Land Subsidence in Coastal Lowlands

Saskia Jelgersma

ABSTRACT: Causes and ranges of coastal lowland subsidence are varied, but in general natural subsidence amounts to centimeters to a few meters per century, while human-induced subsidence can amount to meters in a few decades. As a result, coastal subsidence must be taken into account when predicting relative sea-level rise over the next century.

Introduction

An increasing body of evidence suggests that within the near future, global warming due to the greenhouse effect could lead to a substantial rise in sea level. Most estimates of this rise range from 0.2 to 1.4 m for the next 100 years (Villach conference, 1985). These contrast with Warrick and Oerleman's estimates (1990), given in the report of the Intergovernmental Panel of Climate Change (IPCC). For their best estimate for the year 2030, the Business-as-usual scenario, 10 cm comes from thermal expansion, 7 cm from the partial melting of mountain glaciers, 1.8 cm by melting of Greenland ice, and -0.6 cm from the buildup of Antarctic ice due to increased precipitation. Their best estimate for 2090 is +66 cm, which is higher that the +48 cm estimate of Wigley and Raper (1992). This wide range in estimates is due to the many uncertainties of the input to the predictive models.

A large portion of the world population lives in low lying areas near the sea and, consequently, a rise in sea level will have an important impact on society. Most low lying coastal areas, especially deltas, are subject to marked subsidence. In densely populated deltaic areas with heavy agriculture and industrial development, accelerated subsidence due to overdraining of ground water is already a serious problem. Further human induced subsidence is caused by draining of the land to make polders in these areas. Because local subsidence can be much greater than the maximum expected sea-level rise due to global warming, these must be considered when estimating the expected sea-level rise in any given area.
Geological Setting

Many coastal lowlands and deltaic plains are underlain by subsiding basins. Such basins are the sites of a considerable accumulation of Cenozoic sediments, sometimes several thousand meters thick. The position of the shoreline in these basins depends on the rate of subsidence and the rate of influx of sediments. In a geological time frame, these two factors have varied and together with eustatic sea-level shifts have caused alternating periods of shoreline regression and transgression. In general, sea level during glacial periods dropped 100 m or more, while during interglacials sea level remained near or slightly above the present level. Because of these factors there are often alternating marine and fluvial deposits buried below the surface of many coastal areas.

These deposits from different environments show various lithologies. In general marine deposits are fine-grained, in contrast to the alluvial deposits, which are much coarser grained. It is also clear that the pore water of marine deposits was originally saline or brackish and that the alluvium originally contained fresh water.

The environment of deposition and their lithologies can be summarized as follows: In an alluvial valley, meandering river systems the point bars of the river deposits consist largely of coarse grained sands; levees are silty clays; and the backswamp contains clays and peats. The braided river system shows a different sedimentation pattern due to the irregular and abundant sediment supply. With tectonic subsidence, river deposits can contain alternating layers of fine and coarse grained sediments (Fig. 1). Changes in tectonic movement and or precipitation in the drainage basin can give rise to successive cycles of meandering and braided river deposits in the subsurface of the alluvial valley.

River deltas consist of deltaic and tidal plains. In the deltaic plain, distributaries with sandy deposits are bordered by marshes, swamps and muds. The tidal plain shows tidal channels with sand bordered by tidal deposits like mangrove swamps and muds. In general, deltaic sedimentation on tidal plains is influenced by waves and tides as well as the rate of sediment influx. Therefore sediments can range from sand (beach ridges) to mud (tidal flats, lagoonal clays and peats).

The offshore zone can show an accumulation of mud deposits, in some places alternating with sandy shoals and banks. These environments shift landward and seaward with time due to tectonic subsidence and sea-level change.

Due to the postglacial rise in sea level, recently formed wedge-shaped layers of sediment often are found in low-lying coastal areas. In The Netherlands and the Mexican Nayarit coast, sandy coastal barriers and ridges border lagoonal and peaty deposits (Fig. 2). In the Louisiana coastal segment west of the Mississippi Delta, a thick layer of bay mud sediment is present with a series of sandy cheniers imbedded in this bay mud (Fig. 3). The same can be found in the coastal plain north of the Yangtze Delta (China) and along the northern coastline of Malaysia. In other areas, such as Bangkok Bay, a thick layer of clay represents the sediment deposited during the post-glacial rise in sea level.

Between 3000 and 8000 m of Cenozoic sediments have been deposited in the sedimentary basins of the Nile, the Mississippi and the North Sea (Figs. 4, 5 and 6,