KRIM

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Probabilistic Risk Analysis in Coastal Defence

Introduction

Due to increasing stress on costal defence systems, e.g. caused by accelerated sea level rise or economic restrictions, the coastal hinterland management has to be integrated in coastal defence planning. For this purpose a suitable method of risk analysis was developed in KRIM to include the safety of coastal defence systems and the financial losses to be expected in the hinterland in case of failure.

Risk =

probability of failure * expected loss

of the coastal defence system [1/a] in case of inundation [€]

Safety of Coastal Defence Systems

The calculation of the safety of coastal defence systems comprises:

- Identification of failure modes of coastal defence systems
- Description of statistics referring to hydrological and hydraulic loads due to water levels and waves
- Description of statistics of the resistance of coastal defence systems
- Calculation of failure probability

At the German North Sea coast the sea dike is the most important coastal defence element. The major failure mechanism is wave overtopping (Figure 1).

Figure 1: Failure mechanism of the dike

The calculation of the failure probability requires the description of statistics of hydrological or hydraulic loads resp. due to water levels and waves. In order to estimate the wave load numeric models are used.

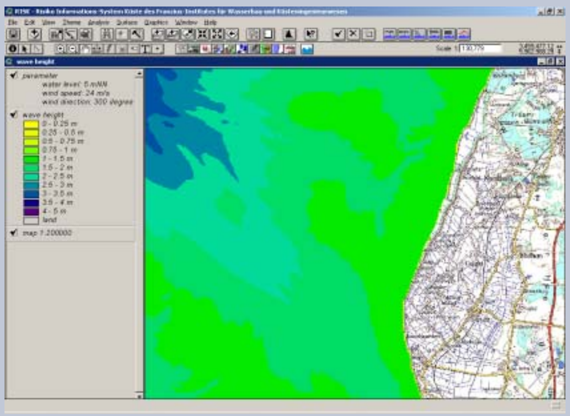

Figure 2: Calculated wave height at water level of 5 mNN and a north-westerly wind of 24m/s speed

Failure Probability

For today's conditions of water levels, waves and winds the annual failure probability varies between approx. 1/6000 and 1/600. In case of water level rise of 55 cm the failure probability increases to approx. 1/1000 or 1/100 resp.

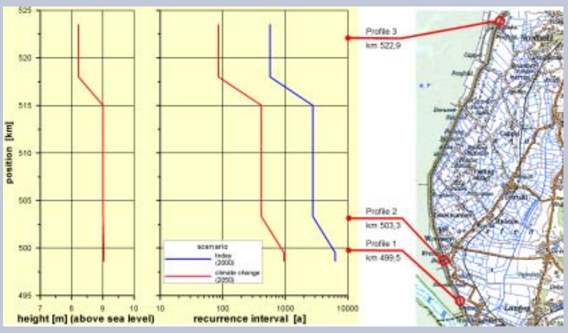

Figure 3: Recurrence interval of failure (wave overtopping) of sea dikes on the coastline north of Bremerhaven calculated without and with water level rise of 55 cm

Loss Function

As second element for the calculation of loss in case of flooding so called loss functions derived from empirical damage data are used. The graph shows the degree of loss for different value categories depending on inundation depth. The loss in a residential area in case of an inundation of 1 m would be 20% of the residential assets.

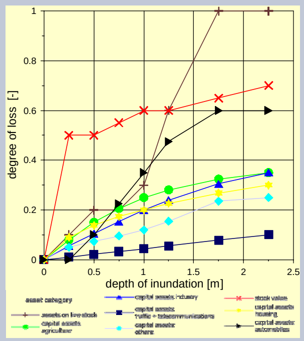

Figure 4: Loss functions for different asset categories (based on Klaus & Schmidtke)

Analysis of Flood Scenarios

Basis of flood damage calculation is the flooded area and depth in zone under risk, which are analysed by means of the tool 'Flood-Analyser'. A screenshot shows the result of the analysis of a simulated dike breach scenario near Cappel-Neufeld (north of Bremerhaven) during the storm surge on 3rd January, 1976. The Digital Landscape Model ATKIS-Basis-DLM is used as information on land uses. It shows that 100 hectares of residential areas and 1300 hectares of farmland would be flooded.

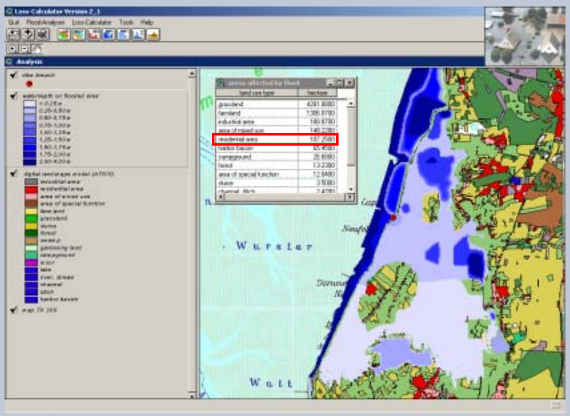

Figure 5: Analysis of the flooding process with results showing inundation areas and type of land use

Extension and Water Depth of the Inundation

Analysing each time step of the flooding scenario leads to a statement about the chronological process of the inundation, e.g. for housing areas (Figure 6).

In addition to the flood extension, the maximum water depth is an important parameter to calculate the loss because this factor determines the degree of damage for the various property assets. The allocation of maximum water depths in residential areas shows that the inundation mostly reaches values of up to 0.75 m (Figure 7).

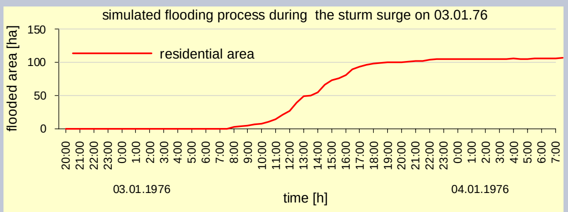

Figure 6: Flooding process in residential areas during the storm surge on 03.01.76

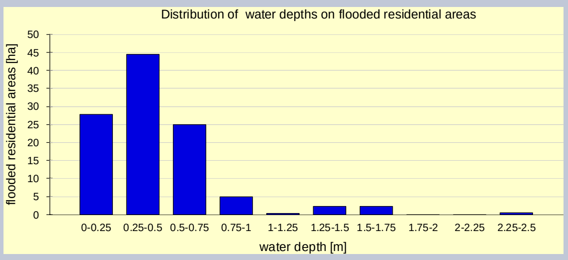

Figure 7: Distribution of water depths in flooded residential areas

Quantification and Spatial Modelling of the Damage Potential

A third input is the damage potential, i.e. the socio-economic values located in the coastal hinterland. For this purpose monetary assets from official statistics are combined with the German digital landscape model ATKIS-Basis-DLM (Figure 8 and Figure 9).

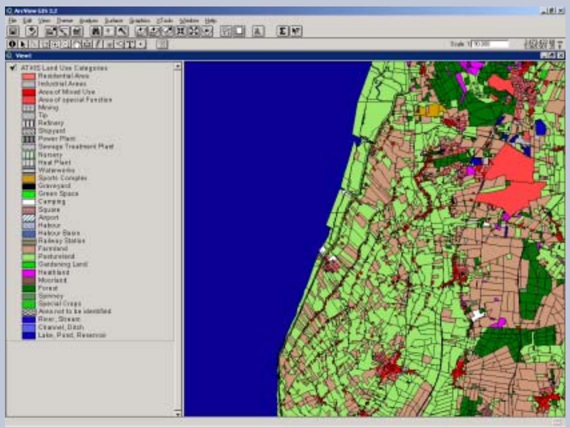

Figure 8: Land use data from digital landscape model ATKIS-Basis-DLM

The different value categories are referred to the regional level of the municipalities. Population figures were acquired and all values were recorded in monetary units: Residential capital, household goods, value of automobiles, fixed assets, stock assets and gross value of the different economic branches, roads and railway networks as well as land value. Each value category is stored in the GIS including information on location and concentration (in €/m²).

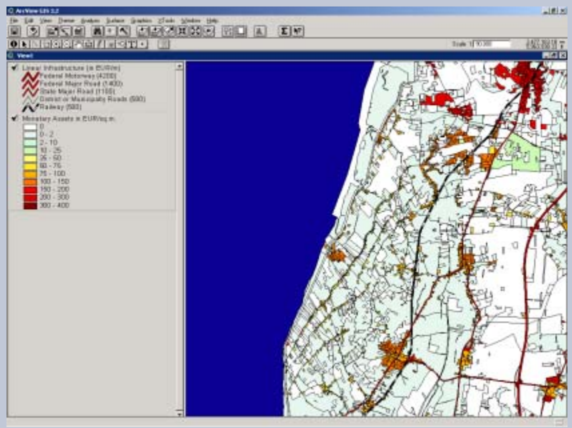

Figure 9: Distribution of monetary assets

Automated Forecast of Loss

In order to automate the calculation of loss the tool ‚Loss-Calculator' was developed. The tables in figure 10 show the detailed loss for the object type "residential area" subdivided into municipalities. In case of failure of the coastal defence system the expected loss in the municipality Nordholz in residential areas would be 6.88 million Euro, subdivided into 4.46 million Euro for residential capital, 1.85 million Euro for household goods and 0.57 million Euro for automobiles. Adding all partial results for the land use types amounts to a total loss of 32.6 million Euro in case of a dike breach near Cappel-Neufeld.

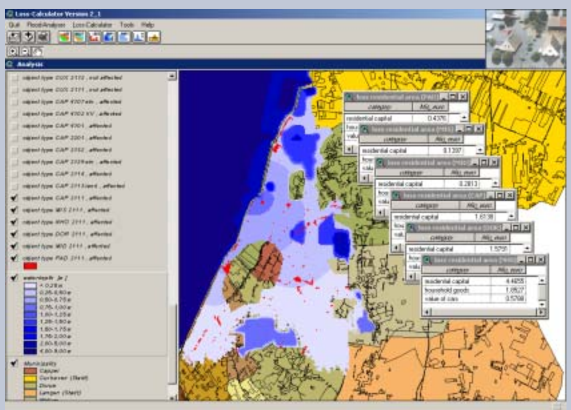

Figure 10: Loss calculation from dike breach scenario near Cappel-Neufeld for land use type „residential area", subdivided into municipalities

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