
Artificial Beach Nourishment:
Lessons learned from Field Experiments
Hans Kunz
International Conference
Development of Artificial Lands on Shores,
Near-Shore and Off-Shore Zones
Novosibirsk, Russia, July 2009

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Aerial View from Baltrum West to Norderney East

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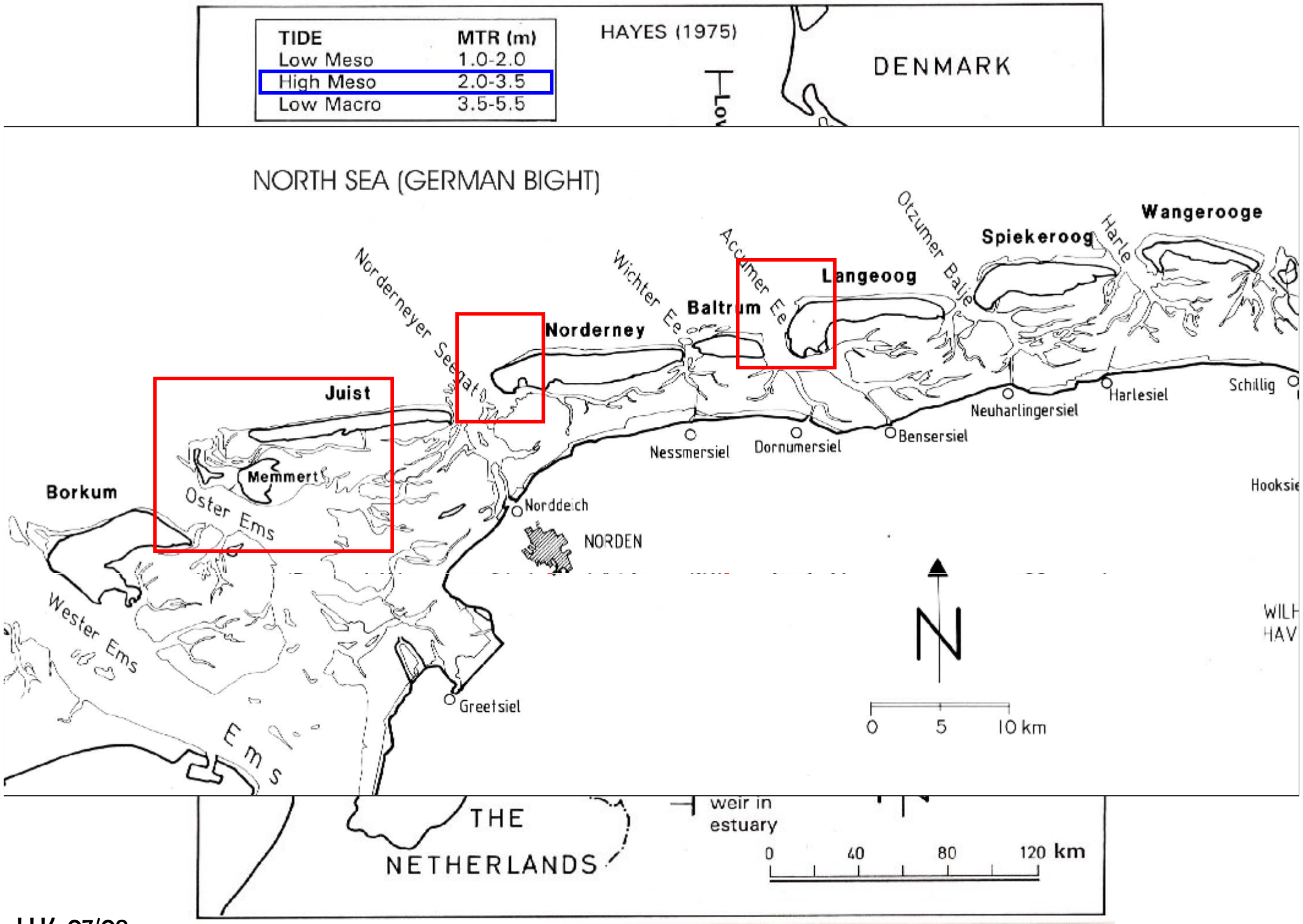
TIDE
MTR (m)
Low Meso
1.0-2.0
High Meso
2.0-3.5
Low Macro
3.5-5.5
HAYES (1975)
DENMARK
NORTH SEA (GERMAN BIGHT)
Norderneyer Seegat
Wichter Ee
Accumer Ee
Otzumer Balje
Harle
Spiekeroog
Wangerooge
Langeoog
Baltrum
Norderney
Juist
Borkum
Memmert
Oster Ems
Wester Ems
Ems
Norddeich
NORDEN
Greetsiel
Nessmersiel
Dornumersiel
Bensersiel
Neuharlingersiel
Harlesiel
Schillig
Hooksiel
WILH
HAV
N
0 5 10 km
THE NETHERLANDS
weir in estuary
0 40 80 120 km

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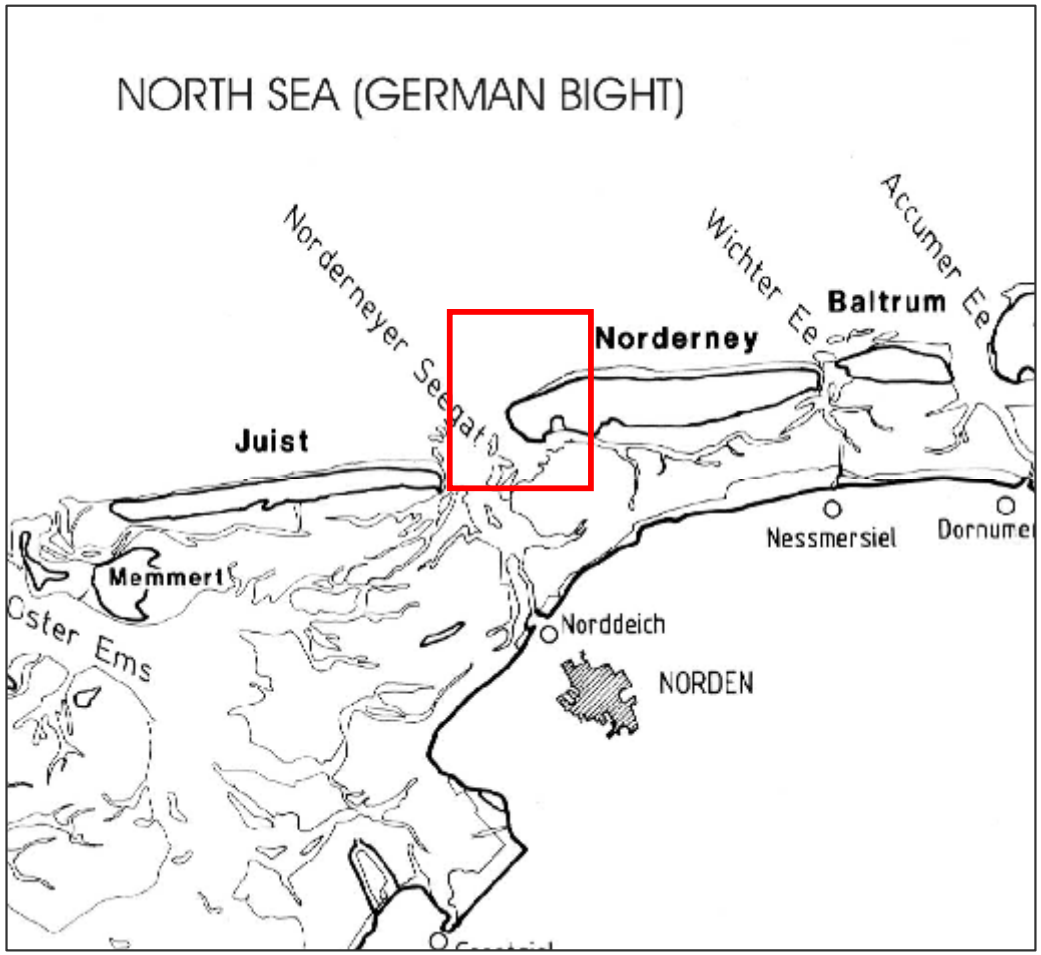
The topic of the Conference “Artificial lands on Shores, Near-Shore and Off-Shore Zones” is directed towards coastal engineering on a large scale.

In contrary, this presentation relates to quite small projects and its focus is rather on technical aspects than on the use of artificial beach and foreshore nourishment as a tool to cope with conflicting demands for an “Integrated Coastal Protection Management”.

Remark

Norderney

Integration of Beach Nourishment (BN) into the historically developed seawall-groyne-system.



Sand Losses from restored beach areas

Field Experiments

Calculation

- Control Volume
- Equilibrium Profile
- Closure Depth
- Half Period
- Cost-Benefit Optimum

Valuation, Perception

Aerial View Norderney West

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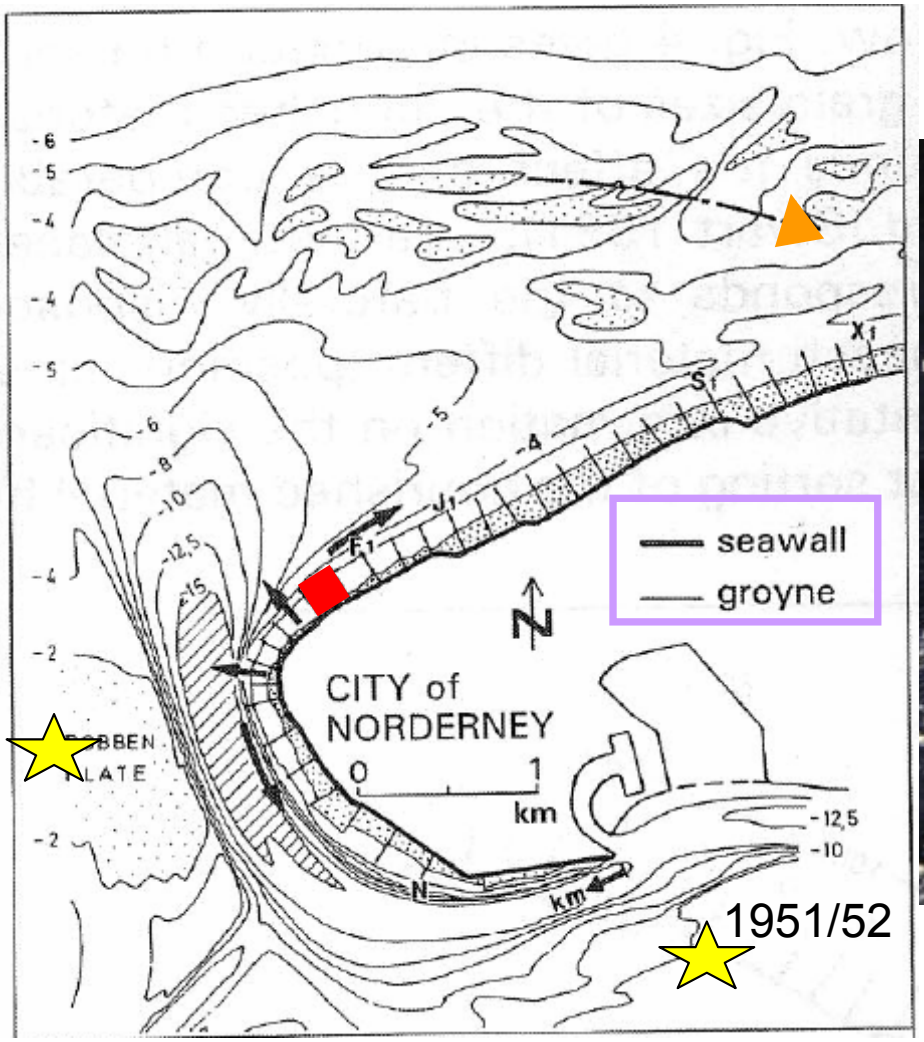
Western spit of Norderney Island with its tidal-inlet and ebb-delta shoals (reef-bow)



Left: Depth-contour lines, resulting currents littoral drift, test site (D1-E1)

Right: Aerial view displaying the reef-bow during low water conditions

Kunz (1993)

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Norderney: Sea wall from 1857/58 (S-profile, lime-stone) with added food protection (basalt) in a status of severe beach erosion: Artificial Beach Nourishment needs to be added

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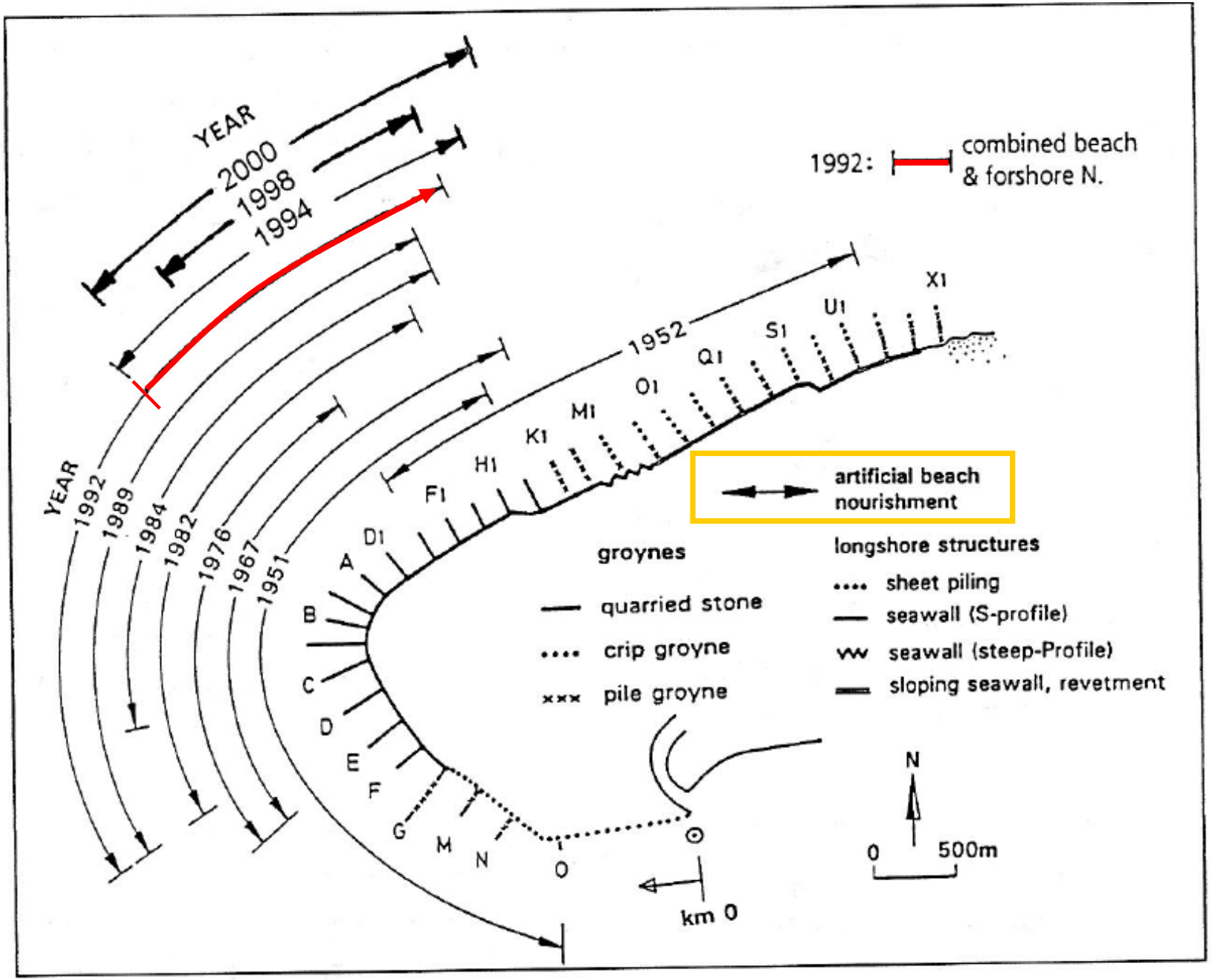
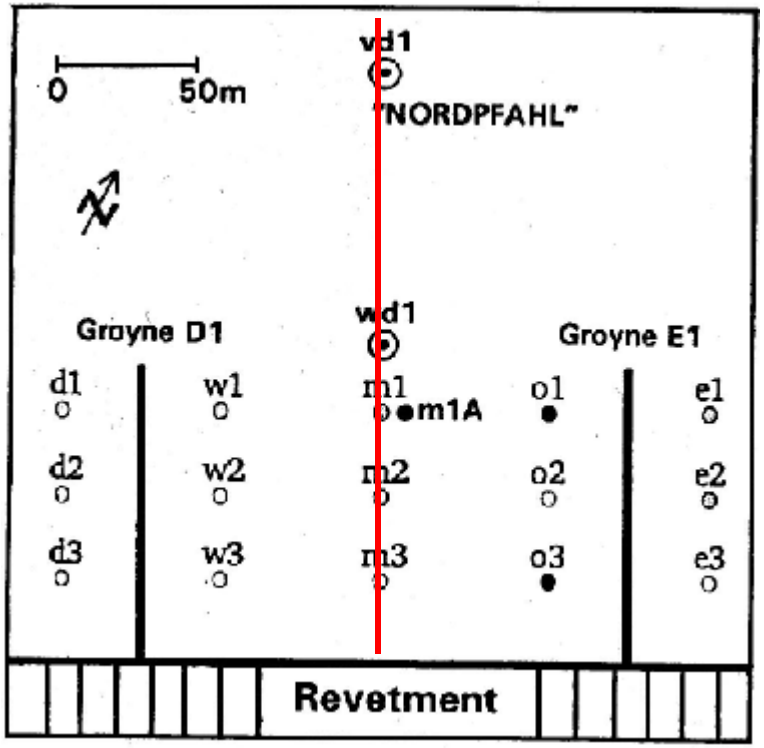
Coastal Protection System Norderney
Groynes, Sea Walls and Beach Nourishment (1951/52 - 2000)

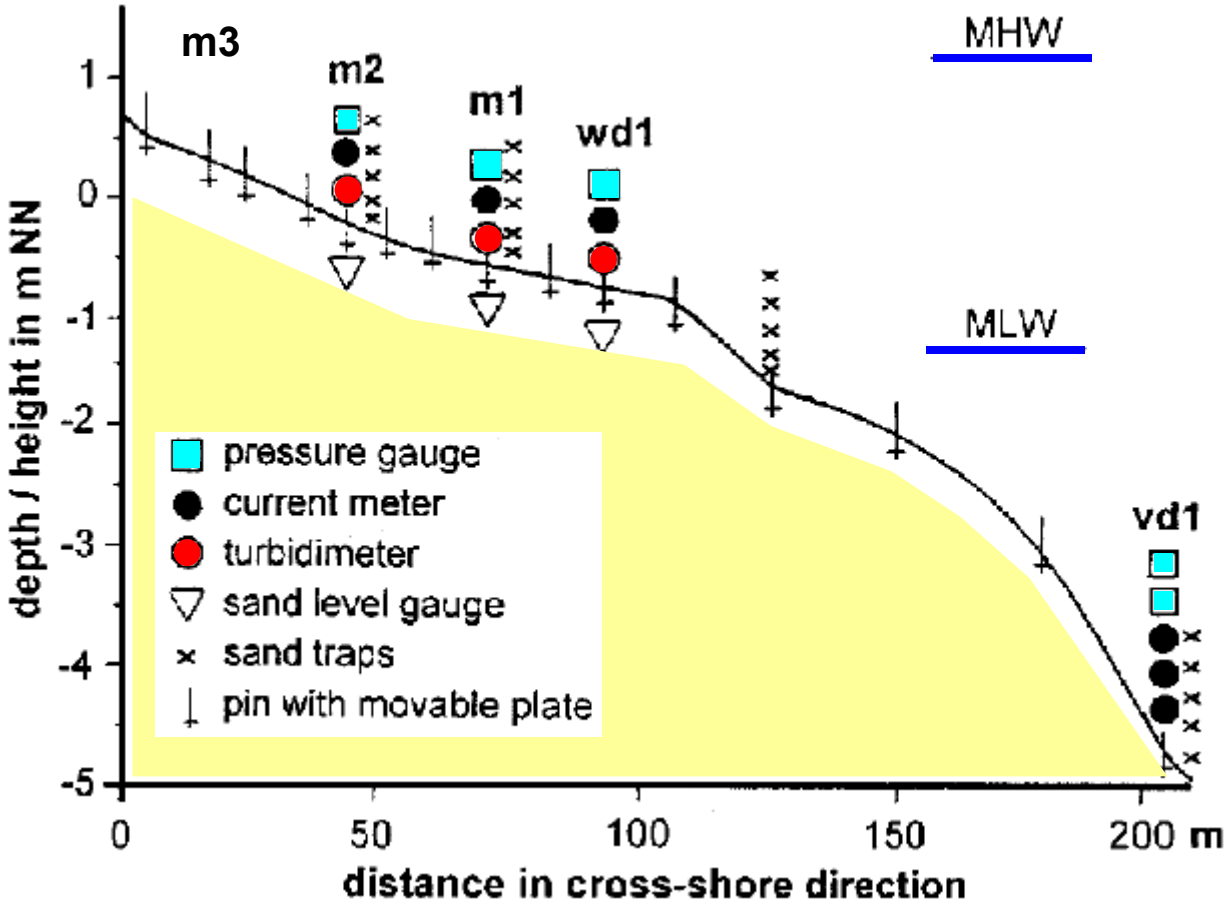


Kunz (1995)

German–Russian Field-Experiment „Norderney 94“ - Location test site (groyne field D1-E1) and Devices



Location of the investigated cross-section and measurement points
(groyne-field D1-E1)



Cross-section with the installed measurement devices
(groyne-field D1-E1)

Kunz (1997)

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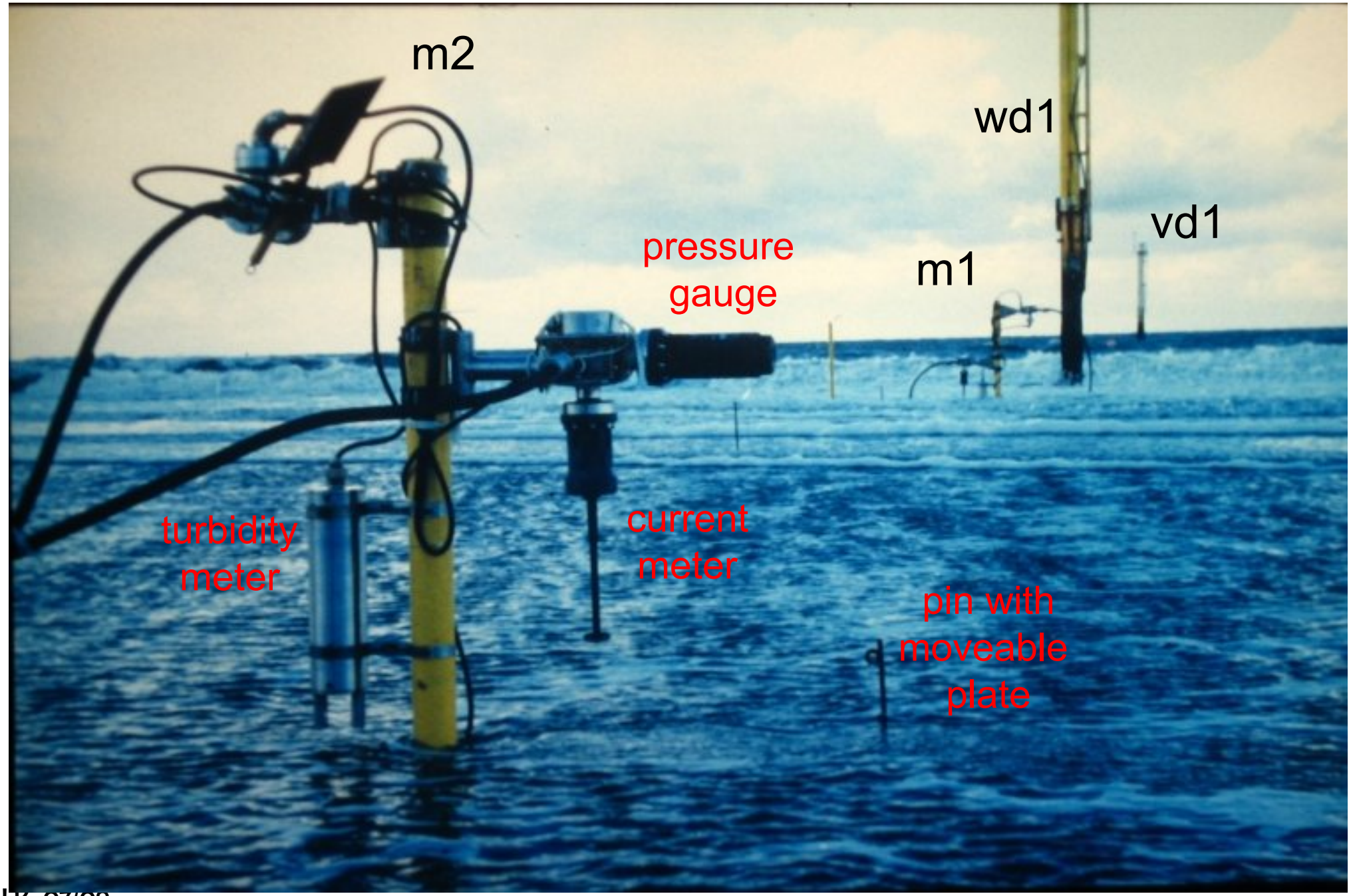
Test Site Norderney (D1-E1), middle cross-section (m) with equipment for the German-Russian Field Experiment Norderney 94



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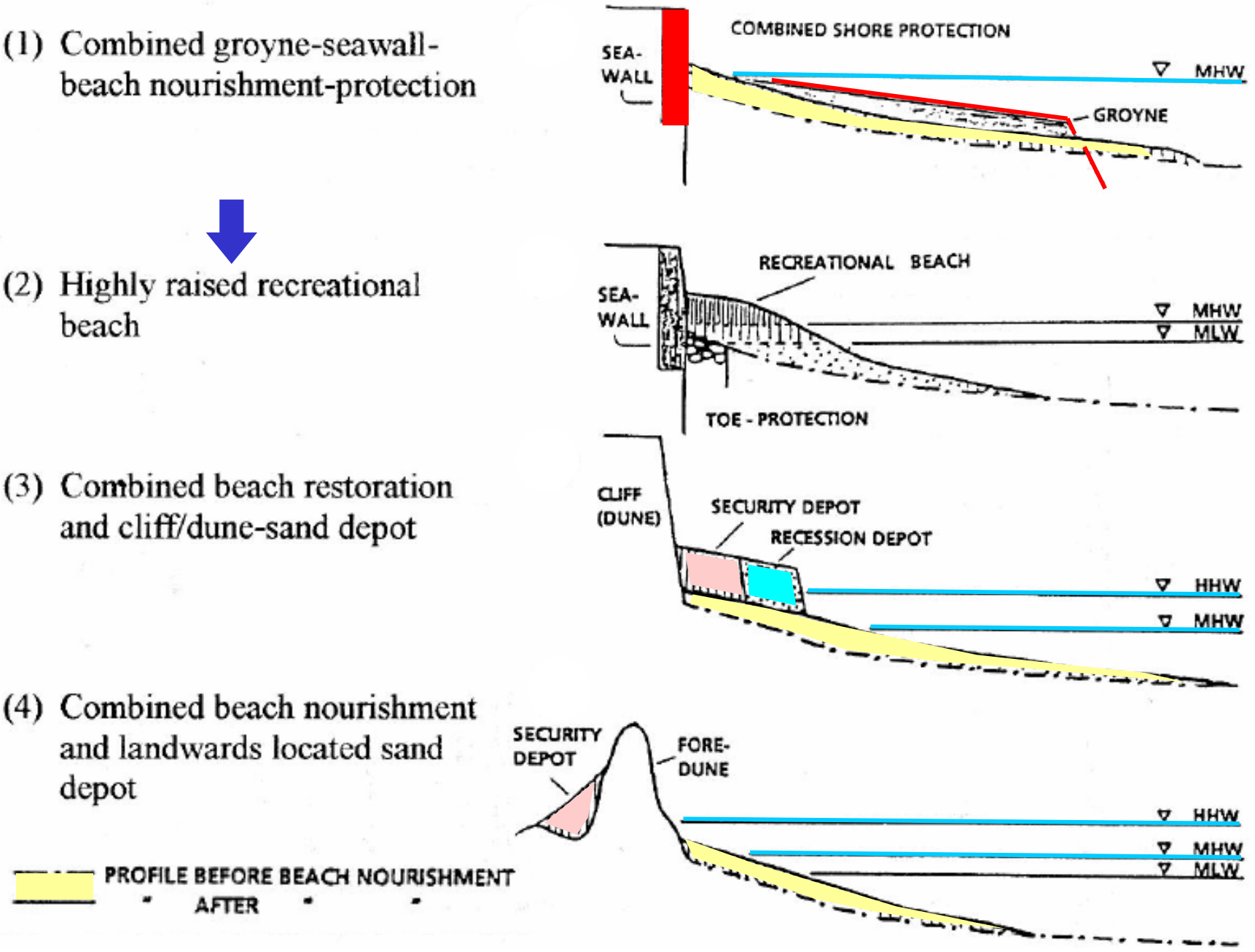
Examples for Artificial Sand Nourishments on German Barrier Islands

(1) Combined groyne-seawall-beach nourishment-protection

(2) Highly raised recreational beach

(3) Combined beach restoration and cliff/dune-sand depot

(4) Combined beach nourishment and landwards located sand depot



Kunz (2001)

Aerial View Wangerooge East

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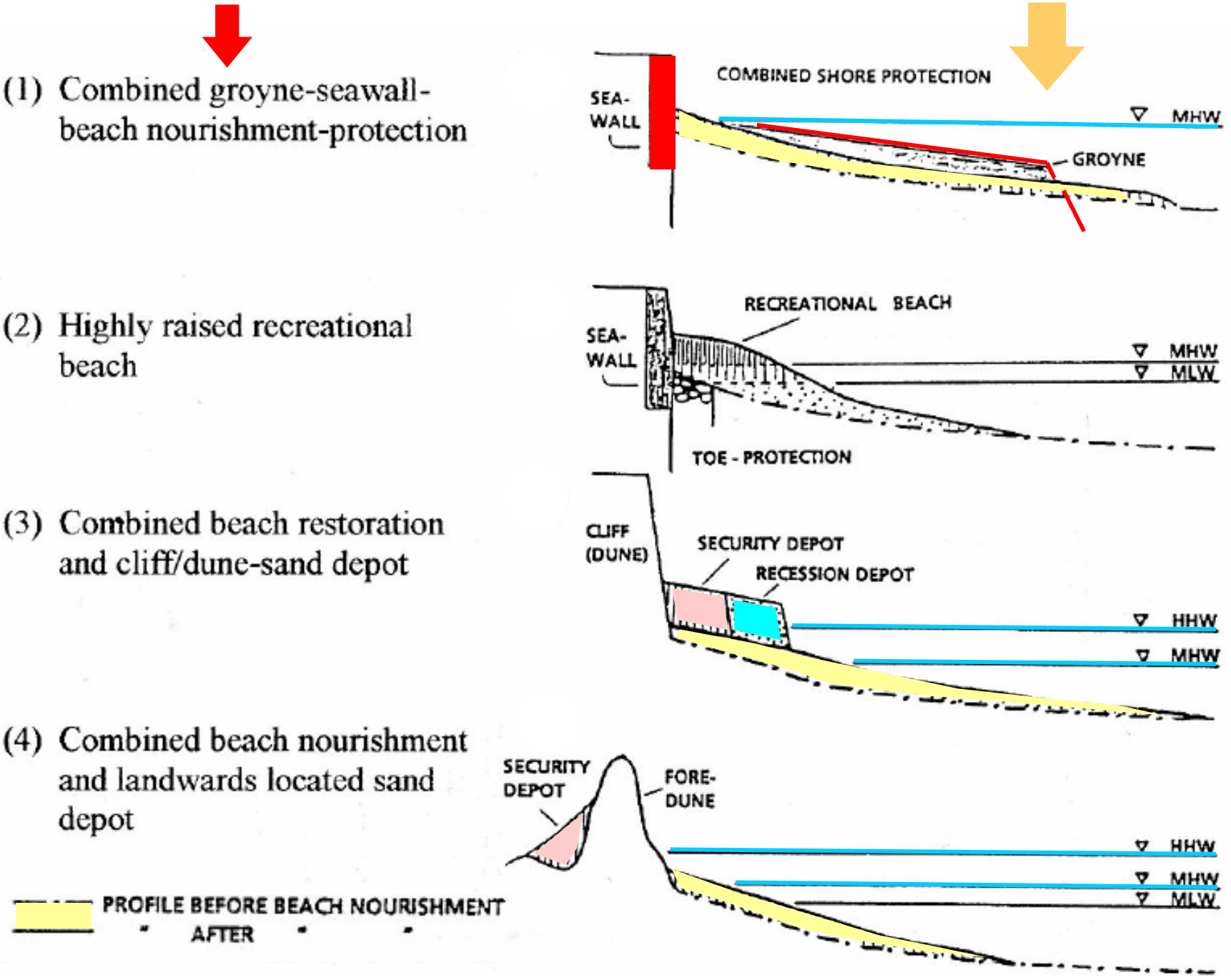
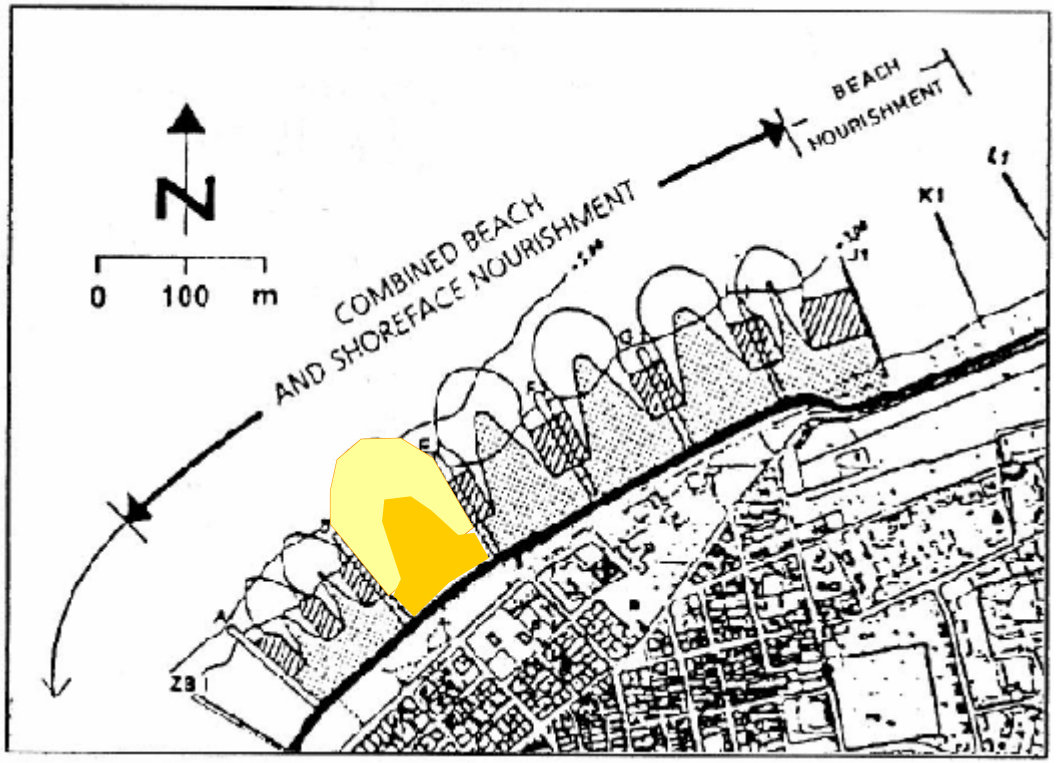
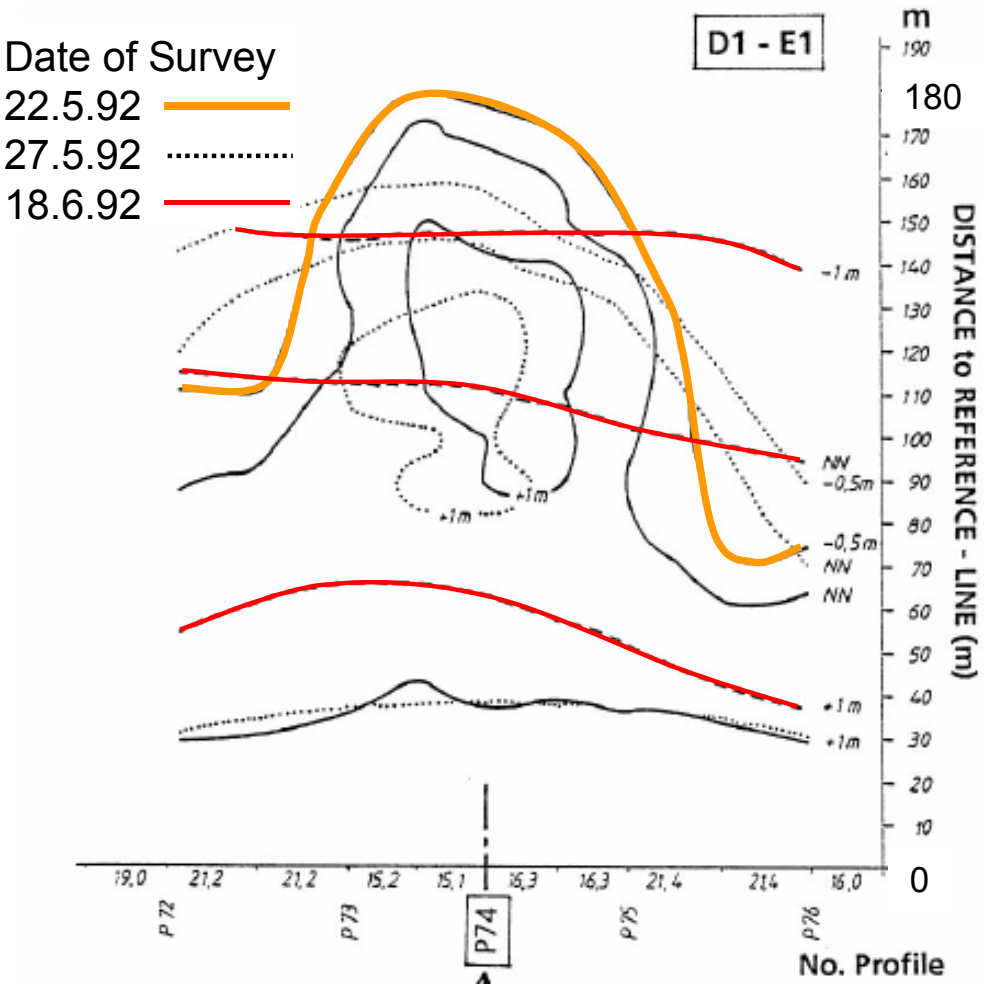


Kunz (2001)

Temporary Sand Groynes as part of the Combined Beach and Shoreface Nourishment, Norderney 1992



Design of the Temporary Sand Groynes



Development of the sand groyne shape (D1-E1) during the first month after BN

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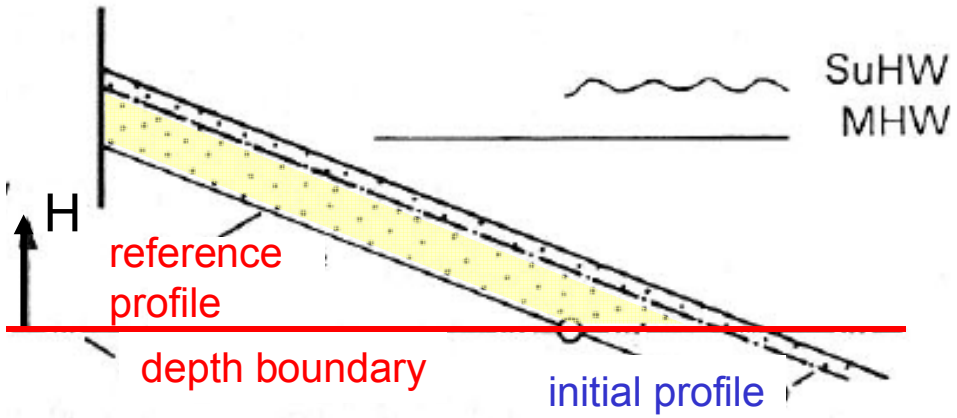
Calculation of Sand Losses out of a defined Control Volume and Example for Volumes (V) and related Half Period (t_h) over time

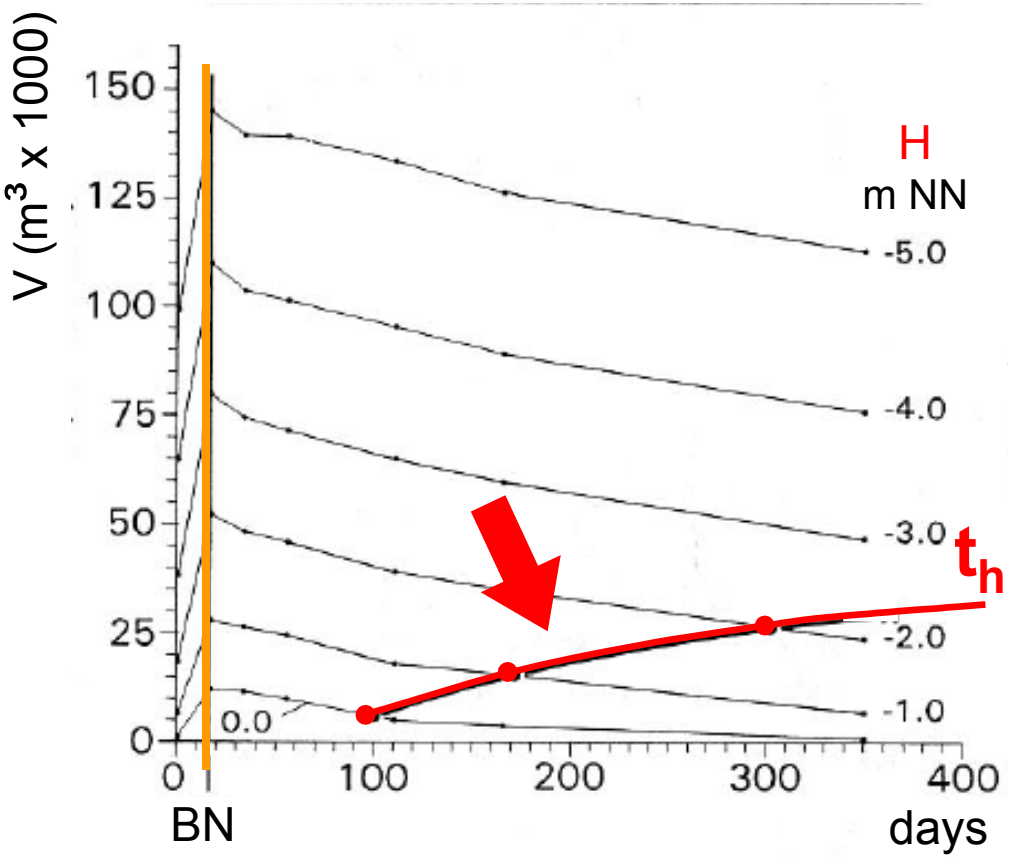
Cross-section BN



Volume of sand above the reference profile (adapted to the „equilibrium profile“) and to the depth boundary (Control Volume)

Reference Profile	Beach Profile which approximates the site specific „Equilibrium Profile“
Initial Profile	Profile of the nourished beach after the natural transformation into a shape which is adapted to the site specific conditions (related Initial Losses)
H	Height/Depth of the Beach

Sand volume V above different Depth Boundary levels H



BN Artificial Beach Nourishment

t_h Half Period: The Sand Losses out of the Control Volume reach 50% of the Initial Volume

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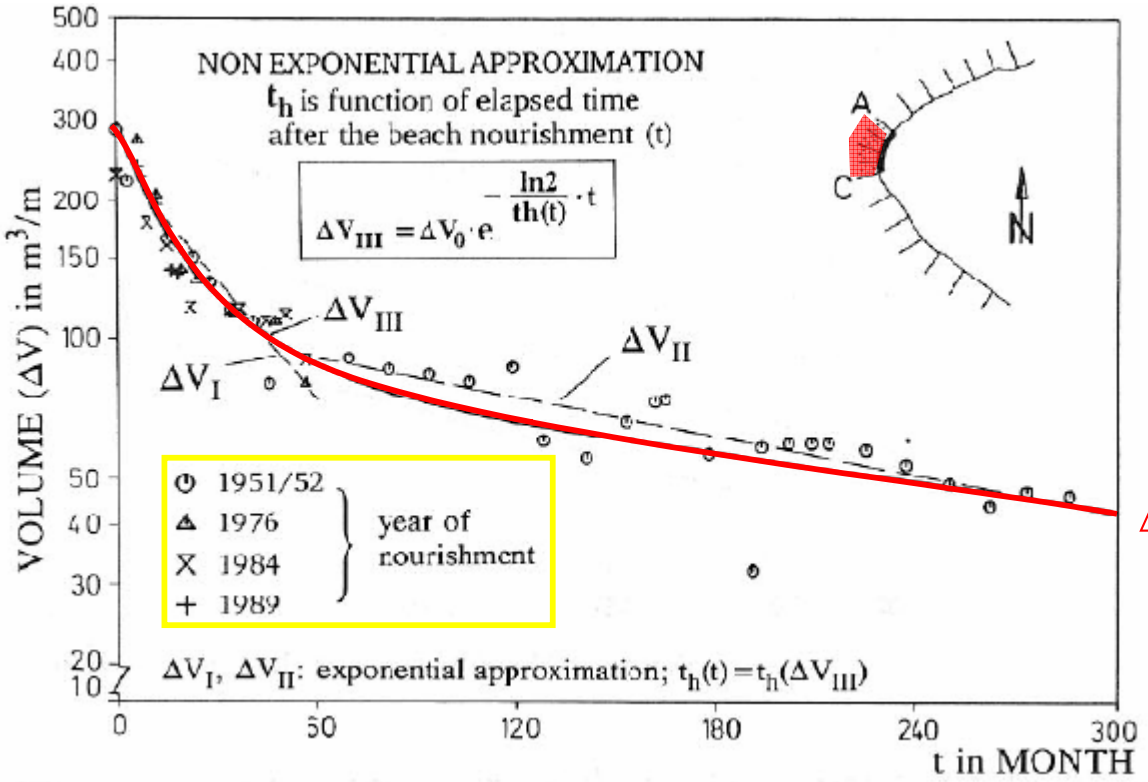
Sand losses over time out of nourished beaches with related approximations – Norderney (Section C-A), Nourishments 1952/52; 1976; 1984; 1989

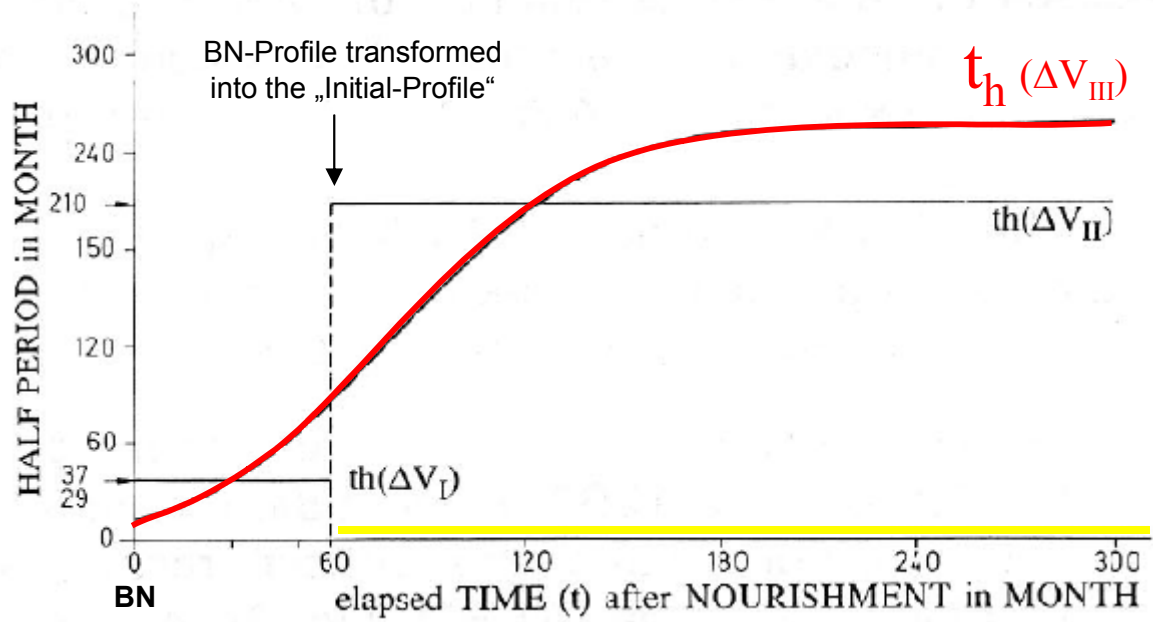


ΔV_{III}

ΔV Sand within the defined Control Volume fixed by the Reference Profile and the Depth Boundary (e.g. „Closure Depth“ – see Kunz 2003).

ΔV_I, ΔV_{II} : Approximation by e-Function

ΔV_{III} : Non-exponential approximation



$t_h(\Delta)$: Half Period related to the Beach Nourishment (BN): Elapsed Time after BN when the losses are 50%

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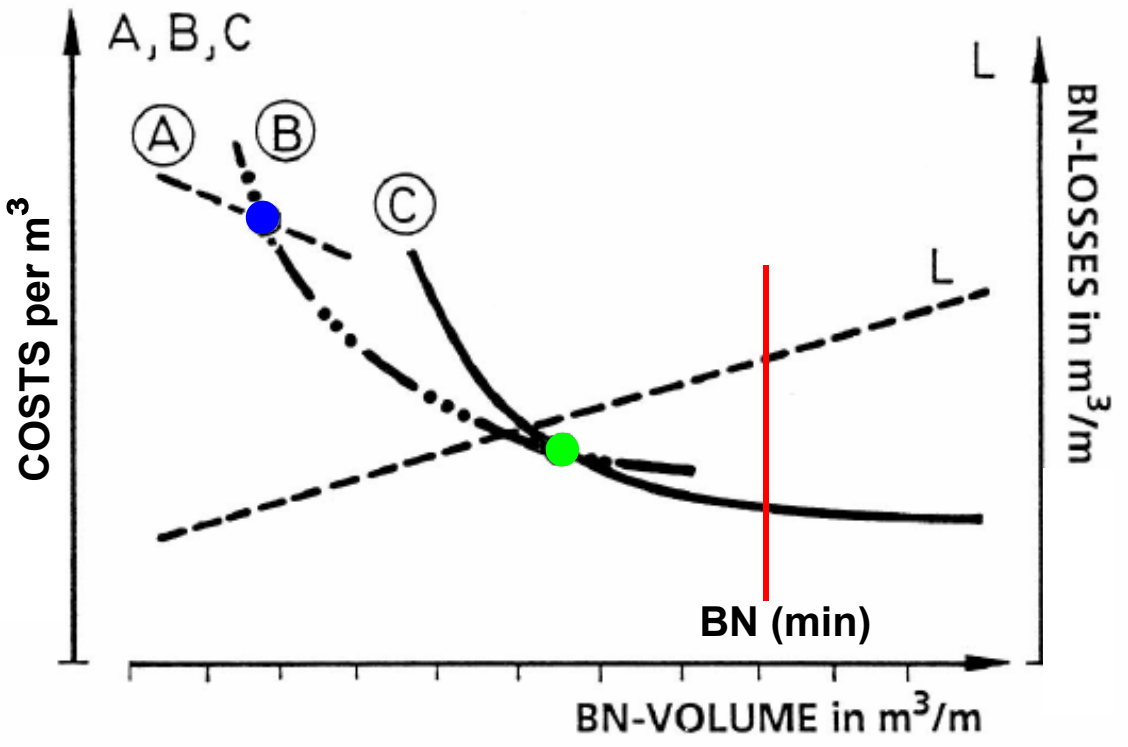
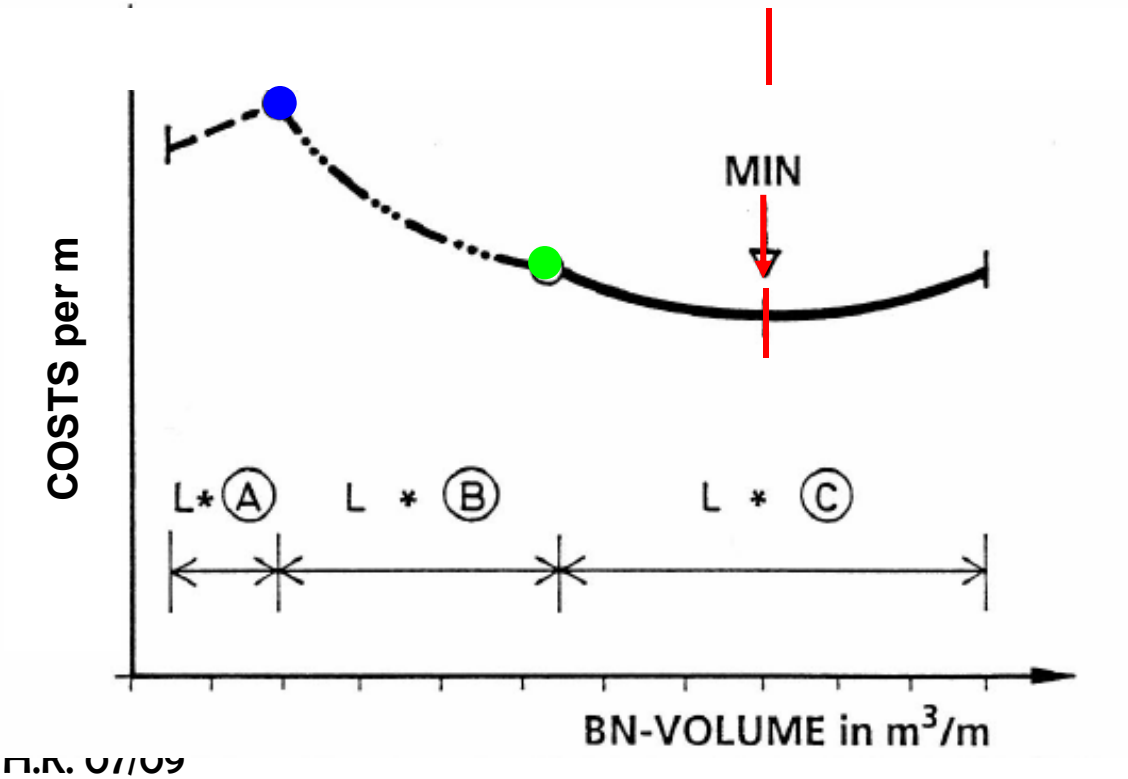
Schematic Sketch: Optimisation of Artificial Beach Nourishment Techniques concerning Specific Costs



Specific Costs of different beach nourishments (BN) - techniques (A, B, C) and associated BN - sand losses from the side specifically fixed Control Volume (L) in relation to the specific BN-volume (m³/m)



Specific Costs per m (e.g. €/m) for the nourished beach until the next BN-project is necessary (beach profile reaches the tolerable depth limit)

Kunz (1995)

The calculation and interpretation of sand losses requires the side specific definition of boundaries

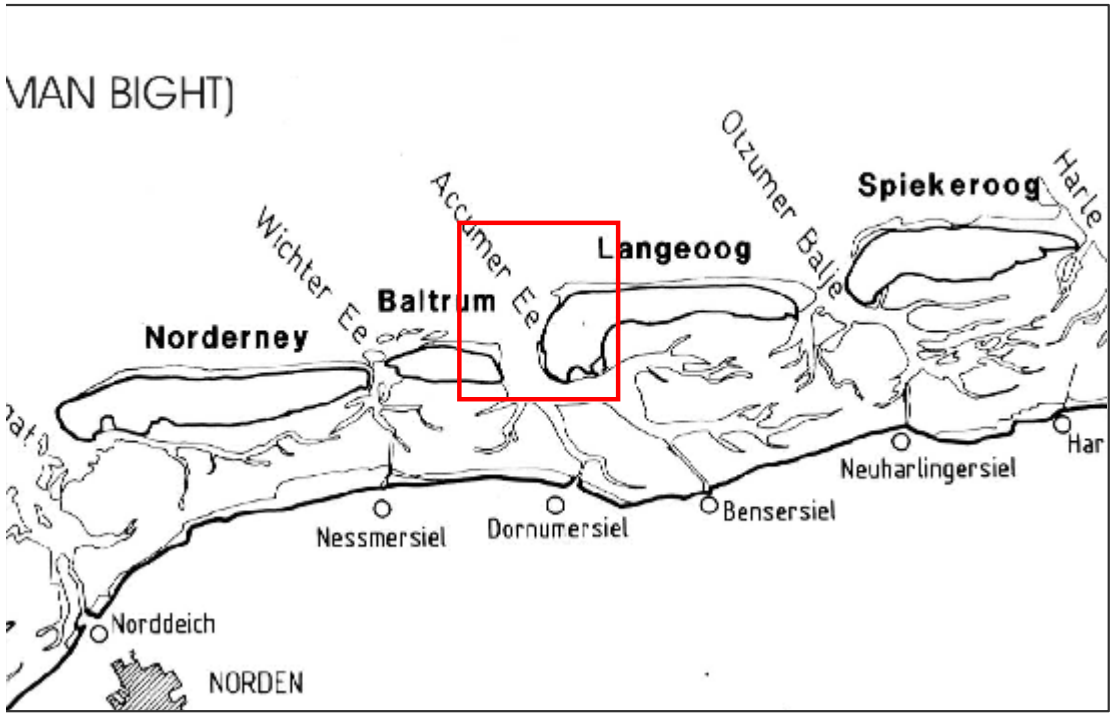
- reference profile ← equilibrium profile
- depth limit ← closure depth

Generally it is not necessary to put emphasis on beach profiling to approach natural slopes, as this will be quickly done by waves and current.

“Visible” losses create “invisible” benefit in deeper parts of the profile and should not be in total misinterpreted as final losses.

Langeoog

Adaptation of artificial sand nourishment on temporary changes of natural boundary conditions.

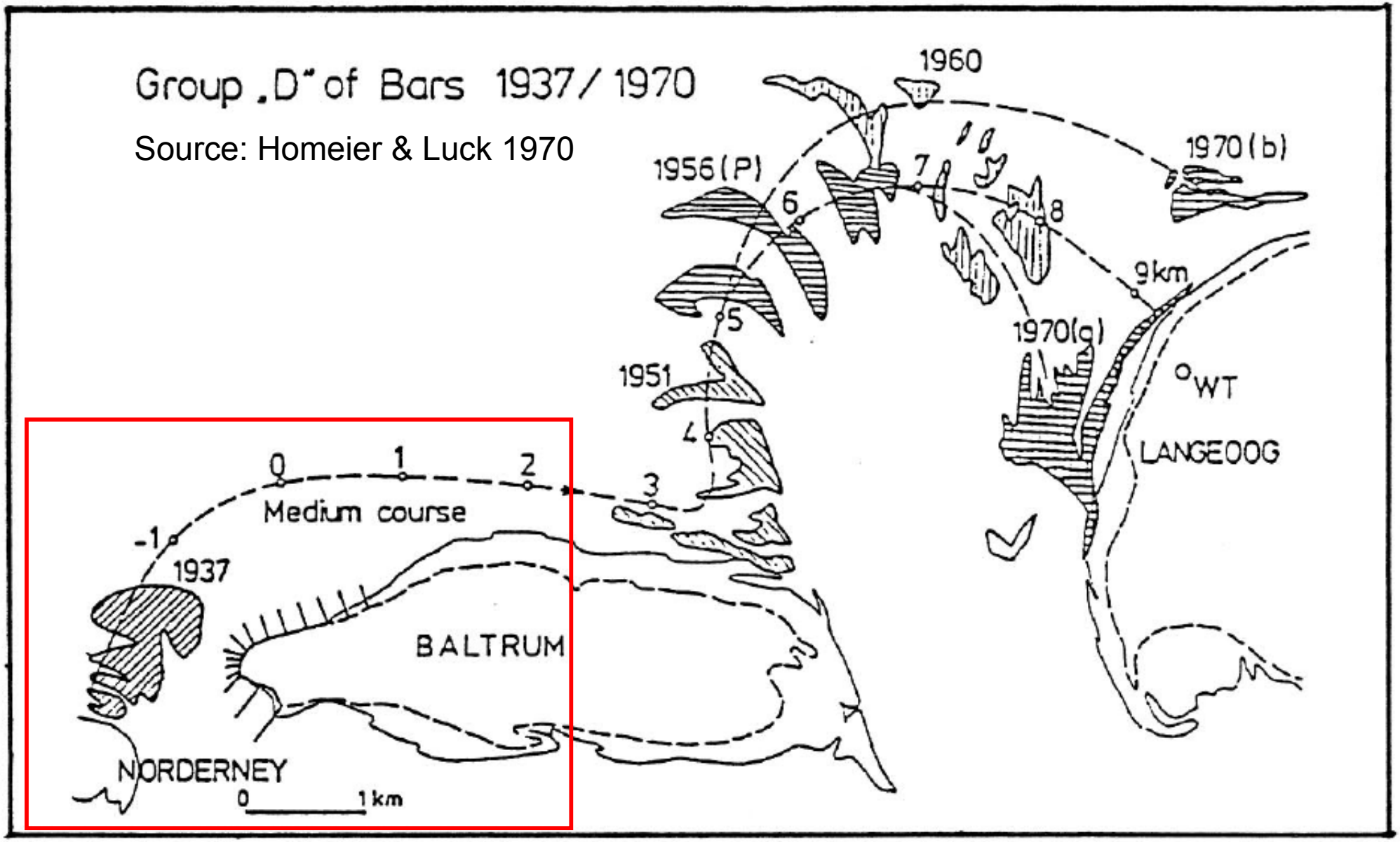


Artificial nourishment in reliance of sand supply by the littoral drift

Examples for projects

Artificial sand nourishment as flexible responses to shore- and beach-erosion

Migration (Littoral Drift) of Sand Bars (1937 to 1970) and development of ebb delta shoals which sporadicly supply Langeoog West with Sand



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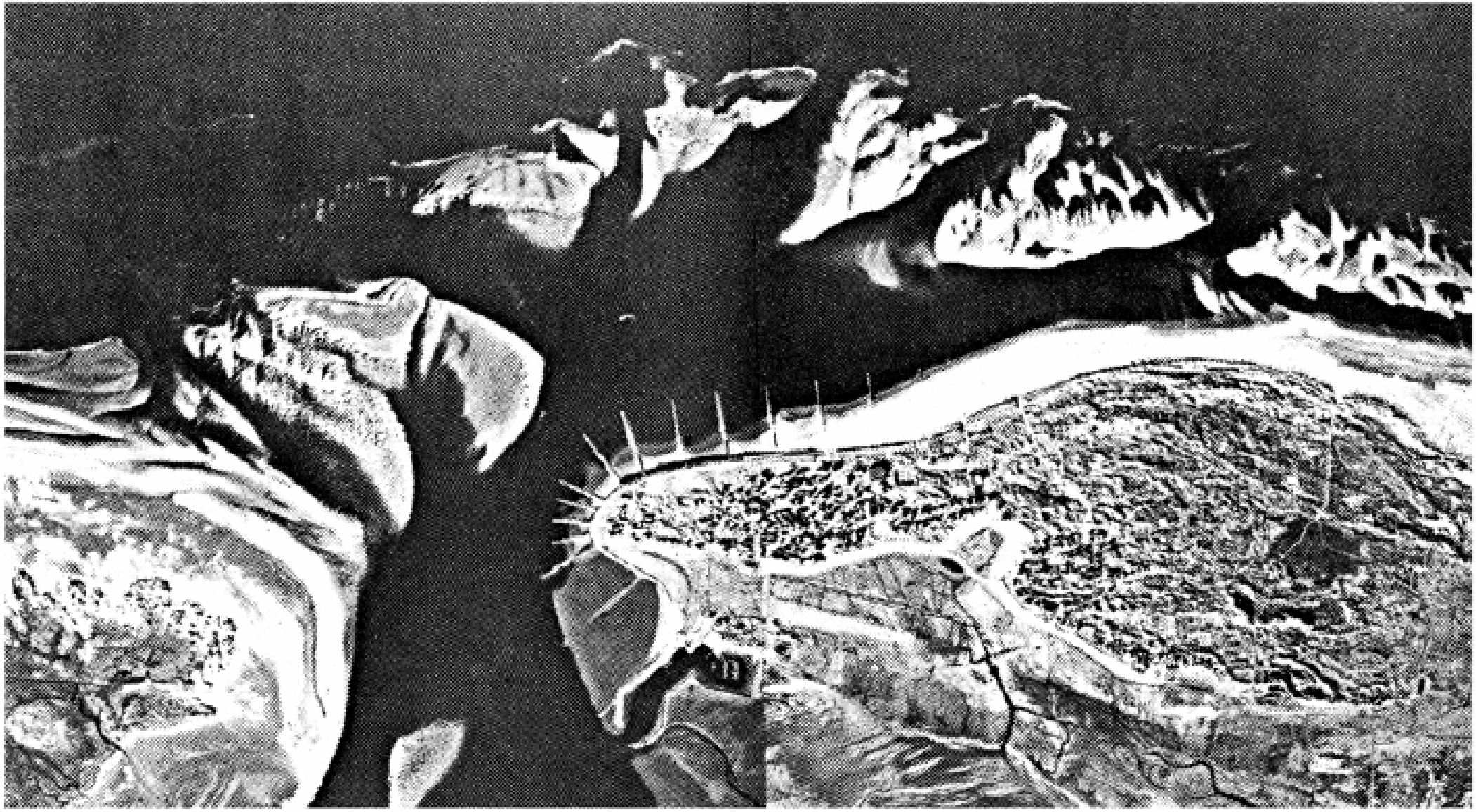
Kunz (1995)

Ebb Delta Shoals of the Wichter Ee-Inlet
Aerial View 1996 during Low Water



Norderney East Wichter Ee Baltrum

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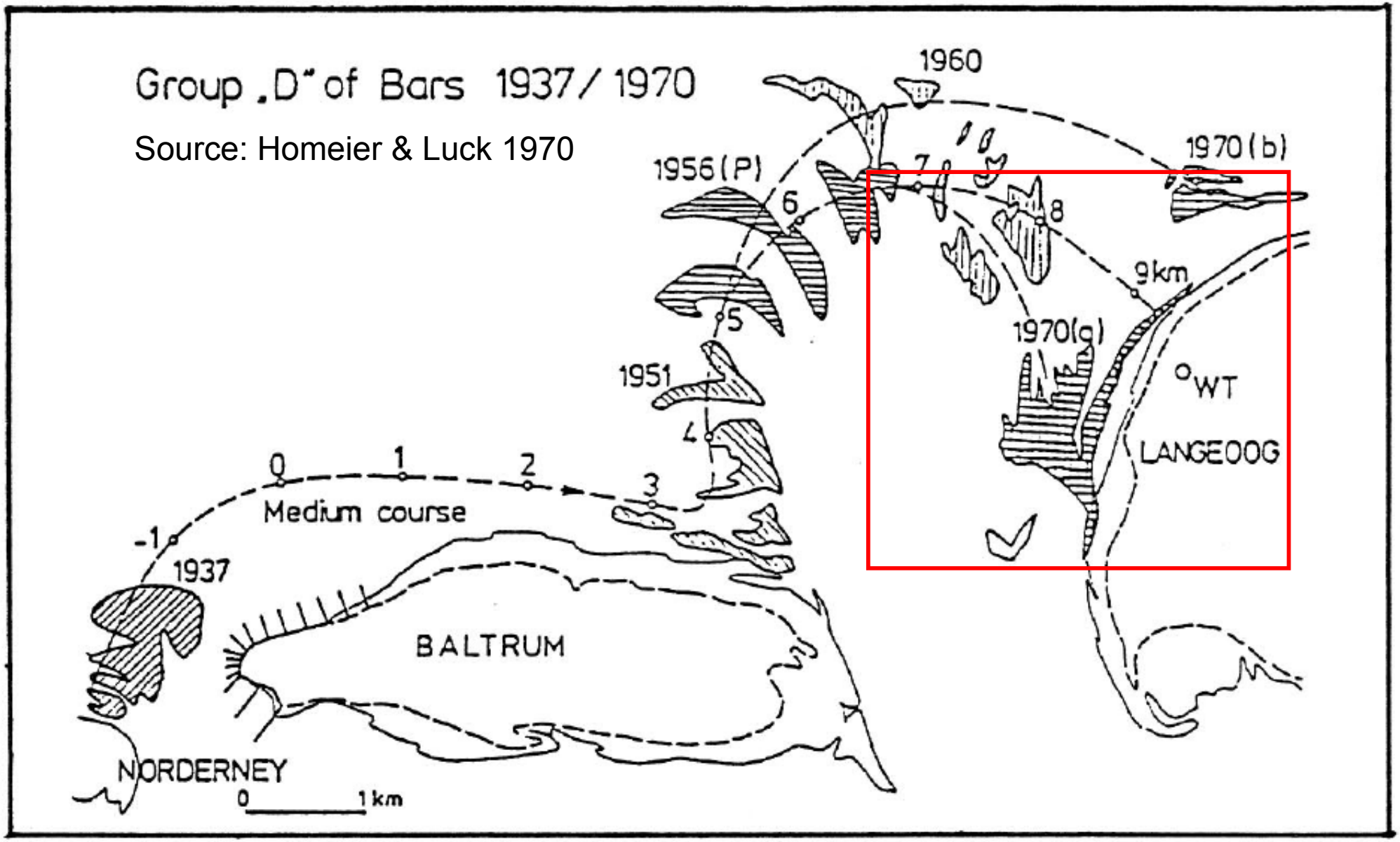
Kunz (1987)

Migration (Littoral Drift) of Sand Bars (1937 to 1970) and development of ebb delta shoals which sporadicly supply Langeoog West with Sand



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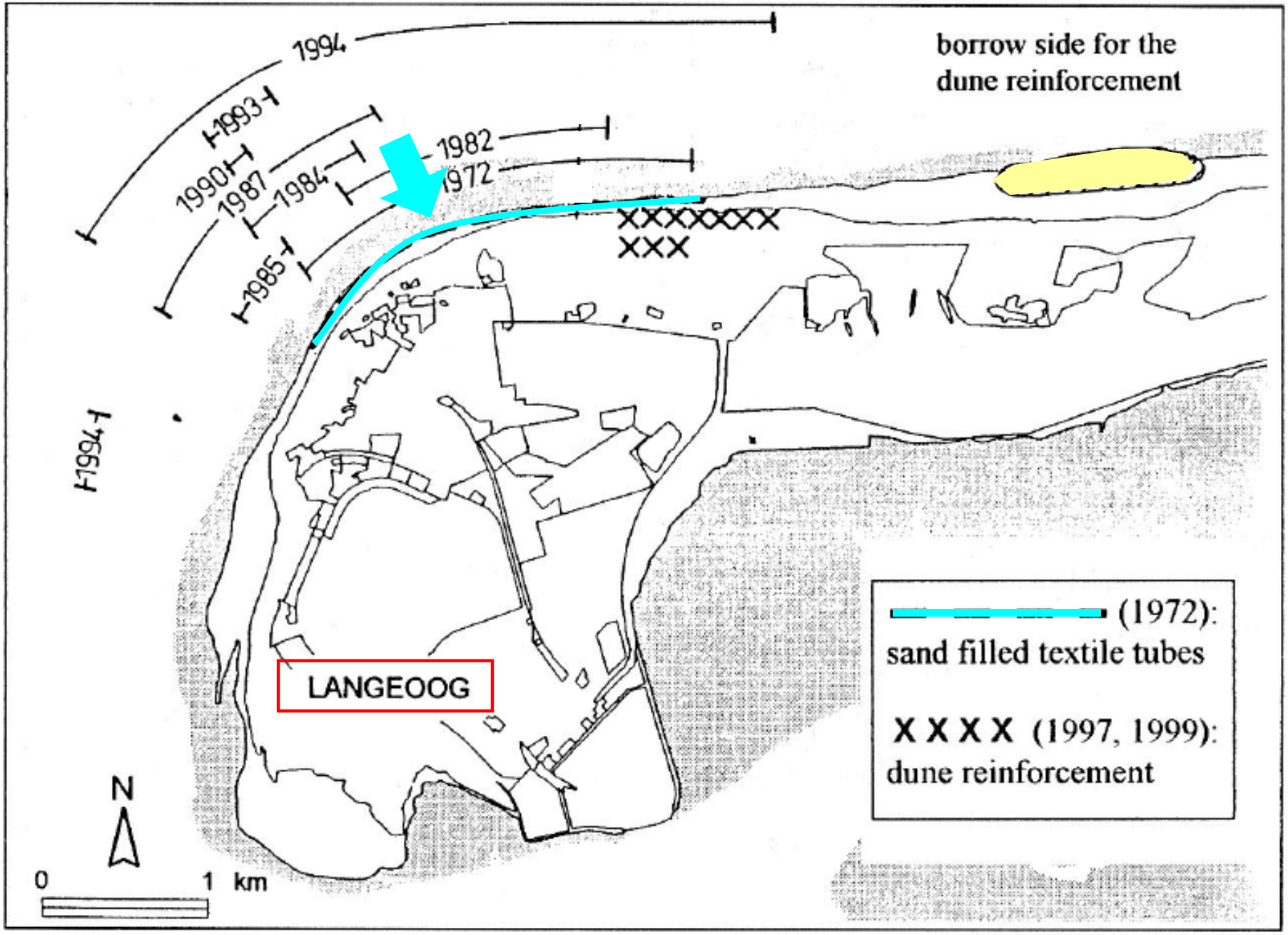
Kunz (1995)

Beach Nourishment and Dune reinforcement on Langeoog Island (1972 to 1994)



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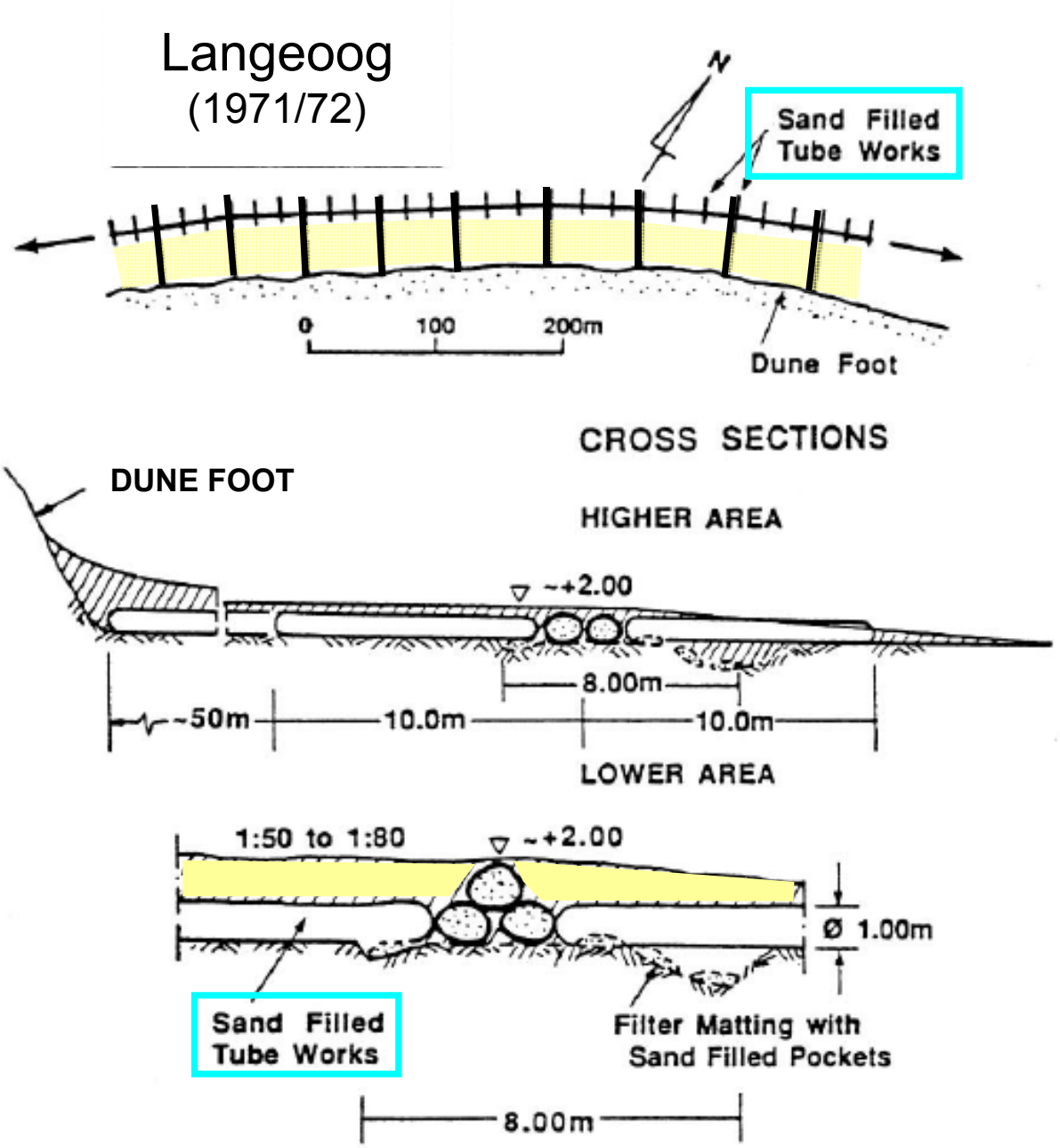
Kunz & Stephan (2001)

Beach Nourishment stabilised by sand filled textile tubes



Kunz (1987)

Sand Filled Tube Works on Langeoog

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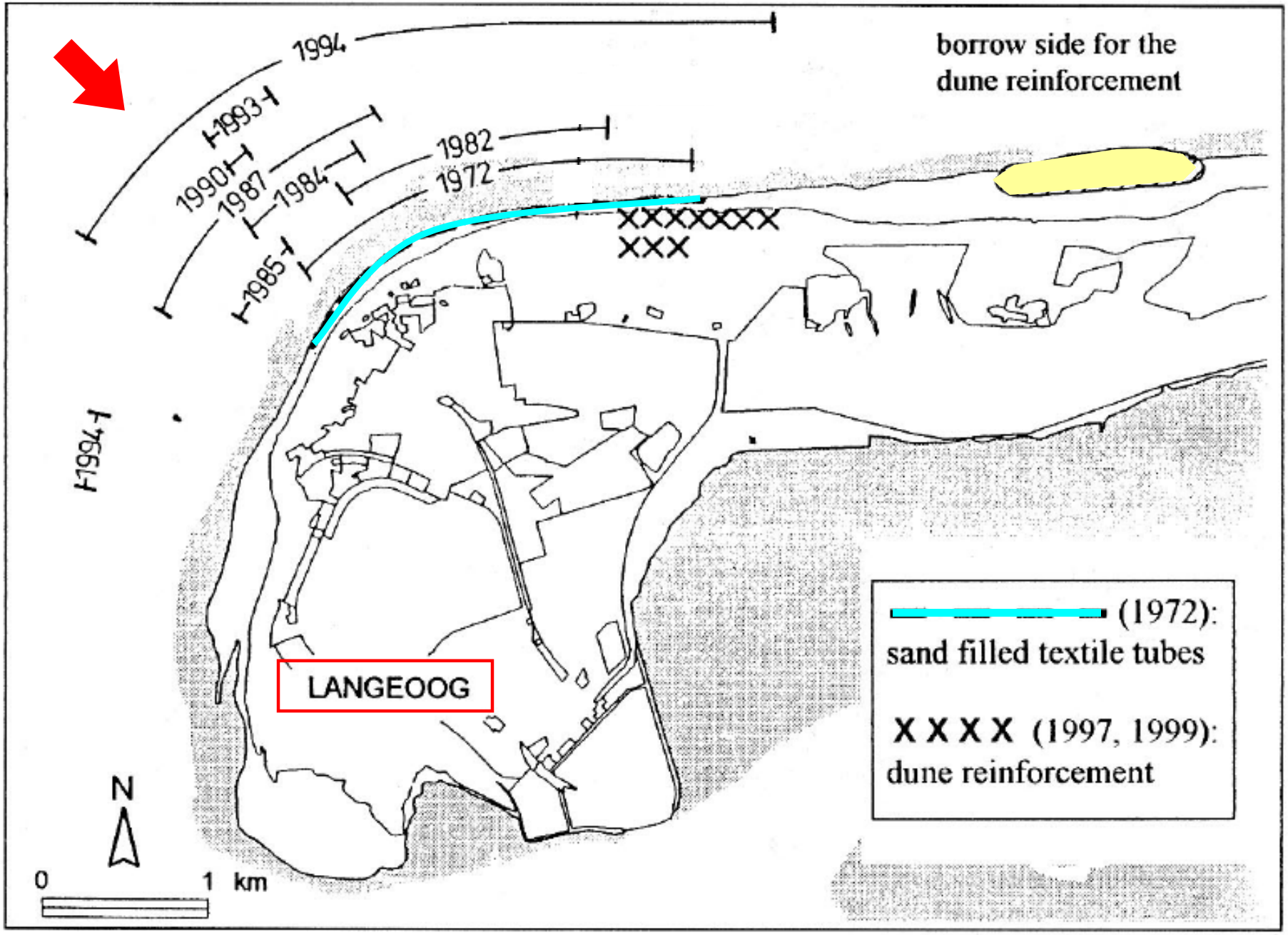
Beach Nourishment and Dune reinforcement on Langeoog Island (1972 to 1994)



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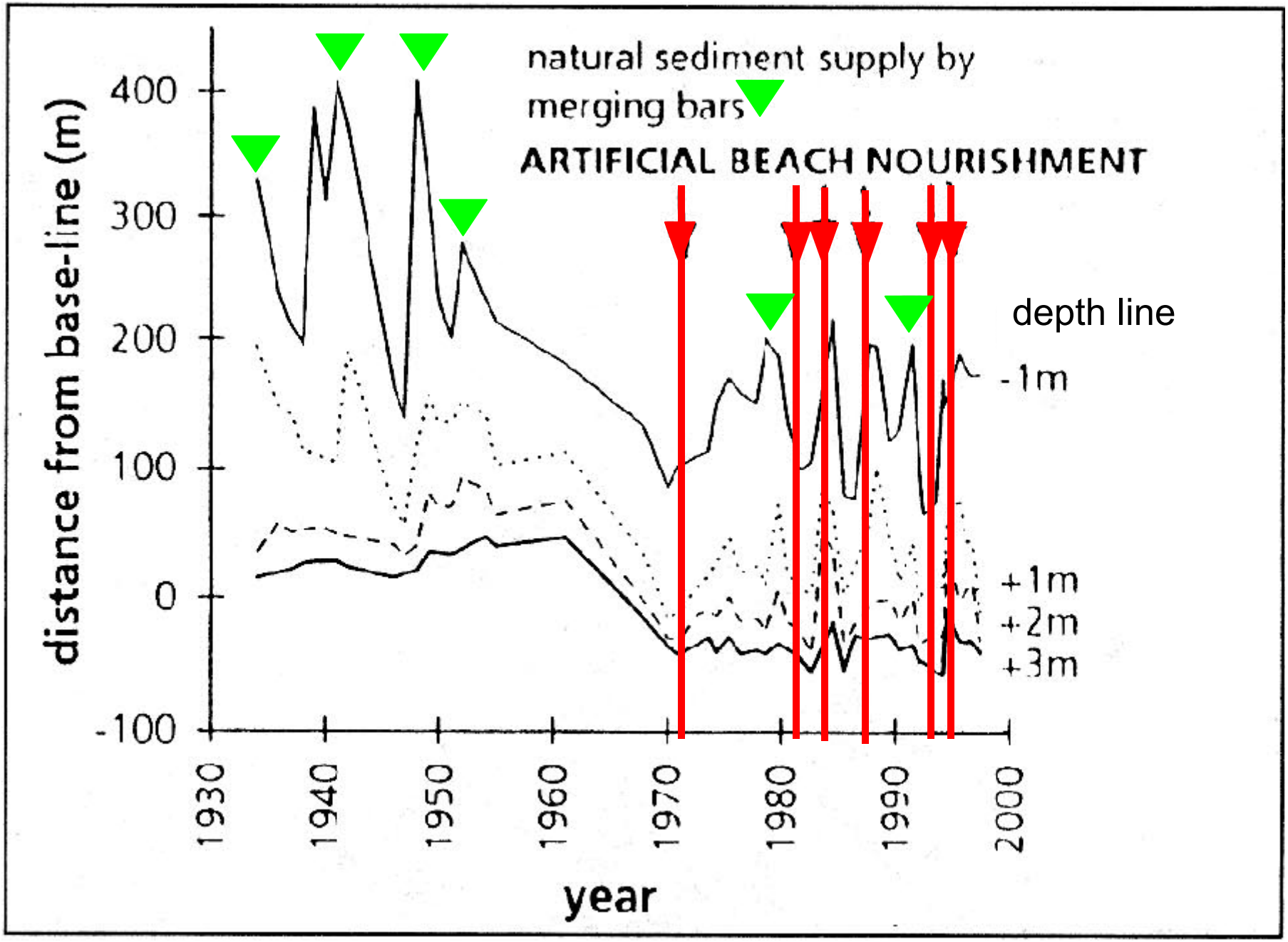
Kunz & Stephan (2001)

Artificial Beach Nourishment on Langeoog during periods without sufficient natural sand supply by merging sand bars



Kunz & Stephan (2001)

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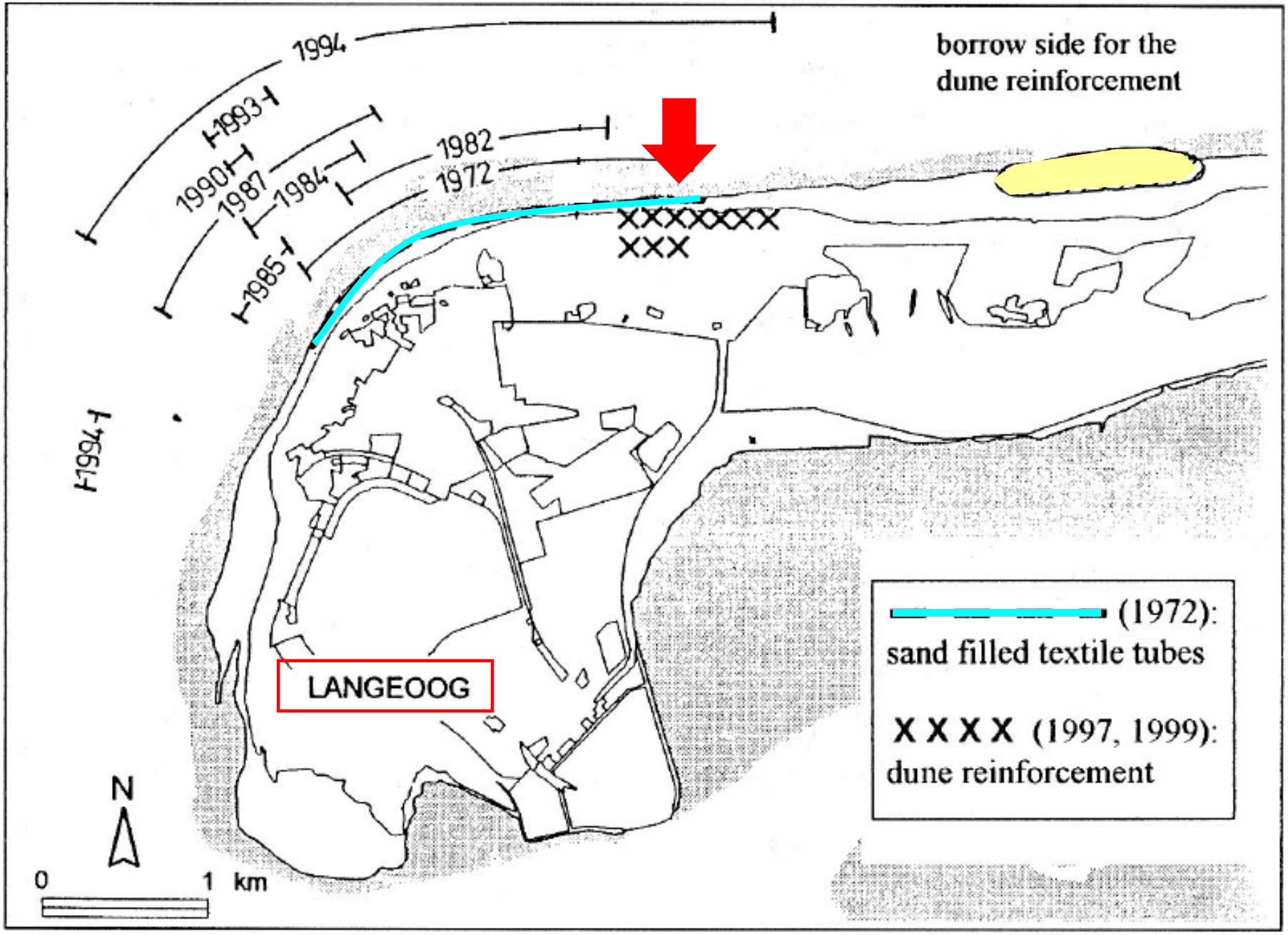

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Kunz & Stephan (2001)


Vulnerable against
Breakthrough
Dune Erosion
Beach Erosion

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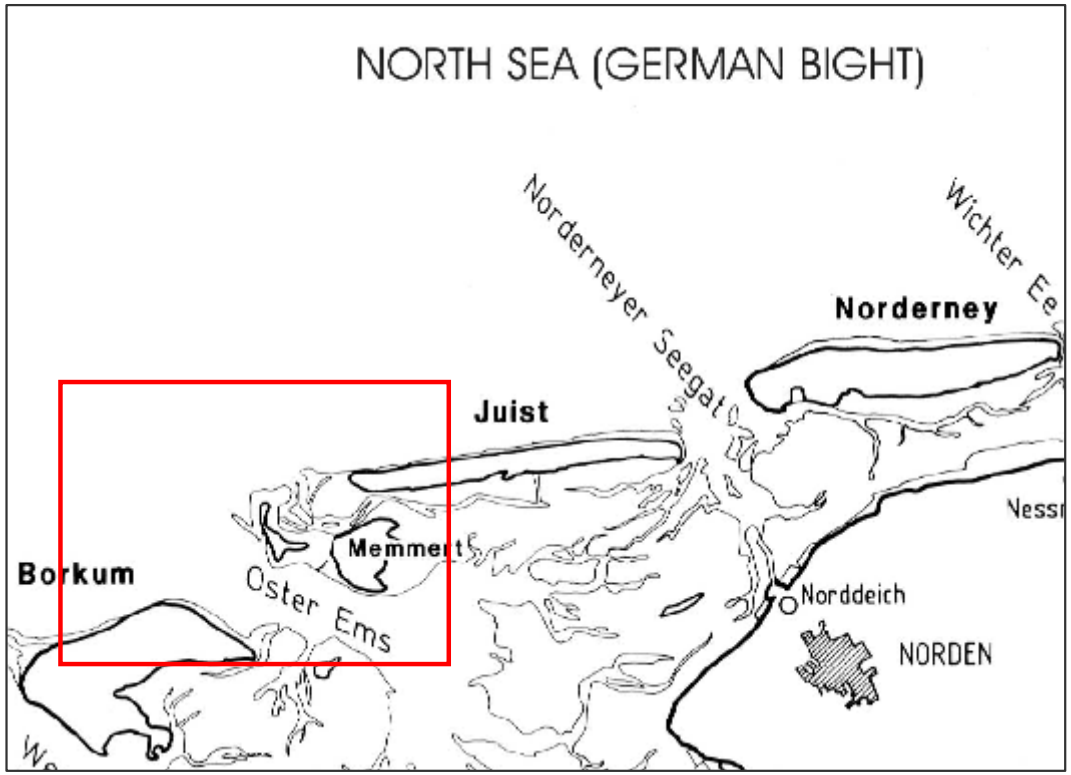
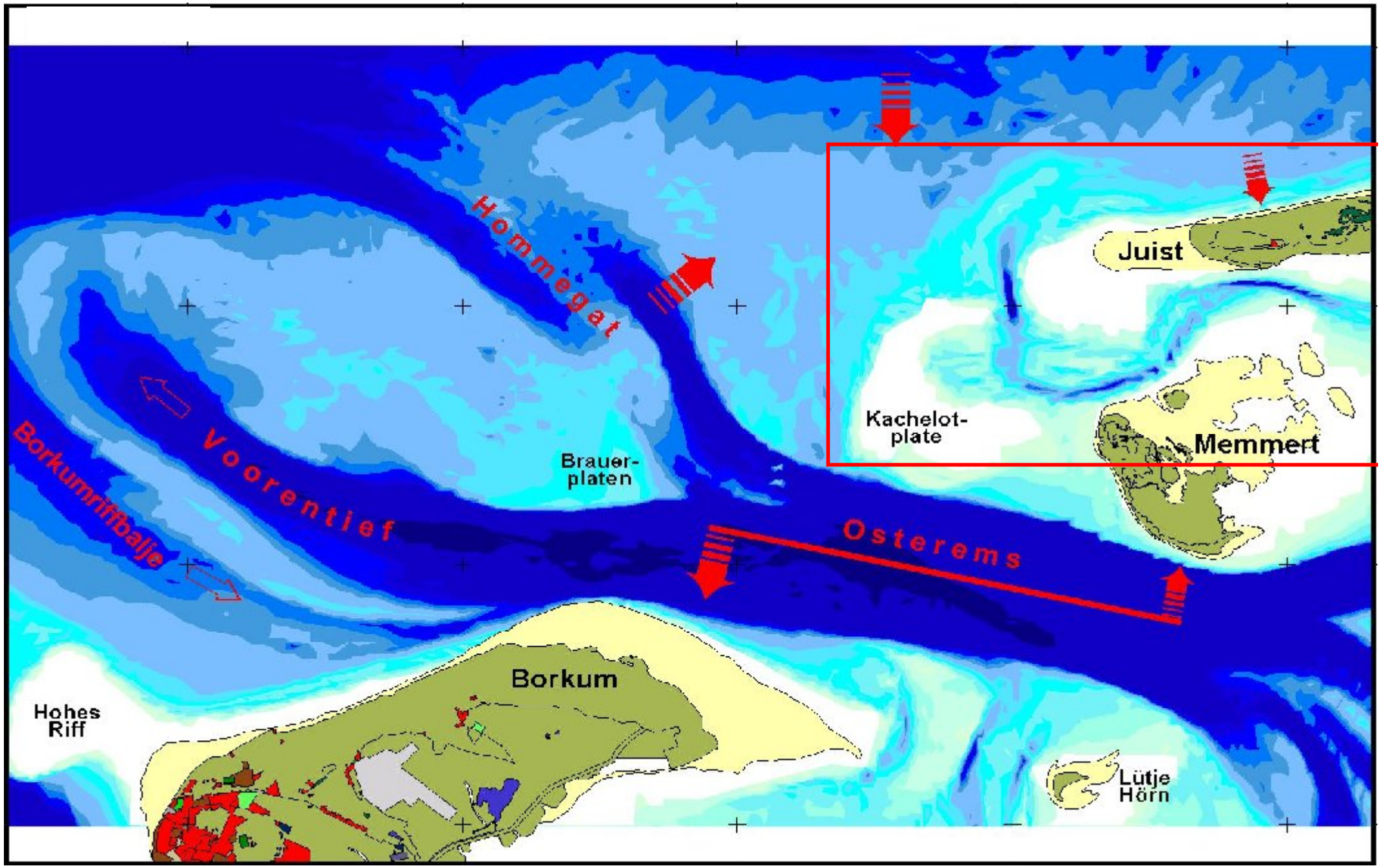
Juist

Erosion on the western part (island and foreshore) created by structural hydro-morphological processes



Artificial Sand Nourishment (“soft”) contra Solid Constructions (“hard”) to cope with the problem of land losses and breakthrough

Impact of Osterems Inlet and of Sand Bars on Juist/Memmert



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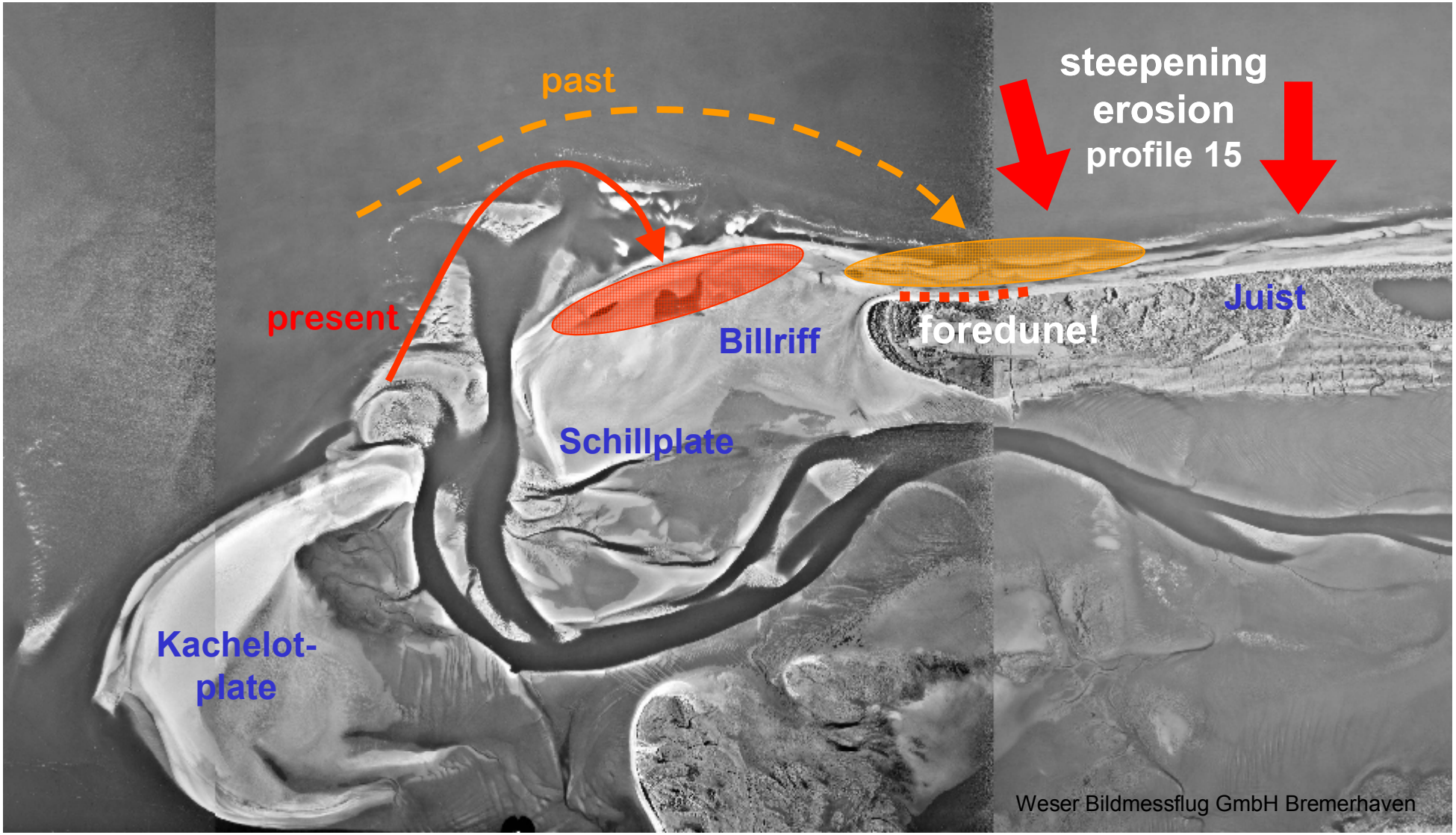
Juist West - Course of Sediment Transport within Sand Bars
Aerial View 2001



Source: Ladage & Kunz (2002)

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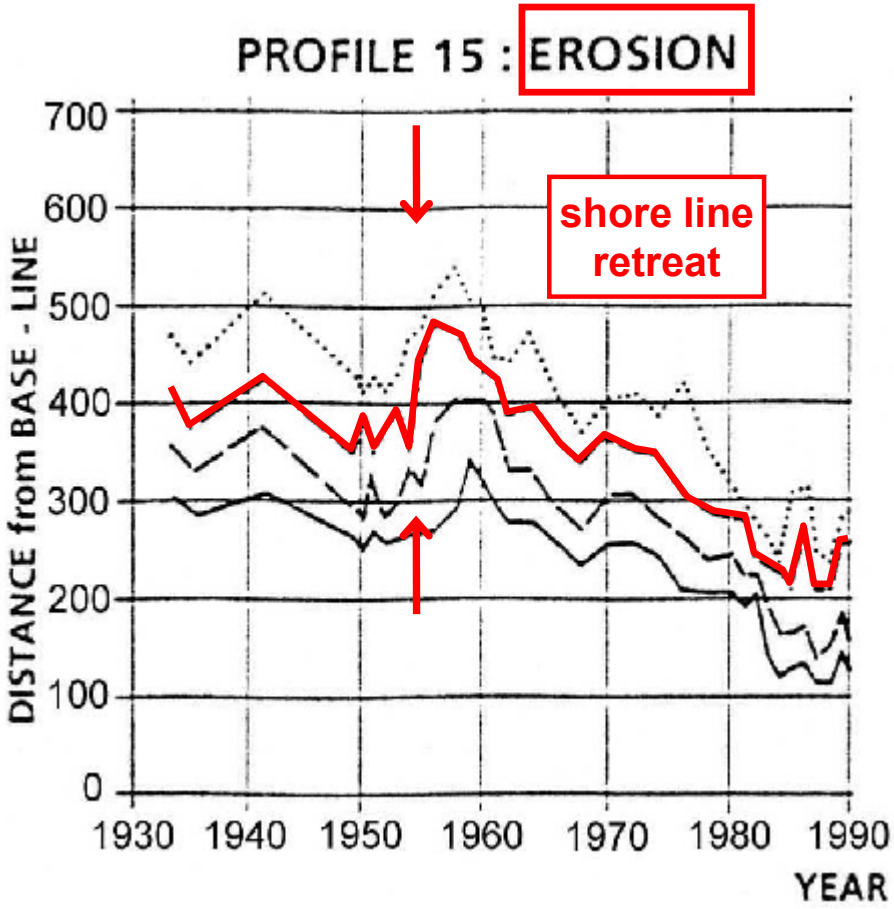
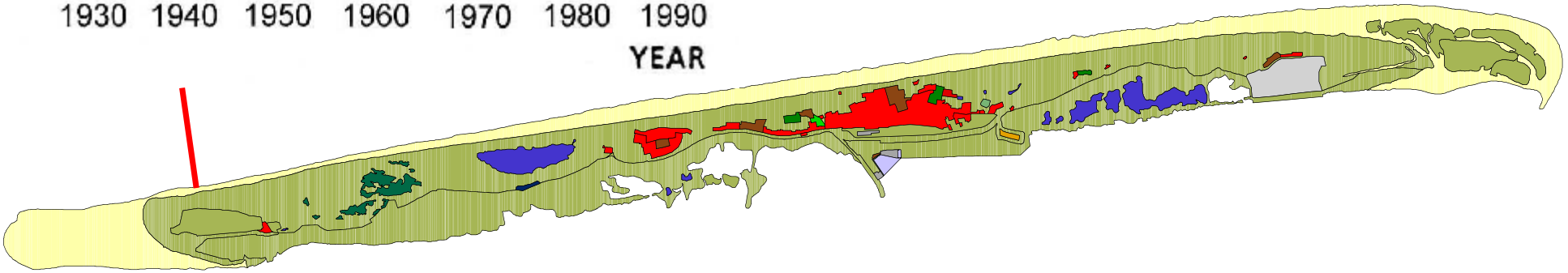
Beach and Fore Shore Juist West: Development 1933 - 1990



Time-Distance Lines

MSL -1.0 m	MSL ±0.0 m
MSL +1.0 m	MSL +2.0 m



Source: Ladage & Kunz (2002)

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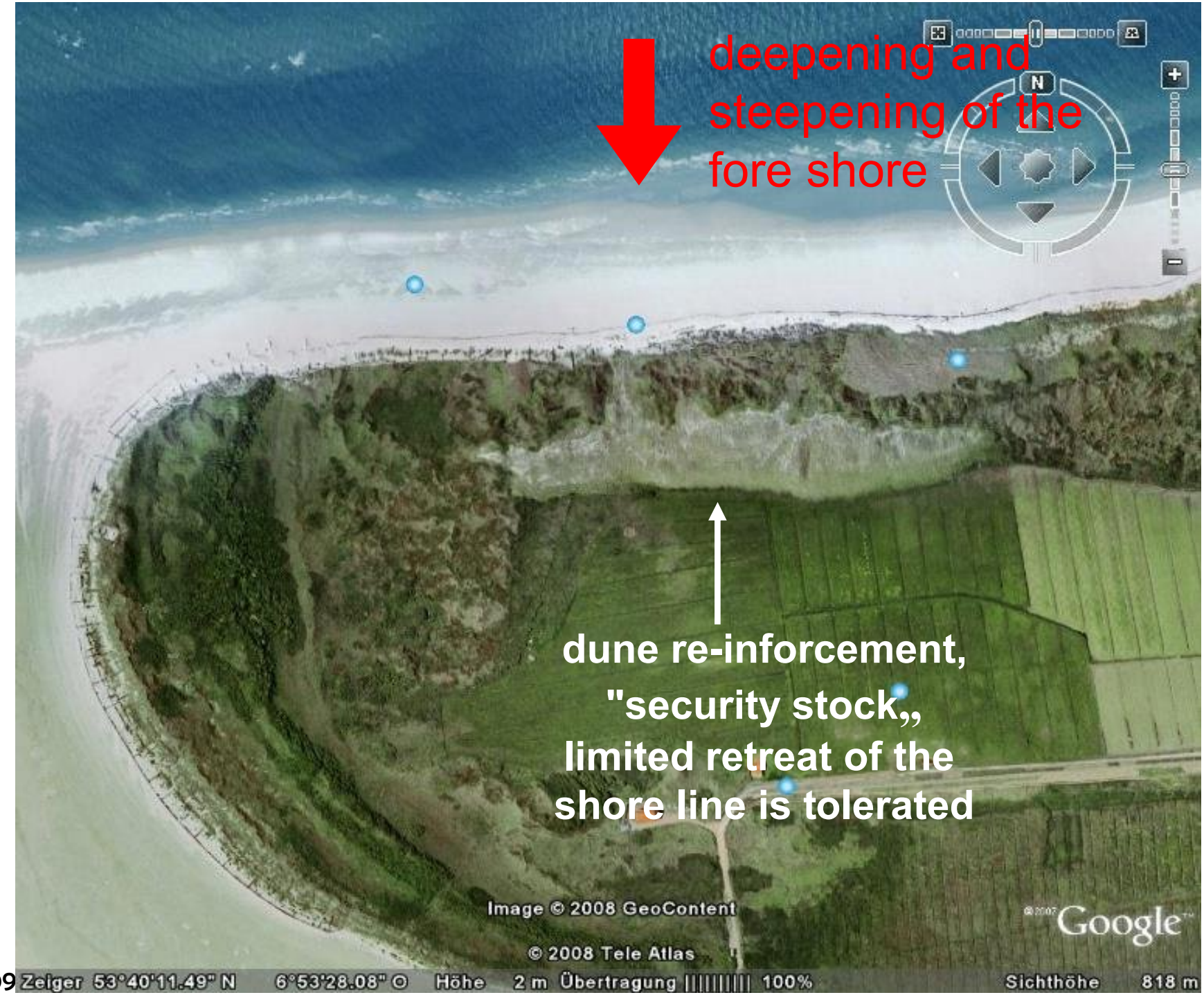
Artificial Nourishment - Juist West



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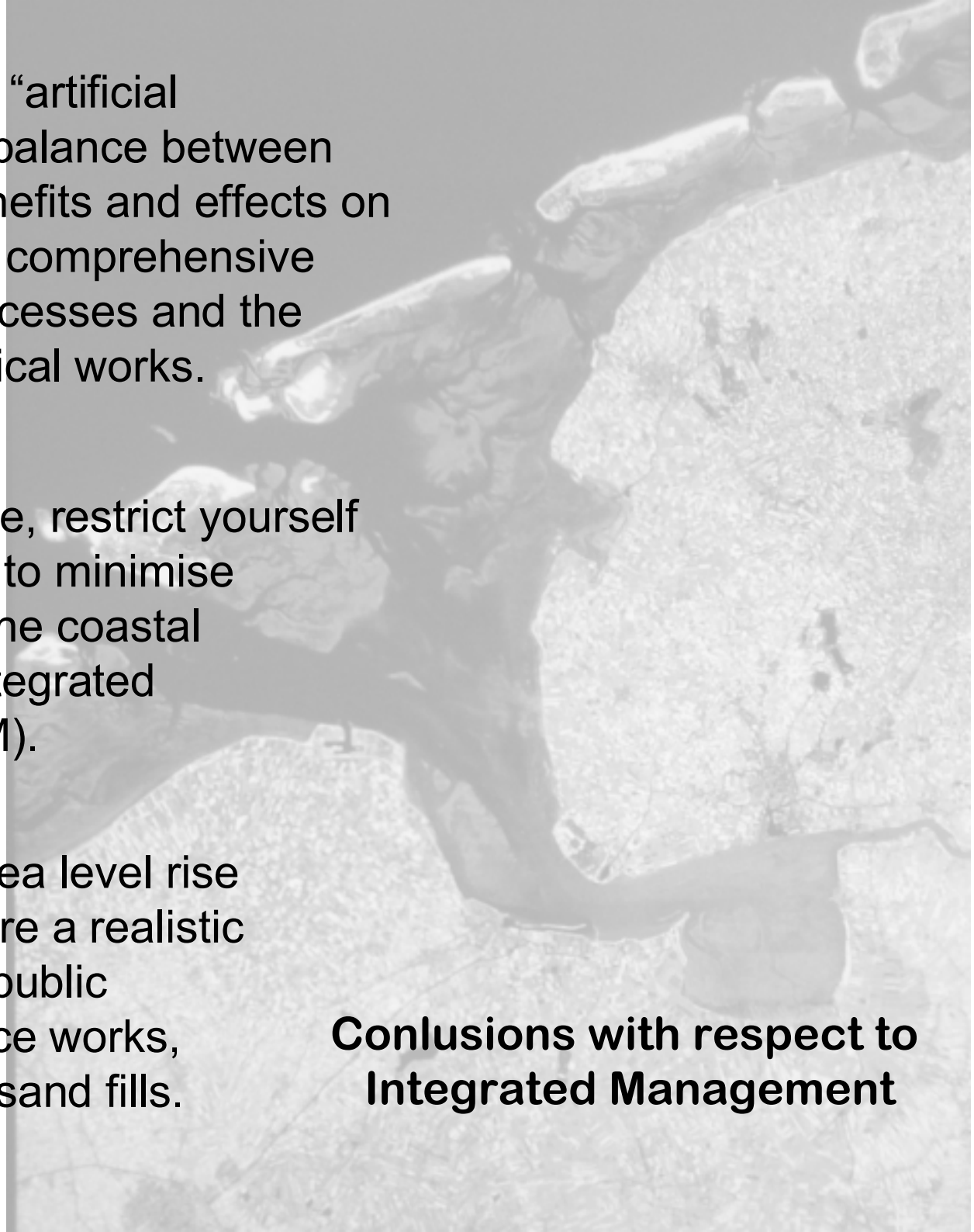

The political valuation of the tool “artificial nourishment” is influenced by a balance between public demands, economical benefits and effects on the environment. This asks for a comprehensive knowledge about the natural processes and the interaction with impacts of technical works.

Accept limitations given by nature, restrict yourself to reasonable targets and agree to minimise harmful impacts of a project on the coastal environment. This calls for an integrated management concept (e.g. ICZM).

An acceleration of the regional sea level rise as well as higher storm surges are a realistic perspective. This enhances the public demands for solid coastal defence works, possibly combined with artificial sand fills.

Conlusions with respect to Integrated Management