our association. The GIFF Academy offers FIATA validated diploma in international freight forwarding and higher diploma in supply chain management.

What does the port expansion mean for your association?

There are many landlocked countries to the north of Ghana. The port expansion is needed to serve these countries, and for Ghana itself. As you know, we struck oil about 10 years ago. To export this resource we need improvement in infrastructure and other resources to receive bigger vessels such as tankers and Panamax vessels. We expect the turn-around time to be swift and expect a high throughput of cargo.

Containerisation and freight concepts such as intermodal and multimodal transport have changed the way cargoes are sent across the world. The advent of door-to-door services, technological advancements, have resulted in unfair and inequitable shares in supply chain services that accrue to the benefit of multi-national and big companies. This has resulted in lack of jobs and contracts to small firms like many of our corporate members. In spite of their competency in the industry backed by hands-on-experience by members and their staff, the local small companies no longer have leverage.

These are real issues confronting our association and its members.

How could the work of your association be made better or easier?

The freight forwarding and customs brokerage industry is under-resourced. Unlike our colleagues abroad, and except for a few corporate members, most of the small and medium-sized freight forwarders are unable to access financing from banks in our countries.

We also need to provide hands-on industry experience, so that people can acquire competence. Some of the companies in our association consist of talented people that have trained themselves on the job. But, the Ghanaian people who have knowledge, the human capacity, are often picked by the bigger companies. It is difficult for the smaller companies to find and keep employing such people. Also, the bigger companies have expensive machinery and equipment whereas the companies in our association might not have this and yet need to compete with them. So, they don't get the job.

We need the rail link to connect with the interior and the landlocked countries. If Ghana does not have the money to put the

railway in, then the conglomerates will join forces to do this, as in Cote D'Ivoire. Then they have the captive market for themselves and we are excluded.

Perhaps the local content laws may have to be re-visited to provide more clarity and openness to scrutiny in order for its implementation to achieve the reasons they were enacted. For example, in Philippines trade on the seas is considered international, but from the ports every activity in the supply chain services becomes national. A similar law would help our industry.

What do you think of a sustainable port?

You know, people in Africa are very fertile and the population in Africa is growing. For a sustainable future, we need to consciously make the attempt that people get a share in the benefits from development, like the port expansion. This may not look very responsible or make financial sense now, but it does if you project it into the future. Security guarantees a long-term future, but today's situation cannot guarantee a stable future. Africa is tired of only hope. It is now the third generation who is hoping, and they are less patient. Everybody knows on paper what has to be done, but who does the work? You know that he who pays the piper calls the tune. But, people need to be able to have a share in the supply chain.

Bas de Vaal

Shipping agents
Tema Port

Who are you and what is your background?
I am Bas de Vaal, managing director of Ports Marine and MTG. We are a shipping agents and logistic company delivering ship agency and freight forwarding services for importing and exporting in Africa. We are located right outside the port at the fishing harbour gate. We operate liner services and chartered vessels, which call at Tema port with project and any other types of cargos. And we operate a container depot, where we store containers for various companies. On our premises we also have a warehouse, used to store tuna cans for a tuna-canning factory; these are sent to the Netherlands.

How are you and your company involved with the expansion of Tema port?
I am personally not involved in the expansion itself, the project is fully done by the MPS group. But I am very interested in it because it will bring a lot of changes. All container traffic will go to the new port and that might have impact on our depot. I'm sure the expansion will also affect my business.

10-8. Bas de Vaal. © Bas de Vaal

What is a Sustainable Port to you?
For me it means that a port is fair. It's a place for fair employment. A safe place to discharge and load cargos. Sustainability means that an eye is kept on the environment, even in the difficult West African conditions. These are very different from the Dutch conditions and conduct, but for a sustainable port we must try to keep certain standards.

When I speak of difficult conditions, I mean issues like the heat, the dust, the age of the port, and the kind of products that are being discharged; for example cement clinker that is very dusty. And also the pollution by the trucks, this is incomparable to the new trucks we have in Holland. For sustainability, we have to try to slowly raise the standards and improve the conditions in the port, within the means we have here in Ghana.

Azonko Simpi

Greenwich Meridian Tower and Cruise Terminal
Tema Port

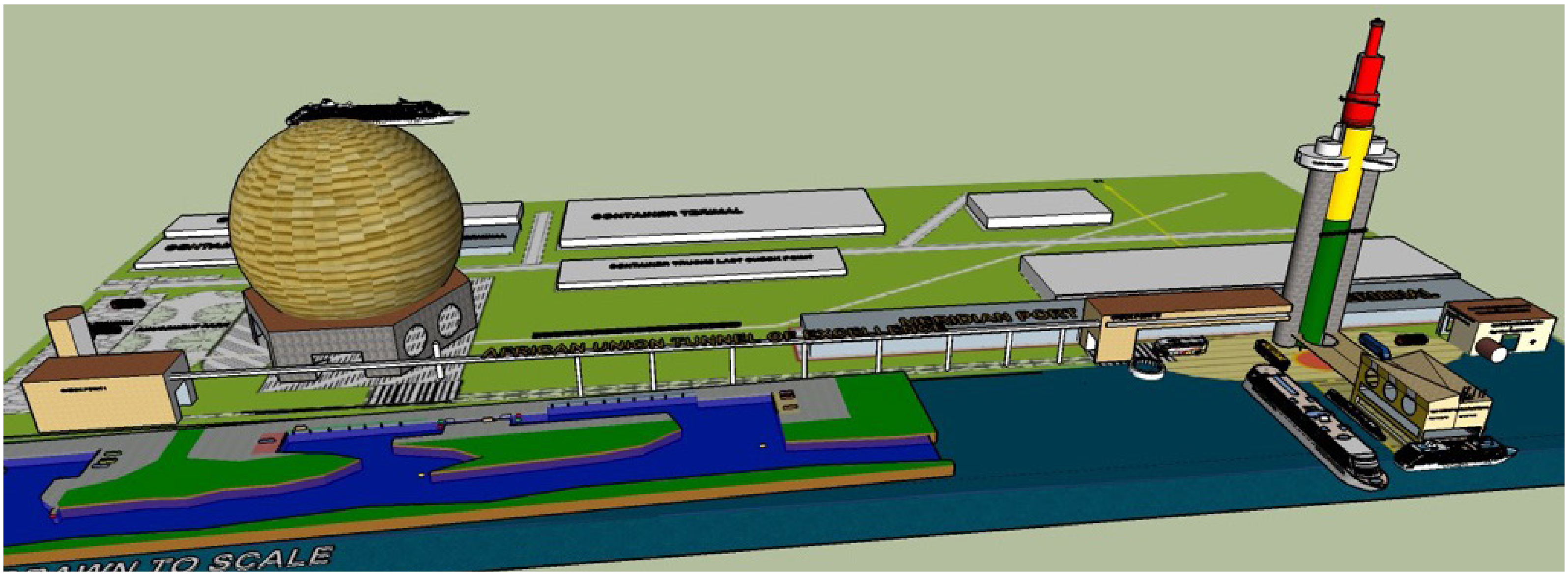
10-9. *Azonko Simpi. © Baukje Kothuis*

Who are you and what is your background?
I am Azonko Simpi. I am a musician by my degree, a sound engineer and acoustician, inventor, and the CEO of World Time Limited.

How did you become involved with Tema Port?
We want to get world time from a passive state to an active state by connecting the time clock to music. To give authenticity to the world time clock, we realised we had to go to the Greenwich Meridian, and in Ghana this is of course in Tema. But when I came to Tema, I realised it was not fully clear where the meridian is. So we developed a landmark that would signify the location of the Greenwich Meridian at the last point on land towards the Equator and the South Pole. We have called this point Terra Nihil Locus Mundiale (Land Zero Global Position). It is located at Latitude 5.37N, Longitude 0 and is right at Tema Port.

What the landmark about?
We envision the landmark as a tower combined with a cruise terminal. Part of that landmark is a pillar right on the Greenwich Meridian. It is to be located in the so-called Tema Time Park, where we will connect the time culture to the music culture with

the Classic Africa Sync Clock that we invented. The landmark will be the Center of the World, incorporating an educational center where the port can present itself and scientists can connect to the public. It's a wonderful location for concerts for Classical African Music, and of course for all kinds of innovative experiments with time, music and the sea.



10-10. *Rendering of envisioned Greenwich Meridian Tower and Cruise terminal. © Azonko Simpi*

Barnabas Apom

Consulting for the Water Sector
Accra

Who are you and what is your background?
I am Barnabas Apom, consultant for the water sector at GNBCC, the Ghana Netherlands Business and Culture Council, and CEO of RESEARCHLIME Ltd, Survey data collectors.

I have been involved as a focal person in a lot of stakeholder involvement for projects in the port and the water sector. For GN-BCC I also work with a lot of water organisations in Ghana, like Unicef and WaterAid. I have a broad overview of the water sector: the rural stakeholders, the districts, the businesses, the rural communities and district assemblies, mostly bottom-up.

How is GNBCC involved with the Tema port?
GNBCC is a membership organisation and we work to resolve our member's challenges. Quite a lot of them are involved in export, logistics, and taking care of container shipments, for instance. Often they are stationed in the port or in the so-called free zones around the port. A free zone is an area that the government has established for Foreign Organisations to operate as if they are operating in international environment. GNBCC helps

10-11. Barnabas Apom. © Barnabas Apom

our members to engage with stakeholders that are involved in the port sector, which is a major sector in Ghana. We use our

network - for example the Dutch Embassy, the companies, the district assemblies and the government - to bring the interests of the stakeholders to the forefront of decision makers at a national level. GNBCC links the businesses and find the challenges that they are facing; and then tries to bring the stakeholders and the decision makers together to address these challenges.

How is the work of GNBCC related to the port expansion?
The expansion of the port will open up all kinds of business. There will be a lot more involvement of our membership companies in the port interactions. It might also attract more companies from The Netherlands to work in Ghana. GNBCC is basically facilitating business between the Netherlands and Ghana. Once the new port opens and business is started, we will have a lot more events. So it will definitely affect GNBCC's work.

What is a Sustainable Port to you?
I think for a port to be sustainable, there are two main points. Firstly, it has to take into account the needs of all the stakeholders involved. Their consent, and their grievances. If the port is benefitting, and the majority of the people like communities and smaller companies are not involved in any way, it will lead to violence and destruction later on. Even the fishes in the port should be considered, because they are also going to be affected.

Secondly, sustainability is about ownership. The local people have to feel that they are all part of this expansion of the port. The indigenous should feel that it belongs to them; that is necessary for the sustainability of any project. I have a lot of examples of water points and water stations that are abandoned because the local people don't feel that it belongs to them. That is why ownership is very important for sustainability.

Meet Some Tema Residents

Here you will meet a wide range of residents of the wider Tema area. These include:

- **Mr. Solomon Tetteh**, an opinion leader in Tema New Town. Tema New Town represents the area where the original inhabitants of Tema were resettled when Tema Port was constructed in the 1960's;
- **Mr. Edem Agortey**, a taxi driver who lives in Tema Church Village with his family;
- **Mrs. Faustina Afrah Yeboah**, who works in port logistics and lives in the city of Tema;
- **Mr. Christopher Afedzi** and **Mrs. Monica Afedzi** run a hotel in Tema, near the upper reaches of the Sakumono Lagoon; and
- **Mr. John Nyahe** tells us all about the situation of the secondary school in Sakumono Village, a fishing village located to the west of the Sakumono Lagoon.

All the interview information derives from:

Kothuis, B., Slinger, J. (2018). *Voices on sustainable ports in Africa. Stories from Tema Port, Ghana*. Delft University Publishers, Delft, Netherlands. ISBN 978 94-6186-945-6. 76pp.

Solomon Tetteh

Opionion Leader
Tema New Town

Who are you?
I am Solomon Tetteh and I was born in this community. I used to work as machinist on a tanker and as a fisherman.

Can you introduce your community?
This community consists of the indigenous people of Tema. We had to move when the port was developed between 1958 and 1962, but we are not benefitting from the port. Barely any of us works there. Many of us are fishermen, but it becomes harder to catch fish, we now have to go further away and use four times as much fuel and spend a full night and day at sea to fish.

The port has degraded our community; there is no more sand here. Before, we used to be able to walk to the fishing harbour,

10-12. Mr. Solomon Tetteh. © Baukje Kothuis but now the beach is gone and there are buildings in between. In the early morning a power barge wakes us up and vibrates through the community. If you lean against the wall of your house, it is moving. The power barge also emits gasses that might be bad for our health.

Does the new port development affect your community?
In a way it is good, bigger vessels will come with major commodities. But we will lose fishing grounds, which will negatively impact our catch, maybe by 10 to 15%. But this is not the biggest problem; we will lose more land in our community as the sea takes it away. People will have to relocate. Pollution will also become worse, and it is already very bad.

How can the port development become better for your community?
It would be better if most of the workers for the new port could be taken from our community, so that the benefits also come here. Many of us cannot afford to go to school or stay in school. Maybe the port can also support us with education and provide health facilities.

Edem Agortey

Taxi Driver
Tema Church Village

What do you do for a living and where do you live? I am a taxi owner and drive my own taxi. I live in Tema, next to the Sakumono Lagoon in Community 5, Church Village. I live here now for 6 years with my family, but originally we came from the Volta Delta region. In my taxi, I take customers from around this area, from Tema city and from the port to places around here and in Accra.

How will the new port development affect your work?
I can't tell now. I do not know this while they are still building it. First the port expansion has to be finished and then we can see what happens. But it will be good for my business if more workers

in the port will come to this area. It gives me more work from the port, because I also drive customers from Tema port to the airport in Accra.

You live so close to the lagoon, do you use the water of the lagoon for fishing or go there to swim?
No, I do not go to the water, because I can't swim. So I do not like it and it's too dangerous. Also you cannot drink the water of the lagoon, it's very dirty. But yes, you can eat the fish. Only it is not us that fish in the lagoon; that is for the people from the other side, from the Sakumono Village. Every year, around June, the lagoon floods. Sometimes more, sometimes less. In 2015, on June 3rd, the water came very high, while in 2016 and 2017 it also came, but less high.

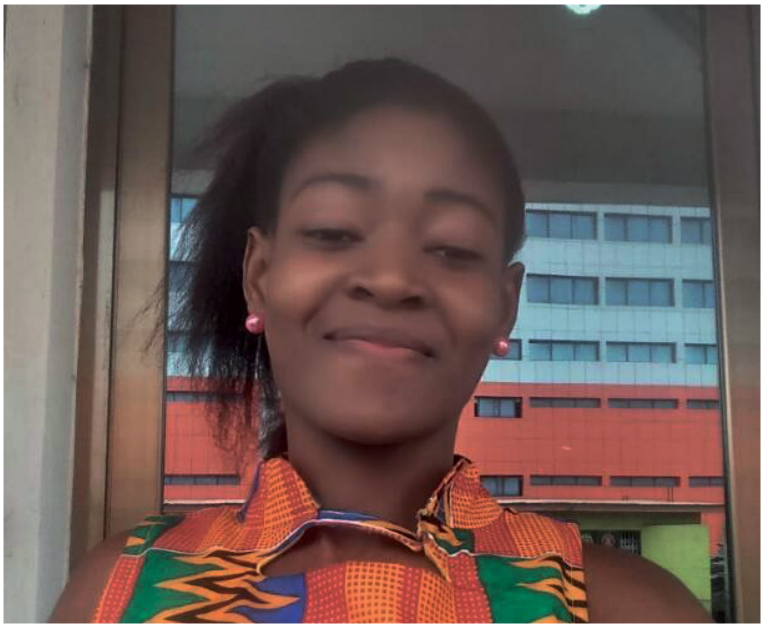
What impact does the flooding of the lagoon have on your life?
Each year we have to leave our houses during the floods, and live at the higher grounds of the church, or go to the school area. Sometimes for a few days to a week, but in 2015 it was for more than two weeks. We try to take as many things with us as we can. But if the floods come in the night, you don't know and can lose many things, like my wife did from her store. Afterwards we have to clean a lot and for a long time because the water brings lots of dirt and animals. All our houses are covered in mud and dirt from the lagoon. We then do communal labour to clean up the area; this is organised by our local committee.

10-13. Mr. Edem Agortey. © Baukje Kothuis

Faustina Afrah Yeboah

Working in the Port: Logistics
Tema City

Who are you and how is your work connected to the port?
My name is Faustina Afrah Yeboah. I live in Tema and for three years now I've worked at the Cargo Center Ghana Ltd, a company that works on clearing cargo and the logistics linked to this. We have an office just outside the port premises, and in our company about 27 people are employed. I'm a data-entry officer, I enter information into the system for goods going in and out of the port.



10-14. Ms. Faustina Afrah Yeboah. © Faustina Afrah Yeboah

How does the new port development affect your work?
The new port development is very good, because it cuts delays and therefor minimises workers stress. As the port expands, the trucks will have more physical space to turn and move around. This will reduce much of the congestion within the port itself. Currently, when there's a lot of on and off loading, the trucks often get blocked and have difficulty getting in and out of the port. Furthermore, the new development is aimed at a paperless system. This makes my work easier; I can enter information quicker, and get my data in the shortest time possible. We then work with barcodes that are scanned, instead of people having to walk from place to place to get the information and then bring it to us, as we do now. The automated system will make everything faster.

Christopher & Monica Afedzi

Running a Hotel
Tema City

What is your business and how long have you lived here?
We are the owners and managing directors of the Crismon hotel in Tema Community 5. We started this business in 1998. First we had only two rooms, but we have consistently reinvested the profits. We built it up to the current luxurious hotel with a pool, lounge and dining area, and party and conference rooms.

10-15. Mr. and Mrs. Afedzi. © Baukje Kothuis

Does the new port development affect your business?
Well, it will a little for sure, as we are here in Tema and close to the port. Some contractors from the new port development come here, which creates extra business for us. We are currently expanding our hotel, which we would have done anyway, also without the new port; but of course we hope this port will help the

business to grow. The port can create an inflow of people. But if we want to keep them in Tema, this city needs to be attractive.

Could the port expansion help to make Tema more attractive?

As we said, Tema needs to adjust. Look outside! We still have a dirt road in front of our hotel. We keep everything clean, but guests are surprised when they first see it, they do not expect this for such a good hotel. With the port expansion, first of all the infrastructure needs to be upgraded to good standards. They have started with some roads now, and this is really the number one challenge and necessity. To manage entrance to the new port and prevent traffic building up, we need network planning for traffic flow. That and better quality roads will ensure a faster flow and everything will look nicer.

Another way to make Tema more attractive is development of tourist attractions. That would be fantastic. At this time, people don't have any reason to stay in Tema; they all go to Accra. We have the Greenwich Meridian that could be exploited for example; and look at the Sakumono lagoon. When we started the hotel here, we could walk from the entrance to the green shores of the lagoon and enjoy views of nature. Now there are many illegally built houses in between and the lagoon itself is dirty and not accessible. But it was named a protected RAMSAR site, because some birds come every year, and it could be made into a national asset. If it would be dredged and opened up, all the way from the Green Mountains at Ashana to the sea, it would attract tourists. There could be little boats on it. And maybe a bridge crossing, which would ease the traffic even more.

John Nyahe

Sakumono TMA Junior High School
Sakumono Village

What is your relation to this school and community?

I am John Nyahe, I came here in 2017 to be Principal and Head Master of this school. Before I worked as an officer in the Education Office, coordinating for the whole district. So I know many of the schools here. God has been good to me; I love my work very much.

Does the new port development affect Sakumono village?

Construction has come very close to our community, but it does not affect us directly because the water does not come all the way to this place. The road is still in between. But if the port is bigger, it will bring about more business activity. So who knows? It might benefit us in a way. If our people would have access, that might transform their life style. If it keeps them out, for technical

10-16. Mr. John Nyahe. © Baukje Kothuis reasons, no one knows, then it is only an inconvenience to them.

The new port is positioned in the major fishing grounds of this community, and fishing and fish processing is our only activity here. So by taking these grounds away, it also takes away the future for our children.

How can the port development make things better for your community?

Honestly, this school is so full of destitute children, of very poor background and a good number of broken homes. We have some charitable organisations that are supporting us; like the church and the assembly, this helps our school. So we can educate them to abstain for immoral behaviour. But only very few can afford to pay fees, so most cannot get further education. And the only business is fishing, so most of them will assist the fishermen or the netters to earn some money for a living.

The only way to change things is to empower them though education. The port could help build that, imagine a government project of a higher school, or even a university in this place. Because in the future, children can only be employable after they have specialised.

Meet the Fishing Folk

Here you will meet a range of people involved in fishing and related work. They include:

- **Mr. Justice Atla** and **Mr. Peter Mesah**, who fish by canoe and bring their fish into Tema Fishing Harbour to be sold;
- **Mr. Francis Hukporti**, who fishes for crabs in Sakumono Lagoon;
- **Mrs. Faustina Nomo** and **Mrs. Juliet Adam** who sell fish in the Tema Fishing Harbour; and
- **Mr. Emmanuel Obulu** and **Mr. Derrick Acquah** who are involved in chandling and transportation in the Tema Fishing Harbour.
- To learn about the dependence of the Sakumono Village on fishing and the implications of the harbour expansion for this village, you can consult the interview with the **Community Leaders of Sakumono Village.**

All the interview information derives from:

Kothuis, B., Slinger, J. (2018). *Voices on sustainable ports in Africa. Stories from Tema Port, Ghana*. Delft University Publishers, Delft, Netherlands. ISBN 978 94-6186-945-6. 76pp.

Justice Atla & Peter Mesah

Fishing by Canoe
Tema Fishing Harbour

What is your job?
We are fishermen, we fish from the ship called ‘Shining Star’ from Chemu Beach. We have been fishing here in Tema for the past three years now, but we are only in the port for berthing. When we go fishing, we take the boat to the beach and from there we pull the nets into the sea with our boat and then pull them back to the beach. The fish are then hauled onto the beach.

Will your work change with the expansion of the port?
I don’t think the expansion of the port will change much for us. The big ships don’t catch the fish we want to catch, because they go much further out to sea than we do. The big tuna-boats also use different hooks, we fish with nets, and we fish with canoes. So when there are more big boats, it will be good for us fishermen, there will be more opportunities for employment. We will have more work. The containerships sail into the port, but they work with cargo, not with fish, so they do not threaten our jobs. But these ships do make it difficult for the fish. The fish stay very much further down because of the big tankers and container ships, and that makes it more difficult for us to catch them, because we cannot reach that deep with our nets.

10-17. Mr. Justice Atla & Mr. Peter Mesah. © Baukje Kothuis

Could your work be made better or easier?
It would be great of we could also fish in the port area, because there is much fish there, but we are now not allowed to fish there.

Francis Hukporti

Lagoon Crab Fishing
Sakumono Lagoon

What is the Sakumono Lagoon used for?
Some people come here to worship the gods of the lagoon; they used to come every year around Easter before they started their fishing season. But now I do not see them. I myself go to the lagoon to fish for crab. I go around looking for the holes. When I find a hole, I’ll mark it with a red rubber and set the trap. First you have to open the trap, then put some cassava in and set a small broomstick on it. If the crab enters, it will pull the cassava under the stick. The crab is the trigger, it catches itself! I know how it works; I come here for a long time already, started crab fishing in 1982.

Has the lagoon changed much since that time?
Yes, it has changed very much. Before, there were many, many

10-18. Mr. Francis Hukporti. © Baukje Kothuis coconut trees, all lined along the beach. And the fishing boats went fishing from there. Now it is all rocks along the coast. Because the sea is eating the land; the sea is chopping the land, it wants to take the road.

In earlier times, a lot of seawater was coming in and out, but now it is only very little water. There is much pollution coming into the lagoon. It does not damage the crabs but it damages the fishes.

That is because of all the grass you see. There used to be a little bit of grassy area: there was a river over here, and a lagoon. But the polluted water that enters the lagoon from the upper side is now making this grass, lots of grass, it has covered almost every place. The water in this part of the lagoon used to be very salty. But now, it is not salty anymore; it's dirty. You cannot drink it: in the old times because of the salt, and now because it is polluted.

Faustina Nomo & Juliet Adam

Selling Fish
Tema Fish Market

What is your job?
We are traders. Janet sells tomatoes and we sell fish from the sea, that we buy directly from the fishermen here in the fishing harbour. We buy from different fishermen, whatever they will bring in. Do you want to buy one of my fish? Look, they are big and beautiful.

Will the expansion of the port of Tema, or many big ships coming in, change your situation?
No, I don't think it will. The expansion will not cause any harm to us. About the effects of the big ships you cannot ask us, you will have to ask the big bosses. But the fish depends on the sea, not on big port expansion. The fish will stay here, in the same

place, the same situation. No problem. Sometimes you get a lot, sometimes you don't. If more people come to the fishing harbour, we will sell more fish. And the people that buy fish will also buy tomatoes, so we all will sell more.

What could be done to make selling your fish better?
It would be much better for us if we could have better cooling for our fish; we would like brand new fridges. Now we only use our fridges as cooler-boxes. And we have to buy ice, much ice because it melts very fast. It would be much better if we could have these good (polystyrene) boxes.

10-19. Mrs. Faustina Nomo & Mrs. Juliet Adam. © Baukje Kothuis

Emmanuel Obulu & Derrick Acquah

Chandling & Transportation
Tema Fishing Harbour

Mr. Derrick Acquah is one of Mr. Obulu's employees, who helps with translating our questions.

What do you do for a living?
I am a seaman, and owner of a fishing and chandler business called By the Grace of God Ltd., We bring supplies to the ships that are anchored in the bay, waiting for entrance in Tema Port. We take the goods out to them and transport their crew members ashore. I have speedboats to do this, canoes with a large outboard motor.

Does the port expansion affect your business?
No, it does not affect my work right now. It is no problem. It will bring more business to me, because I can go with the speedboat to the new vessels and that will make an even better business flow. In what way could the expansion of the port be made even better for you? Well, I would like many more vessels to come, but preferably these should be smaller tankers and fishing ships, because that is better business for me. The very large (container) ships are not good for me, because I cannot get alongside

10-20. Mr. Emmanuel Obulu. © Baukje Kothuis

and pick up people or deliver goods. Also the big containerships won't allow us near when they are anchored, and we cannot get to them once there are berthed in the port, because we are not allowed in there by the port authorities.

Meet the Community Leaders and City Planning Authority

Here you can learn about the challenges facing the communities of Sakumono Village and Tema Church Village and the issues faced by the Tema city planners by meeting:

- **Mr. Nene Mantey**, **Mr. Nene Akpaglik**, **Mr. Moses Teye**, **Mr. John Tettehocansey Maklalo**, **Mr. Richmond Sogbaton**, **Mr. Doglas Amatey Sogbaton** and **Mr. John Nyamedji** the community leaders of Sakumono Village;
- **Mr. Philip Seshie** of the Community Committee for Tema Church Village; and
- **Mrs. Francisca Okyere** and **Mr. Ali Amadu** of the Tema Metropolitan Assembly who are responsible for spatial planning in the city of Tema.

It is important to realise that Ghana, in common with many African countries, has a dual governance system. This means that traditional community leadership arising from tribal lines is respected in addition to the governance structures determined spatially according to municipal, city, provincial and national lines and organised sectorally through ministeries such as Economic Affairs, Environment, Agriculture and so on.

All the interview information derives from:

Kothuis, B., Slinger, J. (2018). *Voices on sustainable ports in Africa. Stories from Tema Port, Ghana.* Delft University Publishers, Delft, Netherlands. ISBN 978 94-6186-945-6. 76pp.

Nene Mantey, Nene Akpaglik, Moses Teye, John Tettehocansey Maklalo, Richmond Sogbaton, Doglas Amatey Sogbaton & John Nyamedji

Community Leaders
Sakumono Village

Who are you?

We are the community leaders of Sakumono Village: Nene Mantey, Chief of Sakumono; Nene Akpaglik, Chief fisherman; Moses Teye, Chief of the youth; John Tettehocansey Maklalo, in charge of the community; ; Richmond Sogbaton, Assembly man; Doglas Amatey Sogbaton, secretary to the Chief fisherman; and John Nyamedji, Deputy Chief.

How does the new port development affect your community?

Before the port was here, we were catching a lot of fish, but since the development of the port it has become more difficult. Our fish catch has reduced to almost nothing. It is only plastic. Some rubbish is cleaned out, but more than that is put in again every day. Since the expansion of the port it has become very much worse. Because of the new breakwater all the rubbish comes back to our fishing area, and the plastic tears our nets. It is very difficult to make any income. This is very bad, because all livelihood in this community is related to fishing.

Can the port development be made better for your community?

Before, we could also use the lagoon for fishing. But now there is also too much pollution in the lagoon because of rubbish and discharge flowing in when it rains. The water is dirty and the smell is bad, and there is not much water. The lagoon is choked at the exit. Many years ago, there was a lot of water and the sea entered the lagoon, but now the sea cannot come in anymore. Long ago, we used to catch big fish here, fresh water fish. Now there are only very small fish in the lagoon. The lagoon must be dredged and also opened; the sea must come in again.

10-21. Community leaders of Sakumono Village. © Baukje Kothuis

Philip Seshie

Community Committee
Tema Church Village

Who are you and what is your connection to the community here?

I am the chairman of the local Community Committee ‘Centro Mosque Zongo Association’. We try to coordinate some communal issues for people living in Tema Community 5, Church Village. Our community consists of about 220 structures: churches, some small shops and living quarters. The buildings are mainly made out of wood, and each house can contain man, wife and 2 to 4 children. Some structures have electricity and we have a water tank and tap, where people can get clean drinking water. More than 600 people are living here.

We meet with the full community once every month, to discuss our issues. We want to stay in Tema; but to rent a house here is very expensive. Therefore the Committee works hard to make life for the people better here, to develop the place. So for example, we have gone to all houses for a contribution to build a toilet block. The first 3 toilets are almost completed now. They will be for women only. The men come later, as 3 toilets for over 600 people are not enough. We need more.

10-22. The community committee. © Baukje Kothuis

How does the new port development affect your community?

I don’t think the new port will affect our community; there is quite a distance between here and where it is coming (about two kilometres). The expansion is closer to the mouth of the lagoon, that’s not close to us. But the new port will need many new workers, and some of us work there already. Other workers will come in from outside, and they too might want to live in our community

because this is cheaper living. But I don’t know where they are going to live: the closer you live to the lagoon, the more you get flooded.

How do the floods affect your community?

Well, when the water comes, it is dirty and full of silt because there has never been any dredging here. I know because I was born here, and in all my life, that is over 40 years, I’ve never seen any dredging of the lagoon. When I was a teenager in the 1980’s we would fish and swim in the lagoon. But now that’s impossible because of all the silt. And with the flooding all this silt pollutes our community. We then take refuge in the churches. The National Disaster Funds provided mosquito nets and the churches gave mattresses and blankets, so the people have a place to sleep. There are some promises for more help, but we cannot wait for the government. So with the Committee we organise the communal labour, for example to clean up after a flood.

Francisca Okyere & Ali Amadu

City Planning - Tema Metropolitan Assembly
Tema City

What is your task?

The Assembly, under the Local Governance Act, 2016 Act 936, is the highest political, planning and administrative authority in its area of jurisdiction. Thus, the Assembly is responsible for the overall planning, development and management of all development activities within its area of jurisdiction.

The exclusive development and management functions of the Assembly as mentioned above have been further set out in the Land Use and Spatial Planning Act, 2016 (Act 925). The Act further emphasises, in Section 34 of Act 925, the purposes of establishment of a District Planning Authority, that:

A District Assembly or a spatial planning authority is for the purpose of this Act the spatial, human settlement and planning authority for its area of authority.

This mandate, in practice, includes development and building permitting, which is a requirement for all physical developments undertaken within the Metropolis.

10-23. Mr. Ali Amadu and Mrs. Francisca Okyere. © Baukje Kothuis

Relative to the Tema Port the Assembly's development management authority covers all ancillary activities within the Port area; that means those activities which are not core port infrastructure.

How do your responsibilities relate to national level planning?

Ghana's decentralisation process is designed to ensure that policies and programmes at the National level inform planning, decision making and implementation at the local Assembly level to fa-

cilitate the achievement of overall national goals. Meanwhile, the planning and policy formution at the National level, which translates into projects that are eventually executed at the Assembly, is informed by comments, proposals and feedback gathered from consultative and participatory processes and structures at the local Assembly level. There is a foward and backward linkage in the national and local level planning.

In regard to spatial planning, there is also the adoption of the three-tier planning system, which requires the preparation of a National Spatial Development Framework (upper tier/National level), that translates into the preparation of a Structure Plan (middle tier/Sub-national or Regional level), which finally informs the preparation of Local Plans (lower tier/Local level) at the Assembly. By implication, whatever spatial plan is prepared at the Assembly to facilitate the discharge of its responsibilities must have emanated from a higher level plan, to ensure better coordination, harmonisation and/ or integration of plans and projects.

What does the port expansion mean to you and your organisation?

The Tema Port expansion obviously comes with some positive and negative effects. Currently, a new well equipped hospital has been built by the Port Authority, which will provide improved access to healthcare for the community. In addition, road improvements are being done to some major road corridors in the Metropolis; a proposed construction of a new container and truck parking terminal, which we envisage will help decongest the existing situation in and outside the port area, amonsgs others. All of these support the Assembly's development agenda.

However, there is also the attendant negative effects that we envisage to come with the port expansion including a greater incidence of floating population which come in and out to do business with the port and its related activities, increased waste generation and management challenges, increased damage to the city's inner road corridors by heavy duty trucks which often divert onto these roads to avoid traffic on the main roads and also park indiscriminately along the shoulders of the roads and cause damage to the drains, invasion of open spaces and slum developments by additional squatter population which are likely to migrate into the city to seek job opportunities, etcetera.

The inner city of Tema, for instance, was built to complement the port activities then. Presently, the city on all fronts has grown beyond what it was planned for. One of the very affected sectors of the inner city is the housing situation - requiring critical interventions like redevelopments and making a conscious effort to provide for the urban poor; given that the expansion will most likely drive more activities and attract even more people to the city.

All these will call for well coordinated, integrated, intersectoral and participatory approaches to managing or resolving the emerging issues; which means it cannot be done by the Assembly alone.

How do you include stakeholders in your planning for Tema?
Nowadays, we use more consultative and participatory methods in our planning and decision making processes. In planning for what programmes and projects to be done in a given period the Assembly consults with focused groups including representatives of civil society and community based organisations, NGOs, Residents Associations, relevant public and private institutions, etcetera, to solicit for their comments and proposals, to inform the plan.

The Assembly engages these groups - either separately or together at public hearings or town hall meetings as may be necessary for the identification of proplems or issues confronting the city, proposal of relevant strategies, and prioritisation of interventions and actions to resolve the issues, amongst others.

10-392

Meet the Delta Alliance & Strategic Network Partners

Finally, you will meet strategic network partners:

- **Mr. Ken Kinney**, Executive Director of the Development Institute and Coordinator for the Ghana wing of The Delta Alliance;
- **Mrs. Afke van der Woude**, a project manager representing the Ghana Netherlands Business and Culture Council (GNBCC) in Accra; and
- **Mr. Fred Smiet** and **Mr. Jan Anne van der Veer**, representatives of the Embassy of the Netherlands in Ghana.

All the interview information derives from:

Kothuis, B., Slinger, J. (2018). *Voices on sustainable ports in Africa. Stories from Tema Port, Ghana.* Delft University Publishers, Delft, Netherlands. ISBN 978 94-6186-945-6. 76pp.

Ken Kinney

The Development Institute
Accra

Who are you and what is your background?
My name is Ken Kinney, I am Executive Director for The Development Institute and Coordinator for the Delta Alliance Ghana Wing. I've been working in the Volta delta for six years now, and my real passion is about sustainable management, which involves conservation, livelihoods and economic development. One of things I am advocating for is complete land use. This means all the available lands should be put to the use they are suitable for, and then there should be spatial planning. That can be the beginning of sustainable management of all the resources.

How is the Development Institute involved with the Tema port project?
We became involved trough the Delft University of Technology, our role in the project is to facilitate local contacts and arrange logistics; and I also support Dutch students who come to Ghana. The work of The Development Institute is not directly connected to the port expansion.

10-24. Mr. Ken Kinney. © Baukje Kothuis

What is a Sustainable Port to you?
A sustainable port should involve places that are conserved. It should involve livelihoods for the communities that are around the port. And it should really, really bring about economic development. So in the absence of all these three components, even with the hard component of a port expansion in place, I would say it is not sustainable.

As Tema port stands now, it wouldn't be called a sustainable port. A lot of the development is just done with the technical issues in mind: How do we ensure we have space for ships to dock, have a place to keep our containers, and that the government derives maximum revenue. But there seems no thinking about issues concerning: How do we create areas for conservation? How do we connect the port to people's livelihoods?

How could sustainability in the Tema port area be enhanced?
Firstly, Chemu Lagoon and Sakumono Lagoon are both wetlands - the latter is even protected: it is a RAMSAR site. It is supposed to be a place for resupplying water and for migratory birds. And a place where communities should be able do some level of fishing and recreation. But we see a lot of pollutants and encroachment, and the places have no regulation and management. Basically, the lagoon is being filled for housing. For Chemu lagoon there is not even a vent to enter the sea, so there is no recharge from the sea. That makes it a closed system, which is not the best. It is choked, it needs to be dredged; this will increase fish life in the sea and the lagoon. We are looking into this with The Development Institute. Improvement is strongly needed for the people of Tema New Town. When they were relocated in the sixties, they used to have the Sakumono lagoon as a resource, and then shifted to the Chemu lagoon. Now, there are no resources left at all. We have found out that it is possible to do sanitation of the lagoon; but an adaptation fund still has to come through.

Secondly, it is very important to re-demarcate the boundaries of the lagoons. Make sure that regulations are strengthened, as there should be no more encroachment in these areas. If we need to use pillars and barbed wire totally around it to achieve this, government is to invest in that. There should to be a couple of entrances for people to enter, but they cannot start building in the area. We need strong measures to prevent that and the fencing would regulate entrance. Tema municipality then could even collect fees, which can be used to develop or manage the lagoon. There can be recreational activities: fishing, relaxing and enjoying the nature. For that you need facilities, which the municipality should invest in; and there could also be some revenue out of that.

Finally, the Tema planning department should consider the Building with Nature concept. Now most of the houses are already virtually halfway in the lagoon, and not well built nor built with the right materials. People fill up the lagoons with sand, which is not sustainable because of the salt content. The salt easily overpowers and degrades all the cement. I think there is a system to ensure they could build specific kinds of houses that can co-exist with the entire ecosystem and not harm the lagoon.

Afke van der Woude

Connecting Business in Ghana and the Netherlands
Accra

Who are you and what is your profession?
I am Afke van der Woude, since two years I am working in Accra at the GNBCC, the Ghana Netherlands Business and Culture Council, as a project manager. Together with the Dutch Embassy and other Dutch organisations, we do a lot of projects to broadly promote business between Ghana and the Netherlands.

How is GNBCC involved with the Tema port?
GNBCC is involved in the port through several projects, organising activities for our partners that have an interest in the port and the port expansion. I first got to know about it because of the Sustainable Ports project we do together with the consortium that Delft University of Technology is also part of. For this project we facilitated several things, such as workshops in the port, which also enabled us to meet a lot of stakeholders.

And on the other hand GNBCC also knows about current developments and expansion of the port through our members.

There's a lot of trade between Rotterdam and Tema, so many of our members, either Ghanaian or Dutch, are active in the port and in the free zone around the port.

How is the work of GNBCC related to the port expansion?
In 2015 GNBCC was involved in a tender towards the port expansion, we acted as a facilitator for the Dutch partners that submitted a proposal for this tender. That is how we work, we usually don't initiate, but facilitate. In the practical sense of organising things for members, but also with relations and connections.

What is a Sustainable Port to you?
A sustainable port would be a port that is eco-friendly, inclusive towards the people living in and around the area, and economically sustainable. With that I mean that the companies and people working there can sustain a profit, can benefit. Furthermore a sustainable port means that it is well connected to other areas and actors around the port. Not only the port in itself should be sustainable, but also the connections to the hinterland.

10-25. Afke van der Woude. © Afke van der Woude

Fred Smiet & Jan Anne van der Veer

Embassy of the Netherlands in Ghana
Accra

10-26. Fred Smiet & Jan Anne van der Veer. © Baukje Kothuis

Who are you and what is your profession?
I am Fred Smiet, First Secretary, Water & Climate affairs (left on the picture). My work deals with development cooperation in the water and sanitation sector, and trade promotion issues. Currently, we also started focusing on integrated water management and coastal zone issues in Ghana.

And I am Jan Anne van der Veer, Second Secretary of the Dutch Embassy in Ghana, Trade & Private Sector Development (right on the picture). I work for Dutch companies that want to do business in Ghana and with young Ghanaian entrepreneurs that want to set up their business here in Ghana.

How is the Dutch Embassy in Ghana involved with the Tema Port expansion?
We used to have a ports development program, and currently maintain contact with companies that are involved with the port. The port expansion touches on the work of a lot of companies that either are Dutch, or have strong ties with the Netherlands. In fact, many shipping lines and shipping agencies have their European head quarters in Rotterdam. So for the Dutch embassy there is definitely a strong link between the port of Tema and Dutch companies, as the port development affects their work and business.

What is a Sustainable Port to you?
In my perception this is a facility that does not impact negatively on its environment, being the social and ecological surroundings. In that sense you can call it a green, or eco-friendly port. Apart from that, it should also be commercially sustainable, so that companies working in this port are able to make a profit and to keep developing.

10.3 Assignment 10.1

Introduction

In Assignment 10.1 you will apply the knowledge you have gained in the preceding chapters to design your own stakeholder-inclusive, ecosystem-friendly strategy for coalition building in Tema, Ghana.

You will need to consult the extensive material on Tema, the port, and the people, in the previous section before starting this assignment. You can view and complete the form that will take you through the 5-step analysis on the following pages.

The self-assessment has a number of steps. You can already consult the grading rubric to understand what is expected of you. After critically assessing your own strategy, you can then also read more about the strategy applied in the Sustainable Ports in Africa project. Remember there isn't one correct answer.

Enjoy completing the assignment!

Assignment 10.1: Towards Coalition Building in Tema, Ghana

Introduction

In this assignment you will apply the knowledge you have gained in the preceding weeks to design your own stakeholder-inclusive, ecosystem friendly strategy for coalition building in Tema, Ghana. You will undertake this in 5 stages in this form.

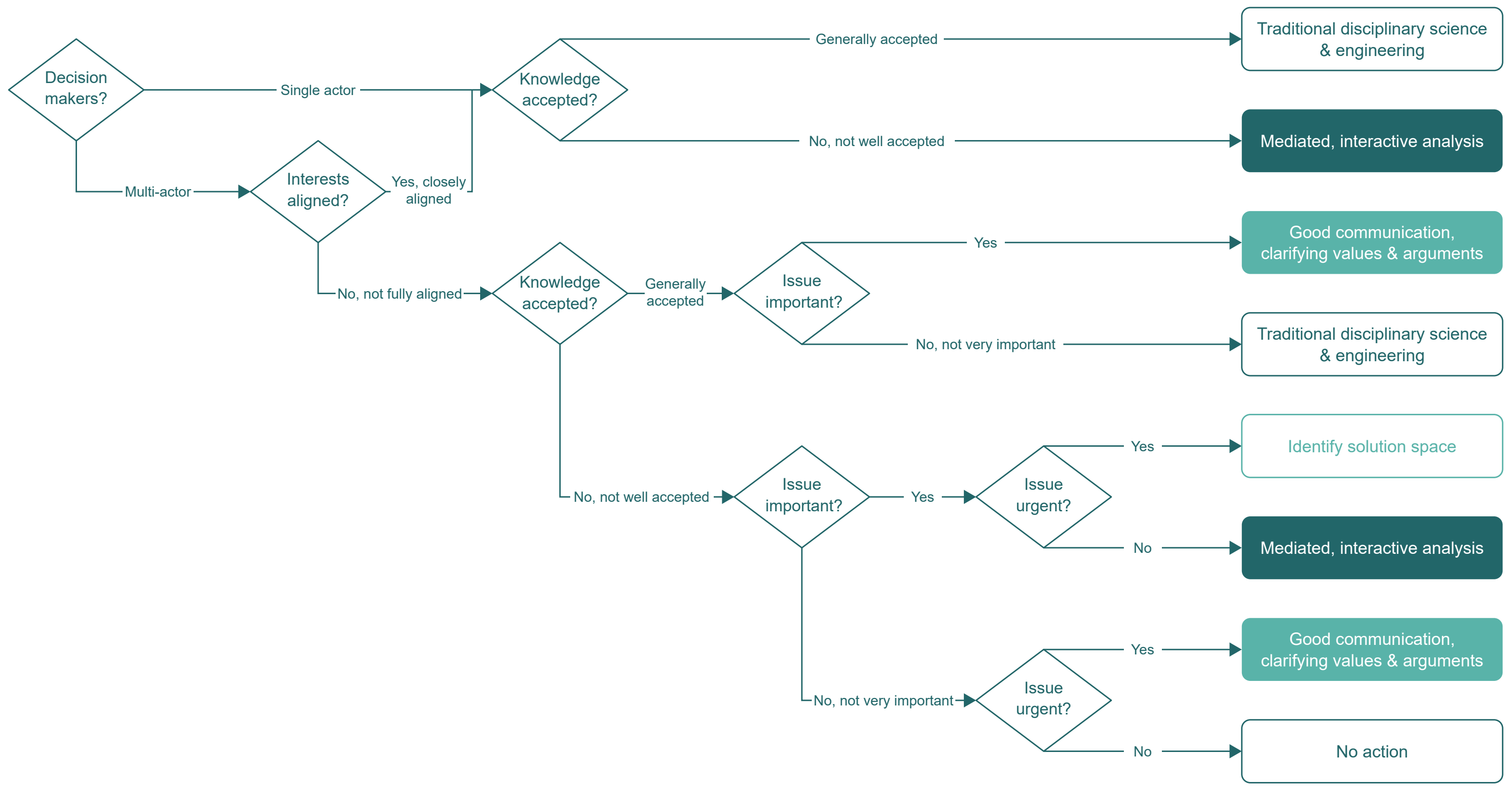
Title:

Locational Focus (and why?):

Stage 1 – Diagnosis for Stakeholder Engagement

Indicate the type of stakeholder engagement. You choose on the basis of the 5 diagnostic questions. Draw in your choice path. Consult the Feedback on Assignment 6.1 if you are unsure how to determine the type of stakeholder engagement required.

Justification (Give your reasoning in the box below):

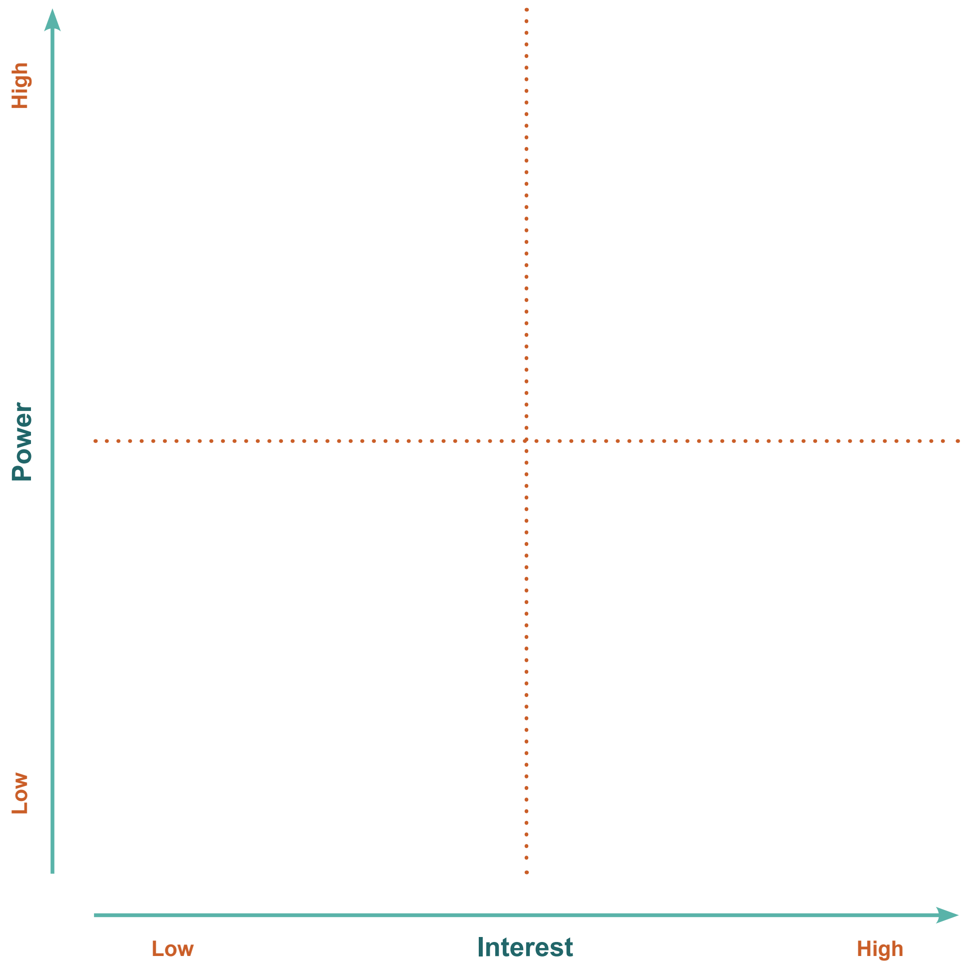


Stage 2 – Identify and Map Key Stakeholders

The key stakeholders, their power and interests and key resources should be specified below. Consult the Feedback on Assignment 7.1 if you are unsure of the 4 steps that you need to follow to identify and map stakeholders and arrive at the summary table and power-interest grid (next page).

Initial List of Key Stakeholders	Important Resources
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	

10-397



Identifying Potential Coalitions (Record your ideas of potential coalitions below):

Stage 3 – Apply the Social Design Principles

First, apply the Normative Social Design Principles, determining how you stand in relation to the problem situation and the people to be involved in the stakeholder engagement process.

Next, apply the Social Design Principles for Transdisciplinarity to determine how you will design the process of engagement. Finally, apply the Substantive Social Design Principles to determine what will form the content focus of the engagement process.

Normative Social Design Principles	Checkboxes *Minimum-maximum*	Explanation
1. Complexity-informed stance 	○ ○ ○ ○ ○	
2. Stakeholder-inclusive 	○ ○ ○ ○ ○	
3. Value-based 	○ ○ ○ ○ ○	
4. Adaptive 	○ ○ ○ ○ ○	
5. Coalition-building 	○ ○ ○ ○ ○	

Social Design Principles for Transdisciplinarity	Checkboxes *Minimum-maximum*	Explanation
1. Tolerance	○ ○ ○ ○ ○	
2. Aha moments	○ ○ ○ ○ ○	
3. Enquire, listen, share	○ ○ ○ ○ ○	
4. Tolerance, integrity, trust	○ ○ ○ ○ ○	
5. Reflection	○ ○ ○ ○ ○	

10-400

Social Design Principles for Transdisciplinarity	Checkboxes *Minimum-maximum*	Explanation
6. People, ideas	○ ○ ○ ○ ○	
7. Discontinuities	○ ○ ○ ○ ○	
8. Perserverence	○ ○ ○ ○ ○	
9. Multidimensional people	○ ○ ○ ○ ○	

Substantive Social Design Principles	Checkboxes *Minimum-maximum*	Explanation
1. Way of life	○ ○ ○ ○ ○	
2. Culture	○ ○ ○ ○ ○	
3. Community	○ ○ ○ ○ ○	
4. Political systems	○ ○ ○ ○ ○	
5. Environment	○ ○ ○ ○ ○	
6. Health and wellbeing	○ ○ ○ ○ ○	
7. Personal and property rights	○ ○ ○ ○ ○	
8. Fears and aspirations	○ ○ ○ ○ ○	
9. Cumulative effects	○ ○ ○ ○ ○	

10-401

Stage 4 – Cooperative Game Theory

Apply cooperative game theory to identify players, moves, pay-offs and outcomes, either in past games e.g. the Tema Port Expansion approval, or as input for coalition building in present and future games to increase social inclusion and benefit sharing from the port. Consult the Feedback on Assignments 8.1 and 8.2 if you are unsure how to apply game theory.

Translating real world elements into Game Theory equivalents:

Constructing and Interpreting the game(s):

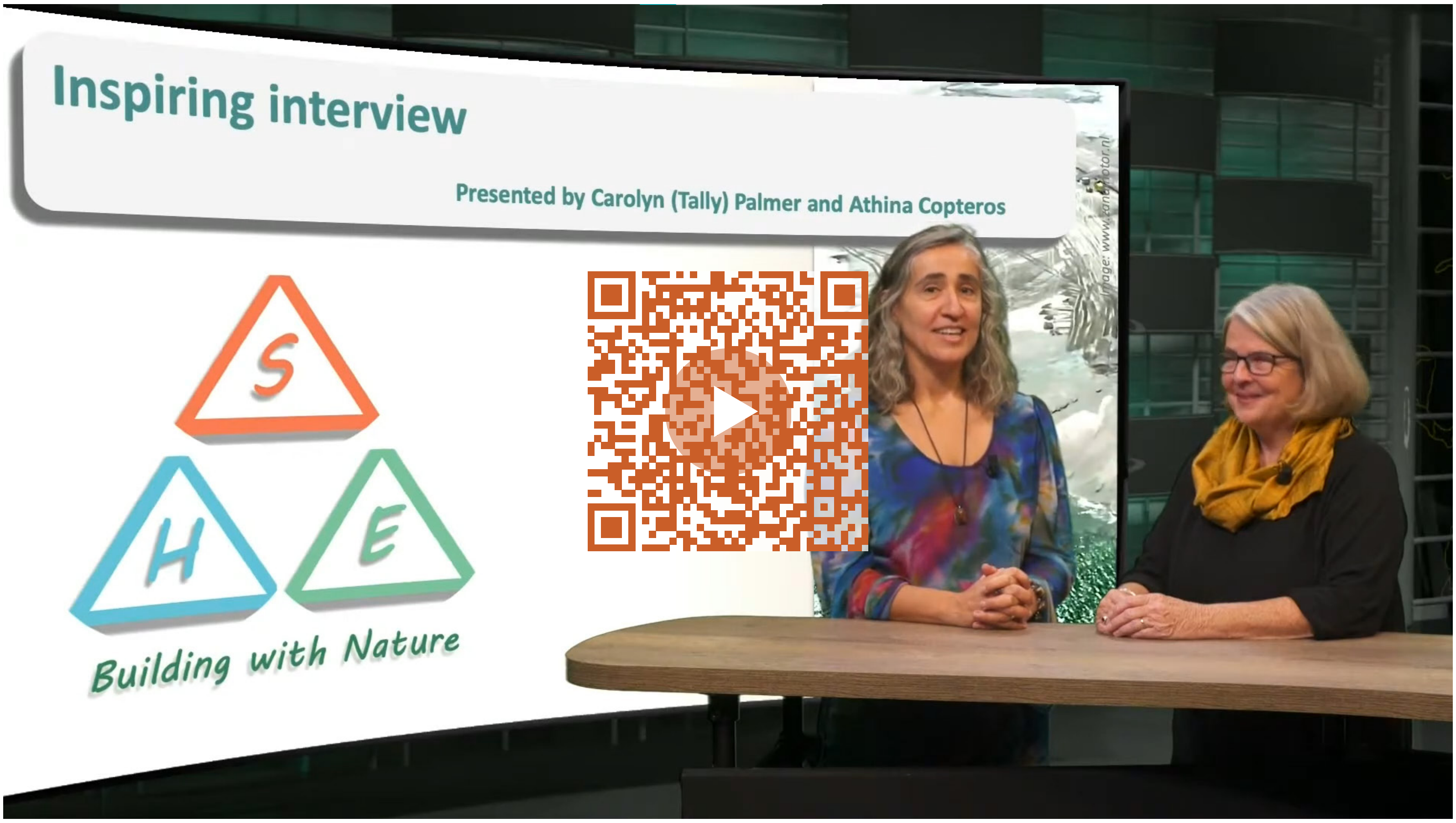
Does this Change your Ideas for Potential Coalitions?:

Stage 5 – Issues of scale

Reflect on your choice of scale and how this relates to the issues associated with the expansion of the Port of Tema. What does this mean for the coalitions you have identified, or for your engegement strategy?

Reflection:

10.4 Moving Beyond Engineering Towards Coalition Building



10-404

Video: An Inspiring Interview - Tsitsa Catchment

In this section, eminent scientists share their experiences and insights in developing and applying stakeholder-inclusive, ecosystem friendly approaches with you.

In the first video **Prof. dr. Tally Palmer** talks to **Dr. Athina Copteros** about the inspiring example of transdisciplinary engagement in the Tsitsa catchment in South Africa. This video is wirtten by **Tally Palmer**, **Jill Slinger** and **Athina Copteros**.

You can cite this video as:

Palmer, C. (Tally), Slinger, J.H. (Jill), Copteros, A. (Athina) (2021). *Beyond Engineering: Building with Nature 2x video #12. Inspiring interview.* 4TU.Dataset. https://doi.org/10.4121/14912559

Video Transcript

Presented by Prof. Tally Palmer and Dr. Athina Copteros

A: Tally Palmer has engaged in many different complex systems and today she's going to be sharing her experiences of engaged research in one such system.

T: So, the system I'm going to talk to you about today, Athina, is the Tsitsa river. Now the Tsitsa River is a tributary of the Mzimvubu River in South Africa which is the last wild free-flowing river that we have.

A: And what unfolded in this particular river or for this river? Well when you are faced by complex systems and they, you, are hoping to intervene in a good way, they don't always start in a promising way. And in this case we had a corrupt president who announced the building of a dam in a wild free flowing river without consultation with his engineers.

A: And what were some of the opportunities in that if there can be opportunities?

T: Well it raised expectations in local people and it was also dangerous because the landscape was highly erosive and a dam in a very nearby catchment had silted up in five years. And so it stopped being able to deliver water. Now one of the difficulties with big dams and big infrastructure is that they do offer tremendous developmental opportunity but generally those opportunities come for people downstream of the dam. And in this case the problem and the threat to the dam was being generated by the upstream area.

A: So for opportunities to be actualised certain players had to come together. Can you speak to us about that?

T: Well this was one of the unusual things that sometimes just emerges. Our Department of Environment and Affairs saw an opportunity and then engaged with Water Affairs to say we can engage with our land restoration in order to slow down and move towards stopping the high levels of erosion. And if we can restore the landscape we get better vegetation cover and the plants that we need for the livestock that local people have, also our restoration processes can be speeded up with particular plants and they can be grown by local people. And we will buy them from them so that we also stimulate local

livelihoods and particularly taking account of women who are often excluded in traditional areas.

A: And in this land restoration project a lot of different ways of knowing came came together?

T: They did and I work in participatory governance because I believe that in land restoration at some point the government department will leave. And what we need to leave behind are local people better enabled to engage with local decision-makers. And for that to happen we need to encourage a space where local people experience and are respected. And also where they share their local knowledge, but they also learn knowledge and language that allows decision-makers to hear and respect them. Now the way we started with that was that we held workshops and we started with something called learning words and we engaged in these processes in isiXhosa, which is the local language. And we started with the word ikhaya which is home and everybody from grannies to chiefs to local people could talk equally about ikhaya. They could talk about cats and dogs and cows and family and from that sharing of words they knew we moved into the river and the landscape and the catchment. Catchments are used by the municipal planners, There isn't an isiXhosa word for catchment, but we built an understanding and a way of knowing about that.

A: So this was a very particular learning pathway?

T: It was and what we have now are community liaison oficers; local people who are now the champions of working between local people and decision-makers.

A: Thank you. We hope that the story has inspired you for your work!

10-406

Video: Aligning Building with Nature and Environmental Assessment in Port Development

'Green handbrake' or 'equal partner' in port development?

Prof. Susan Taljaard explains how environmental assessment can be aligned with all of the different phases of the port development cycle to move the environment from the role of 'green handbrake' to 'equal partner'. This video is wirtten by **Susan Taljaard**, **Jill Slinger** and **Steven Weerts**, **Sumaiya Arabi** and **Heleen Vreugdenhil**.

You can cite this video as:

Taljaard, S. (Susan), Slinger, J.H. (Jill), Weerts, S. (Steven), Arabi, S. (Sumaiya), Vreugdenhil, H.S.I. (2021). *Beyond Engineering: Building with Nature 2x video #13. Aligning Building with Nature and environmental assessment - Port development and planning.* 4TU.Dataset. https://doi.org/10.4121/14912643

You can download this paper by Susan Taljaard, Jill Slinger, Surnaiya Arabi, Steven Weerts and Heleen Vreugdenhil about the 'Green handbrake' or 'equal partner' in port development by clicking the link or scanning the QR-code below:

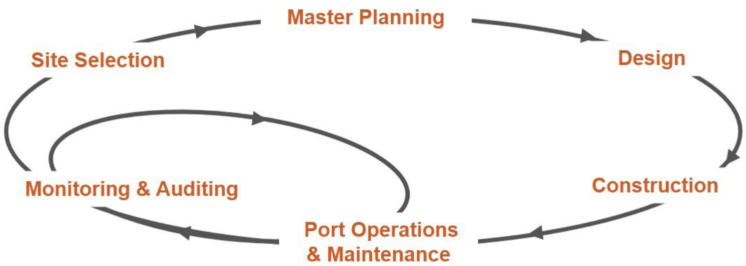
Paper: The natural environment in port development: A 'green handbrake' or an equal partner?

Video Transcript

Presented by Prof. Susan Taljaard

The notion of environmental assessment first emerged in the 1960's, reflecting society's growing awareness of the environment. It strives to ensure social and ecologically sustainable use of our natural resources, through participatory approaches that are supported by sound science. Because Building of Nature also has sustainable development at heart, let's explore how these two concepts fit together. We will take port planning and management as our example. Thinking of port planning and management practically, a new development typically starts with the selection of a suitable coastal site to locate the port.

During master planning, the overall vision and various port layouts are considered. And the design phase drills down deeper into the individual infrastructure projects at the selected sites, and then it goes into construction. Within the port planning and management cycles, there are long-term processes and they are only addressed at about 10 - 20 year time spans.



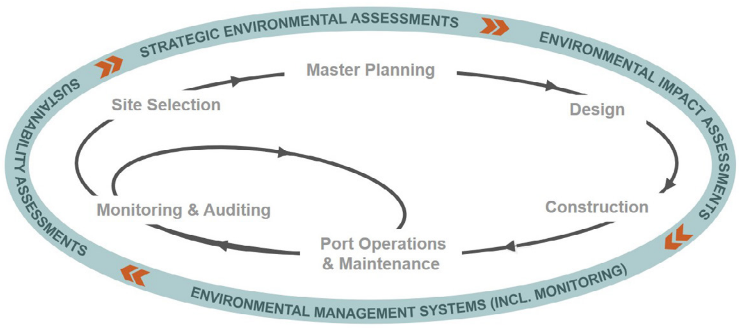
10-27. Port Planning & Development Cycle. © Susan Taljaard. Adapted from Taljaard et al. (2021).

Strategic Environmental Assessment	Pro-active, participatory process to assess ecological, social & economic sustainability of development (including design) scenarios (place-based)
Environmental Impact Assessment	Participatory process assessing potential ecological & social impacts, and mitigation of specific projects
Environmental Management Systems (incl. Monitoring)	Assessing operational performance & compliance with ecological & social objectives
Sustainability Assessment	**Assessing performance & compliance against**

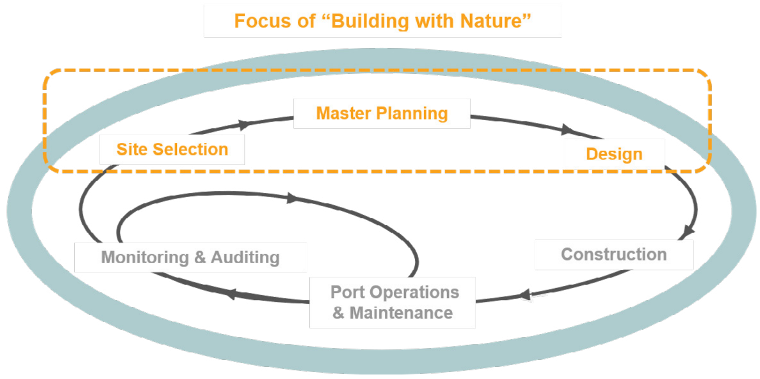
10-28. Environmental Assessment [EA] Processes. By Susan Taljaard. Adapted from Taljaard et al. (2021).

However, once a port has been built, operations and maintenance as well as monitoring and auditing activities happen on much shorter time scales, literally on a day-to-day basis. Now, environmental assessment, on the other hand, comprises a range of different processes, including: Strategic Environmental Assessment (SEA). This entails a pro-active participatory process within a specific geographical area aiming to assess the ecological, social and the economic sustainability under the various development scenarios. Strategic Environmental Assessments are also not project-specific. Rather, they are overarching assessments of the potential and the suitability of a particular area for different types of development. Then there's Environmental Impact Assessment, also a participatory process, but this is primarily aimed at assessing the potential ecological and social impacts in a specific project. It also considers means to mitigate such impacts. Environmental Management Systems, aimed at assessing operational performance and compliance with ecological and social objectives that were agreed as part of the strategic and the environmental impact assessment. Here during this phase - sound, ongoing environmental monitoring - is of critical importance.

And then finally, Sustainability Assessments aim to assess performance against the United Nation's 14 Sustainability Development Goals which countries agreed as part of Agenda 2020. Now, if we align these environmental assessment processes with components in port planning and management. It becomes clear that the strategic environmental assessment aligns well with site selection, master planning and the initial stages of design all of these pro-active investigations into - "what might be possible". Environmental Impact Assessment is often a legal requirement prior to construction of any new development. So, it is usually performed in phase with a detailed stages of design. It also stipulates requirements to be met during the construction or infrastructure construction. Environmental Systems align best with operations and maintenance, providing the structured platform within which to conduct ongoing environmental performance and compliance assessments. And finally, Sustainability Assessment, aligns best with the overarching monitoring and auditing phases, providing a means of assessing the overall social and ecological sustainability outcomes in a particular port. But, how - would a Building with Nature approach then align with environmental assessment processes in port planning and management?



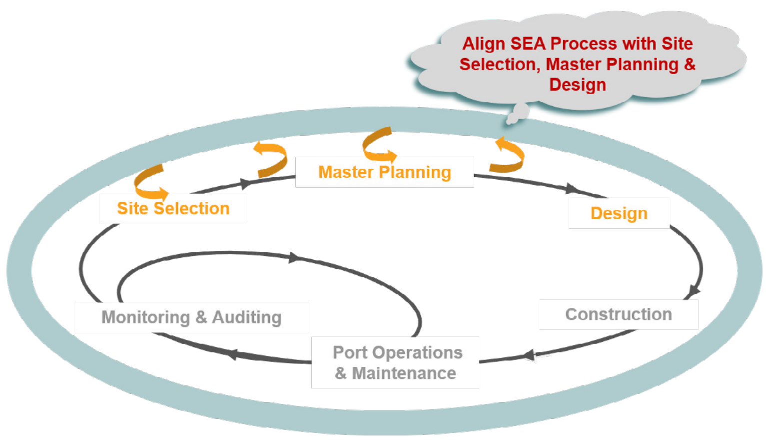
10-29. *Aligning Port Planning & Development with EA. © Susan Taljaard. Adapted from Taljaard et al. (2021).*



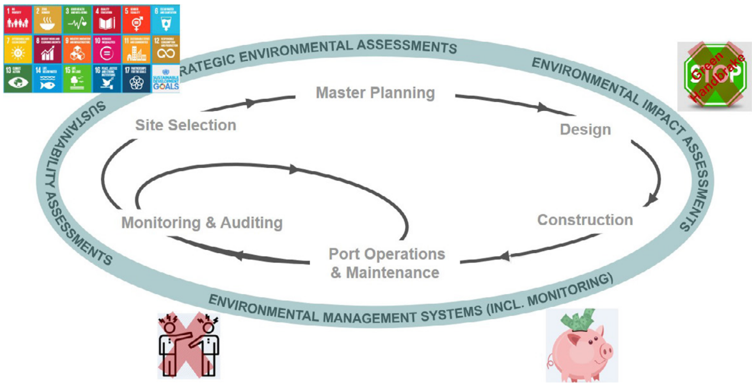
10-30. *Aligning Building with Nature [BwN] and EA. © Susan Taljaard. Adapted from Taljaard et al. (2021).*

First, let's locate Building with Nature in relation to the activities in port planning and management. It spans the site selection, master planning and the initial stages of design. Building with Nature and Strategic Environmental Assessment are both ecologically friendly processes looking for development opportunities through participatory approaches. While Building with Nature - the process of Building with Nature - often enters from the engineering perspective, Strategic Environmental Assessment is more strongly grounded in the social and ecological opportunities of the new development.

So, these processes are complementary and can mutually benefit if they align through their knowledge and participatory platforms. So why then do we want to bring a SEA and Building with Nature design processes together, trying to use the one to inform and refine the other? What is the added value? Most social and ecological issues in port development only emerge during the EIA phase. So, by pro-actively identifying and addressing these in the early planning and design stag-



10-31. *Aligning BwN and EA... © Susan Taljaard. Adapted from Taljaard et al. (2021).*



10-32. Value of Alignment. © Susan Taljaard. Adapted from Taljaard et al. (2021).

es, EIAs will no longer be perceived as "green handbrakes" to port development. In many instances in the past, port development has been stalled by social and ecological conflicts that could have been foreseen and addressed in advance, or even seen as opportunities for nature development. Port operators are also often bogged down in social and ecological conflicts that could have been identified in the planning phases. So addressing these early on can save them a great deal of effort later on during operations.

Maintenance costs can also be reduced significantly if ecological processes are taken into account. For example, taking account of water circulation processes in the design phase can later reduce the need for maintenance dredging. So, finally, by considering social and ecological values early on in port planning and development, a port's ability to comply with international sustainable development goals will be enhanced

10.5 Feedback

The assessment rubric for Assignment 10.1 is provided immediately below so that you are aware of the evaluation criteria for this assignment. The assignment feedback is placed on the next pages. Remember the approach adopted by the Sustainable Ports in Africa project is only one of many possible approaches. More information on this strategy is available in the next section.

Table: Self Review Grading Table

Components	Indicative questions (Criterion)	Options	Grade
Title and location focus	Are the title and locational focus specified? Is there a reason given for the locational focus?	**Fair:** There is a title **or** there is a locational focus. The reason for the locational focus of this place-based study is not made explicit.	5
		Good: There is a clear title **and** a locational focus is chosen and specified	10
Diagnosis for stakeholder engagement	Are the 5 diagnostic questions applied to establish whether and how stakeholders are included?	**Poor to Fair:** No, the questions are not applied.	3
		Fair to Good: The questions are applied, but there is no or little supporting argumentation.	7
		Good to Excellent: The questions are applied and the argumentation is supplied that justifies the choices made.	10
Stakeholder Identification and Mapping	Are key stakeholders identified? Are stakeholders mapped in terms of their power and interest? Is interdependency between stakeholders considered? Are stakeholders who don't initially fall into the high power, high interest quadrant considered as potential coalition partners i.e. is the approach stakeholder-inclusive?	**Poor to Fair:** Key stakeholders are identified and mapped, but insightful analysis of their interdependencies is lacking. The approach is conventional, adhering to established, powerful interests rather than stakeholder-inclusive.	10
		Fair to Good: Key stakeholders are identified and mapped. There is an analysis of interdependencies. The approach departs from the purely conventional and considers more than the established, powerful interests. It includes a wider set of stakeholders.	15
		Good to Excellent: Key stakeholders are identified and mapped. There is insightful analysis of interdependencies and potential coalitions start to emerge. The approach departs from the purely conventional, considering more than the established, powerful interests. It is stakeholder-inclusive in character.	20

Table continues →

Components	Indicative questions (Criterion)	Options	Grade
Social Design Principles - Normative	Are at least 2 of the Normative Social Design Principles ranked in the last two boxes? Are the explanations placed in the correct boxes? Do the explanations match the scoring of the principle? Is sufficient explanation provided for each choice?	**Poor to Fair: Less than 2** of the Normative Social Design Principles are ranked in the last two boxes, **or** the explanations are placed in the incorrect boxes **and** the explanations do not match the scoring of the principle. **Fair to Good: At least 2** of the Normative Social Design Principles are ranked in the last two boxes **or** the explanations are placed in the correct boxes **or** the explanations match the scoring of the principle. **Good to excellent: At least 2** of the Normative Social Design Principles are ranked in the last two boxes **and** the explanations are placed in the correct boxes **and** the explanations match the scoring of the principle.	**3** **7** **10**
Social Design Principles - Process of Engagement	Are at least 4 of the Social Design Principles for the Process of Engagement ranked in the last two boxes? Are the explanations placed in the correct boxes? Do the explanations match the scoring of the principle? Is sufficient explanation provided for each choice?	**Poor to Fair: Less than 3** of the Social Design Principles for an engagement process are ranked in the last two boxes, **or** the explanations are placed in the incorrect boxes **and** the explanations do not match the scoring of the principle. **Fair to Good: At least 3** of the Social Design Principles for an engagement process are ranked in the last two boxes, **or** the explanations are placed in the correct boxes, **or** the explanations match the scoring of the principle. **Good to excellent: At least 4** of the Social Design Principles for an engagement process are ranked in the last two boxes **and** the explanations are placed in the correct boxes **and** the explanations match the scoring of the principle.	**3** **7** **10**
Social Design Principles - Substantive	Are at least 4 of the Substantive Social Design Principles ranked in the last two boxes? Are the explanations placed in the correct boxes? Do the explanations match the scoring of the principle? Is sufficient explanation provided for each choice?	**Poor to Fair: Less than 3** of the Substantive Social Design Principles are ranked in the last two boxes, **or** the explanations are placed in the incorrect boxes **and** the explanations do not match the scoring of the principle. **Fair to Good: At least 3** of the Substantive Social Design Principles are ranked in the last two boxes, **or** the explanations are placed in the correct boxes, **or** the explanations match the scoring of the principle. **Good to excellent: At least 4** of the Substantive Social Design Principles are ranked in the last two boxes **and** the explanations are placed in the correct boxes **and** the explanations match the scoring of the principle.	**3** **7** **10**

10-411

Table continues →

Components	Indicative questions (Criterion)	Options	Grade
Cooperative Game Theory	Is the potential to influence strategic decision making through coalition building explored? Is game theory used in this analysis?	**Poor: No** use of game theory is made **or** the argumentation / analysis is very weak.	3
		Fair: Little use of game theory is made **or** the argumentation / analysis is weak.	7
		Good: Use is made of game theory **and** the argumentation / analysis is sound.	10
Issues of Scale	Are issues of scale addressed? Is there reflection on the implications of locational choice for the findings, or for the selection of stakeholders, or the potential coalitions identified?	**Fair:** Issues of scale are **not** considered **or** the implications of scale choices are not analysed well.	5
		Good: Issues of scale **are** considered well.	10
Comparison with Sustainable Ports in Africa Strategy (located in section 10.5)	How does the overall stakeholder engagement strategy compare with that taken in the Sustainable Ports in Africa project?	**Could be better:** My strategy needs to improve. **I didn't** include as many stakeholders **or** I followed a more conventional approach **or** I focused on the authorities (who change jobs often and quickly in Africa) rather than people who live and work in Tema or with the port.	5
		Comparable or Better: My strategy for stakeholder-inclusion compares well with the strategy followed in the Sustainable Ports in Africa project, because I include as wide a range of stakeholders **or** have sound arguments for who to include and who to leave out **or** focus on a different aspect and include relevant stakeholders	10

Feedback on Assignment 10.1: Towards Coalition Building in Tema, Ghana

Introduction

In this assignment the stakeholder-inclusive, ecosystem friendly strategy for coalition building in Tema, Ghana adopted by the Sustainable Ports in Africa project is described, according to the 5 stages of Assignment 5.1.

Title:

Stakeholder-inclusive Approach to a sustainable Tema Port and Coast

Locational Focus (and why?):

Tema Port and coastal environs (taking into account the location of Tema as the nearest city to the Volta Delta and its closeness to Accra).

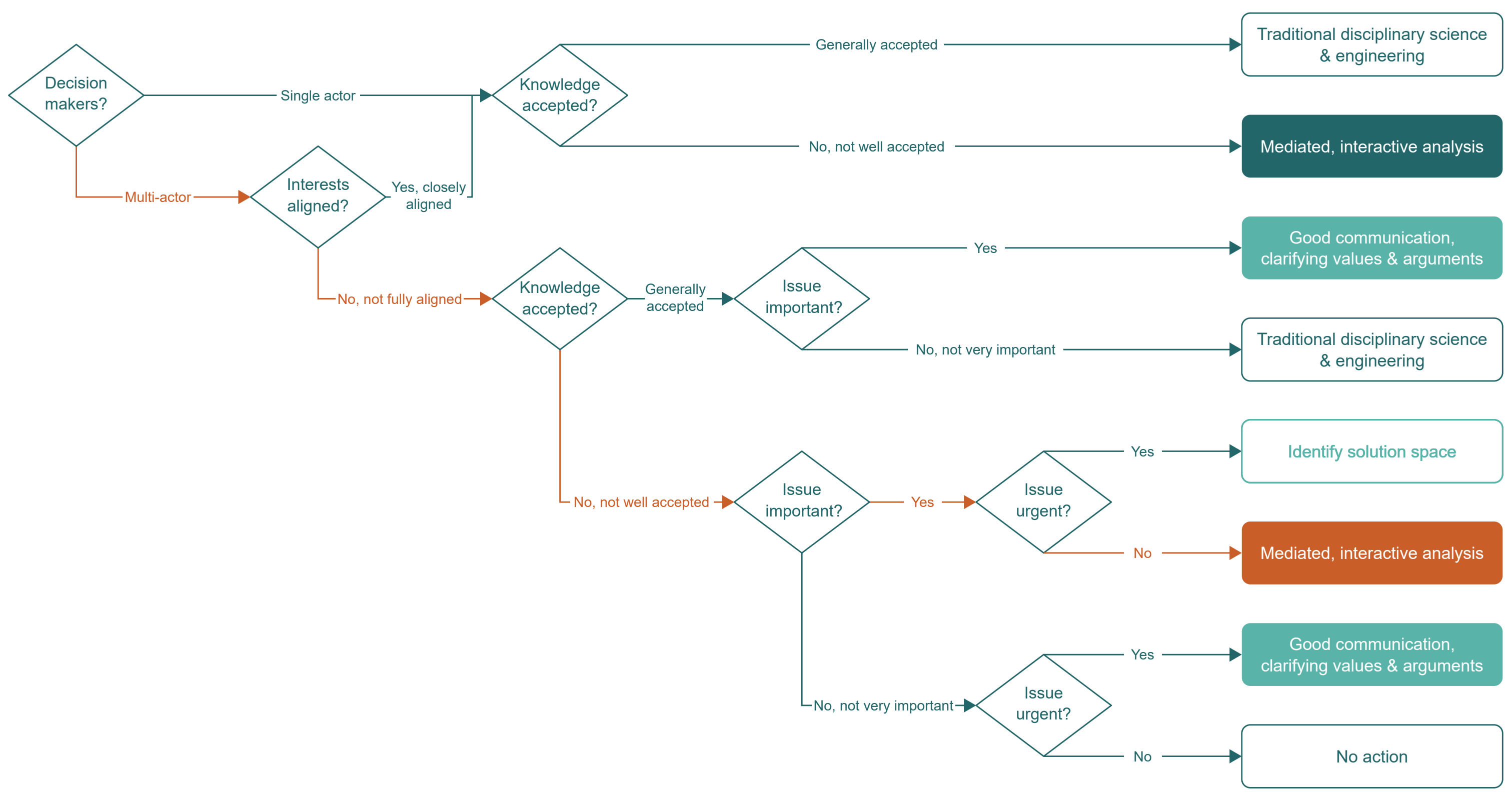
Stage 1 – Diagnosis for Stakeholder Engagement

Indicate the type of stakeholder engagement. You choose on the basis of the 5 diagnostic questions. Draw in your choice path. Consult the Feedback on Assignment 6.1 if you are unsure how to determine the type of stakeholder engagement required.

Justification (Give your reasoning in the box below):

The high level decision to expand Tema Port has been taken and this interest is now represented by Ghana Ports and Harbours Authority (GPHA), but decisions on the the outworking of the expansion in terms of Building with Nature options and effects on other stakeholders still need to be made. Multiple decision makers are involved in this, and their interests are definitely not aligned. These can differ from subsistence fishing interests to harbour employee safety issues amongst others. Knowledge on the effects of the environment or the social impacts of port expansion is not necessarily universally accepted. Some people do not consider that the social impacts on the people of Church Village should be taken into account, for instance, as this is an illegal settlement. The issue of Tema Port expansion is important as it will affect the livelihood of many people, the future development of the Tema area and in the long term the welfare of Ghana. The issue is not urgent as the expansion of the port will take time and there is sufficient time to implement enhanced sustainability measures, even though it would be better to start earlier rather than later.

Accordingly a strategy of mediated, interactive analysis is selected.



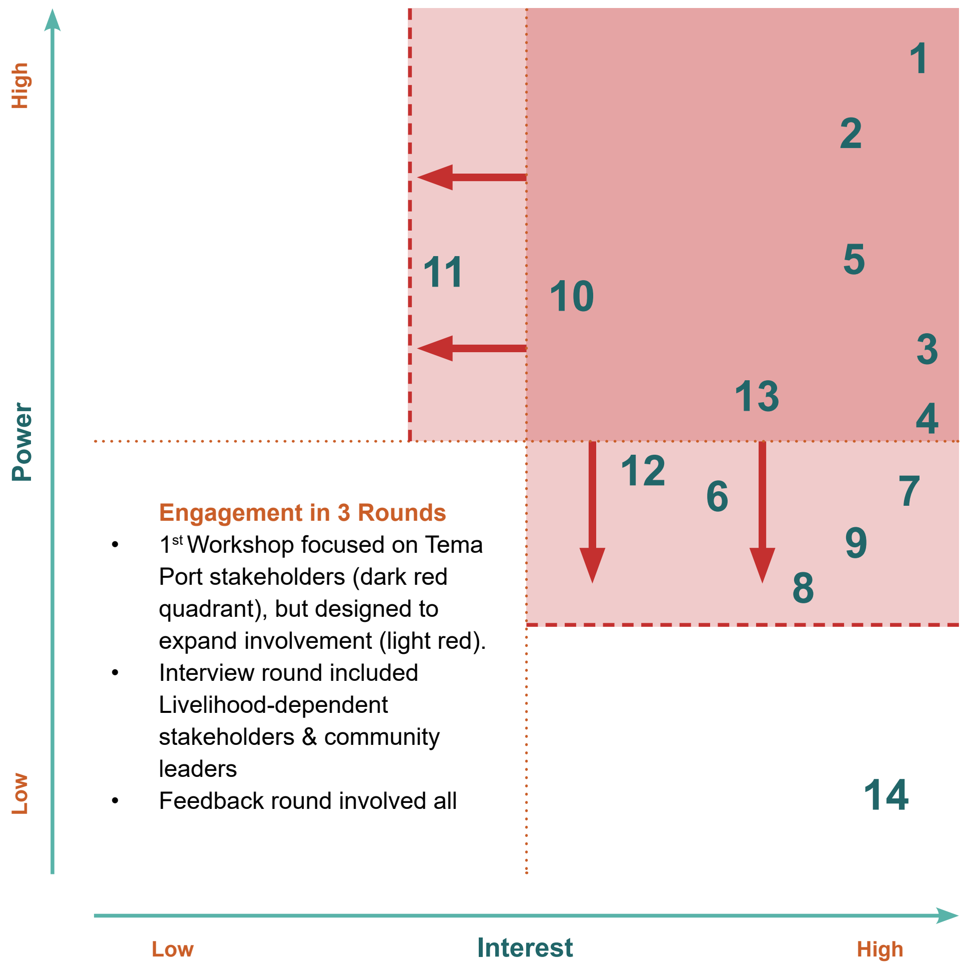
Stage 2 – Identify and Map Key Stakeholders

The key stakeholders, their power and interests and key resources are specified below.

Note that stakeholders are already grouped according to their interests here.

	Initial List of Key Stakeholders	Important Resources
1.	Ghana Ports and Harbours Authority & Tema Port (Represented by the Director of Tema Port)	National authority over Tema Port, Financial and information resources, high level network connections within Ghana.
2.	Port developers - MPS	Contract to expand the port, knowledge of lay-out designs and choice of materials, high level network connections internationally and within Ghana. Financial resources.
3.	Employees of GPHA at Tema Port	Access to information on Tema Port, knowledge of procedures in Tema Port, dependent for job on GPHA.
4.	Harbour employees (wider group of people employed within Tema Port, many are members of labour unions)	Suppliers of labour, have blocking power through the power to strike. Fear loss of jobs from high level of automation.
5.	Logistics and transport companies (Ghana Institute of Freight Forwarders represents local interests, International shipping companies)	Critical to cargo throughput and the efficacy of the port, possess knowledge resource, systems and labour in a critical process. Also potentially provide the means to upgrade knowledge and connect more effectively internationally.
6.	Tourism related to the Harbour, Tema and its environs (include Cruise terminal lobbyists, hotel owners, taxi drivers etc.)	Tourism knowledge, lobby for cruise terminal and more local tourism, can connect Sakumono Lagoon to wider tourism interests.
7.	Tema City Planning (Tema Metropolitan Assembly)	Knowledge of spatial planning, licensing regulations, water supply and sewerage services, road congestion, health and safety services.
8.	Environmental scientists, University of Ghana, Khomazi University	Knowledge of coastal and delta dynamics, local situation knowledge, connections to international scientists and into local governmental networks.
9.	International interdisciplinary scientists and engineers	Knowledge of transdisciplinary science in complex, dynamic environmental and social systems, access to state of the art tools.
10.	NABC, GBNCC	High level international and local business network connections, Can mobilise knowledge from individual members.
11.	The Netherlands Embassy in Ghana	High level governmental connections and strong business network both locally and internationally.
12.	Delta Alliance, The Development Institute	Knowledge of delta and coastal processes, science network.
13.	Wetlands Associations (e.g. RAMSAR, Wetlands International, WWF)	International influence, wetland knowledge, know how to reconcile environmental and tourism uses of wetlands.
14.	Livelihood-dependent stakeholders & community leaders	Fishing communities dependent on resources at sea and in the Sakumono Lagoon, Tema Church Village subjected to flooding from the lagoon, Animistic believers who revere the Sakumono Lagoon and a rock in Tema harbor, Tema New Town residents with an eroding beach, overcrowded Tema Fishing Harbour.

10-414



Identifying Potential Coalitions (Record your ideas of potential coalitions below):

1. Sakumono Lagoon Restoration Coalition

Potential Members - Sakumono Fishing Village community leaders and fisherman; Tema Church Village; Tourism and Cruise Terminal; RAMSAR wetlands; Hotel owners; Taxi Driver; GPHA; Tema City Planners

Common Interest - rehabilitating the lagoon, improving the road over the entrance and widening it, dredging the channels to alleviate flooding and allow a return to the intrinsic character and functioning of the tidal wetland, increased tourism **with** strict control of new settlement, provision of services to existing settlements.

2. Anti-Coastal Erosion

Potential Members – Tema City Planners, Tema New Town Residents, Fishermen from Tema Fishing Harbour

Common Interest - Sand nourishment at Tema New Town beach providing more space for berthing of fishing canoes and improving the quality of the living environment

3. Freight Forwarding Training

Potential Members – Ghana Institute of Freight Forwarders, GPHA, MPS, Tema City Planners, Harbour Employees; Transport & Logistics companies, people of Tema

Common Interest – Enhanced capacity in the local freight forwarding and logistics capacity, particularly in coping with automation and globalisation. This will help to minimise traffic congestion in Tema, and potentially increase jobs in the medium to long term.

Stage 3 – Apply the Social Design Principles

First, the Normative Social Design Principles are applied. They determine how you as designers of the stakeholder engagement process stand in relation to the problem situation and the people involved.

Next, the Social Design Principles for Transdisciplinarity are applied to determine characteristics of the process of engagement. Finally, the Substantive Social Design Principles are applied to determine the content focus of the engagement process.

Normative Social Design Principles	Checkboxes *Minimum-maximum*	Explanation
1. Complexity-informed stance	○ ○ ○ ● ○	Partial solutions rather than one comprehensive solution were envisaged from the outset. Elements included: # a history of the development of Tema, # stepping into the future via visioning, and # explaining the dynamics (spatial and temporal) of the coastal environmental system through modelling and scientific knowledge presentations.
2. Stakeholder-inclusive	○ ○ ○ ○ ●	**3 rounds** of stakeholder engagement were envisioned. **First** a workshop at the Tema Harbour to widen the issue scope of the harbour-related stakeholders and explore the elements that they include in their future visions and an interview with Port Director; **Second** a broad livelihood and living environment consultation round with interviews with stakeholders, captured in witten story form; **Third**, feedback to all stakeholders, allowing for discussion and integration of knowledge.
3. Value-based	○ ○ ○ ○ ●	Diverse perspectives were explicitly introduced in the 1st Workshop in Tema Port. Global-local mismatch in port expansion were explained.
4. Adaptive	○ ● ○ ○ ○	An adaptive perspective was not explicitly included. Implicitly it is present in the exploration of utopian and dystopian future visions within the 1st Workshop.
5. Coalition-building	○ ○ ○ ● ○	A game structuring approach was chosen for the 1st Workshop. This includes identifying key stakeholders and their preferences regarding different future visions. Key stakeholders that prefer the same futures are natural coalition partners.

10-416

Social Design Principles for Transdisciplinarity	Checkboxes *Minimum-maximum*	Explanation
1. Tolerance	○ ○ ○ ○ ◉	People were unfamiliar with the level of interaction planned in the 1st workshop. The participants provided information on the history of Tema, her port and her people. Key stakeholders identified themselves and envisioned utopian and distopian futures. Initially they were uncomfortable, but the majority persisted till the end.
2. Aha moments	○ ◉ ○ ○ ○	The stakeholder engagement was designed for 3 rounds, but did not extend intensively over a long time. This means that Aha moments were less apparent and possibly occurred in between the face-to-face engagements.
3. Enquire, listen, share	○ ○ ○ ○ ◉	This attitude characterised the workshops and the interviews and was explicitly communicated by the facilitators on multiple occasions during the 1st workshop. It also characterised the interactions of the international research team with attention giving to exchanging opinions and knowledge of what might or might not work in stakeholder engagement activities in Ghana.
4. Tolerance, integrity, trust	○ ○ ○ ◉ ○	This attitude also characterised the workshops and the interviews, and required a high level of investment. Ghana is a country used to foreign donors and it took time for both the Ghanaian researchers, Dutch researchers and the stakeholders to move beyond the usual project-based way of acting.
5. Reflection	○ ◉ ○ ○ ○	Reflective moments were designed into the process for the research team, but not with all stakeholders.
6. People, ideas	○ ○ ○ ◉ ○	Free expression of ideas was encouraged in all engagement activities.
7. Discontinuities	○ ○ ○ ○ ◉	This is a critical component of evey stakeholder engagement process extending over a longer period of time. It is unlikely that all of the same people will be able to be present throughout and engagement is dependent on who is there. In our case, there were discontinuities in who was the Port Director of Tema. This position has been occupied by 3 different people over the length of the project. In each case, we have engaged with the present encumbent, explaining our process and previous engagements. Each of the Port Directors were invited onto the Advisory Board of the Sustainable Ports in Africa project.
8. Perserverence	○ ◉ ○ ○ ○	There was a relatively smooth process. Perseverence was required in delivering copies of the book “Voices on Sustainable Ports” to each of the interviewees as many did not have postal addresses.
9. Multidimensional people	○ ◉ ○ ○ ○	This was accommodated by having different types of engagement activities, and varying these within the time of the interactions e.g. standing, sitting, drawing, talking.

Substantive Social Design Principles	Checkboxes *Minimum-maximum*	Explanation
1. Way of life	○ ○ ○ ○ ●	Accounting for effects on the way of life of the people of Tema is taken into account through the layered stakeholder engagement approach, first allowing key port stakeholders to realise the ramifications of a port for all of Tema and her coastal environs and then bringing in the voices of the people such as fisherman, migrants, who had not yet been heard.
2. Culture	○ ● ○ ○ ○	Explicit attention for culture is not a focus of the approach. Yet, the spiritual significance of the rock in the harbour to animist believers and the Gao tribe came up in the stakeholder engagement process and were discussed with the Tema Port Director.
3. Community	○ ○ ○ ○ ●	First, the formally recognised stakeholders relevant to the port were engaged. Thereafter all communities were considered, not just those that are formally recognised. So, the traditional leaders of Sakumono Village were consulted, as were Tema Church Village and Tema New Town leaders.
4. Political systems	○ ● ○ ○ ○	The stakeholder engagement process extended beyond the formally recognised authorities. Different rounds of engagement were used to accommodate power differences, which would have made face-to-face meetings between stakeholders awkward and potentially unhelpful. Instead we, as scientists and facilitators, moved between the groups.
5. Environment	○ ○ ○ ○ ●	A wide range of BwN measures were envisioned. State of the art scientific knowledge on coastal dynamics, ecosytem-based design and environmental economics was shared with stakeholders. Offering this type of knowledge exchange provided a major reason for stakeholders to attend workshops.
6. Health and wellbeing	○ ○ ● ○ ○	The effects of Tema port expansion on fishing livelihoods, and the health and wellbeing of people who depend on the Sakumono estuary was considered explicitly, as were issues of flood safety. But, general health and safety in the harbour or safety from road accidents were not considered.
7. Personal and property rights	○ ● ○ ○ ○	Not dealt with explicitly. By considering the people of Tema Church Village, an illegal settlement, human dignity is considered.
8. Fears and aspirations	○ ○ ○ ○ ●	This formed a focus of the stakeholder engagement. In the 1st workshop future visioning (utopic and dystopic) was applied, allowing people to depict their fears and aspirations. In the 2nd interview round, people were explicitly asked about the future and how they imagined Tema and her port would look.
9. Cumulative effects	○ ○ ○ ○ ●	Again, this is a strength of the engagement process. Interdisciplinary science was applied throughout so that cumulative and interconnected effects would become apparent rather than hidden.

10-418

Stage 4 – Cooperative Game Theory

Cooperative game theory is applied here to identify players, moves, pay-offs and outcomes, in the game of Sakumono Lagoon Restoration.

Translating real world elements into Game Theory equivalents:

Players

1. GPHA, MPS form the player Port Development
2. Delta Alliance, RAMSAR, City Planning, Scientists form the player Environment
3. Sakumono Fishing Village, Tema Church Village, Tourism form the player Sakumono Locals

Moves

1. Increase the common solution space (core) by lobbying Port Development to help in restoring Sakumono Lagoon,
2. Persuade Port Development to negotiate better tidal interaction at the mouth when the coast road is renewed in 5 to 10 years

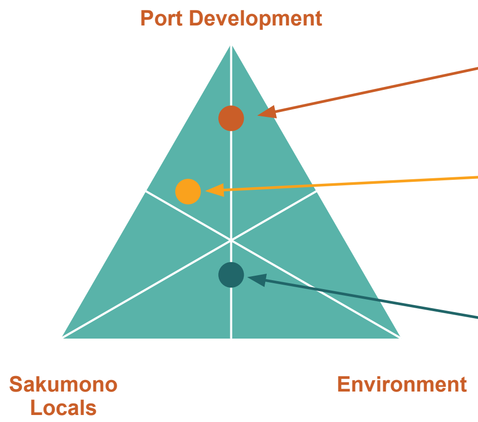
Pay-offs

Enhanced fishing, restoration of livelihood, increased tourism, better environmental protection, wetland habitat restored and conserved, less flooding, perceived benefit from the port expansion

Potential Outcomes

Coalition between Sakumono Locals and Environment; Potentially broad coalition with Port Development

Constructing and Interpreting the game(s):



Present situation where Port Development gains at the cost of others.

Partial restoration of exchange with the sea through larger culverts. Less beneficial to Environment and Sakumono Locals than full BwN alternative, but less costly for Port Developers and maintenance free.

Restoration of Sakumono Lagoon, beneficial to Environment and Sakumono Locals, but requiring Port Development to invest in relationships, lobbying and possibly maintenance.

Does this Change your Ideas for Potential Coalitions?:

Yes, a lot of work will have to go into such a Sakumono Lagoon restoration and it would probably require international pressure from Wetland Associations to achieve. Perhaps the most likely coalition is the Freight Forwarding Training as this has strong commercial benefits and would also help in alleviating a 'felt' problem of congestion by trucks in Tema City.

Stage 5 – Issues of scale

The choice of scale determines the issues associated with the expansion of the Port of Tema and the coalitions identified. It partially determines the 3-round engagement strategy.

Reflection:

If a narrow focus of Tema Port and its expansion had been chosen then all the BwN and stakeholder engagement would have focussed only within the port area. To gain benefits from the engagement the scale of analysis has to be wider. That is why we chose the focus of Tema City and its coastal environs. Only then can feasible options to share benefits be developed and can a focussed engagement process be applied. A still wider scale that included the Volta Delta is also possible, but then the focus on the port would be diluted.
The choice of scale is a trade-off that brings some issues into focus and others not. Here we chose for a focus on the port and the city in which it is located.

The Stakeholder-inclusive Approach Adopted by Sustainable Ports in Africa

The Sustainable Ports in Africa project is a joint research initiative led by Delft University of Technology (TU Delft), together with the University of Ghana (UG), the Free University of Amsterdam(VU), Wageningen University (WUR), IHE-Delft, Deltares, the Netherlands African Business Council (NABC) and many industry and business supporting parties. The project is financed by the Urbanising Deltas of the World (UDW) programme of the Dutch Research Council (NWO) under project number W07.69.206.

The following organisations are represented on the Advisory Board:

- Boskalis
- Ghana Ports and Harbour Authority, Tema Port
- Ghana Netherlands Business and Culture Council (GB-NCC)
- World Wild Fund for Nature, the Netherlands
- Netherlands Commission for Environmental Assessment
- Dutch Development Bank (FMO)
- Witteveen+Bos
- Port of Amsterdam

The structured, stakeholder-inclusive, ecosystem-based approach applied to the case study of Tema Port Expansion is described in the material available for download hereafter. You may cite the material as:

Slinger, J.H. (2018). Learning a practical stakeholder-inclusive, ecosystem-based design approach. Technical Session (papers 1 - 4), 34th PIANC World Congress, 7 - 12 May 2018, Panama City, Panama.

Paper: Designing for Stakeholder Values in Port Development in Africa

Presentation: Designing for Stakeholder Values in Port Development in Africa

Paper: The Contribution of Nature-Based Concepts to Sustainable Port Development

Paper: Towards a Framework for Integrated, Ecosystem-Based Port Development

Paper: Diffusing Knowledge on Sustainable Port Development

10.6 Bibliography

Literature

van den Houten, J. (2017). *A system dynamics exploration of port-city development. The case of Tema, Ghana*. MSc Thesis, Delft University of Technology, Delft, Netherlands.

Kothuis, B., Slinger, J. (2018). *Voices on sustainable ports in Africa. Stories from Tema Port, Ghana.* Delft University Publishers, Delft, Netherlands. ISBN 978 94-6186-945-6. 76pp.

Taljaard, S., Slinger, J.H., Arabi, S., Weerts, S.P., Vreugdenhil, H. (2021). The natural environment in port development: A 'green handbrake' or an equal partner? *Ocean and Coastal Management 199:* 105390. https://doi.org/10.1016/j.ocecoaman.2020.105390

Figures

10-1. Fishing Harbour, Tema Ghana: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-2. Kwasi Appeaning Addo: This image is Copyright protected. © 2018 Ascha Simons. All Rights Reserved.

10-3. Edem Mahu: This image is Copyright protected. © 2018 Ascha Simons. All Rights Reserved.

10-4. Barnabas Akurigo Amisigo: This image is Copyright protected. © Barnabas Akurigo Amisigo. All Rights Reserved.

10-5. Map of Tema: This image by Jill Slinger is licensed under CC-BY-NC-SA 4.0.

10-6. Edward Kofi Osei: This image is Copyright protected. © Edward Kofi Osei. All Rights Reserved.

10-7. Kwabena Ofosu-Appiah, Joseph Agbaga & Robert Baffo Dapaah: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-8. Bas de Vaal: This image is Copyright protected. © Bas de Vaal. All Rights Reserved.

10-9. Azonko Simpi: This image is Copyright protected. © 2017 Baukje Kothuis. All Rights Reserved.

10-10. Rendering of envisioned Greenwich Meridian Tower and Cruise terminal: This image is Copyright protected. © Azonko Simpi. All Rights Reserved.

10-11. Barnabas Apom: This image is Copyright protected. © Barnabas Apom. All Rights Reserved.

10-12. Mr. Solomon Tetteh: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-13. Mr. Edem Agortey: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-14. Ms. Faustina Afrah Yeboah: This image is Copyright protected. © Faustina Afrah Yeboah. All Rights Reserved.

10-15. Mr. and Mrs. Afedzi: These images are Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-16. Mr. John Nyahe: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-17. Mr. Justice Atla & Mr. Peter Mesah: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-18. Mr. Francis Hukporti: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-19. Mrs. Faustina Nomo & Mrs. Juliet Adam: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-20. Mr. Emmanuel Obulu: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-21. Community leaders of Sakumono Village: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-22. The community committee: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-23. Mr. Ali Amadu and Mrs. Francisca Okyere: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-24. Mr. Ken Kinney: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-25. Afke van der Woude: This image is Copyright protected. © Afke van der Woude. All Rights Reserved.

10-26. Fred Smiet & Jan Anne van der Veer: This image is Copyright protected. © 2018 Baukje Kothuis. All Rights Reserved.

10-27. Port Planning & Development Cycle: This image by Susan Taljaard is adapted from Taljaard et al. (2021) and is licensed under CC-BY-NC-SA 4.0.

10-28. Environmental Assessment [EA] Processes: This image by Susan Taljaard is adapted from Taljaard et al. (2021) and is licensed under CC-BY-NC-SA 4.0.

10-29. Aligning Port Planning & Development with EA: This image by Susan Taljaard is adapted from Taljaard et al. (2021) and is licensed under CC-BY-NC-SA 4.0.

10-30. Aligning Building with Nature [BwN] and EA: This image by Susan Taljaard is adapted from Taljaard et al. (2021) and is licensed under CC-BY-NC-SA 4.0.

10-31. Aligning BwN and EA...: This image by Susan Taljaard is adapted from Taljaard et al. (2021) and is licensed under CC-BY-NC-SA 4.0.

10-32. Value of Alignment: This image by Susan Taljaard is adapted from Taljaard et al. (2021) and is licensed under CC-BY-NC-SA 4.0.

Closing Message

Closing Message

Dear Building with Nature & Beyond reader,

You have reached the end of **Building with Nature & Beyond: Principles for designing nature based engineering solutions**. Well done! We hoped you enjoyed reading this book and completing the exercises.

In working through the first **5 Chapters** you learned that Building with Nature is about using natural materials and working with natural processes in hydraulic design. So, it is nature friendly hydraulic engineering with, and for, society. The idea is that if hydraulic engineering can take account of ecosystem character and functioning at the outset, the infrastructural designs that result will be more in tune with nature. However, in **Chapters 6-10**, you learned that it is necessary to go beyond integrating ecosystem consideration into hydraulic engineering design processes. It is necessary to undertake stakeholder-inclusive design to truly address society's long term needs.

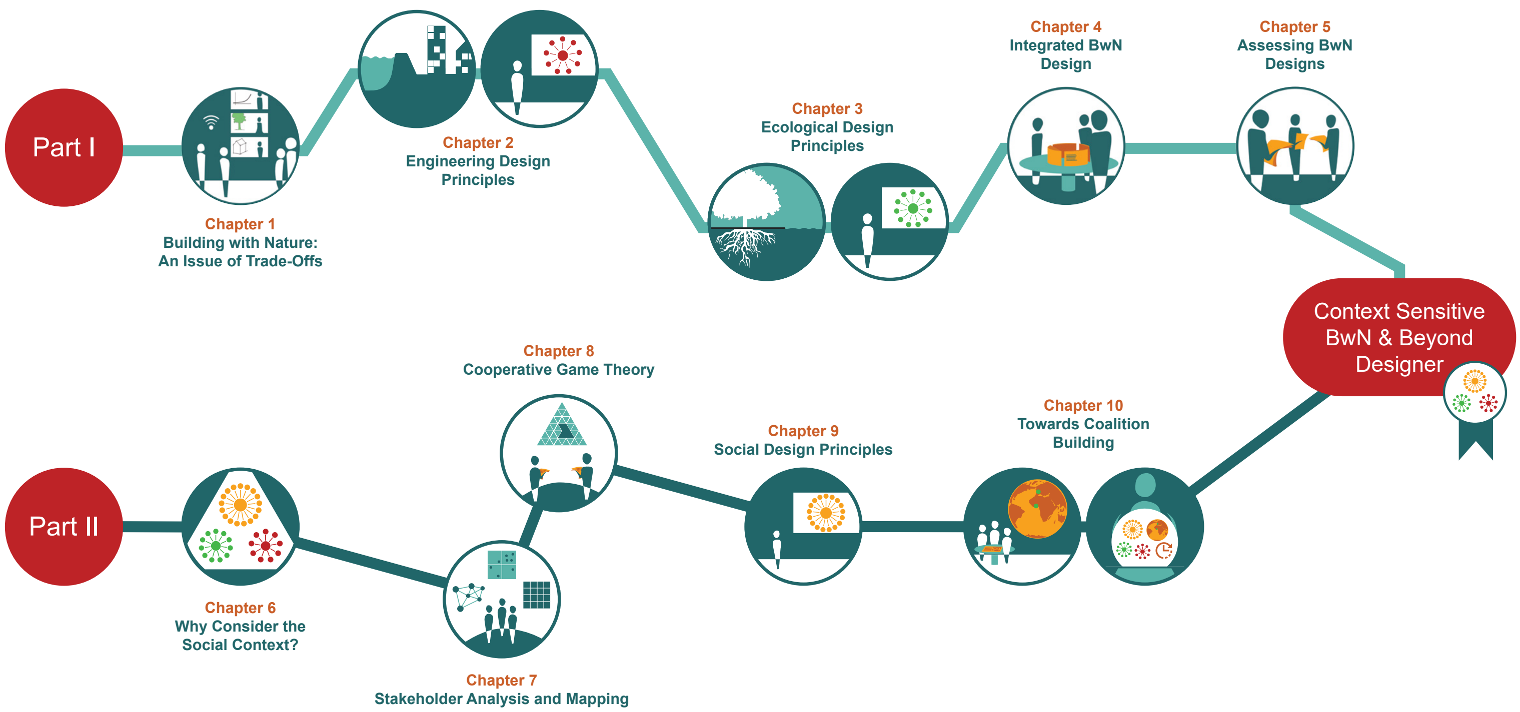
Engineering, Ecological and Social Design Principles, are distilled for the first time in this book. You can now explain why they are important and how they are applied in a number of case study examples. Moreover, you have learned that Building with Nature is not about getting other people to share your viewpoint, but about creating a multidisciplinary design space in which many different viewpoints and knowledge sources are welcomed.

We are also sure you now realise how complex it is to engage with stakeholders meaningfully in their Building with Nature contexts, how difficult it is to do no harm, and how truly challenging it is to accomplish stakeholder-inclusive, ecosystem friendly infrastructure development. We hope that you have been inspired by our examples. We would love to continue to learn from your experiences and invite you to share them with us by joining the Ecoshape network (www.ecoshape.org) and explicitly mentioning the book in your correspondence.

Finally, we would like to acknowledge and thank all our collaborative partners for their valuable contributions to the content development and case material of the MOOCs. This book would not have been possible without their contributions, involvement and support.

Best regards,

Jill Slinger, also on behalf of all book contributors.



Building with Nature & Beyond:
Principles for designing nature based engineering solutions

Jill Slinger (Principal Author and Editor) with contributions of others

This book is based upon the edX MOOCs *Engineering: Building with Nature* and *Beyond Engineering: Building with Nature*. The *Engineering: Building with Nature MOOC* explores the use of natural materials and ecological processes in achieving effective and sustainable hydraulic infrastructure designs, distilling Engineering and Ecological Design Principles. In the *Beyond Engineering: Building with Nature* course, the missing element of Social Design Principles is developed and taught.

Join us in exploring the interface between hydraulic engineering, nature and society!

Prof. Dr. Jill Slinger
TU Delft | Technology, Policy & Management

The primary author and editor, Prof. Jill Slinger is a Building with Nature specialist at Delft University of Technology where she holds an Associate Professorship in the Policy Analysis section of the Faculty of Technology, Policy and Management. She is also Visiting Professor at the Institute for Water Research at Rhodes University in South Africa. Her research in water and coastal management utilises both qualitative and quantitative methods to advance stakeholder-inclusive, model-based decision making and co-design. She teaches post-graduate courses in Policy Analysis in Multi-Actor Systems, Building with Nature, and Advanced System Dynamics Modelling.

She is a member of the coastal working group of the advisory body Expertise Network for Flood Safety (ENW) in the Netherlands and the National River Programming Committee. Prof. Slinger serves as co-Editor in Chief of the journal Environmental Development and is an Associate Editor for the International Journal of Water Governance.

TU Delft

ISBN (e-book) 978-94-6366-457-8
DOI https://doi.org/10.5074/T.2021.006

textbooks.open.tudelft.nl