KFKI
German Coastal Engineering
Research Council

Research Framework

Content of the KFKI Research Framework

Application-oriented research in coastal engineering – An overview

The coastal areas of the North Sea and the Baltic Sea, with around 4,000 km of coastline, have a long history of increasingly intensive settlement and economic activity. Around 15 million people today live in the five German federal states (Länder) with coastlines; of these, around 2.4 million people live in coastal lowlands which are threatened by storm surges. Harbours and shipping, industry, commerce, tourism and agriculture are all of vital importance, and not merely for the coastal areas. At the same time, these coastal waters and estuaries, which are to a large extent subject to natural processes, are especially valuable ecosystems that are in need of protection.

The wide-ranging and increasing use of these areas and the complex interactions between habitats and economic and natural zones along Germany's coasts are associated with growing societal challenges.

While for centuries one of the key challenges has been to protect the coastal population against flooding and loss of livelihoods, the focus of attention is now widening to embrace economic issues and the intrinsic importance of coastal ecosystems. The coastal engineering responsibilities that this entails for federal and coastal state agencies are also affected by the consequences of anthropogenically driven climate change. The impact of climate change is set to become increasingly apparent in coastal areas as sea levels rise.

The coastal defence management and flood protection work carried out by federal and state agencies, as well as the work they perform on improving and maintaining waterways and harbours, is permanently confronted by the need to meet new challenges. It is therefore important that Germany retains its outstanding coastal engineering expertise. The relevant knowledge and experience must not only be made as widely available as possible, but must also be permanently developed to find practice-oriented responses to the challenges of the future. Research in coastal engineering is therefore an indispensable element for the sustainable development of coastal regions.

The coastal federal states and the federal government have been working together in the Coastal Engineering Research Council (KFKI, see page 7) since 1973 with the aim of coordinating valuable, practice-oriented research.

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Almost a half-century of KFKI research has already produced wide-ranging, practice-oriented findings and contributed to a much improved system understanding of coastal regions and to their sustainable use and development. Findings are made available in documents published by the KFKI in the journal Die Küste (The Coast) and on its website at www.kfki.de.

The successful research, coordinated by the KFKI over the decades, is characterised by the continuous enhancement of scientific knowledge in a highly complex field of research that is subject to the permanently evolving challenges confronting society as a whole. There is a greater need than ever to expand our knowledge as new challenges continually arise and expectations for KFKI research to produce practice-oriented, ready-to-use in-depth findings increase. The thematic fields on which KFKI research focuses are therefore updated approximately once every ten years in response to existing responsibilities, knowledge gaps and challenges.

In 2020, the KFKI, the specialised administrations associated in the KFKI and the research institutions active in the field of coastal engineering and research identified four thematic fields for future KFKI research.

The thematic fields described in more depth in the following form the framework within which the KFKI perceives the need for future research. KFKI funding announcements, which define the current issues that are of particular relevance to current practice, are published on this basis.

- **Making coastal infrastructures safe and sustainable**
- **Capturing and processing natural and structural data in a targeted manner**
- **Understanding dynamic coasts as systems**
- **Climate change – Recognising impacts and developing adaptations**

Coastal Engineering Research Council (KFKI)

The federal and state ministries active in the field of coastal engineering have been coordinating their work in the Coastal Engineering Research Council (KFKI) since 1973. The mission of the KFKI is the joint coordination of the coastal engineering research that is necessary to fulfil the tasks of the federal government and the federal states in the field of coastal defence management and flood protection and for the improvement and maintenance of waterways and harbours.

Application-oriented KFKI research is interdisciplinary and integrated in the federal government's 'MARE:N – Coastal, Marine and Polar Research for Sustainability' research programme. Its purpose is also to implement the United Nations' Sustainable Development Goals[1] and Germany's Sustainable Development Strategy[2]. For the federal and coastal state agencies involved, KFKI research provides indispensable foundational engineering and scientific expertise that they can use to carry out their tasks. KFKI research not only supports larger-scale joint projects on interdisciplinary issues but also, and in particular, research projects that focus on specific technical topics.

Close feedback and ongoing exchange between research and practice in project-accompanying expert groups in current KFKI research projects ensure that new scientific findings can be used in practice. In this respect KFKI research differs from fundamental research, upon which it builds and for which it can provide valuable impetus for its thematic focus. At the same time, KFKI research lays important groundwork for other areas of research, such as in the field of nature conservation and environmental protection as well as integrated coastal management, and this research is also used in the framework of joint projects.

1 *Transforming our world: the 2030 Agenda for Sustainable Development, UN General Assembly, 21 October 2015, A/RES/70/1, available at: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf, last verified on 15 December 2020*

2 *Sustainable Development Strategy – 2018 update, Press and Information Office of the Federal Government, October 2018, cabinet decision of 7 November 2018, available at https://www.bundesregierung.de/resource/blob/975292/1559082/a9795692a667605f652981aa9b6cab51/deutsche-nachhaltigkeitsstrategie-aktualisierung-2018-download-bpa-data.pdf?download=1, last verified on 15 December 2020*

Source: LSBG, 2019

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Source: Archiv Boskalis Hirdes

Making coastal infrastructures safe and sustainable

The technical and nature-based infrastructures for coastal defence, shipping and drainage of coastal hinterlands have long been key elements of KFKI research. In this context the term infrastructure includes structural elements in the form of coastal dikes, groynes, revetments, breakwater structures, river engineering works and port facilities as well as natural and near-natural structures, such as dunes, beaches, salt marshes, reedbed habitats and escarpments.

This includes all potential interventions and measures associated with technical and natural structures. These might be the sustainable maintenance of waterways, sand replenishment to replace lost sediment or the establishment of groyne fields to encourage the development of salt marshes as a coastal protection measure. The latter are one example – alongside technical issues relating to optimal function, stability or integrity, dimensioning or efficient upkeep – of the important role played by certain aspects of ecosystem-based coastal engineering (see below).

Other themes are responses to the risks arising along coasts as a result, for example, of sea flooding, coastal erosion and loss of land. An inherent component of this is the creation and ongoing development of concepts and strategies for the evaluation and reduction of the resulting dangers and risks.

Components of ecosystem-based coastal engineering

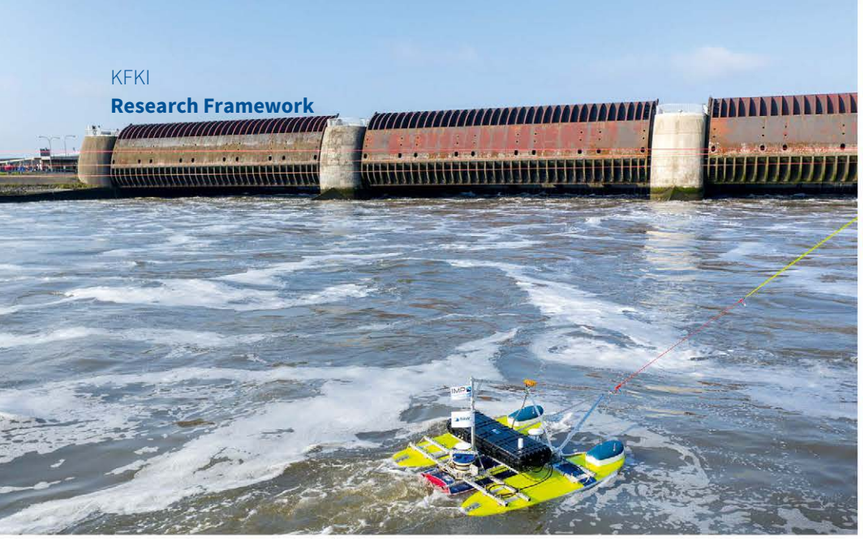
What ecosystems do: The ecosystems of coasts, estuaries and coastal lagoons can fulfil tasks that would otherwise have to be met by structural measures and planned interventions. This potential can be exploited to support coastal engineering processes.

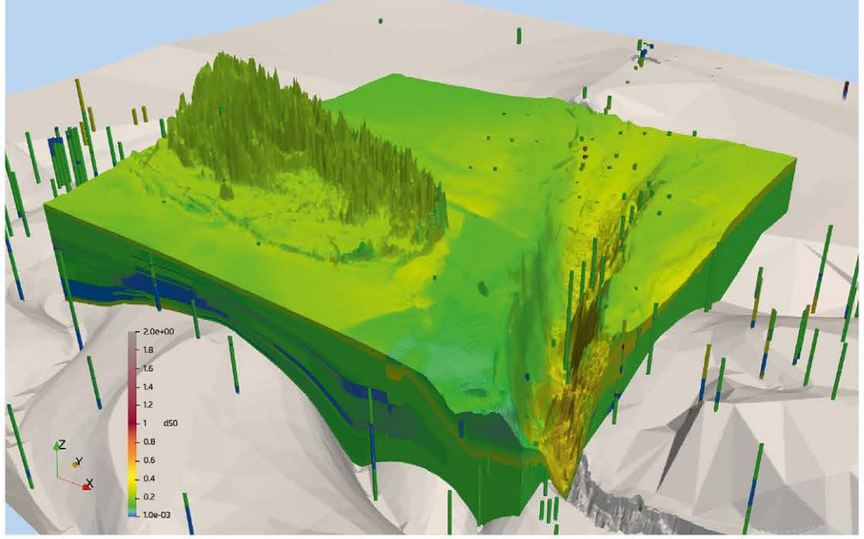
Understanding the system: Measures taken on German coasts, including estuaries and coastal lagoons, that conserve and permanently sustain natural resources, are based on a full understanding of ecosystems that consist of abiotic factors, or non-living parts, and the biotic or living communities that interact with them.

Minimising interventions: The inherent natural properties of ecosystems must be considered if measures designed and implemented on coasts, in estuaries and coastal lagoons are to be sustainable. Coastal engineering measures and procedures are consequently based on the principle of minimising and avoiding interventions.

Current research and development needs

- Further development of design procedures
  - To account for the loads induced by winds, tides, waves, storm surges, ships, surges, inland flooding and the interactions between them
  - Accounting for large-scale and long-term hydromorphological changes
  - Accounting for uncertainties
- Lifecycle management of infrastructures, including in particular the development of maintenance concepts, bearing in mind variable but as yet unquantifiable impacts
- Optimisation of structures
  - Functional and structural design, such as improved absorption of hydrodynamic forces
  - Interactions with ecosystems
- Development and use of different types of innovative and sustainable structures and designs, also integrating ecosystem-based approaches and taking account of variable availability of resources
- Improved knowledge of the interactions between infrastructures and their environment on various spatial and time scales, including developing sustainable and innovative options for action
- Further development of long-term focused, scenario-based holistic and anticipative strategies for dealing with risks and uncertainties





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Capturing and addressing natural and structural data in a targeted manner

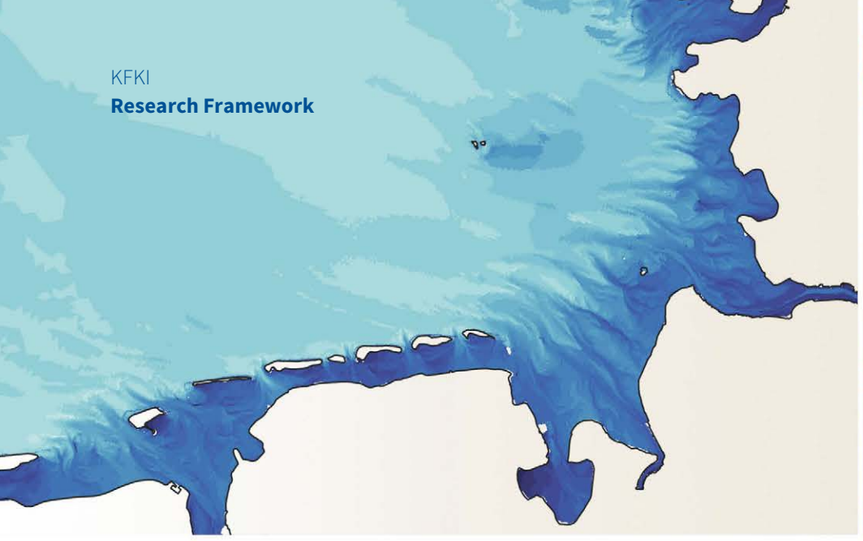
Knowledge of the state of and changes in natural systems and infrastructures on the coast and the interactions between them are of fundamental importance for coastal engineering. The required information is obtained from data that must be captured.

Coastal engineering primarily depends on hydrological, morphological, geotechnical, meteorological, hydrochemical and biological data as well as information about the condition and behaviour of structures. This data is collected using a number of different measurement methods that enable it to be captured systematically and precisely and to be used for scientific purposes.

Digitalised and automated data acquisition and the increasing use of remote sensing methods and areal high-resolution measuring systems have resulted in a substantial increase in the volume of data captured in recent years. This creates enormous opportunities for improving our understanding of natural systems, coastal infrastructures and the interactions between them. This means that optimised planning and dimensioning data, which is based on a profound knowledge of the system, and structure surroundings, can be provided in order to implement sustainable management strategies and to construct, operate and maintain infrastructures.

Current research and development needs

- Further development of measurement systems with a focus on in situ procedures, laboratory examinations and remote sensing
  - Measurement technology innovations
  - Higher degree of digitalisation and automation
  - Integrated, harmonised and scale-bridging measurement and evaluation procedures
- Validation, preparation, provision and archiving of data
- Development of methods for the automated, metrological monitoring of coastal infrastructures along their entire lifecycle
- Processing of historical data and the homogenisation of data series accounting for changes in measurement techniques
- Further development of methods for the analysis of data for various system states, including the integration of artificial intelligence methods



Understanding dynamic coasts as systems

Sustainably designed infrastructures and management strategies along coasts, in estuaries and coastal lagoons are dependent on a comprehensive system-based understanding of the complex interaction between hydrological and hydrodynamic, morphological, meteorological and biological processes. The more reliable this knowledge is, the easier it becomes to develop plausible, robust and predictive models that can then be used to better understand and simulate these processes in order to establish a planning basis for infrastructures.

Predictions of expected system states and developments, such as bathymetries, sediment balances, water levels and currents, can be made using models and targeted methods of analysis. The results establish an important foundation for the development of management strategies and the functional and structural design of infrastructures for coastal defences, waterways and harbours. Examples of this can be large-scale sediment transportation simulations using mathematical models that deliver fundamental boundary and input values for studies of sediment replenishment measures on erosive sandy coasts or for strategies for maintaining navigable channels. Large-scale simulations and analyses of tidal dynamics or of the higher water levels induced by storms also provide an important basis for the ongoing development of coastal flood defence strategies and the design of defence systems.

Current research and development needs

- The analysis of hydrodynamic and morphodynamic processes and their non-linear interactions on various time and spatial scales including scale-bridging and with consideration of biological and geochemical processes, including in particular:
  - Water level and current regimes
  - Salt and suspended matter dynamics
  - Sediment balance and dynamics within and between coastal systems
  - Properties and dynamics of fluid mud in estuaries and sea ports
- Capture and analysis of long-term hydrological and morphological developments, including their interactions
- Further development of mathematical models and analysis methods applicable to special issues:
  - Improvement of modelling of hydromorphological processes, such as turbulent mixing and layering, surf and drift currents, dune erosion and cliff falls as well as the behaviour of fluid mud
  - Consideration of geochemical and biological processes
  - Long-term simulations and projections of system states
  - Extreme value statistics focusing on multivariate analyses and joint probabilities
  - Probability-based scenarios for the non-linear interaction of storm surges and waves
  - Analysis of multiple hydro-meteorological risks, including cascading effects

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Climate change – Recognising impacts and developing adaptations

Climate change is likely to have considerable and multiple impacts on communities – particularly along coastlines. The Special Report on the Ocean and Cryosphere in a Changing Climate[3] produced by the UN Intergovernmental Panel on Climate Change (IPCC) in 2019 documents scenario-based projections of a significantly higher rise in sea level. Accordingly, greater exposure to the ocean and higher storm surges are expected at the coast resulting in considerable ramifications for all coastal regions. This includes:

- Changes in hydrodynamics and their interaction with morphology
- Higher loads on coastal infrastructures
- Changes in the navigability of coastal waterways and harbours
- Increasing risks of flooding along vulnerable coastal lowlands
- Greater erosion at sandy coasts as well as shrinking tidal flats and salt marshes
- Less effective draining of hinterlands

As well as dealing with the consequences of climate change itself, such as the accelerating rise in sea level or potential changes in meteorological conditions, the large uncertainties and range of different climate change scenarios present a huge challenge for forward-looking coastal engineering planning and action. The impact of climate change and the feasibility of taking adaptation measures must therefore be considered in order to ensure that the livelihoods and fundamental necessities of the population in coastal areas and, given their overall economic significance, the functions of waterways and harbours are safeguarded in the long term and that coasts can continue to be used sustainably in the future. The KFKI Research Framework consequently addresses climate change and its impacts as a separate thematic field.

All the issues tackled in this thematic field relate to one or several of the other thematic fields. Long-term load situations based on possible scenarios are needed for the sustainable design of coastal infrastructure and the development of ways of adapting to the impact of climate change.

For this purpose, the impact of climate change first needs to be better understood, including in terms of interactions and at the regional level, so that a projection-based understanding of future system states of the coasts, estuaries, and coastal lagoons can be developed.

Current research and development needs

- Development of sustainable technical and non-technical solutions for adaptation to the impact of climate change
- Optimisation of the foundations for functional design and structural dimensioning of coastal engineering infrastructure with regard to changed and uncertain boundary conditions
- Establishment of planning bases by developing regional projections of hydrodynamic and morphological system states along coasts, in estuaries and in coastal lagoons
- Development of procedures for the detection of climate-related changes

3 *IPCC, 2019. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.*

Outlook

All four of the thematic fields of KFKI research represent the framework for KFKI support of future research: The main focus is on technical and nature-based infrastructures as well as action with and in coastal natural systems. The knowledge required in this thematic field is covered by the basic thematic fields ‘Capturing and addressing natural and structural data in a targeted manner’ and ‘Understanding dynamic coasts as systems’. The description of the infrastructures and natural systems, understanding the key processes as well as the related monitoring and projection methods are at the heart of both thematic fields. Given their outstanding relevance, an overarching thematic field is the impact of climate change and adaptations to it.

Funding announcements that focus and elaborate on research topics will be published in the years ahead. This will be based on the current issues raised by the federal government and the coastal federal states as well as on the findings of completed research projects. The applied research organised in the KFKI therefore makes an important contribution to the sustainable development of Germany’s coasts against the backdrop of the major challenges facing them.

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