CHAPTER 149

RESEARCH ON LARGE-SCALE COASTAL BEHAVIOUR
The Dutch Coast: Paper No. 10

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ABSTRACT

Large scale coastal behaviour (LSCB) regards the development of a certain coastal stretch (order tens of km's) in time (order decades). Knowledge of LSCB is still very limited. Three approaches for analysis of LSCB are distinguished with increasing complexity and necessary level of knowledge, viz. the geostatistical, the phenomenological and the modelling approach. Every approach has serious shortcomings to such an extent that predictions of LSCB are as yet impossible. Nevertheless it is necessary to develop a research strategy which may serve future studies on LSCB.

1. INTRODUCTION

The prediction of the development of sedimentary coasts is still a difficult problem. Coastal changes normally have different spatial and temporal scales and are influenced by developments in adjacent areas in variable degrees.

Policy decisions concerning coastal management, including maintenance of beaches and dunes, require a time span of decades and a space scale of entire coastal units, with lengths up to 10^2 km, say. The changes in underwater topography, shoreline position, beach- and dune profiles on these scales are referred to as "large scale coastal behaviour" (LSCB) in this paper.

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Much of the conventional present-day research related to quantitative modelling of coastal behaviour focusses on relatively small-scale processes such as the wave propagation and decay across the surf zone and the associated velocity field for a single sea state or even a single periodic incident wave. The sediment transport is usually considered locally at the scale of the bottom boundary layer. There is also a tendency of this research to go to even greater resolution both in time (resolving the variations between wave groups or even within individual waves) and in space (horizontally: resolving variations within a wavelength, as in diffraction problems; vertically: resolving variations over the depth, in 2½D or 3D models).

We thus see an increasingly wide gap between the practical needs related to LSCB on the one hand and the focus and trend of ongoing research on the other. This raises serious questions, in particular inasmuch as results of the small-scale approach are not directly transferable to the (much) larger scales.

Research on large scale coastal behaviour (LSCB) is important to determine the long term effects of changing boundary conditions (sealevel rise, wave climate) or of huge interferences by man (closure of tidal inlets, construction of extensive breakwaters, dredging and major beach nourishment operations).

In order to discuss possible LSCB research approaches, a Colloquium was held in Amsterdam on July 10-13, 1989 under auspices of the Royal Dutch Academy of Arts and Sciences. A number of experts was invited to express their views on this subject. This paper deals with some general aspects of LSCB. It also gives an overview of the results of this Colloquium and the plans for Phase II of the Dutch Coastal Genesis Project (see also Zitman et al., 1990), which is an interdisciplinary research project aimed at resolving some LSCB-problems of the Dutch coast.

2. THE PROBLEM OF SCALES

A multitude of processes with a range of time - and space scales has to be considered in coastal morphology problems. Starting at the level of turbulent fluctuations with a time scale of about 1 s, and going up through wind waves, storms or tidal cycles, seasons, years and all the way to durations of several decades (10^{10} s) as required in LSCB, we cover a range of 10^{10} . Likewise, going from the length scale of a sand grain (10^{-1} mm) to that of a stretch of coast of 10^2 km we cover a range of 10^9.

In general, a hierarchy is present between the (hydrodynamic and morphological) processes at different scales. The larger scale processes only provide (slowly varying) boundary conditions for the smaller-scale ones. Processes of comparable scales interact dynamically. Smaller-scale processes are just noise for the larger scale processes or they may contribute to them in an averaged sense.

One problem arising in this connection is whether LSCB is "just" the net result of small-scale processes or whether autonomous large(r) scale processes are also at work. An example: has the welding of an offshore bar to the coast on a time scale of many years any relationship with the short-term fluctuations of coastal profiles? Or are the latter just noise for the former and may they be omitted in an analysis of large scale behaviour?

The major problem is to specify the process-systems on the meso and large scales. For the small scale the process-systems are much better known because of the wealth of laboratory and field investigations.

3. RESEARCH APPROACHES TO LARGE SCALE COASTAL BEHAVIOUR

The main objective of LSCB research is to identify, analyse and quantify large scale variations in the position of the coastline and the nearshore bottom for purposes of understanding and prediction. Three approaches with increasing complexity and level of knowledge can be distinguished, viz. the statistical, the phenomenological and the modelling approach.

The **geostatistical approach** is purely descriptive. It envisages a paleogeographical reconstruction of the position of the coastline and coastal profiles. Approaching the present time the information density may increase to such an extent (e.g. in the Dutch data set) that statistical analysis becomes possible. Such data sets may be analysed for areas showing similar trends, and for systematic changes in trend over time (fig. 1). This type of descriptive statistical analysis gives insight in the temporal and areal scales of LSCB. It may be used for the extrapolation of the coastal development under the assumption that the past tendencies will proceed in the future (fig. 2). In addition, the data set may provide net sediment budgets over time and area (Van Vessem and Stolk, 1990). The main difficulties in this approach are: inadequate data sets (too short, too small an area), the development of appropriate methods of analysis, and hidden effects of human interferences.

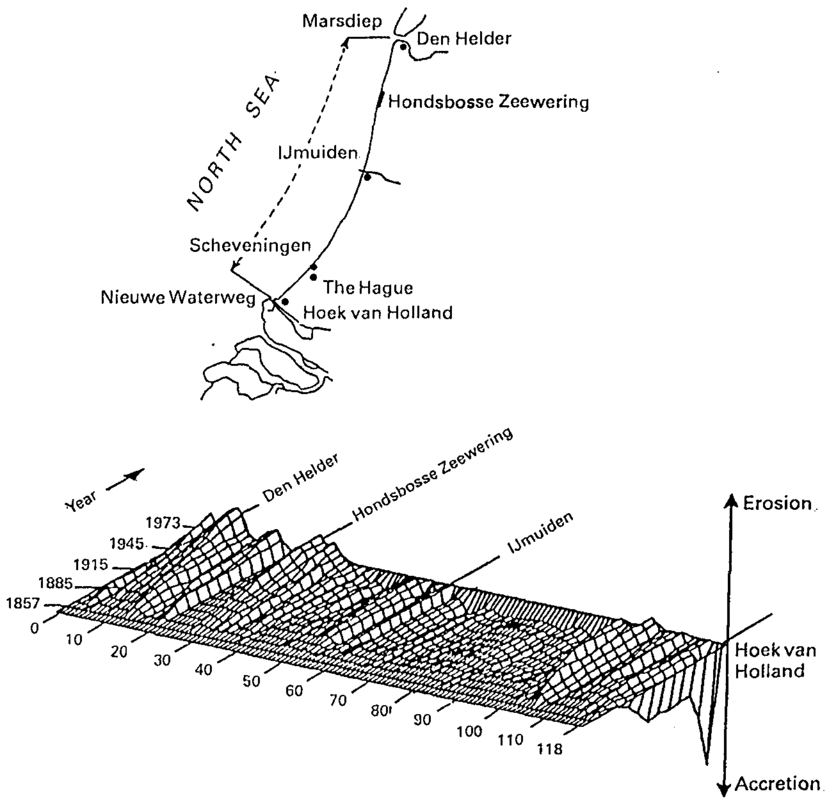

Figure 1 Position of the foot of the dunes along the central part of the Dutch coast as a function of time (1857 as a reference). Note areas showing similar trends in time (e.g. km 65-100; km 8-15 etc.) (after Wiersma 1987).

The **phenomenological approach** tries to find empirical relations for the observed behaviour starting from assumed operating processes. Parameters are selected that are considered relevant to the processes of interest and empirical relations are derived without formulating or using a model for the basic physical processes. For instance, we may try to correlate the Dean and surf-scaling parameters to coastal stages (Wright and Short, 1981). Such parameters include some variables like wave characteristics, slope, sediment size, which are assumed to be of interest for small scale coastal development.

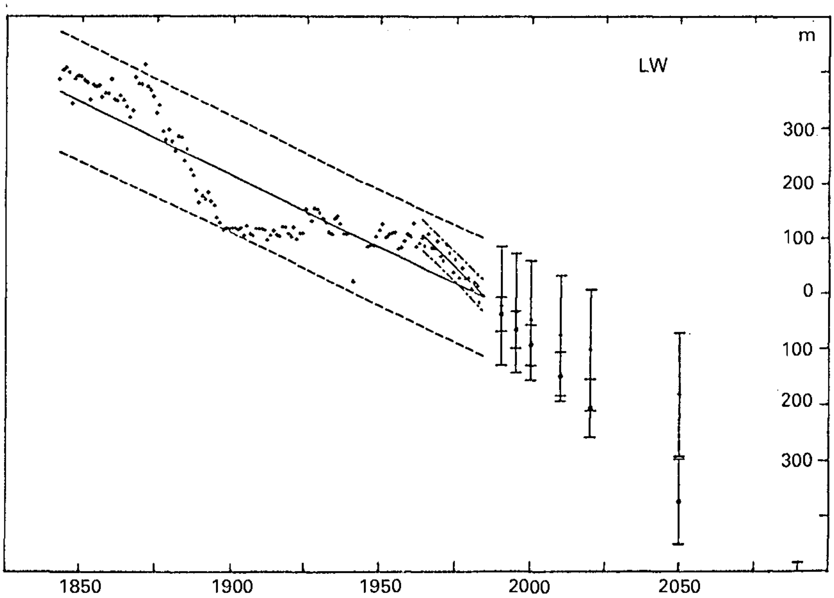

Figure 2 Position of LW-line in time in a line normal to the coast of the island Schouwen. Note the occurence of a beachwave. The extrapolation of the trend over 150 years is different from that for the last 20 years. If another time interval was chosen, say the last 80 years, another extrapolated trend would have evolved (after Van Vessem, 1988).

Perhaps similar parameters, based on the notion of physical processes, may be developed for large scale coastal behaviour. The main difficulty is the specification of "relevant parameters" for these processes and for the morphological responses. Such parameters are not known for LSCB at the present time.

Another challenging example is the prediction of the dimensions of tidal channel and shoal systems on the basis of equilibrium velocity profile/area considerations (O'Brien, 1931; Bruun, 1978). This approach has recently been extended to non-equilibrium situations, e.g. due to human interference or accelerated sea level rise (Eysink, 1990; Kondo, 1990; Gerritsen et al., 1990; O'Connor et al., 1990).

The **process-modelling approach** starts from the basic driving forces leading to the operative processes assumed to govern LSCB. The process systems may be cast in a model. The problem is now: can we specify the driving forces, and identify the processes on a level of integration relevant to LSCB? In the most pessimistic view (the "dooms" hypothesis) LSCB is governed by unpredictable inputs fed into a non-linear system, producing a highly unpredictable outcome. In a more optimistic view LSCB is characterized by rather gradual, apparently non-random developments. In this view the underlying process-system may be very complicated and variable but the response viz. the coastal behaviour is rather gradual. Perhaps we may average or simplify the process-system or its response.

The question arises whether existing small scale models can be used for modelling LSCB. During the Colloquium great sceptisism was expressed about the possibility to scale up small-scale process models to account for LSCB. The main reasons advanced for this sceptisism were: the inadequacy of the present knowledge of small scale processes, especially the sediment transport formulations, and the amplification of errors every time the non-linear mathematical system is integrated to a larger scale.

In this connection it should also be noted that there is a gradual **qualitative** shift in our knowledge as we go from the smaller to the larger scales. The following points are relevant here:

- Residual transports resulting from random advection on the smaller scale can usually be described as diffusion on a larger scale. The Pelnard Considère (1956) approach to the calculation of coastal plan forms is an example where this is utilized. It is deemed likely that the same principle can be extended to other applications.
- Parameterisations of residual effects at each scale require empirical calibration and verification. Small-scale descriptions can be more theoretical, deductive and mechanistic. The larger the scale becomes the more empirical and inductive our knowledge is.
- For empirical investigations relating to small-scale processes, special-purpose, short-term measurements suffice. The empirical input needed in the larger-scale process description calls for more general, continuous monitoring programs.
- The need to go far back into the past to obtain empirical input for LSCB necessitates a multi-disciplinary approach involving not only mechanics but also sedimentology, stratigraphy, geology, climatology and history.

The development of new formulations, appropriate for LSCB, was advocated during the Colloquium. Two ways of arriving at such LSCB-models have been suggested.

The first is to formulate large scale processes, with inclusion of the effects of small scale processes in a parameterized form. The other approach may be the scaling up by filtering the processes at the small scale to arrive at formulations of the larger scale.

As there is so little experience with LSCB-models, several important questions were raised in the Colloquium:
- how to identify processes operating on the larger scales;
- how to cope with catastrophic events like storms which may cause irreversible changes after exceeding threshold values (bifurcation);
- how to introduce the time-sequence of storms. The influence of this parameter is lost in a simple integration over time, although this parameter may be important because of the relatively slow adaption of the coastal morphology;
- how to cope with relaxation times;
- how far is it necessary to solve in detail the small-scale sediment transport problem.

It was generally accepted at the Colloquium that at present long-term prediction of LSCB is impossible. Process-based small-scale simulations remain valuable, not as a predictive tool, but as a research tool, to get a better understanding of the above-mentioned questions.

4. RESEARCH STRATEGIES

The following possible strategy evolved from the discussions during the Colloquium.
1. Make a survey of relevant results of previous studies and reexamine these from the viewpoint of LSCB.
2. Formulate a hypothetical but coherent concept of how the large system works and develop a state-of-the-art model for that. At present such model may be rather rough, but it can serve as a first step (Stive et al., 1990; Roelvink and Stive, 1990). It is expected that different models may evolve for straight coasts and for barrier-island coasts because of the differences in morphology and interaction of the current and wave-system.
3. Make hindcasts of LSCB, on the basis of the aforementioned state-of-the-art model, for field sites for which reliable data are available that can be used for verifications. This may give indications for the potentials and the limitations of the model and it may lead to specific laboratory or field

experiments defined by the applicability of the model.

4. Long-term monitoring programs are indispensible for all LSCB studies. It may be of special interest to select some sites where important coastal engineering works have recently been completed, in order to evaluate the effects of human interference on the coastal system over a long time scale.

The Dutch Coastal Genesis Project Phase I (1985-1989) contains a number of these elements (Zitman et al., 1990). On the basis of the outcomes of Phase I and the discussion at the Colloquium on Large Scale Coastal Behaviour, the following objectives were formulated for the Coastal Genesis Project Phase II (1990-1994).

A distinction is made between the straight central part of the Dutch coast and the intersected barrier island coast in the northern and southern part with their ebb and flood tidal deltas, tidal basins and channel movements affecting coastal developments.

The basic strategies are:
- to continue the paleo-geographic reconstruction of the coastal developments and the statistical analysis of the data on coastline positions and hydro-meteo data in time including geological, sedimentological and historical input;
- to perform theoretical and experimental studies on fundamental gaps in our knowledge (e.g. low-frequency waves, wave-current interactions, bed forms, sand transport with ripples and in sheetflow conditions);
- to conduct some extensive field measurement campaigns in order to increase our understanding of several interacting processes on a natural scale and to provide data for further empirical and modelling studies;
- to explore further the possibilities of morpho-dynamic modelling; this involves:
    * the development of state-of-the-art models for the straight coast and the barrier islands coast;
    * the modelling of the behaviour of banks in open sea, shoreface-connected ridges, and breaker bars;
    * the modelling of the development of channel-shoal system in the ebb tidal deltas and tidal inlets in relation to the morphological developments in the tidal bays;
    * preliminary efforts to perform reconstruction of past LSCB using existing data on wave and current climate and morphodynamical developments.

It should be noted that the Coastal Genesis Project Phase II incorporates efforts on coastal research of Rijkswaterstaat, Delft Hydraulics, Geological Survey and the Universities of Delft and Utrecht. It is an integrated national research plan.

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