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Models of Coastal Waters in Germany – Performance and Application Examples

Harro Heyer

Foreword

This publication is a contribution to ICHE 2014, the 11th International Conference on Hydroscience and Engineering. "Hydro-Engineering for Environmental Challenges" will be the topic with which the international scientific and professional water-related community assembled at the conference will discuss in Hamburg. In general "hydro-engineering" is regarded as the science and the associated technology of water management, the management of natural systems and of resources influenced by water-related processes. Demand for the design and development of technical and environmental measures for marine, coastal and estuarine systems has been growing worldwide, with a view to meeting and mastering present and future economic needs and environmental challenges. In the recent past, this growing demand has meant that there has also been an increasing need for work on fundamental hydraulic principles, data driven methods, process-oriented computer models and numerical techniques as well as on practical applications. Germany is no exception in this respect. This publication focuses on current research topics relating to the German coastal zone.

The science and technology of "hydro-engineering" is mainly based on natural phenomena. It studies fundamental forces and the dynamics of water bodies as they are influenced by the geometry and roughness of their boundaries. Interaction with the atmosphere above and with the sea bed below dynamic water bodies plays a major role in this scientific field. An improved quantitative understanding of how marine, coastal and estuarine systems function, how they have changed in the past, evolved to their present state and how they can be changed in the future, both by natural processes and by engineering structures, is an important goal of scientific work in Germany. The knowledge and understanding of systems obtained to date are based on observable phenomena, on special tools for data analysis as well as and increasingly on sophisticated numerical models. As there are many scientific institutions in Germany working on topics related to the science and technology of "hydro-engineering", our country is able to offer a great deal of professional expertise as regards improvements in the validity of methods and tools. Over the last decade in particular, there has been an increasing demand for water related model studies in Germany.

We report in this publication on many efforts to improve fluids-related research on special natural phenomena and on computational aspects of fluid flow, on large- and small-scale hydraulic modelling including monitoring data and, last but not least, about engineering practice for safety and security on the coast.

The science and technology of "hydro-engineering" increasingly incorporates the ideal of "hydromorphology". This deals with the structure, evolution, and dynamic morphology of hydrologic systems at nearly all spatial and temporal scales and is driven by natural and anthropogenic influences. Hydrologic systems have been transformed for more than a century by human activities that impact water use, land use, and climate. The hydrologic

response of a natural system to specific transformation measures can be monitored directly in terms of water levels, fluid flow and salinity. To date, however, quantifying the exact values of changes in state variables due to the natural variability of coastal systems has remained a problem. One real challenge, therefore, is to predict the hydromorphologic response of the system to anthropogenic impacts. The natural morphodynamics of the system are generally disturbed by human measures. System transformations due to human activities can induce creeping processes affecting the long term natural morphologic evolution of the system. The uncertainty and non-stationarity of coastal systems may therefore increase in times of such transformations.

There are numerous factors which make tidal estuaries extremely complex hydrologic systems: the dilution of sea water with varying fresh water discharges, complex advection and mixing processes, variation of friction in tidal flows affected by different water depths, river training structures and bed roughness as well as varying density fields in the water body influenced by longitudinal and transverse salinity gradients. An increasingly intertwined world economy has resulted in huge growth in ship capacities, not only for oil, but also and mainly for container-shipment around the world. Deeper and wider fairways are needed in coastal regions to accommodate larger vessels. This unavoidable waterborne coastal transport has influenced the hydromorphologic situation of large German estuaries. Human interventions have affected stratification and gravitational circulation processes and have impacted the mass transport of suspended and bed load material as well as the dynamics and location of the turbidity zone. Tidal pumping phenomena have also been intensified due to an increased imbalance in barotropic pressure gradients during flood and ebb current phases. An upstream shift in main dredging areas and the formation of highly concentrated mud suspensions up to fluid mud layers was the byproduct in some areas of German estuaries located at the German Bight. A change in residual tidal processes is often responsible for non-balanced morphological developments. In particular a non-balanced budget of fine sediments in suspension can lead to low oxygen conditions and to a modified distribution of the substrate within the system.

We have learned that human interventions in water systems can cause profound impacts on system dynamics in terms of alterations to nearly all the physical, chemical and biological parameters describing the state of a system. A very important hydro-engineering task today is therefore to advise all stakeholders in water-related projects in the most transparent manner possible. Verified answers to general and special questions are important for planners and also for society as a whole: what is the current system state, which processes have determined this system state, what is the plausible future of the system state in times of increased flooding due to extreme weather conditions and climate change, how will the system-state be changed by economically driven measures, what is the best strategy to improve the system state and to protect against flooding? One overridingly important issue is ensuring that business and environmental stakeholders can remain in contact with each other and continue to discuss issues as equals. Environmental objectives have become, and will continue to become, increasingly important, particularly for policy makers and NGOs. The people who actually live behind coastal protection structures are also forming their own opinions more directly via internet platforms, and this means that the role of public media will gradually decline.

Coastal waters are fundamental natural resources in Germany and all over the world. For many years now, hydro-engineers have been confronted with the major challenge of working on strategies and techniques to protect and improve the environment of coastal water systems. Today, it is of vital importance to society as a whole to retain possession and to achieve sustainable development. The EU Water Framework Directive (2000) and the EU Marine Strategy Framework Directive (2008) were established to this end. These formulate several obligations for the EU Member States with regard to monitoring. The EU implemented the INSPIRE Directive (2007) to facilitate these reporting obligations and to support the development of a European spatial data infrastructure relying on interoperable Web based software components. This has also become a very important task within the realm of hydro-engineering work.

Deep scientific knowledge and technical understanding, combined with specialized skills in discussions and communications as well as transparent state-of-the-art methods and models for the different coastal systems, are needed. This is an extremely demanding task in the field of hydroscience and engineering. This task can best be fulfilled by acting within a national and international collaborative framework.

Harro Heyer
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