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CHALLENGES IN DEVELOPING 'BUILDING-WITH-NATURE' SOLUTIONS NEAR TIDAL INLETS

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Abstract: In the 'Building-with-Nature'(BwN) philosophy, the focus of erosion control no longer is predominantly on counteracting destructive forces, but just as much on stimulating constructive forces. It implies a shift towards a pro-active approach, implying that BwN interventions require a long-term perspective and understanding of the coastal system at a large scale. Furthermore, BwN solutions also require understanding of the social system of stakeholders involved in the coastal problem. It is the interaction between these two that creates a series of challenges for BwN, including the necessity to consider multiple scales in both coastal system and social system and the linkages between them. We argue that a way to meet those challenges may be found in a collaborative design approach (co-design), in which systems understanding is shared between *all* stakeholders involved in the BwN solution. This approach will be practiced and analyzed for its effectiveness in the CoCoChannel project**.**

Introduction

Erosion control along tidal inlets

Natural rhythms in channel migration and shoal attachment govern the development of barrier island coastlines neighboring tidal inlets. These dynamics create phases of coastal erosion, leading to societal problems. For instance, erosion may lead to a decrease in the flood protection level provided by natural dunes, or the loss of recreational area and related infrastructure, which are often important to the local economy.

Traditionally, interventions related to coastal erosion are reactive in nature, designed to prevent local erosion by hard structures or to repair local erosional damage by beach replenishment. The stakeholder community is then well informed about these interventions and generally supports them as necessary. Disadvantages of reactive solutions are that they address consequences rather than causes of coastal erosion, paying less attention (or none at all) to sustainability of the measures or to (adverse) effects on the wider environment and longer term.

Building with Nature

Recent years have shown an increasing interest amongst coastal managers in more sustainable as well as flexible measures for erosion control, amongst others because of uncertainties regarding the rate of sea-level rise and changes in storm climatology. This has led to an innovative approach to hydraulic engineering infrastructure development and operation, referred to as Building with Nature - BwN (e.g. Ecoshape, n.d.; PIANC 2011; De Vriend et al. 2014).

The BwN concept is closely related to the approach of ecosystem services as proposed by the Millennium Ecosystem Assessment (MEA 2005). Considering that humankind benefits in a multitude of ways from ecosystems, MEA (2005) has grouped ecosystem services into four broad categories: *provisioning*, such as the production of food and water; *regulating*, such as the control of climate (e.g. temperature and floods) and disease; *cultural*, such as spiritual and recreational benefits; and *supporting*, such as nutrient- and sediment cycles and crop pollination. Where human interests primarily concern *provisioning-*, *regulating- and cultural* services, a sustainable use of these services is depending on the quality of *supporting* services. Based on this insight, the Building with Nature approach to the development of hydraulic engineering infrastructure takes the natural system as a starting point: paying optimal tribute to and making optimal use of *supporting* services in order to create optimal conditions for a sustainable use of all other ecosystem services. More specifically for the case of erosion control in tidal inlets, this translates into an optimal use of natural morphodynamics in order to create sustainable conditions for flood safety, economic activities and natural values.

The innovative aspect of Building with Nature is the fact that natural forces no longer are considered as being merely the source of coastal erosion problems, but as essential components of solutions. The focus no longer is predominantly on counteracting destructive forces (erosion), but just as much on stimulating constructive forces (sedimentation). As natural processes may be slow but continuous, this implies a shift from a traditional reactive -, towards a pro-active approach.

Studying the possibilities for Building with Nature solutions near tidal inlets

Coastline developments are only experienced as a problem in case there are societal interests at a particular time, at a particular part of the coast. In other words, coastal problems are time- and space dependent and related to developments in the natural system as much as in the social system.

From this perspective, and in line with the BwN guidelines (De Vriend and Van Koningsveld 2012) that imply to respectively think, act and interact differently, the design of BwN solutions will inherently involve understanding of both the natural system and the multi-actor dynamics of the social system. Given the time- and space dependency of any coastal problem, especially the pro-active character of a BwN approach imposes the need for good insight into the multiple scales involved in both the natural and social system.

In this paper we will discuss the challenges that one will face when studying the potential of BwN solutions for erosion control near inlets. More precisely, we will focus on the potential of BwN solutions that involve pro-active manipulation of the natural channel-shoal dynamics for coastline management. These challenges include the nesting and linkages between scales to be considered in both the natural system dynamics and the multi-actor system dynamics individually, as well as the linkage between these two. We also discuss a research strategy to deal with this linkages.

The presented ideas and approaches are the result of discussions in the recently started CoCoChannel project (*Co*-designing *Co*asts using natural *Channel*-shoal dynamics). This project aims at deepening the understanding of the natural channel-shoal dynamics (subproject 1) and the related impact on the adjacent beach-dune system (subproject 2), so as to find new solutions that address the source of the erosion problem in tidal inlets. The social dynamics of the multi-actor system involved in the process of determining a solution for the coastal problem, and the connection with knowledge development in subproject 1 and 2, are studied in subproject 3.

Texel Inlet case

In this section we present an example case of an inlet system in the Netherlands with an actual coastal problem that potentially could benefit from a BwN solution. It was actually this case that inspired the CoCoChannel initiative.

The dynamics of Texel Inlet and its ebb tidal delta (Figure 1) have changed dramatically since the damming of the connected Zuiderzee lagoon that was completed in 1932 (see Elias, 2006, for an extensive treatment of these changes). The reduction in basin dimensions caused significant changes in the tides in the inlet. These resulted in southwestward rotation of the main tidal channels and expansion of the southwestern part of the ebb tidal delta, and large-scale wave-driven erosion in the northwestern part of the ebb tidal delta. The eroded sand was transported both cross-shore to and alongshore of the island of Texel, forcing the Molengat channel to migrate landward. The latter resulted in significant changes in the sediment transport along the SW coast of Texel, resulting in coastline recession. Part of the eroded sediment was transported south where it contributed to the extension of southern tip of the island and formation of new dune fields. Another part of the eroded sediment was carried into the tidal basin.

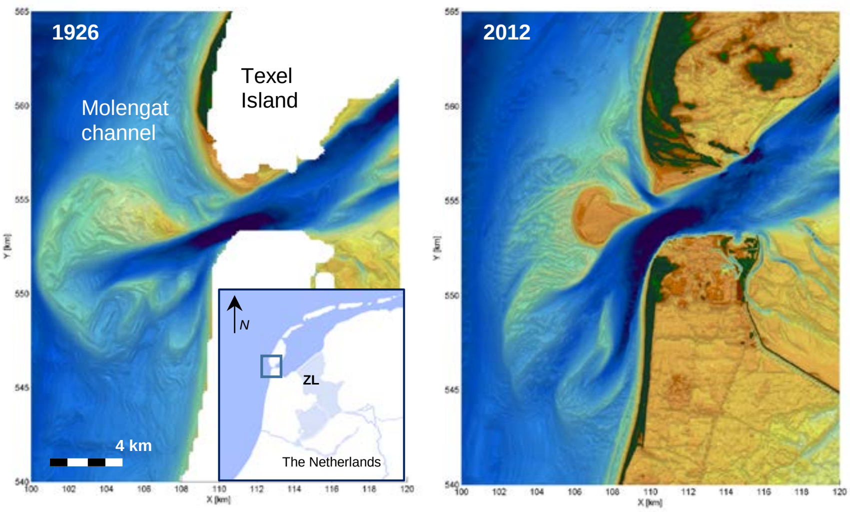

Figure 1: Changes in the ebb tidal delta morphology of the Texel Inlet 1926-2012. Inset shows location of Texel Inlet and the now dammed Zuiderzee Lagoon (ZL). (Maps courtesy Edwin Elias).

The eroding coastal sections are nourished with sand as part of the national Dutch coastal maintenance program. However, the level of protection against flooding that is provided by the dunes is largely sufficient in this area. Hence, the regular nourishment of this part of the Texel coast could potentially be postponed in order to implement an alternative, BwN type solution involving manipulation of the channel-shoal dynamics. In case the BwN solution would not be adequate in solving coastal erosion, the regular maintenance program can be reapplied again.

Challenges related to dealing with a multi-scale problem

In developing BwN solutions to coastline problems near tidal inlets, quantitative models are required to analyze and design possible scenarios for the response of the island coast to interventions on the ebb tidal delta. However, the various components of the coastal system that are of interest to stakeholders in the design of such BwN interventions, are not necessarily acting on the same time scale. On top of that, characteristic time scales of the natural dynamics of different parts of the coastal system do not need to match the time scales of interest to stakeholders. For instance, local fishermen may focus on navigability of channels in the inlet at all times, whereas to coastal managers at the national level these channel conditions are of lesser concern at first, as their prime responsibilities relate to guaranteeing the long-term safety of the dunes as natural flood defense for the island inhabitants. Interestingly, the local fishermen are part of that island community as well. This example illustrates that BwN solutions raise challenges with respect to dealing with multi-scale problems, both in the natural and social system.

Nesting and linkages in the natural system

In order to capture the multiple scales in the natural system, a common geoscientific conceptualization of a sedimentary coastal system is that of a hierarchy of increasingly higher order, sediment-sharing, nested morphological systems (e.g. Cowell et al. 2003). For the case of barrier island - inlet systems, a range of nested morphological systems can be identified. At the largest scale, one would consider the formation and evolution of a complete system of barrier islands and back barrier basins during the Holocene. A nested morphological system would then be that of an individual barrier island – back barrier system, of which the associated time scales for evolution are at the order of decades-centuries (Oost et al. 2012). At this hierarchical level, the morphological system can be considered to consist of major elements like the basin channel and shoal system, the inlet gorge, and the ebb tidal delta. The barrier island component can be considered to be composed of major elements like beach plains, dunes, overwash complexes, saltmarsh-creek systems, beach and shoreface, which are all sediment exchanging units.

Each component of the barrier island – back barrier system, at its turn, can be seen as a nested scale, morphodynamic system, requiring a more detailed description of the underlying morphology and processes. These include, for example, the dynamics of channel and shoal patterns within the ebb tidal delta (having a time scale of years-decades), or the allocation or migration of the inlet gorge. An example of an even smaller nested scale is that of bedforms, like ripple and subaqueous dunes, developing on the channel bed. At the larger scale, these bedforms result in a space and time varying bed roughness in the channel which could be of influence in the prediction of channel-shoal morphodynamics. At present, such small scale processes are often parameterized in numerical morphodynamic models at sub-grid level. Each of the barrier island components also forms a nested scale morphodynamic system of its own, in which again higher order, nested systems can be identified, such as for instance blowouts in foredunes.

When it comes to quantitative modelling of the morphological evolution of a component of a coastal system, the component should ideally coincide with a particular level in the hierarchy in which connections to other components in the hierarchical tree can either be safely ignored at the time-scale of interest, or can be parameterized as some constant. Two main approaches exist to model aggregated scale morphodynamics: upscaling process-based models or taking a behavior-oriented modelling approach (De Vriend et al. 1993). The up-scaling approach involves concepts like 'morphological tide' e.g. (Latteux 1995), and 'morphological factor' (Roelvink 2006). The behavior-oriented modelling approach uses simple behavior rules to drive the morphodynamic model. These rules are derived from empirical insights (through morphological analyses) and from conceptual understanding of the underlying physics (e.g. Kragtwijk et al. 2004; Baas 2002)

In the context of designing BwN solutions using channel-shoal dynamics, also the linkages need to be considered between nested scale morphodynamic systems, as interests of various stakeholders often relate to different elements of the natural system. A maybe even bigger challenge is that linkages need to be made between the submerged ebb tidal delta domain and the subaerial beach-dune domain, to assess the eventual effects of interventions on the ebb tidal delta on the barrier island coast. Models developed for simulating the channel-shoal dynamics in the ebb tidal delta should therefore also properly handle developments at the barrier island coastline, as that forms the expected link to the developments of the beach-dune system near the inlet. Also, in the modelling of the beach-dune system near the inlet to assess impact of BwN interventions, both aeolian processes and hydrodynamic processes (during storm surges) need to be accounted for.

Understanding that BwN-type solutions place new and different requirements on the quantitative models, means that new conceptual designs for model connection are needed. Especially, effectual linkage between submerged and subaerial domains is required.

Nesting and linkages in the social system

The social system encompasses a conglomeration of stakeholders, some of whom hold responsibility for the management of the coastal environment, some of whom live near and use resources from the natural environment and some of whom are involved in research (scientists and engineers) (Figure 2). This conglomeration of stakeholders may be conceptualized as a multi-actor governance system comprising a management system and the (coastal) system to be managed (cf. Sharpf 1997). To study the dynamics of such a multi-actor governance system and its interactions with the coastal environment, some adopt the traditional hierarchical view that the system to be managed is nested within the management system, while others adopt a network-informed stance (cf. Hermans et al. 2013).

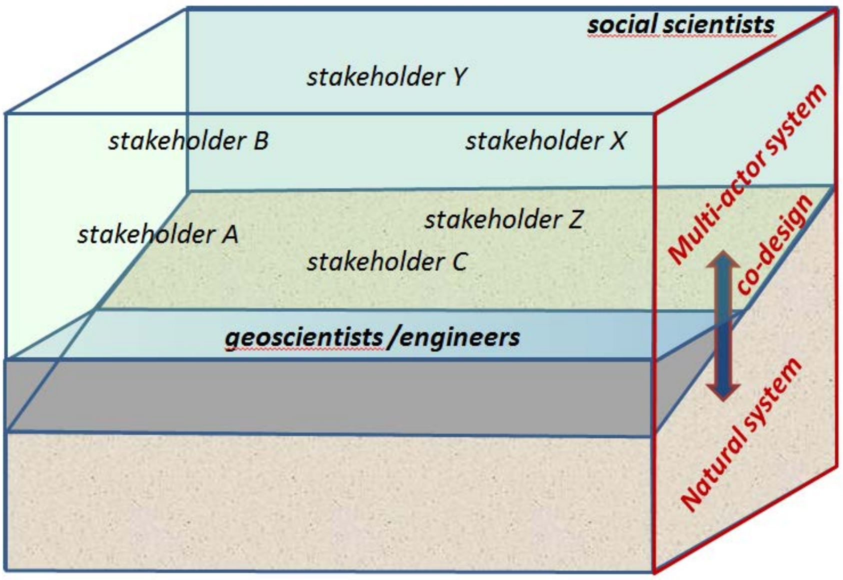

Figure 2: Conceptual diagram visualizing the link between the natural system and multi-actor system in the collaborative design (co-design) of a BwN solution.

In our Texel example, we take account of the spatial and temporal ramifications of the allocation of tasks among Dutch local, regional and national administration levels, the legal jurisdiction associated with sector-based task division amongst authorities, and the knowledge base of citizens who live, work and interact with the coastal system. The linkages between actors and the linkages across administrative levels provide insights in the dynamics of the complex multi-actor system. To understand the role that these linkages play in enabling the multi-actor system to address the new and different governance challenges that BwN-type solutions generate, it is necessary to understand the different perceptions held of the coastal system, its management and the associated actor networks, and to determine how flexible or robust these perceptions and the actor networks are when confronted by new knowledge and new challenges.

In particular, the diverse roles and interactions amongst policy makers, coastal management practitioners, local and regional authorities, local citizens and scientists are of interest, as are their individual responses and collective learning on the dynamics of the submerged ebb tidal delta and the subaerial beach-dune domains.

In research projects that study BwN interventions, it is notoriously difficult to connect scientific understanding of the dynamics of the natural system to the understanding of the dynamics of the multi-actor governance/social system. This is exemplified in the difficulties that many scientists have in crossing the disciplinary divide between the natural sciences and the social sciences. These difficulties are ascribable in part to different research traditions and methodologies.

Whereas the natural sciences often exhibit a high degree of consensus regarding methodology, this is not the case in the social sciences (Collins 1994). The diversity of methodologies employed in different branches of social science means that there is low consensus regarding study approaches. Indeed, for the social sciences, the nuances of the interactions between the context and their particular phenomenon of interest often form the focus of study. This means that ethnographers, historians, psychologists, economists etc. see different contexts, different interactions in relation to their different particular interests. With the exception of economics, they seldom claim generic applicability and are averse to the type of generalizations and typifications that are commonly employed in the conceptualization process of the natural sciences and engineering, particularly when computational modelling is employed (Balstad 2010). For social scientists it is precisely the deviations from the typical, and the distinctive nature of individuals or group interactions that are of absorbing interest. Attempts to homogenize or reduce their insights in a search for universality are often countered with resistance. These differences in stance, expressed in different research traditions and methodologies, lie at the heart of the documented difficulties encountered in interdisciplinary projects between the natural and social sciences (cf. Strang 2009).

Research strategy to meet identified BwN challenges

Shared utility stance and design inquiry

In the case of the CoCoChannel project, we are not attempting to integrate across the full social sciences-natural sciences divide. Rather, a more utilitarian stance has been adopted in this cross-disciplinary collaboration. Methods and approaches from the applied branches of both the natural and the social sciences have been selected. These include methods from collaborative learning/education, policy analysis, applied geoscience and coastal engineering and incorporate a focus on design. The applied branches of the natural and social sciences are viewed as offering a higher potential for effective cross-disciplinary research because scientists from these fields acknowledge the need for research outcomes to be socially relevant and applicable. This shared stance regarding utility represents the first of a series of choices fundamental to this endeavor.

From the shared stance regarding utility, it follows that - in the context of exploring the possibilities for BwN solutions in tidal inlet settings - increased understanding of the natural and social system dynamics should eventually contribute to an optimal design of such an intervention at a particular location. In this case, ‘optimal’ refers to a solution that is tailored to both the specifics of the inlet system at hand and the needs of the specific stakeholders linked to the site specific coastal problem.

When developing a BwN solution, geoscientist and coastal engineers will focus on the tangible aspects of the coastal problem: i.e. the natural system development (Figure 3). In their efforts to model the natural system, they tend to reduce the coastal system to a system in which sediment is moved around by water and wind, considering biological components only where interacting with the movement of the sediment and human activities only where these physically intervene in the flows of sediment. Social scientist, on the other hand, focus on the intangible aspects of the coastal problem (Figure 3), i.e. the involvement and interaction between stakeholders that identified a certain natural coastline development as a problem in the first place. Note that the geoscientists/coastal engineers view of the coastal system is also an *idea* (developed using scientific methods) of how the coastal systems functions, hence intangible.

In the context of the design of BwN solutions, a key to bridging the commonly felt divide between natural systems understanding and social systems understanding, may thus be found by the sharing of *understanding about the functioning* of the natural system (Figure 3, arrow 1), amongst *all* actors in the design process, that is adopting a collaborative design (co-design) and collective learning approach.

This represents a second fundamental choice, namely: to adopt design inquiry (Schon 1995) as a research strategy. Design inquiry consists not only in creating plans but in enacting (simulating) them within particular situations of practice –in our case SW Texel. This employs the knowledge of geoscientists and engineers in designing nature-based interventions in channel-shoal systems, but also allows for the generation and testing of new knowledge. The eventual BwN solution can then be regarded as the product of the shared knowledge in the multi-actor network of scientists, engineers and other stakeholders and its social dynamics (Figure 3, arrow 2). Such an approach also considers how the (network) dynamics of the community located alongside a channel-shoal system fit with the natural rhythms and scales of the coastal system, and with the administrative system.

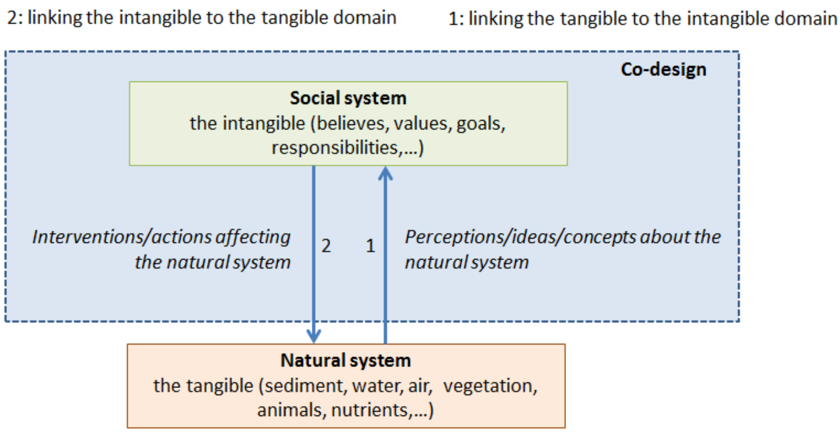

Figure 3: Conceptual diagram visualizing that sharing of systems understanding amongst all actors, including the scientists, can be a key to integrating geoscience and social science aspects.

Co-design and collaborative learning in CoCoChannel

By adopting design inquiry as a research strategy, improved coastal systems understanding regarding linkages between the subaqueous and subaerial part of the coastal system will be developed by testing new ideas about these linkages in the simulation of practical situations. At this point, the linkages involve the translation of the allocation of channel and shoals on the ebb delta into parameters and indicators that are meaningful with respect to the development of the subaerial beach-dune system.

The extent to which improved coastal system understanding, influences and informs decision making regarding BwN interventions is highly dependent on contextual factors inherent to the multiplicity of the involved actors, processes and institutions (e.g. Slinger et al. 2010; Vreugdenhil et al. 2012). The co-production of knowledge and learning have been observed to occur through such engagement, enhancing the understanding of coastal policy implementation (Hermans et al. 2012; Reis et al. 2014). Accordingly, effective implementation of the new Building with Nature concept requires both the planned engagement between stakeholders and scientists, as well as reflective, practice-based learning from case study applications.

To accommodate this requirement the project is designed with multiple reflective layers. Indeed, the co-design process acts to determine the project timetable by drawing together all project participants and stakeholders for the purpose of knowledge exchange, learning and co-design in a series of knowledge exchange events. This facilitates both single loop (acquisition of subject matter learning) and double loop learning (learning what others think or know about an issue and reflecting on this). As both knowledge assemblers and mediators (cf Weber 1949), the geoscientists, engineers and policy analysts will attend, provide input to, and participate in the knowledge exchanges and collective learning evaluations. By creating knowledge exchange events and undertaking design-in-action activities, learning spaces are formed, in which multiple actors (including the scientists themselves) can experience multi-loop learning including reflecting on shared understandings – that is, collective learning.

Conclusions

The natural and social system dynamics associated with coastal erosion problems near tidal inlets are both characterized by nested-scale problems. In both cases this poses challenges to understand and model their dynamics. To develop effectual channel-shoal intervention designs it is also necessary to link these two systems and to understand the extent to which a collaborative design approach can work in this respect. By adopting a network-informed understanding of the governance/social system and focusing on the sharing of understanding about the functioning of the natural system amongst all actors, the role of natural system understanding within the co-design of nature-based interventions is highlighted.

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