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Sand Nourishments: Review of Research and Introduction of the SOURCE Project

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Abstract. Sand nourishments have become a popular management option to mitigate coastal retreat for sites with abundant sand supplies. Off-site sand is placed on the dry beach or under water at typical water depths up to 10 m. This nearshore zone has a high bed level variability and contains a cascade of morphological features. This makes the understanding and forecasting of nourishment morphodynamics and impacts challenging. The emerging climate-change effects, sea-level rise in particular, call for significant progress on this topic in due time. This paper presents an overview of field, laboratory and modeling studies on nourishment morphodynamics. Four key knowledge gaps were identified. First, the spreading of nourished sand through the coastal zone is poorly understood, and has not been quantified. Second, it is unclear how design variables such as size, placement location and grain-size affect the nourishment lifetime, spreading and impact. Third, the cumulative effect of repeated nourishments on the coastal system is unknown. Fourth, models are not capable to reliably predict the morphological development and impact of nourishments. To tackle these knowledge gaps, we have launched the SOURCE research project.

Keywords: Coastal morphodynamics · Field Measurements · Laboratory Experiments · Numerical Modeling · Sand Nourishments

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1 Introduction

Over time, sand nourishments have become a popular management option to mitigate coastal retreat for sites with abundant (offshore) sand supplies. With nourishments, off-site sand is added to the coastal system to replenish sediment budget deficits. A distinction can be made between nourishments where sand is directly placed where it is needed, and nourishments that aim for an indirect effect. In the latter case, sand is supposed to be transported to the area of interest utilizing natural transport pathways.

The most common "direct" type of nourishments is beach nourishment where sand is placed on the above-water beach, or just below mean-sea level. Beach nourishments have been regularly carried out worldwide since the early 1900s. The first shoreface nourishment was implemented in the USA in 1935 [1]. Since the late 1990s shoreface nourishments are common practice in The Netherlands. Shoreface nourishments are typically placed in 4–10 m water depths, which simplifies the construction, and reduces costs and disturbances on the beach.

Projected accelerated sea-level rise requires re-thinking of the nourishment strategy, e.g. whether or not volumes can be simply upscaled. At the same time there is an increasing need to know in more detail how nourished sand spreads and affects the coastal functions and values, such as flood protection, nature and recreation. This requires a sound understanding and reliable modeling of the impact and evolution of nourishments, shoreface nourishments in particular. This paper presents an overview of advances in research, and introduces the SOURCE research project targeted at addressing the identified knowledge gaps.

2 Review of Research on Shoreface Nourishments

2.1 Introduction

With nourishments becoming more and more commonplace there is a wealth of field data. The last decades, the insights obtained on morphological behavior and driving processes have been complemented by laboratory experiments, conducted in controlled settings, and numerical modeling.

More particularly, we have combined data from 40 historical nourishment projects in The Netherlands and USA between 1935 and 2009. Furthermore, we have made an overview of 10 shoreface nourishment laboratory experiments. Finally, we have categorized 13 numerical modeling studies from the period 2004–2024. In total, the review included around 100 coastal nourishment studies.

2.2 Example Result: Active and Stable Nourishments

There is a general understanding of shoreface nourishment behavior and impact. A first estimate of nourishment morphodynamics can be obtained from the depth of the nourishment body (h_{nour}) with respect to the empirical inner and outer depth (h_{outer}) of closure (DoC) equations of [2]. Data from 40 field sites generally confirm that nourishments are stable if $h_{\text{nour}} > h_{\text{outer}}$ and active if $h_{\text{nour}} < h_{\text{outer}}$ (Fig. 1). Active nourishments display

both advection (migration) and diffusion (decay), and strongly interact with the subtidal bar system.

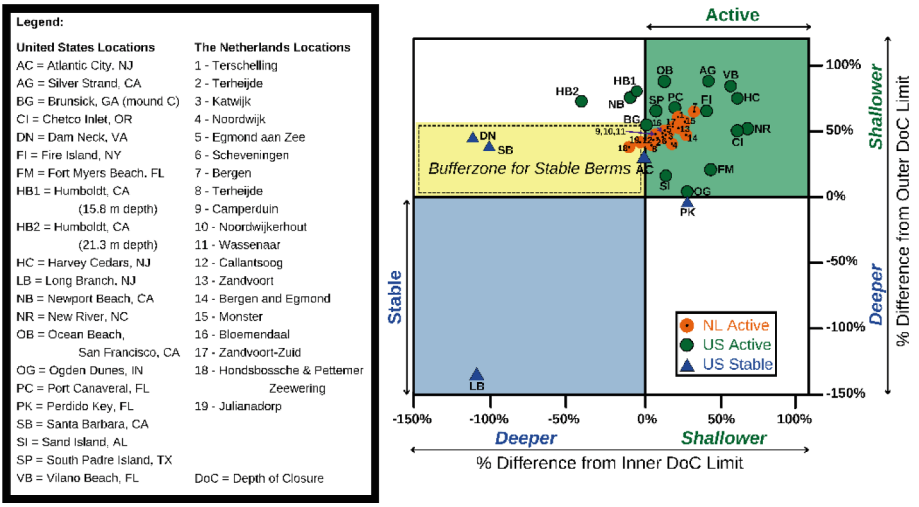


Fig. 1. Activity of historical shoreface nourishments in relation to empirical depth-of-closure (DoC) equations. As these are not based on the same parameters, the outer DoC was calculated as shallower than the inner DoC for 6 projects. Modified from [3] and [4] with ASCE permission.

2.3 Knowledge Gaps

Based on the overview of studies on shoreface nourishment morphodynamics, we have identified the following key knowledge gaps:

1. Spreading of nourished sand is poorly understood, in particular the sediment exchange between the subaqueous and subaerial parts of the beach.
2. It is unclear how design variables such as size, placement location and grain-size affect the lifetime, spreading and impact of shoreface nourishments.
3. The cumulative effect of repeated shoreface nourishments (scale: 1–10 km, 1–10 years) on the coastal system as a whole (100+ km, 50+ years) is unknown.
4. Models cannot reliably predict the nourishment development and impact.

3 SOURCE Project

These knowledge gaps formed the rationale for the SOURCE research project (2024–2030), https://source-research.nl. SOURCE is aimed to deliver the knowledge, models and design tools to develop and evaluate nourishment strategies in a multi-stakeholder co-creation process. This will be accomplished by a unique combination of a fundamental coastal ecosystem understanding, reliable predictive modeling, quantification of both the non-monetized and monetized social costs and benefits, and an integral nourishment design and evaluation process (Fig. 2). There will be 12 PhD, Post-Doc and other researchers at 8 academic institutes in total.

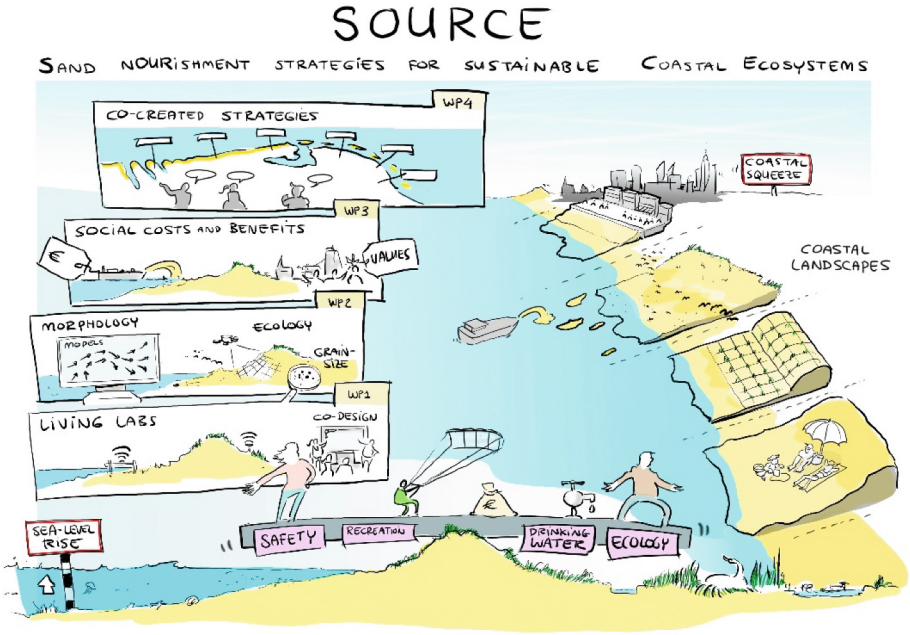


Fig. 2. Illustration of the SOURCE research project, including 4 work packages (WP).

Our Living Labs will comprise two sand nourishments along the Dutch coast. The first Living Lab concerns an innovative shoreface nourishment at Ameland, planned for in 2025, which will consist of 6 elements with systematic variation in nourishment grain-size, height, volume and cross-shore position. The other Living Lab concerns the thinking process and conceptual design of beach nourishments in Zeeland, primarily devoted to support the recreational function of the beach.

These Living Lab nourishments will be co-designed, monitored and evaluated together with 25 partners from international government organizations, research institutes, nature organizations and industry. This is key for the intended societal impact: co-created multifunctional sand nourishment strategies for resilient dynamic coastal flood defenses with high socio-economic and natural values.

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