The N-EWN Knowledge Series

A Continuing Education Series about Engineering with Nature

Dr. Quirijn Lodder

Dutch experience with beaches and dunes as coastal Natural and Nature Based Features for Flood Risk Management - An overview of 30 years of nature-based coastline management

Dr. Evelien Brand

Rijkswaterstaat

Coastal erosion threatens beaches and dunes globally. In the Netherlands, a coastline maintenance policy was implemented in the 1990's to combat this erosion, with sand nourishments as the primary means. As a result, the Dutch coast is one of the most heavily nourished coasts globally with an average of 12 mln. m^3 that is annually added to the coastline of only 432 km for dynamic coastline conservation. Our nourishment approach has evolved over the past 35 years and recently we reported on the lessons learned regarding the nourishment design. Furthermore, we evaluated the cumulative effects of these nourishments against the overarching goals of the coastal policy. Overall, the approach of coastline maintenance with regular proactive nourishments has proven to be successful.

Save the date!

Upcoming webinars will take place the 3rd Thursday of the month.

Mar. 19 12:30pm ET

Dr. Quirijn Lodder and Dr. Evelien Brand, Rijkswaterstaat

Dutch experience with beaches and dunes as coastal Natural and Nature Based Features for Flood Risk Management - An overview of 30 years of nature-based coastline management

Apr. 16 12:30pm ET

Dr. Anthony Aufdenkampe, LimnoTech

Modern, reproducible modeling workflows for water feature design

May 21 12:30pm ET

Sarah Copertino, USACE, Omaha District Planning Branch

EWN Compass Tool

Register here: https://bit.ly/3gR9ADL **or scan:**

1 Continuing Education Credit (CEC) is available to attendees

Recorded webinars will be posted online at: https://n-ewn.org/resources/n-ewn-knowledge-seminars/

Presented by:

NETWORK FOR ENGINEERING WITH NATURE

LimnoTech Water Environment Scientists Engineers

UNIVERSITY OF GEORGIA

ERDC

Questions? Please contact:
Alex Curwin, LimnoTech
acurwin@limno.com

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

Natural and Nature-Based Features

International Guidelines on Natural and Nature-Based Features for Flood Risk Management

Bridges, T. S., J. K. King, J. D. Simm, M. W. Beck, G. Collins, **Q. Lodder**, and R. K. Mohan, eds. 2021. International Guidelines on Natural and Nature-Based Features for Flood Risk Management. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://dx.doi.org/10.21079/11681/41946

Principles and approach to NNBF

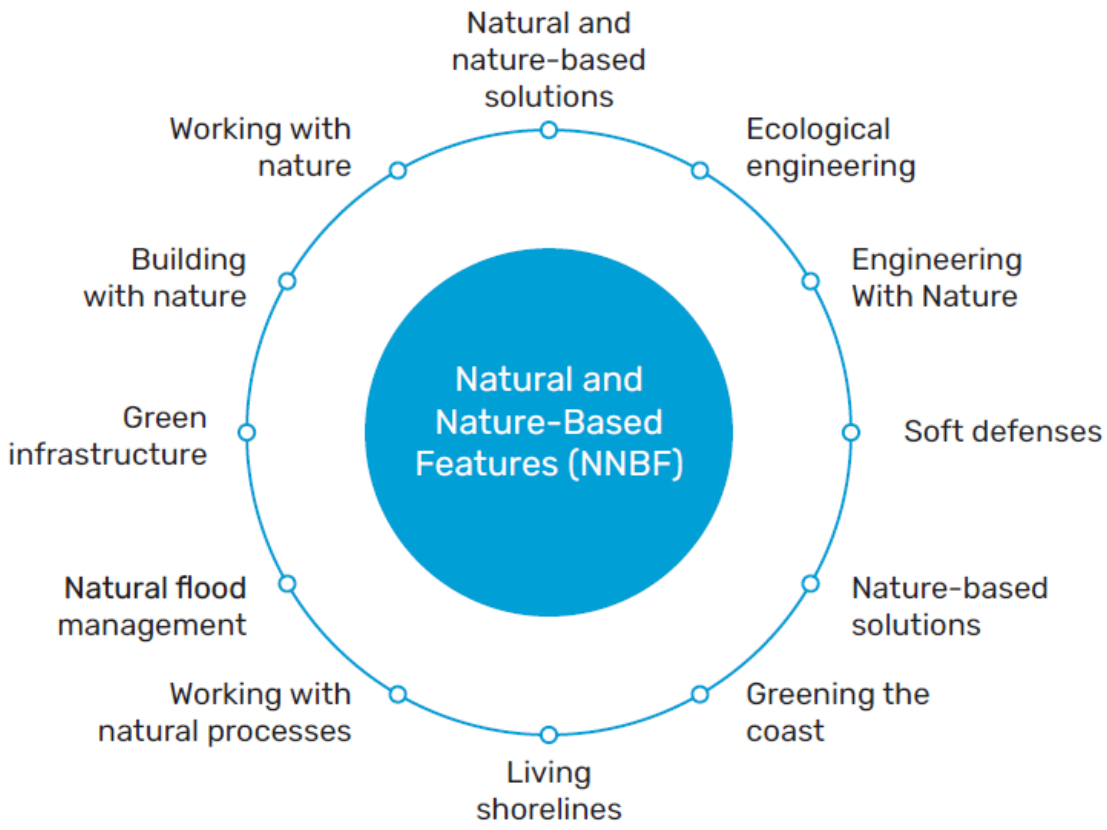
Use a systems approach to leverage existing components and projects and their interconnectivity.

Engage communities, stakeholders, partners, and multidisciplinary team members to develop innovative solutions.

Identify sustainable and resilient solutions that produce multiple benefits.

Anticipate, evaluate, and manage risk in project or system performance.

Expect change and manage adaptively.



Source: Nigel Pontee, Jacobs

Use a systems approach to leverage existing components and projects and their interconnectivity.

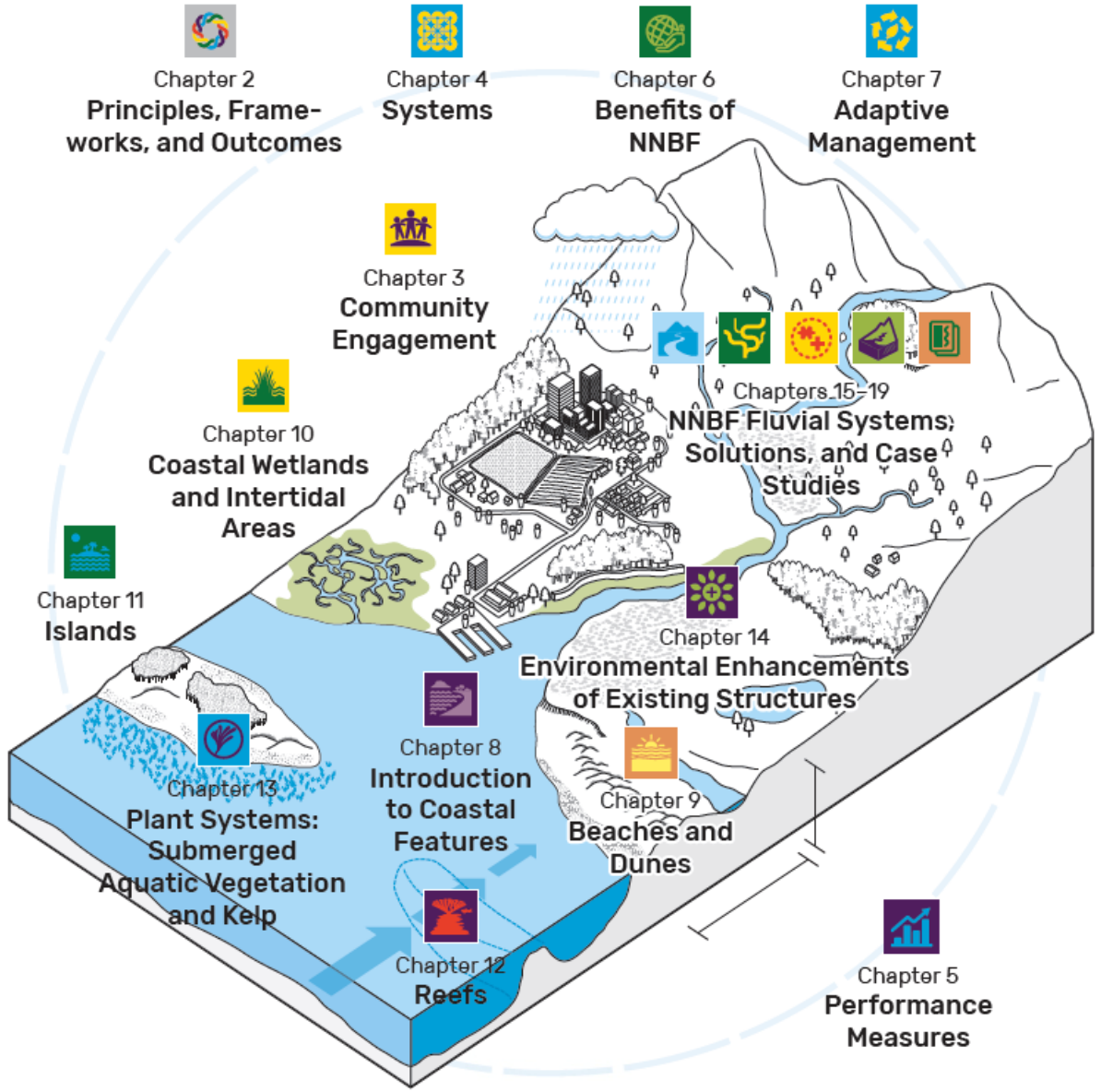
Beaches and Dunes

Principles, Outcomes and Framework

NNBF Performance

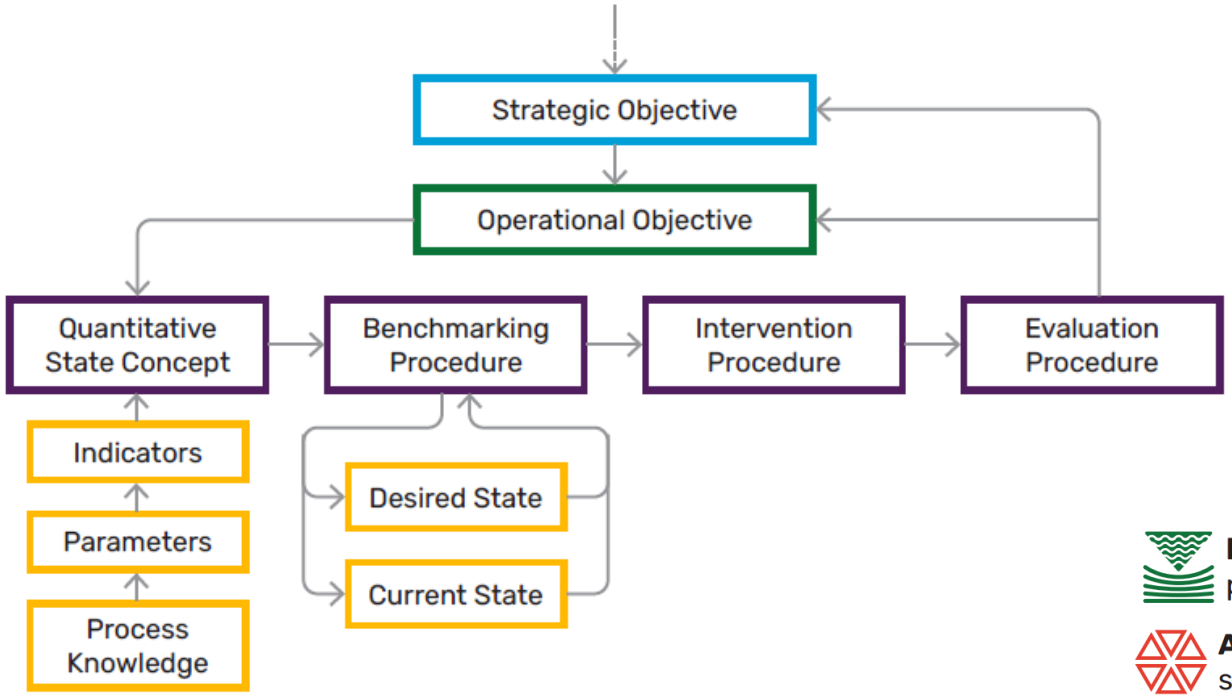
Benefits of NNBF

Figure 1.2. *Contents and Concepts of NNBF Guidelines Linked to a Watershed Approach*



Define objectives at Strategic, Tactical and Operational level

Figure 4.20. *Frame of Reference Management Framework*



Source: Adapted from van Koningsveld and Mulder 2004

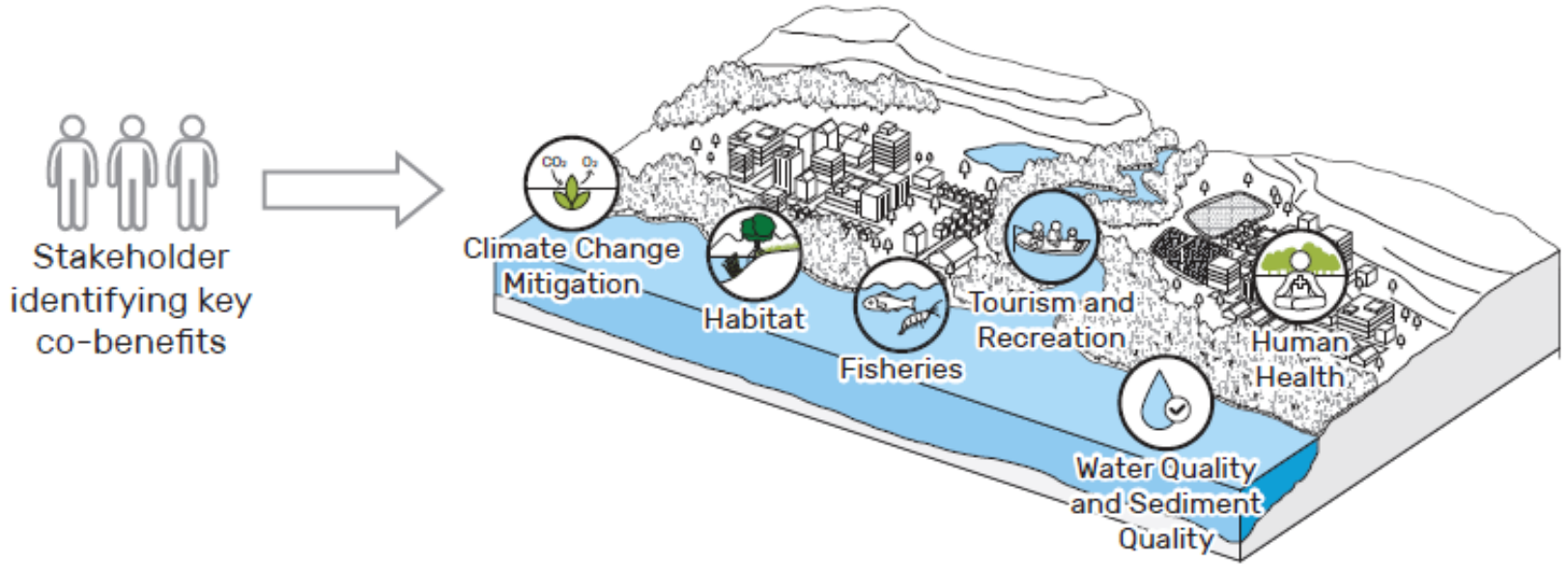
Identify sustainable and resilient solutions that produce multiple benefits.

Anticipate, evaluate, and manage risk in project or system performance.

Expect change and manage adaptively.

Identify key Co-Benefits, not all benefits have to be monitizable

Figure 6.6. *The Scoping and Identifying of Key Co-Benefits for an NNBF Project through Engaging with Stakeholders*

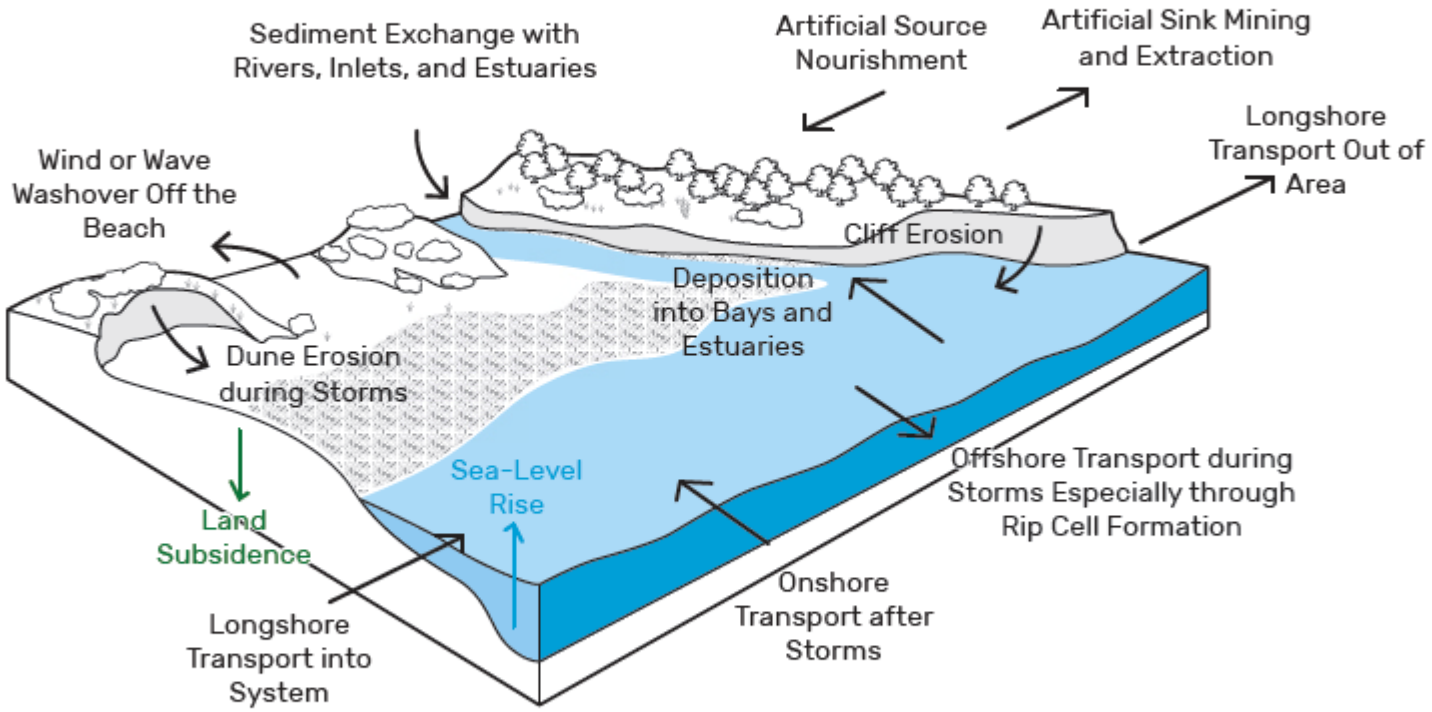


Engage communities, stakeholders, partners, and multidisciplinary team members to develop innovative solutions.

Identify sustainable and resilient solutions that produce multiple benefits.

Draft conceptual models of the physical processes acting in the project larger scale environment

Figure 9.6. ***Conceptual Model of Physical Processes for a Hypothetical Beach and Dune System***

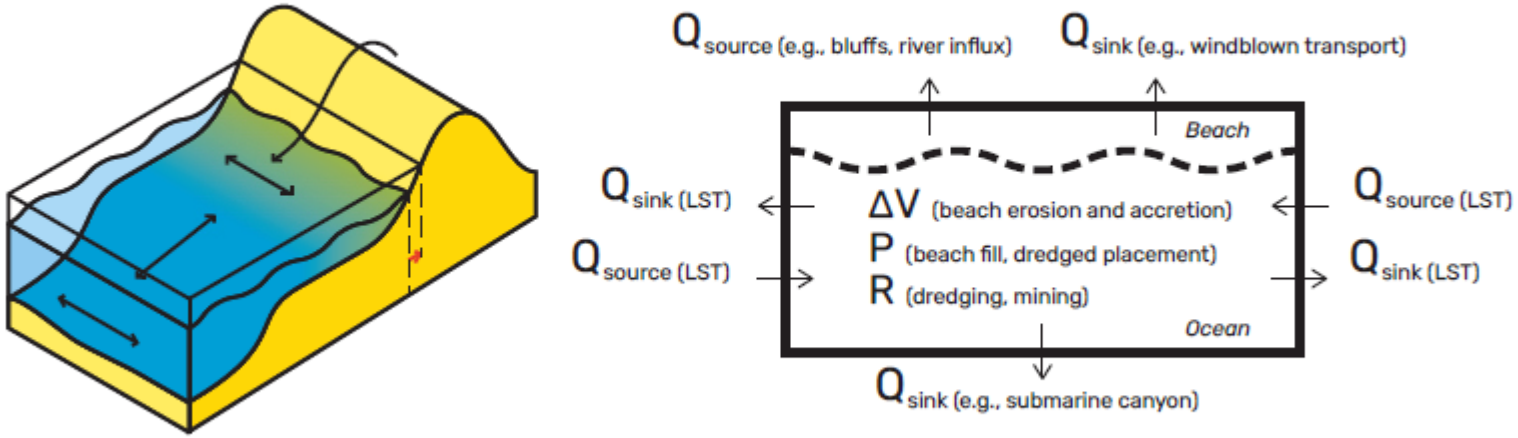


Source: Adapted from DSE 2012, Figure 5-4

Use a systems approach to leverage existing components and projects and their interconnectivity.

Quantify the sediment budgets!

Figure 9.7. *Concept to Quantify the Sediment Budget Analysis of a Coastal System in Terms of Sediment Volume Changes and Estimating Associated Sediment Fluxes and Human Interventions*



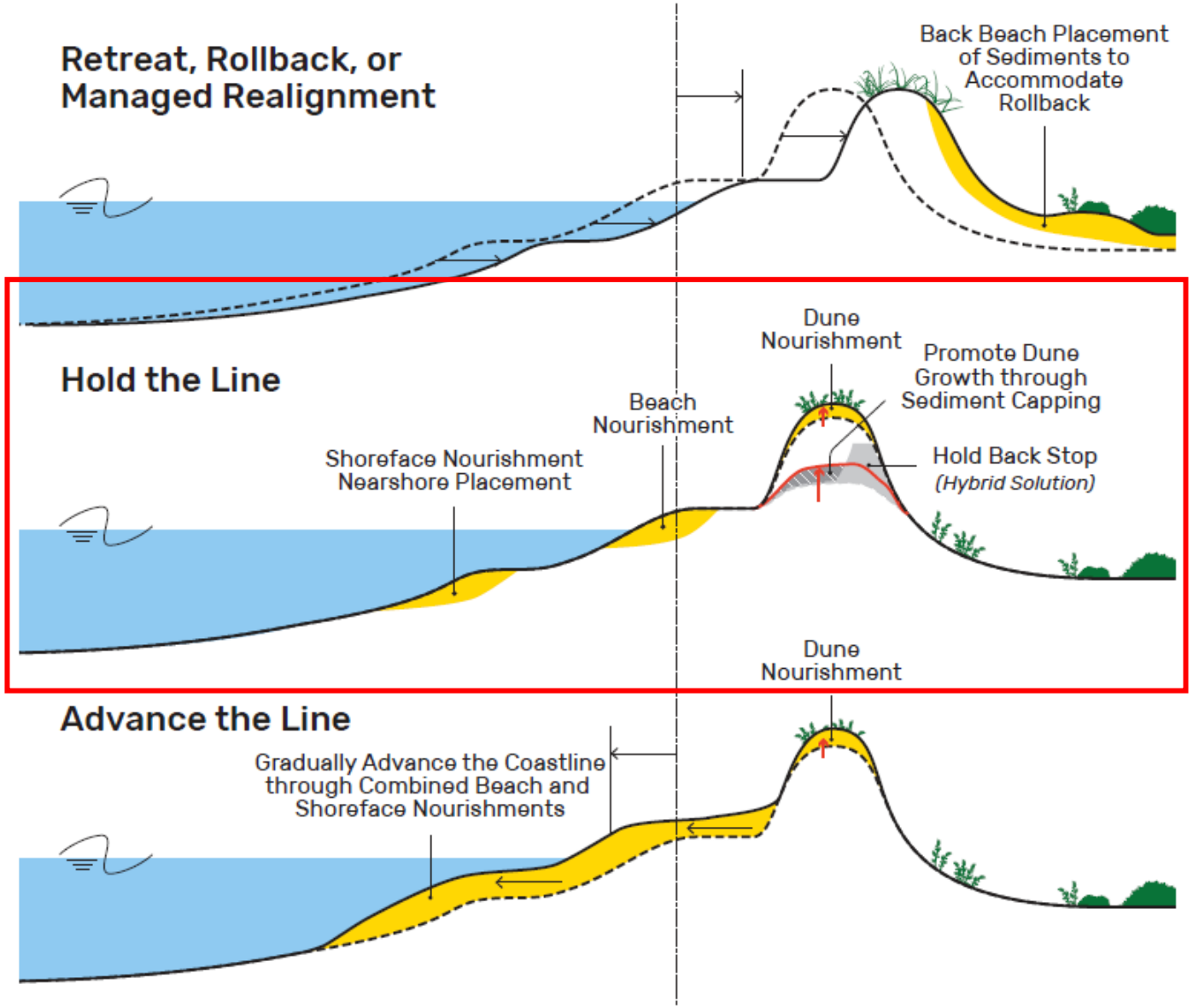
Abbreviation:
LST: longshore transport

Identify sustainable and resilient solutions that produce multiple benefits.

Draft conceptual designs for NNBF at landscape scale.

Connect the designs to generic strategies (Retreat, Hold the Line and Advance)

Figure 9.16. *Three General Conceptual Designs for Beach and Dune Systems*



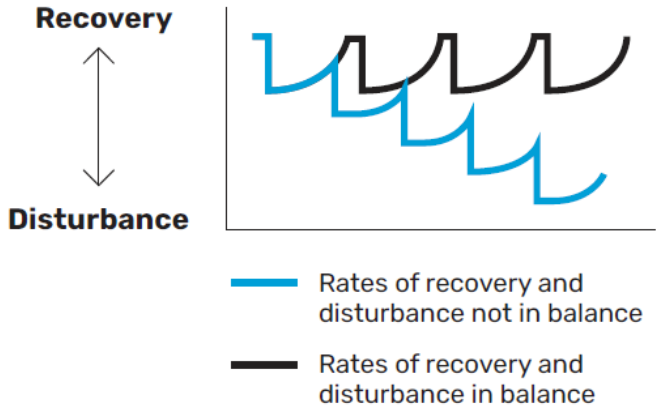
Engage communities, stakeholders, partners, and multidisciplinary team members to develop innovative solutions.

Consider Recovery versus Disturbance

&

Short variations and Long-Term Trends

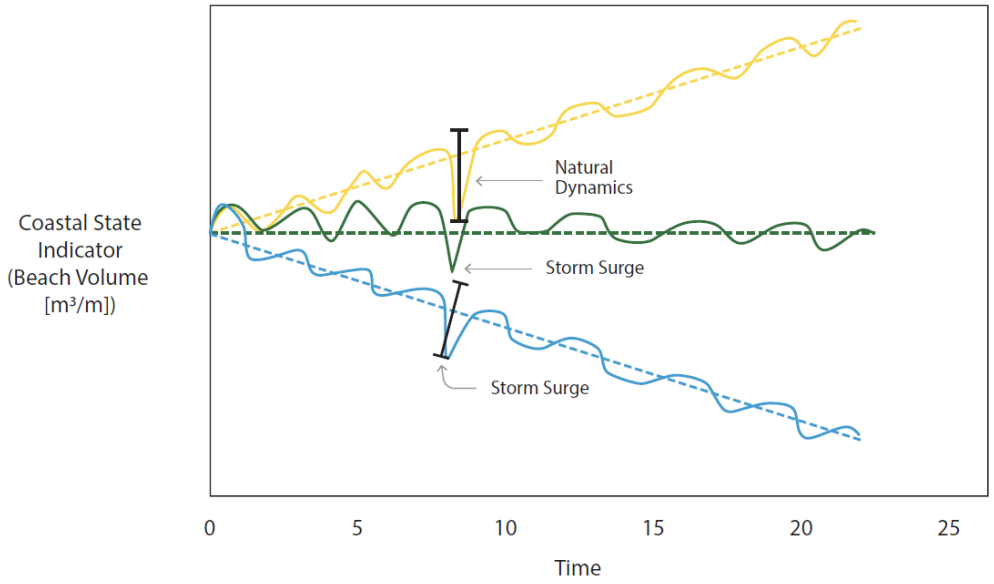
Figure 9.22. *Recovery versus Disturbance*



Note: When disturbance happens more frequently than the time needed for recovery, a negative trend will result. Note that other factors can also influence the patterns in ecosystem functioning (e.g., sea-level rise, pollution).

Source: Adapted from Palumbi, McLeod, and Grünbaum 2008

Figure 9.9. *Conceptual Time Series of Beach Volume, as Coastal State Indicator, Displaying Short Variations and Long-Term Trends in Sediment Volume Changes*



Abbreviation:
m³/m: cubic meters per meter

Key knowledge gap

What is the **cumulative** effect of sediment nourishments at large spatial and long timescales?

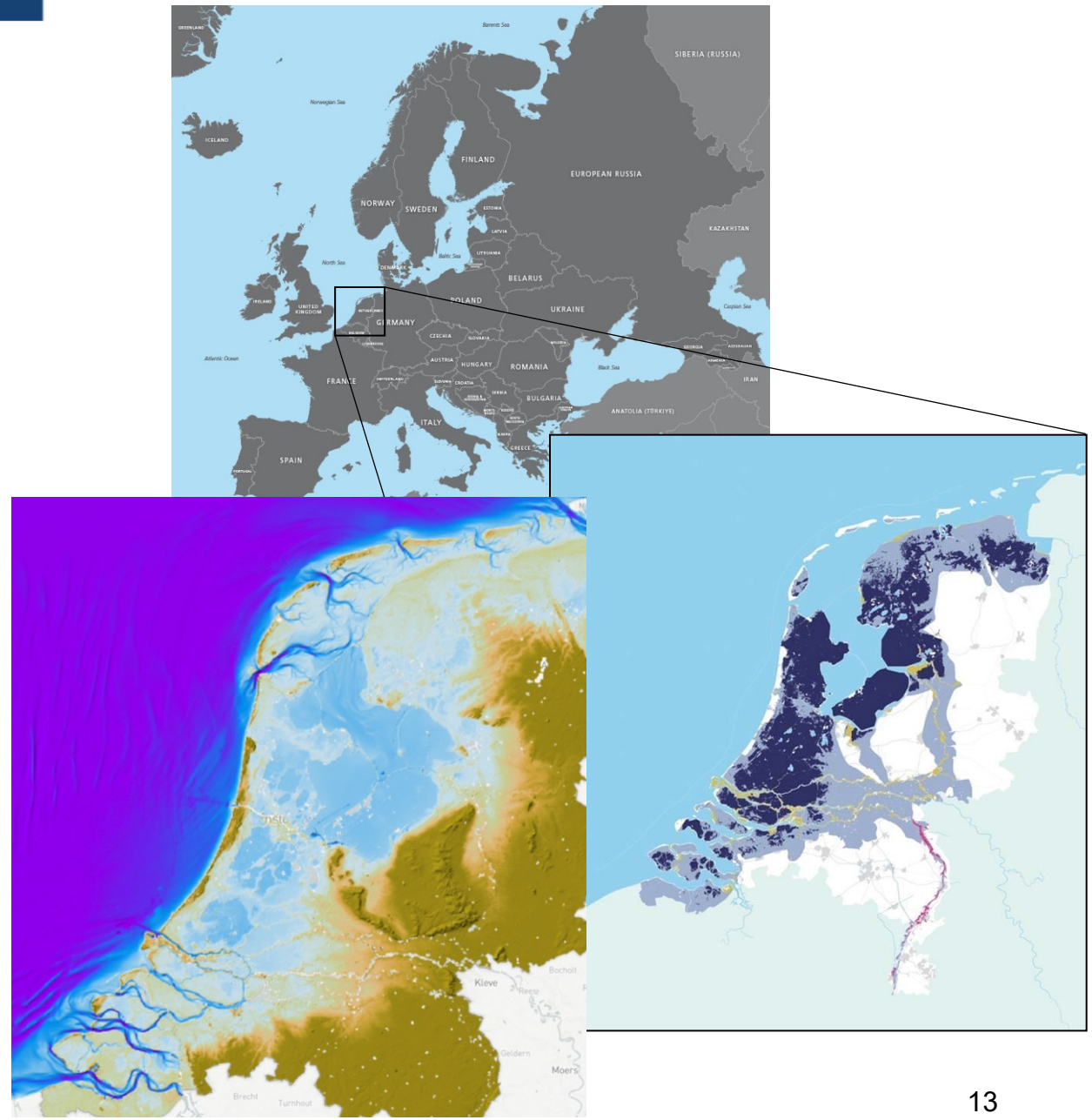
Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

The Dutch coast

And coastal policy

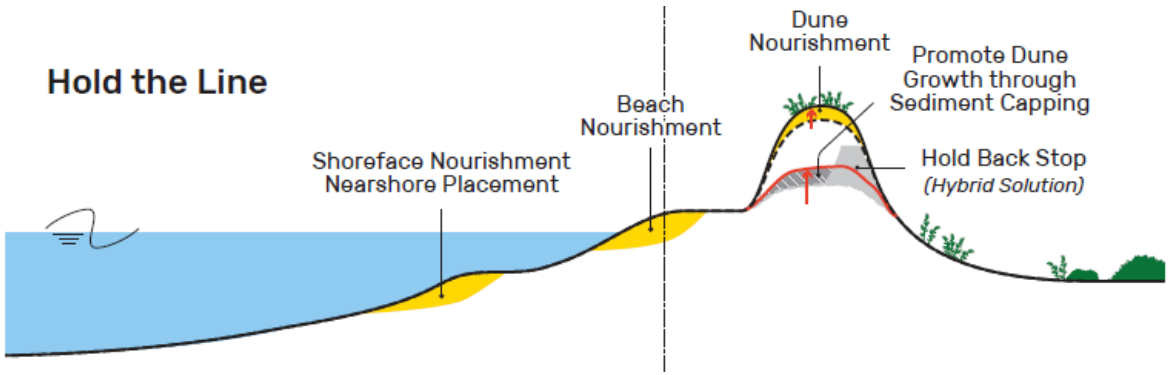
The Dutch coast

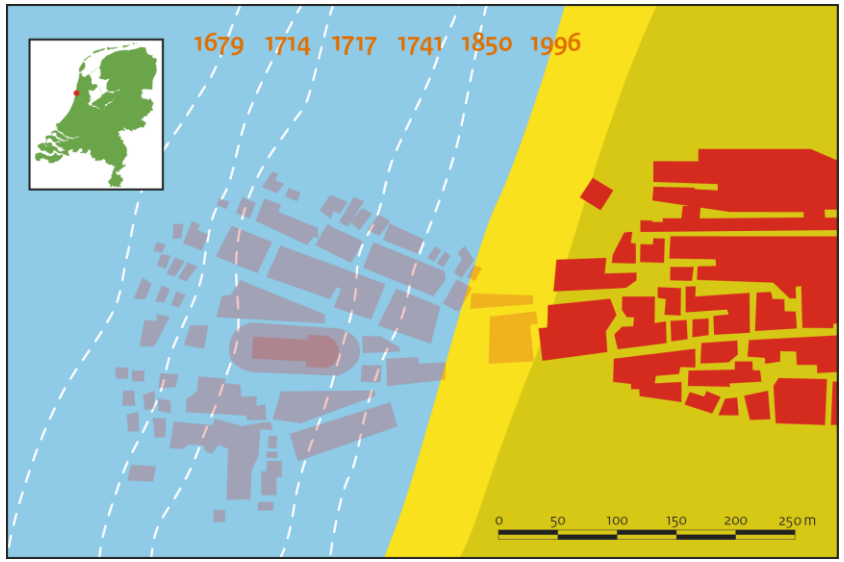
- 26 % below sea level, 60 % of our population lives below sea level
- 432 km of coastline, dunes and hard sea defences
- Varying morphology:
  - Delta with (closed-off) estuaries
  - Straight central coast
  - Barrier islands



The Dutch coast

- A structural sediment deficit resulted in a retreating coastline
- Coastal erosion threatened socio-economics
- Since the 1990's 'hold the line' was set in the coastal policy





The Dutch coast

Strategic goal

Sustainable preservation of flood safety and values of the coast

Tactical approach

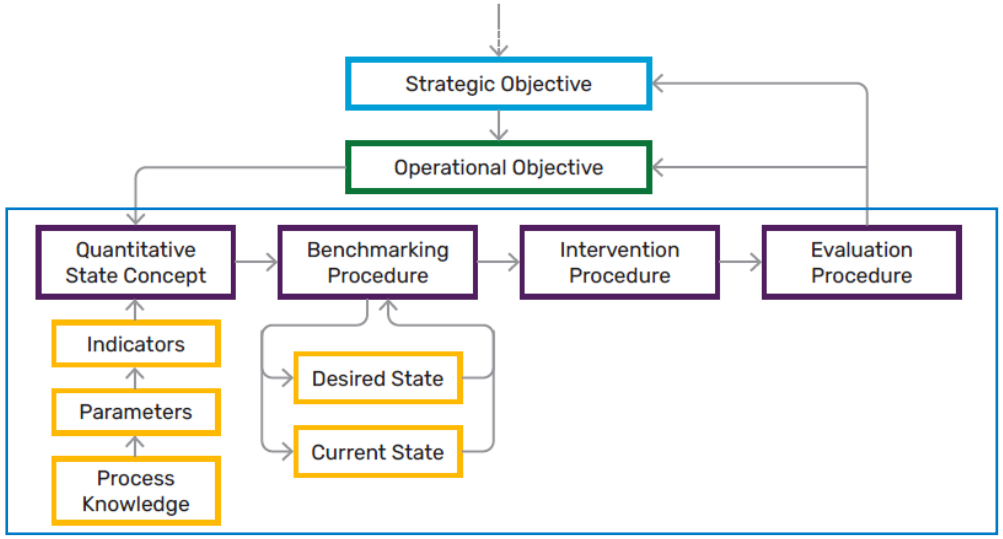
Sediment budget in equilibrium

Operational objectives

Dynamic coastline maintenance

Coastal foundation in equilibrium with sea level rise

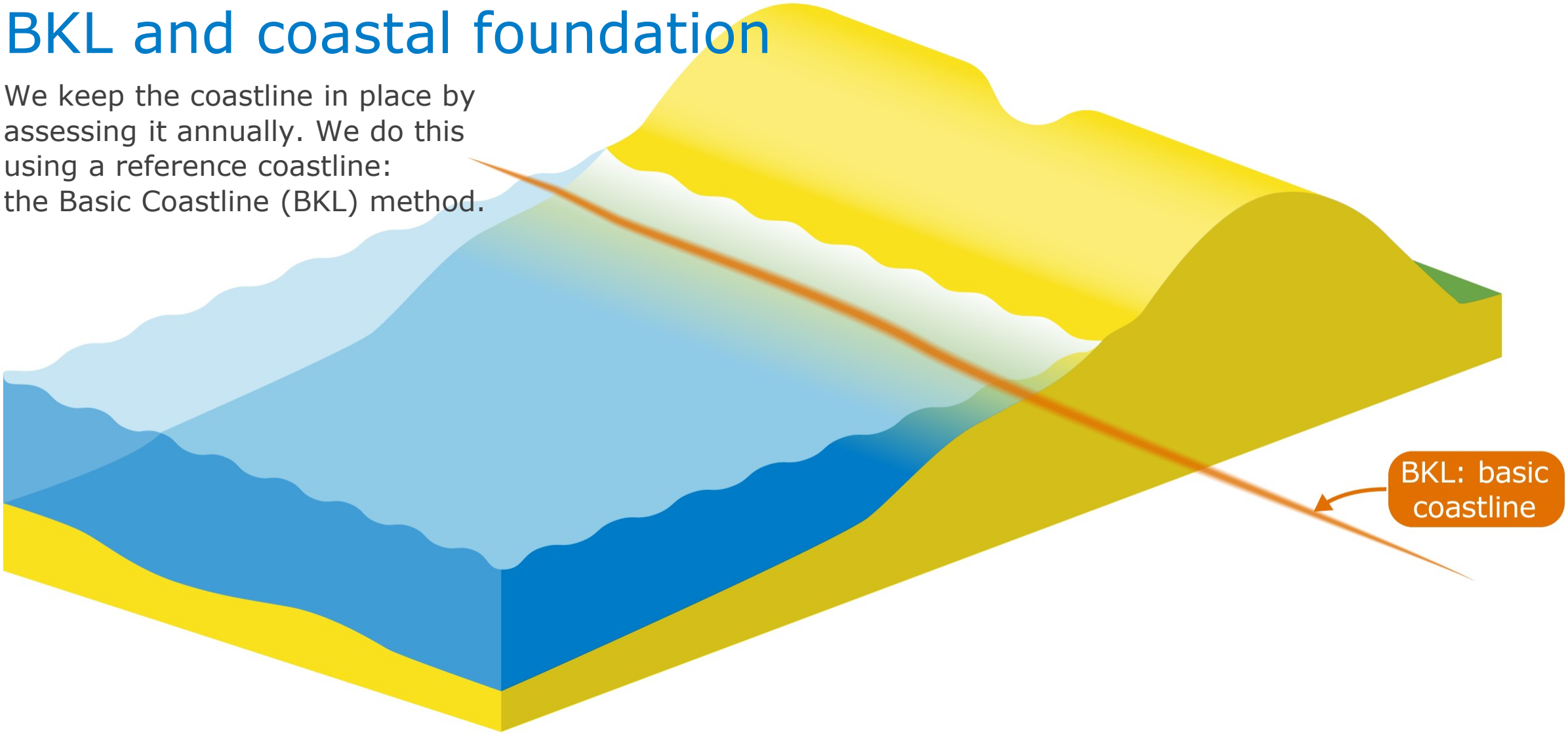
Figure 4.20. *Frame of Reference Management Framework*



Source: Adapted from van Koningsveld and Mulder 2004

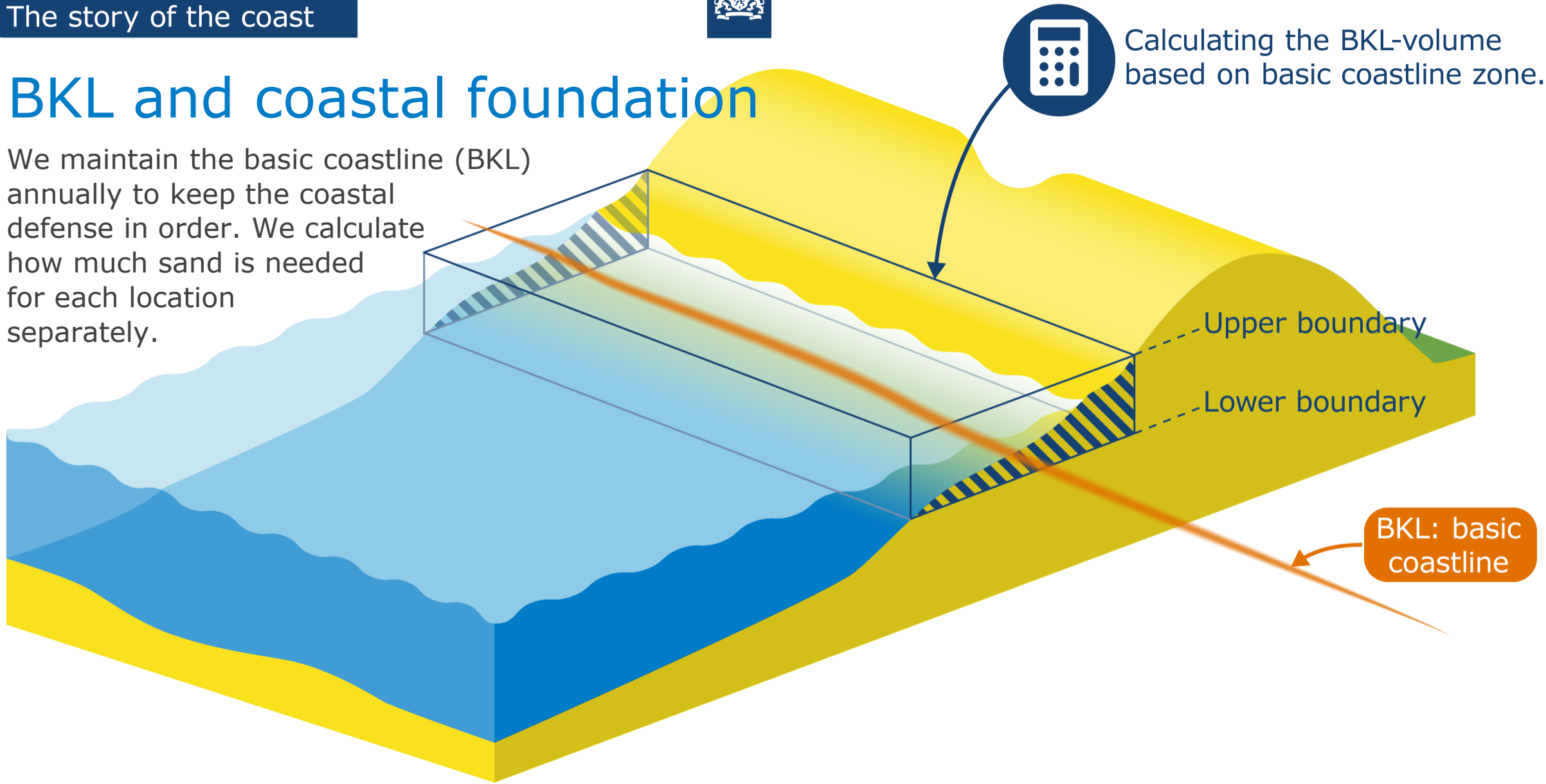
BKL and coastal foundation

We keep the coastline in place by assessing it annually. We do this using a reference coastline: the Basic Coastline (BKL) method.

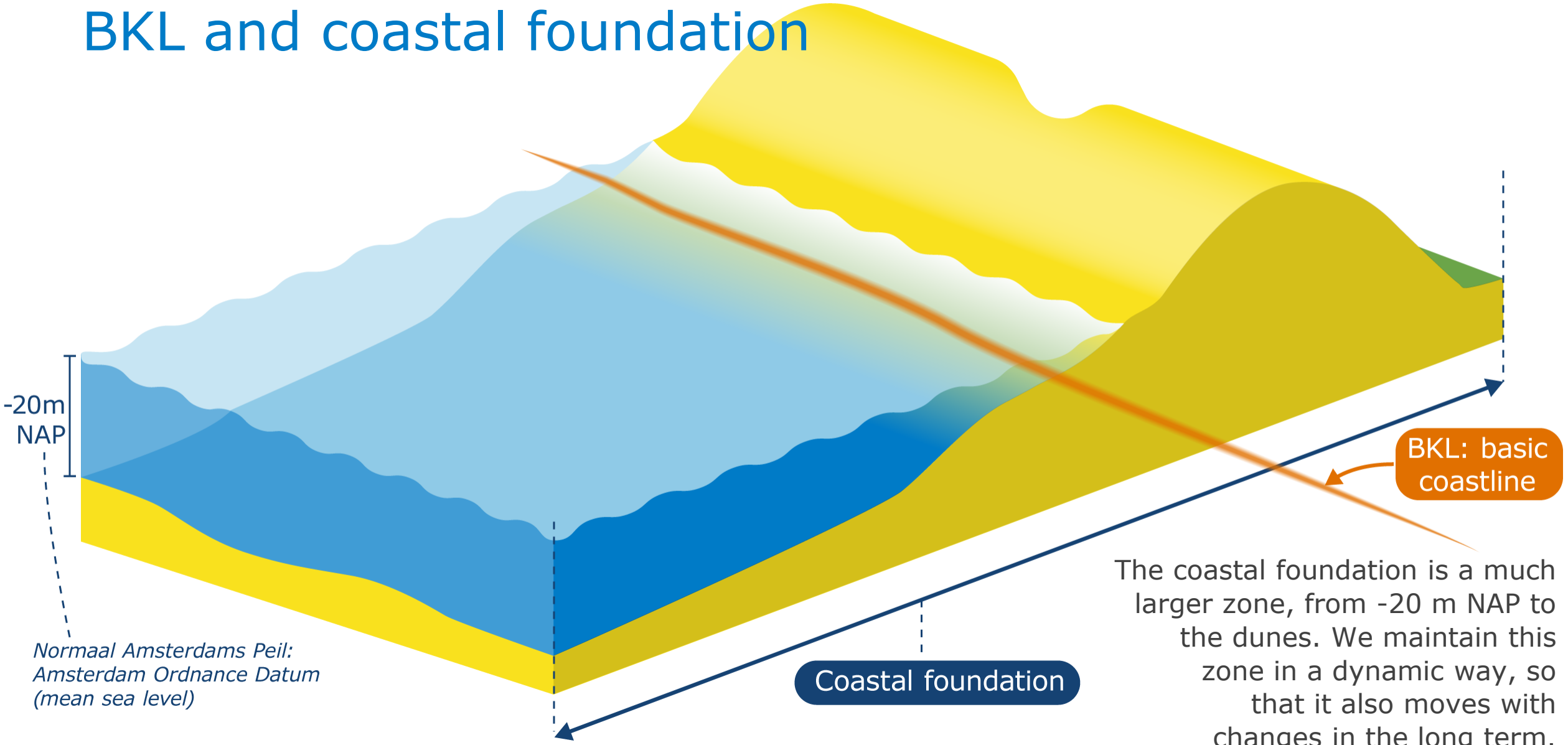


BKL and coastal foundation

We maintain the basic coastline (BKL) annually to keep the coastal defense in order. We calculate how much sand is needed for each location separately.



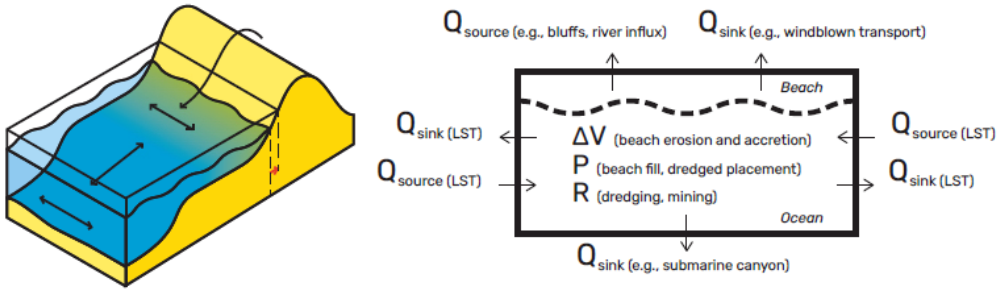
BKL and coastal foundation



The coastal foundation is a much larger zone, from -20 m NAP to the dunes. We maintain this zone in a dynamic way, so that it also moves with changes in the long term.

BKL and coastal foundation

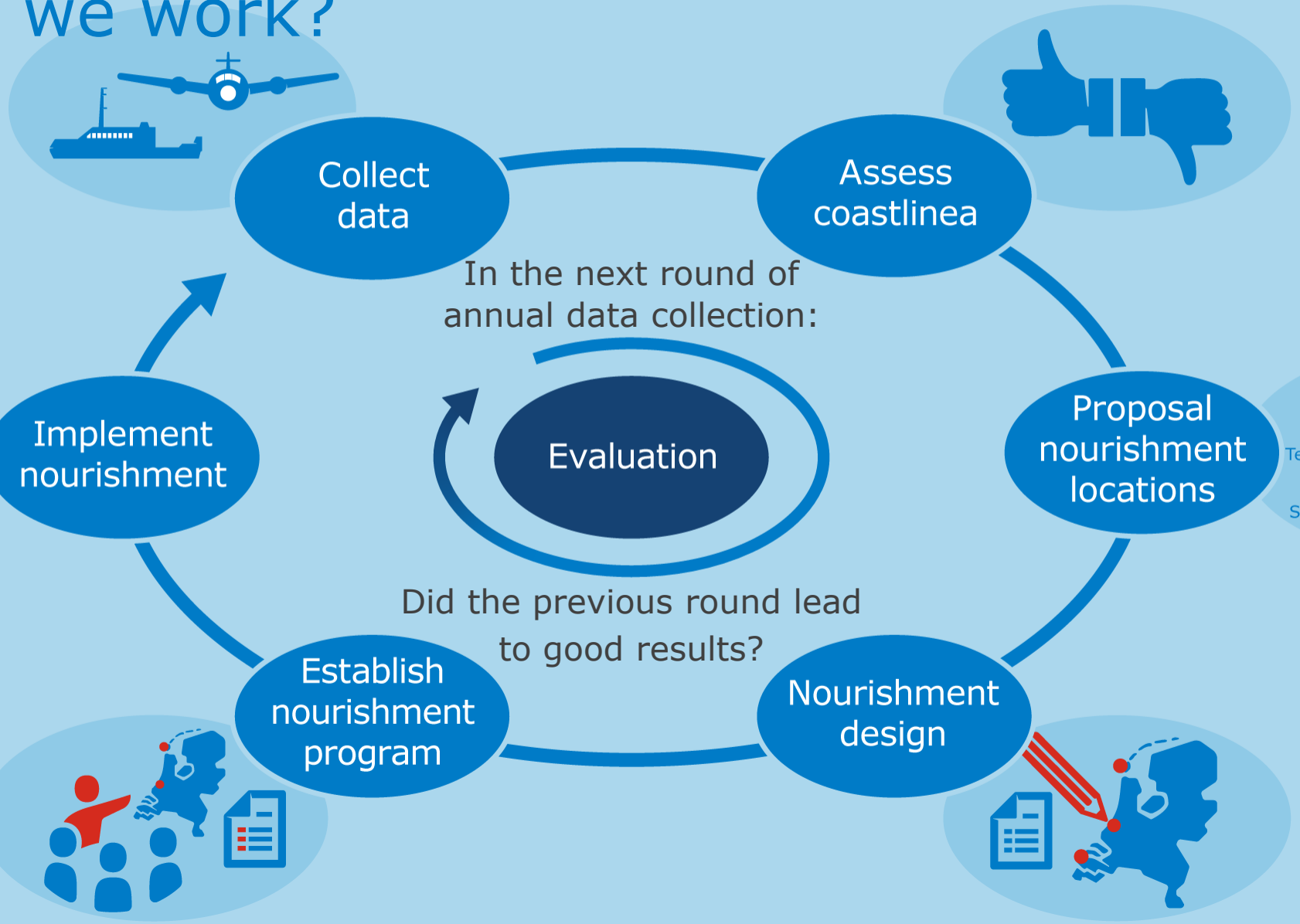
Figure 9.7. *Concept to Quantify the Sediment Budget Analysis of a Coastal System in Terms of Sediment Volume Changes and Estimating Associated Sediment Fluxes and Human Interventions*



Abbreviation:
LST: longshore transport

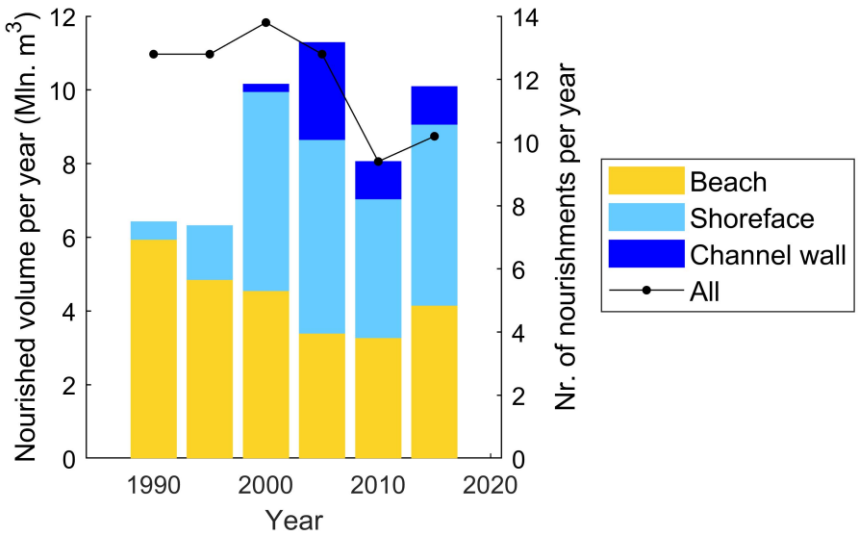
The coastal foundation is a much larger zone, from -20 m NAP to the dunes. We maintain this zone in a dynamic way, so that it also moves with changes in the long term.

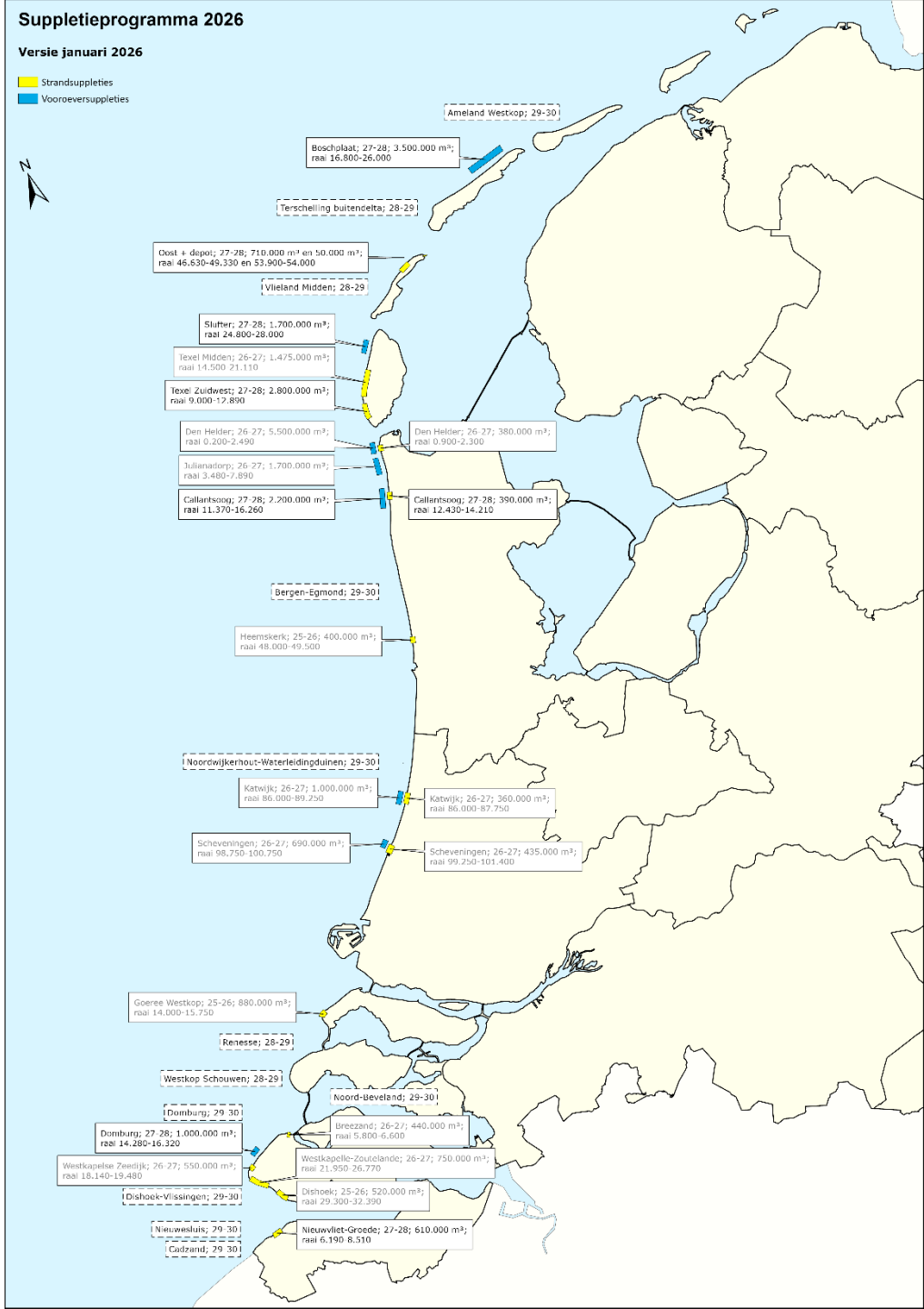
How do we work?



Nourishment program

- 10-15 nourishments with a total of 11 mln. m³ of sand per year
- Around 350 nourishment projects in total since 1990





Nourishment program

Based on assesment of the coastline in relation to the reference coastline, but also on knowledge of the coastal system

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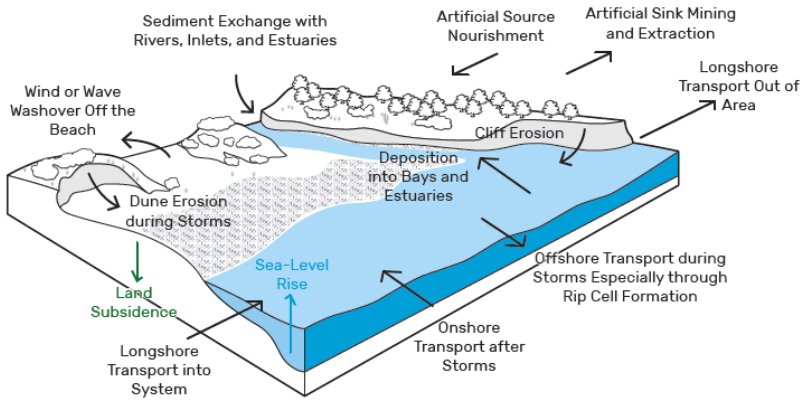
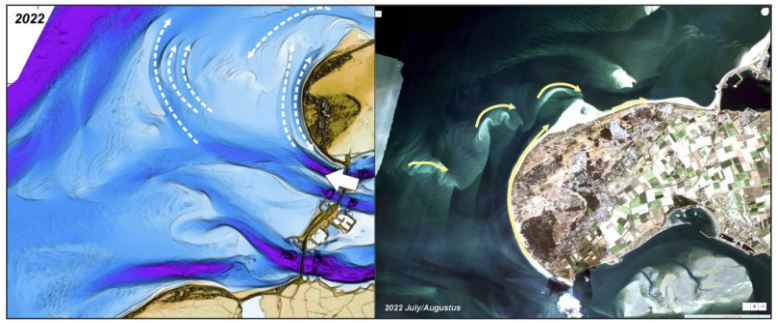
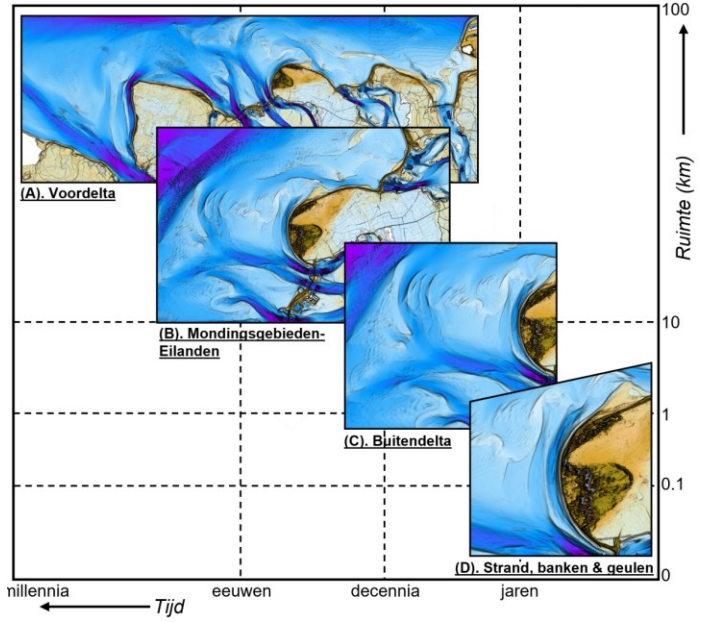
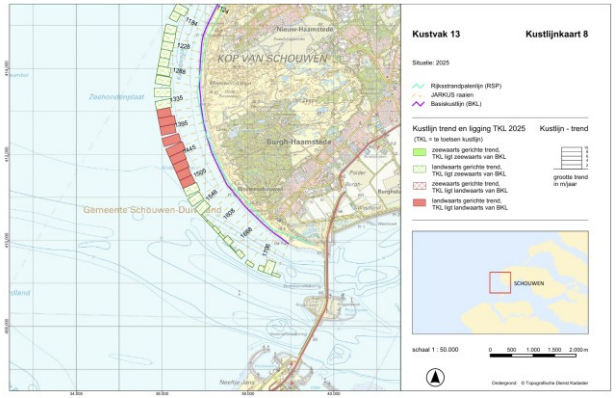


Source: Adapted from DSE 2012, Figure 5-4



Elias & Vermeer 2025
Morfologische Analyse
Kop van Schouwen





Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

Sustainable coastline management

the cumulative effects of 30 years of nourishments in the Netherlands

Evelien Brand, Quirijn Lodder, Ellen Quataert, Jill Slinger

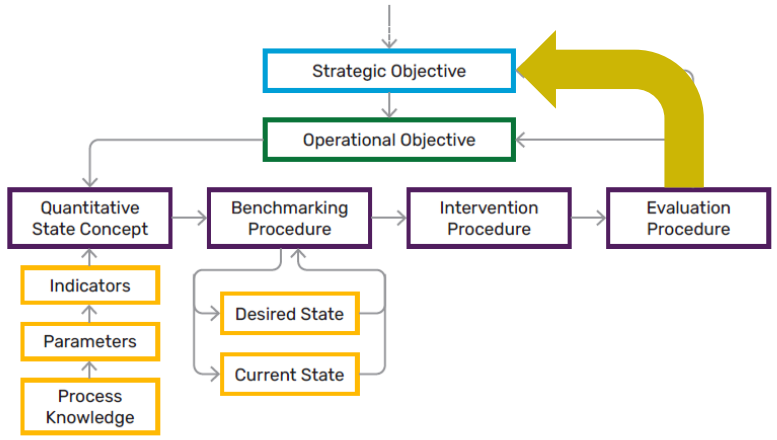
Aim

Are we achieving the strategic goal with our operational approach?

We succeed in ‘holding the line’, but do we sustainably preserve flood safety and values of the coast?

What is the **cumulative** effect of sediment nourishments at large spatial and long timescales?

Figure 4.20. *Frame of Reference Management Framework*



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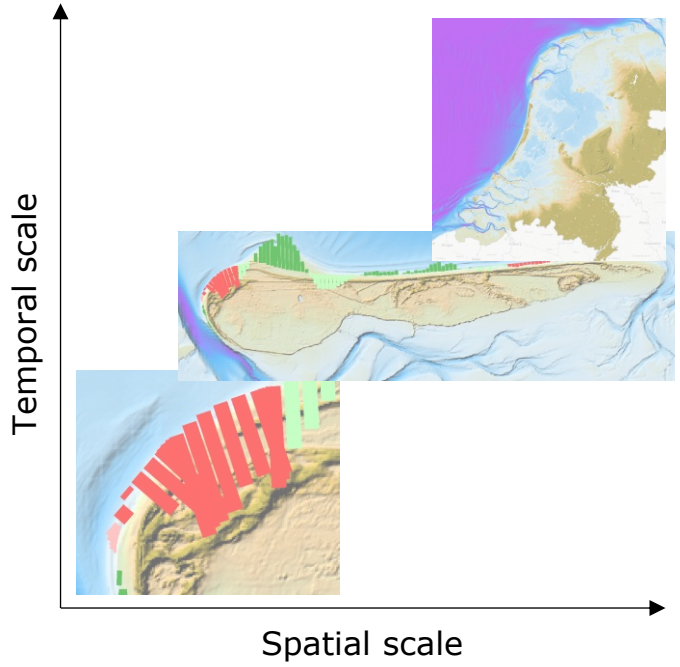
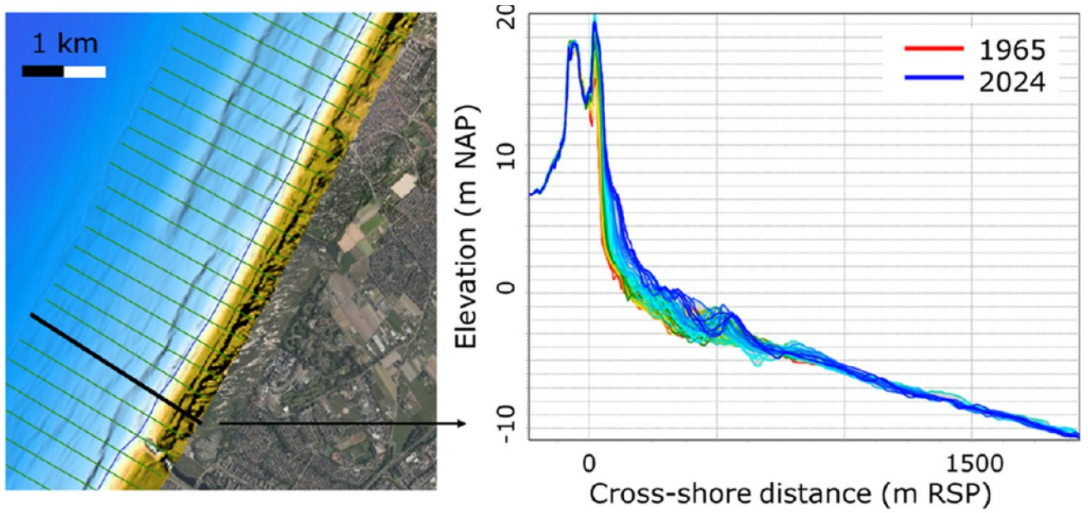
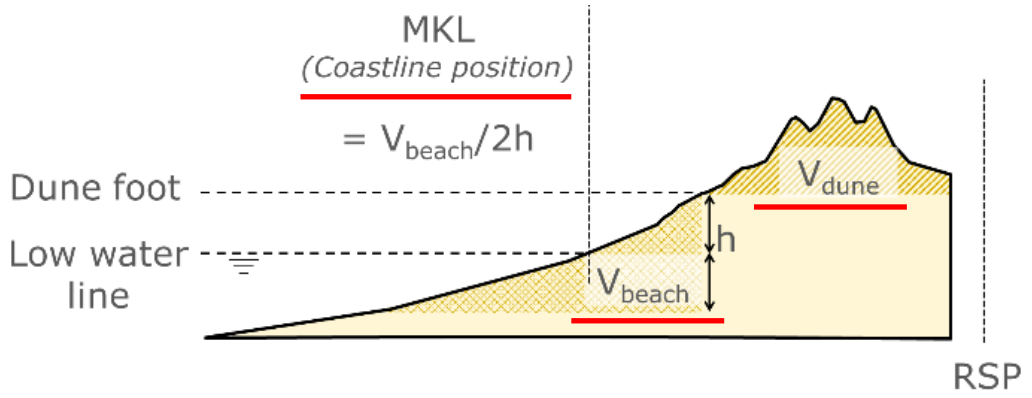
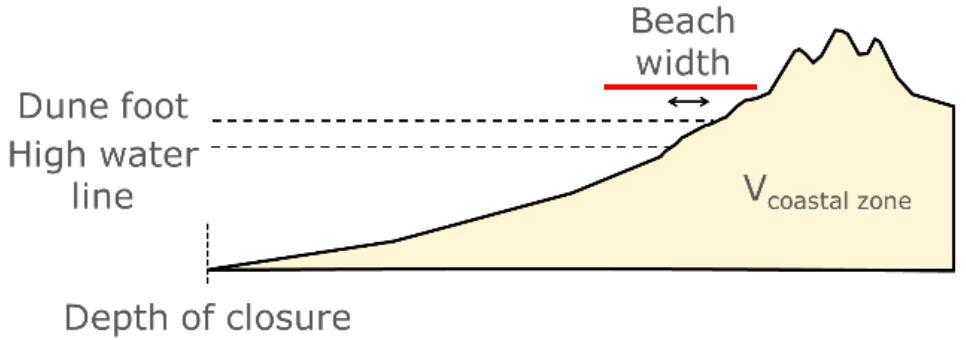


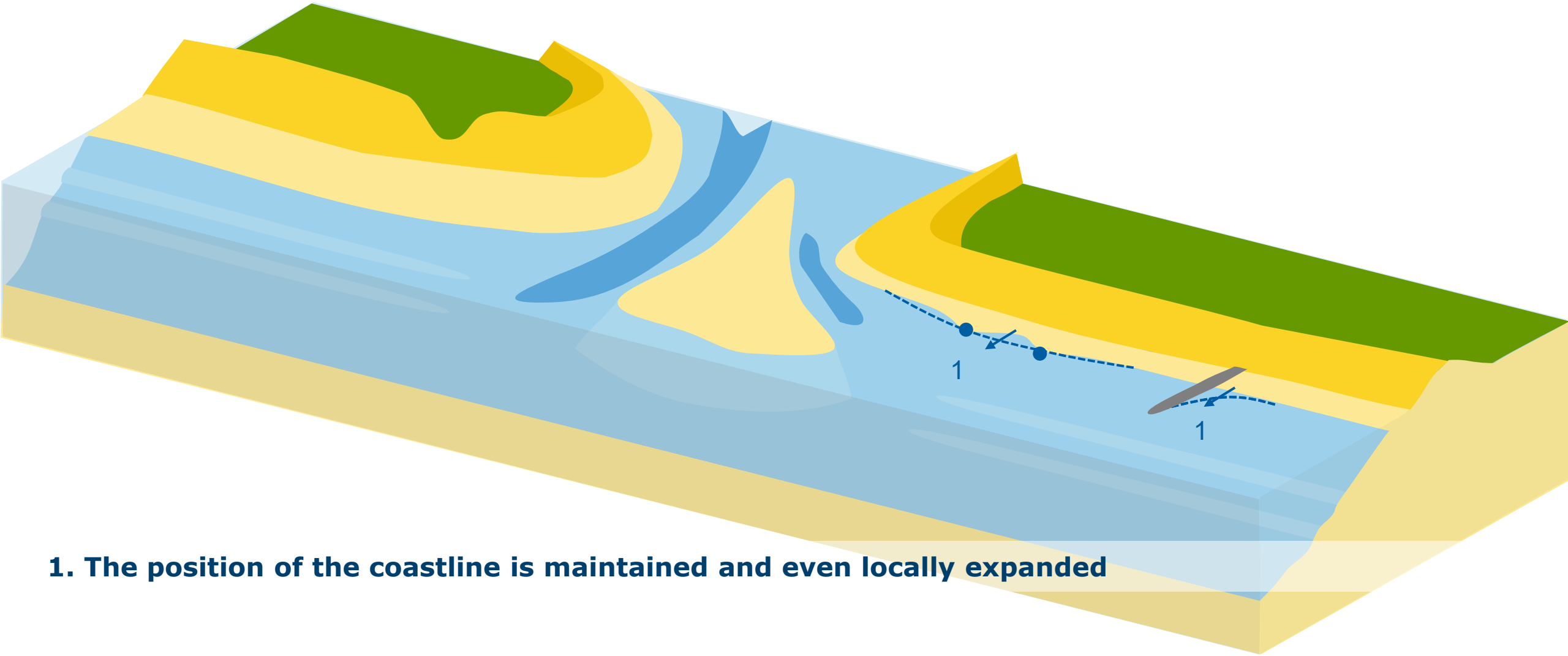
Approach

- Coastal indicators were determined from yearly topographical and bathymetric cross-shore profiles
- A comparison of pre- en post 1990
- Cumulative along the coast and at a transect level
- Literature research for ecological impact and socio-economic developments





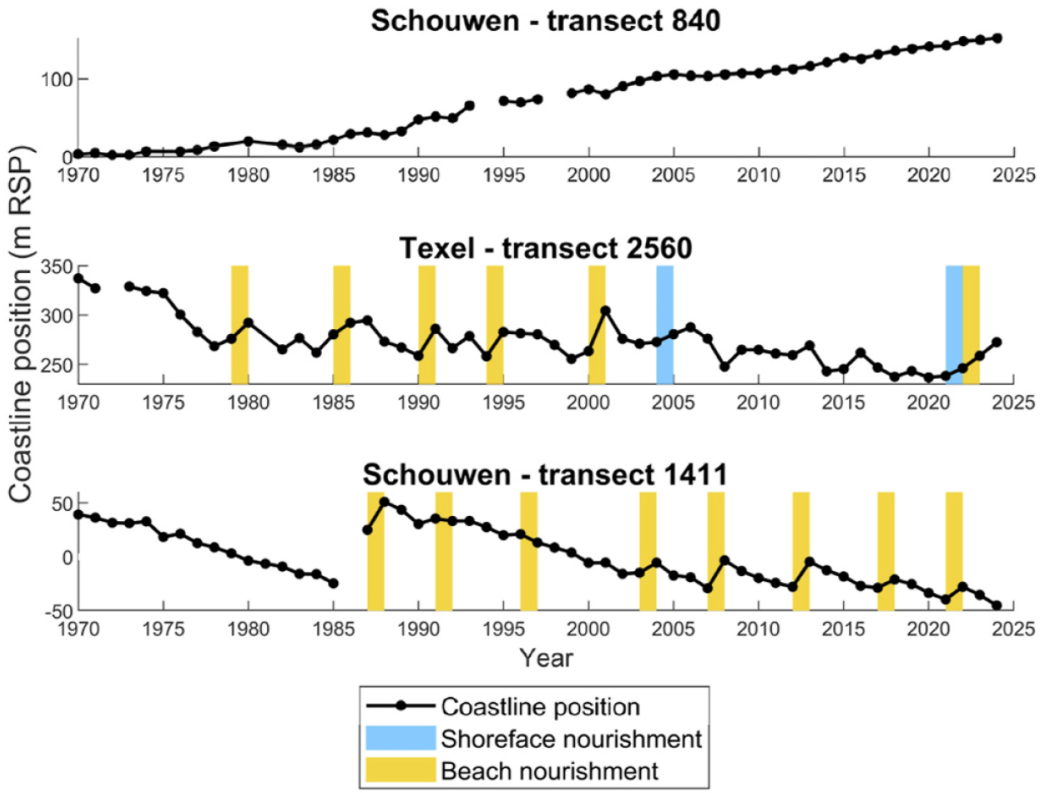




1. The position of the coastline is maintained and even locally expanded

Coastline position

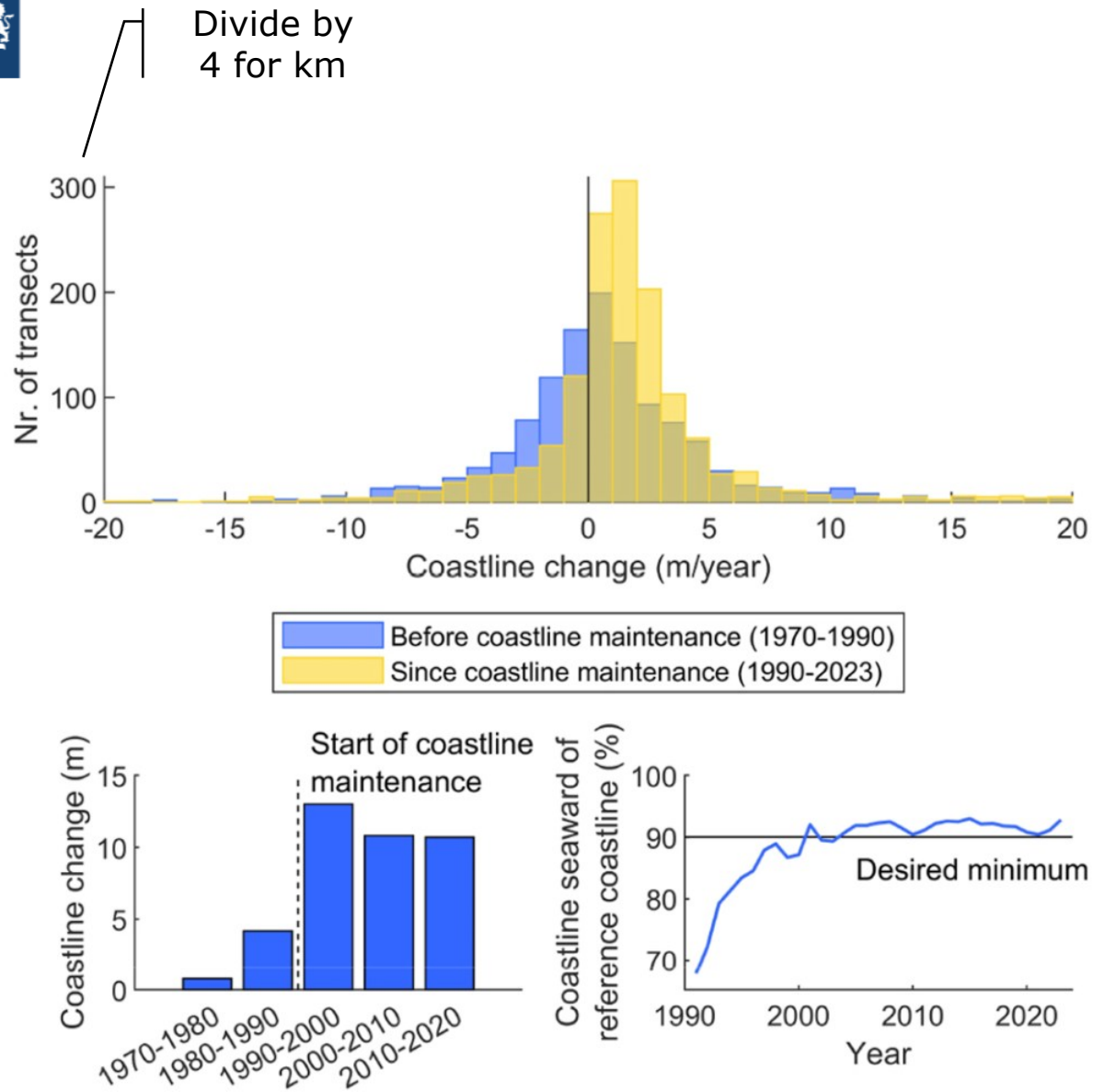
The effect of nourishments is not always clear at a transect level



Coastline position

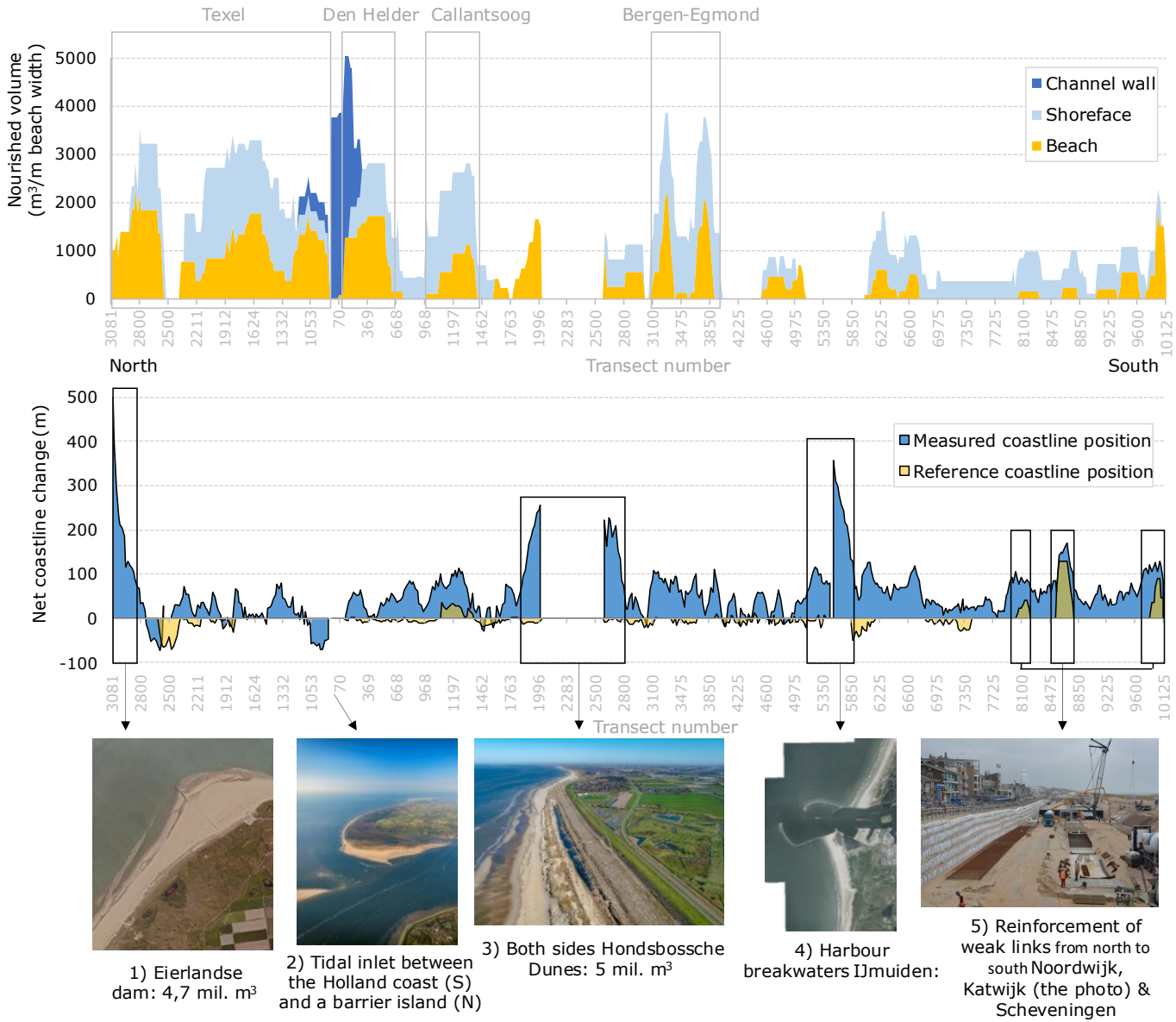
There is a clear trend break in coastline behaviour in 1990:

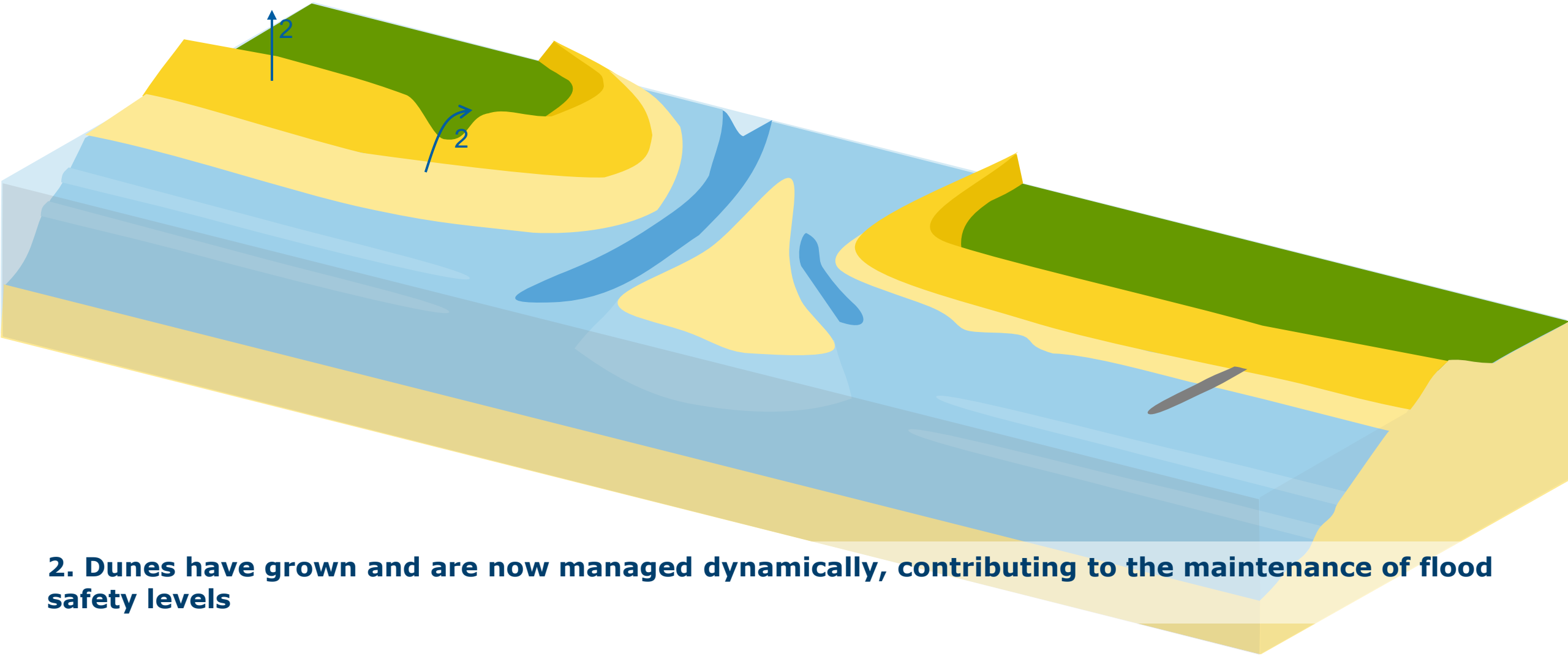
- Before there was on average stable, however with large erosional areas (50% of the coast over periods of 10 year)
- Since 1990 the coastline is maintained, which resulted in an average expansion



Coastline position

- There is alongshore variability
- At nourishment hotspots the coastline is maintained
- Expansions of the coastline are related to:
  - Large-scale morphological developments
  - Alongshore transport of nourished sediment
  - Effect of hard structures

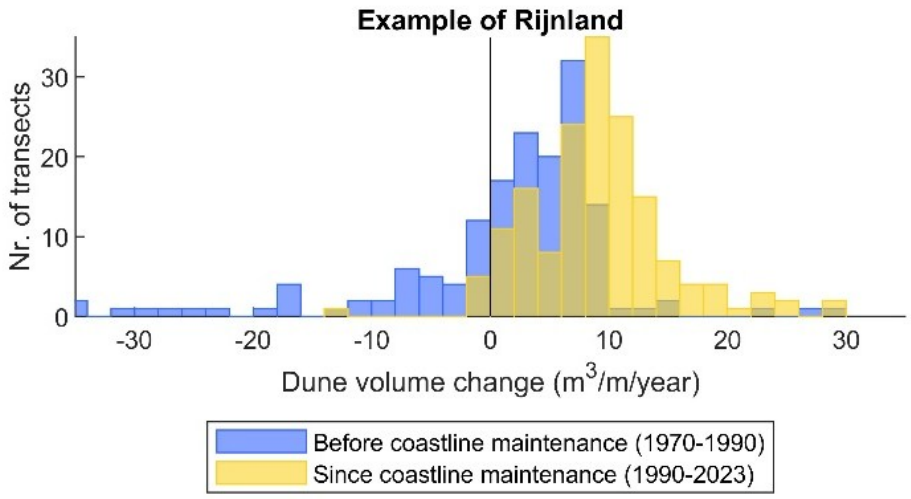


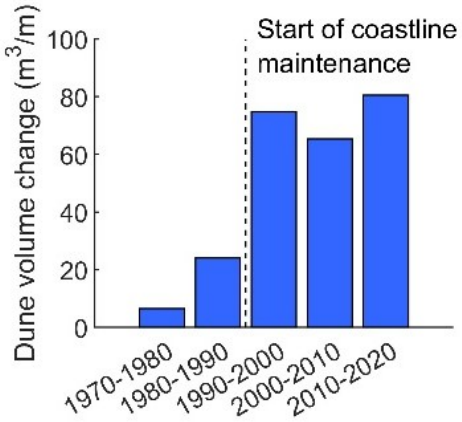


2. Dunes have grown and are now managed dynamically, contributing to the maintenance of flood safety levels

Dune development

- Number of locations with dune erosion have decreased (32 → 13%)
- Dunes are now growing with an average of 7,5 m^3/m/year
- In total the dunes have grown with ~20% of the nourished volume since 1990





Dune development

Because of an increased supply, but mainly because of a more dynamic dune management

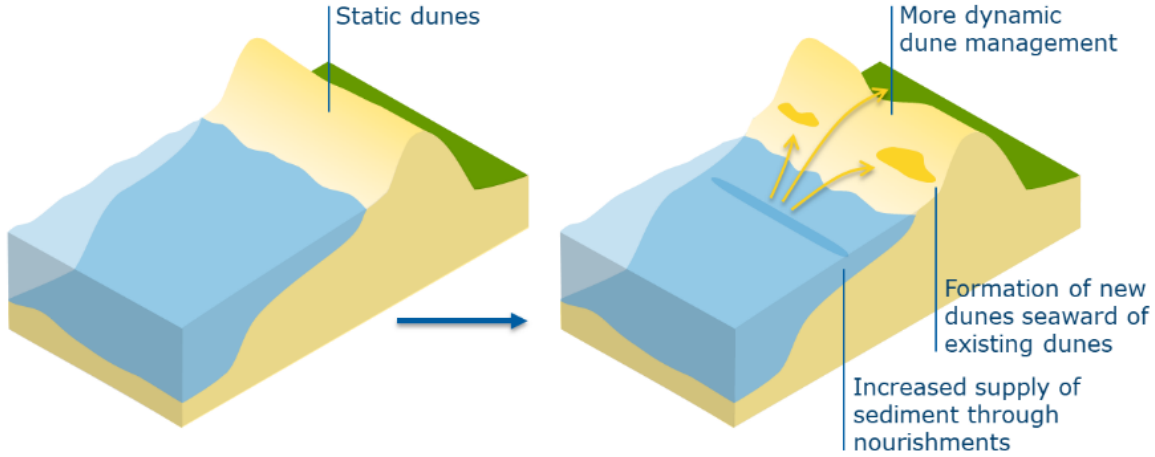
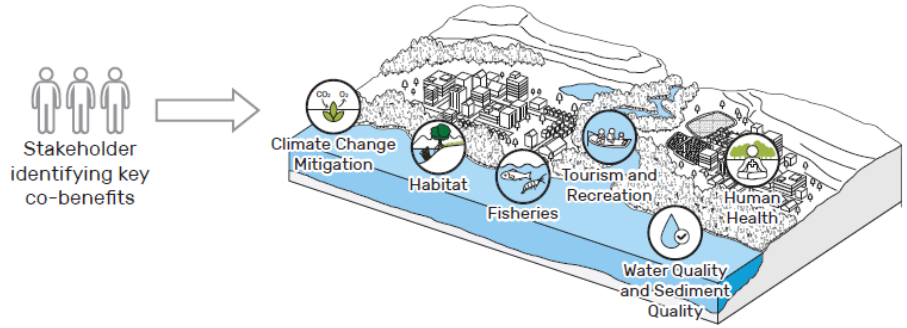
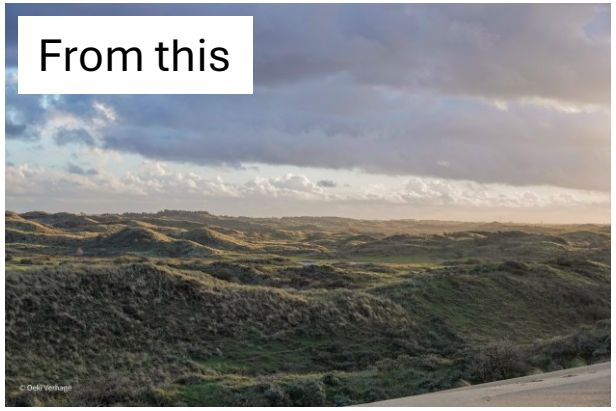
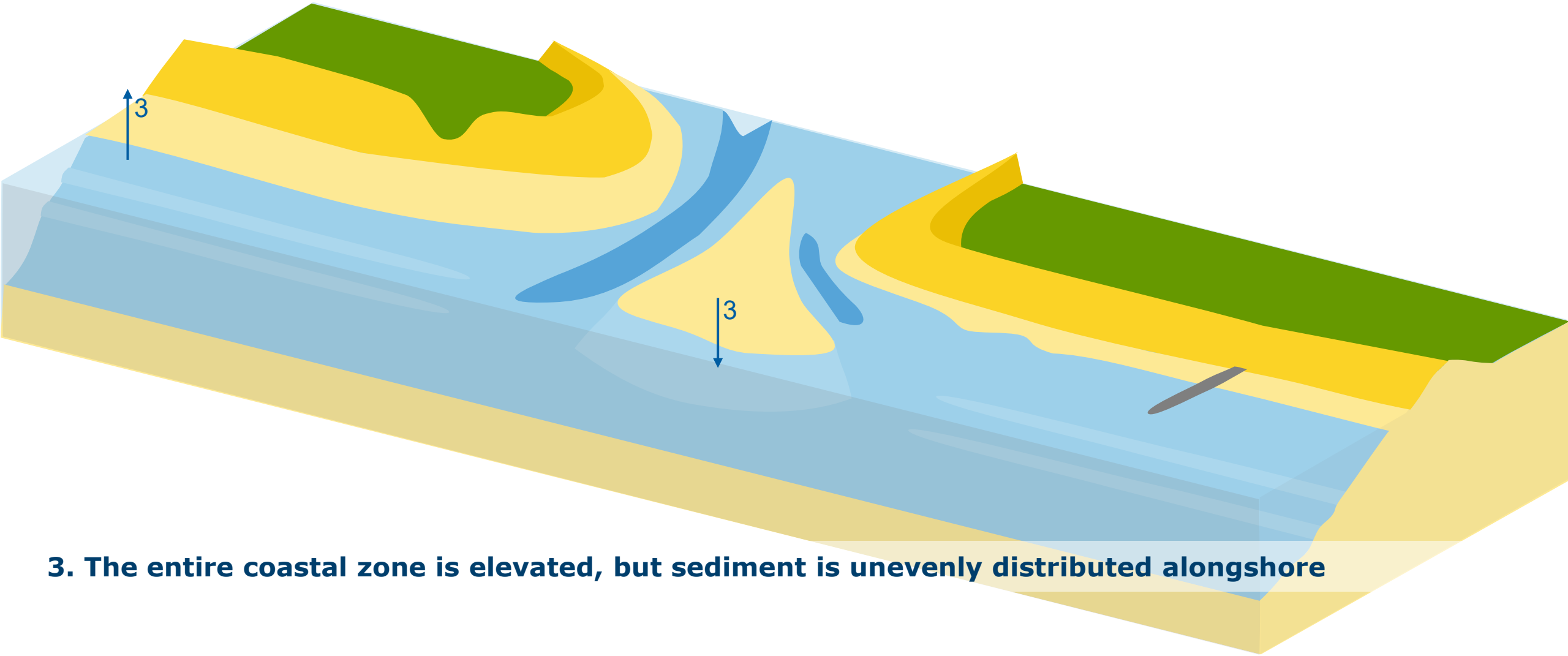


Figure 6.6. *The Scoping and Identifying of Key Co-Benefits for an NNBF Project through Engaging with Stakeholders*





Oeki Verhage (VU/NIOZ)

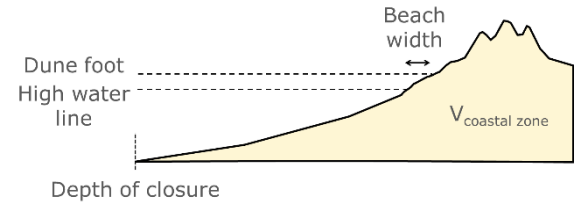


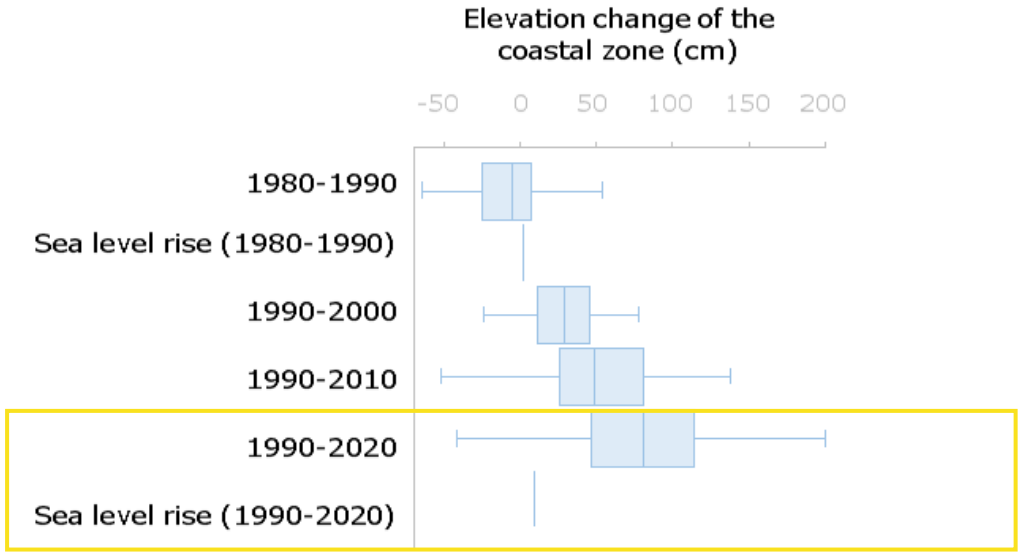
3. The entire coastal zone is elevated, but sediment is unevenly distributed alongshore

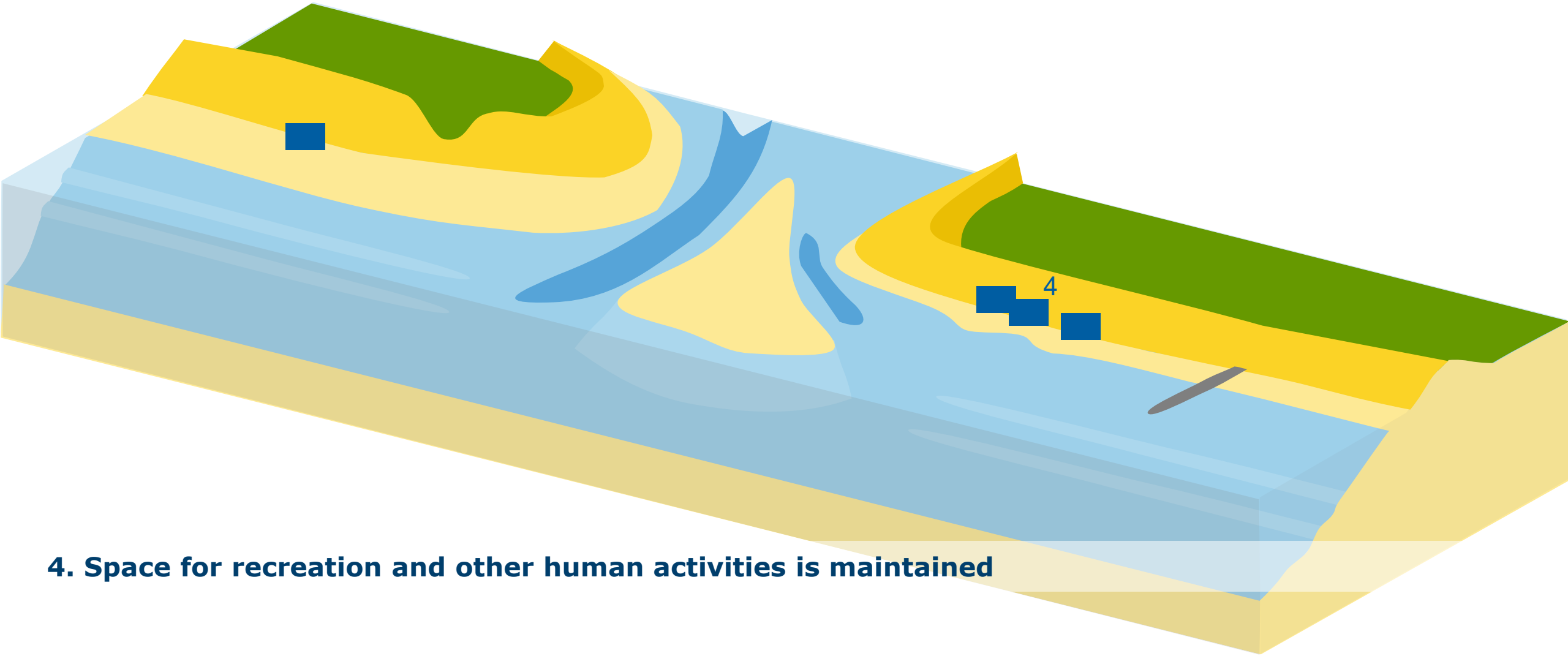
Sea level rise

The coastal zone is elevated more than sea level rise

But (1) there are alongshore variabilities, (2) not the entire shoreface was studied here and (3) this is no guarantee for the behaviour of the coast under accelerated sea level rise



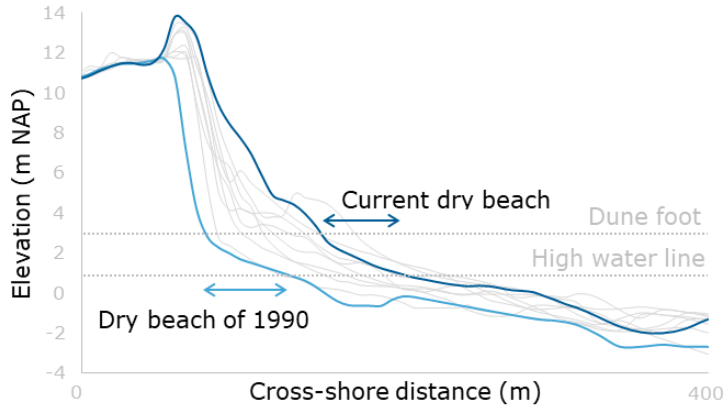




4. Space for recreation and other human activities is maintained

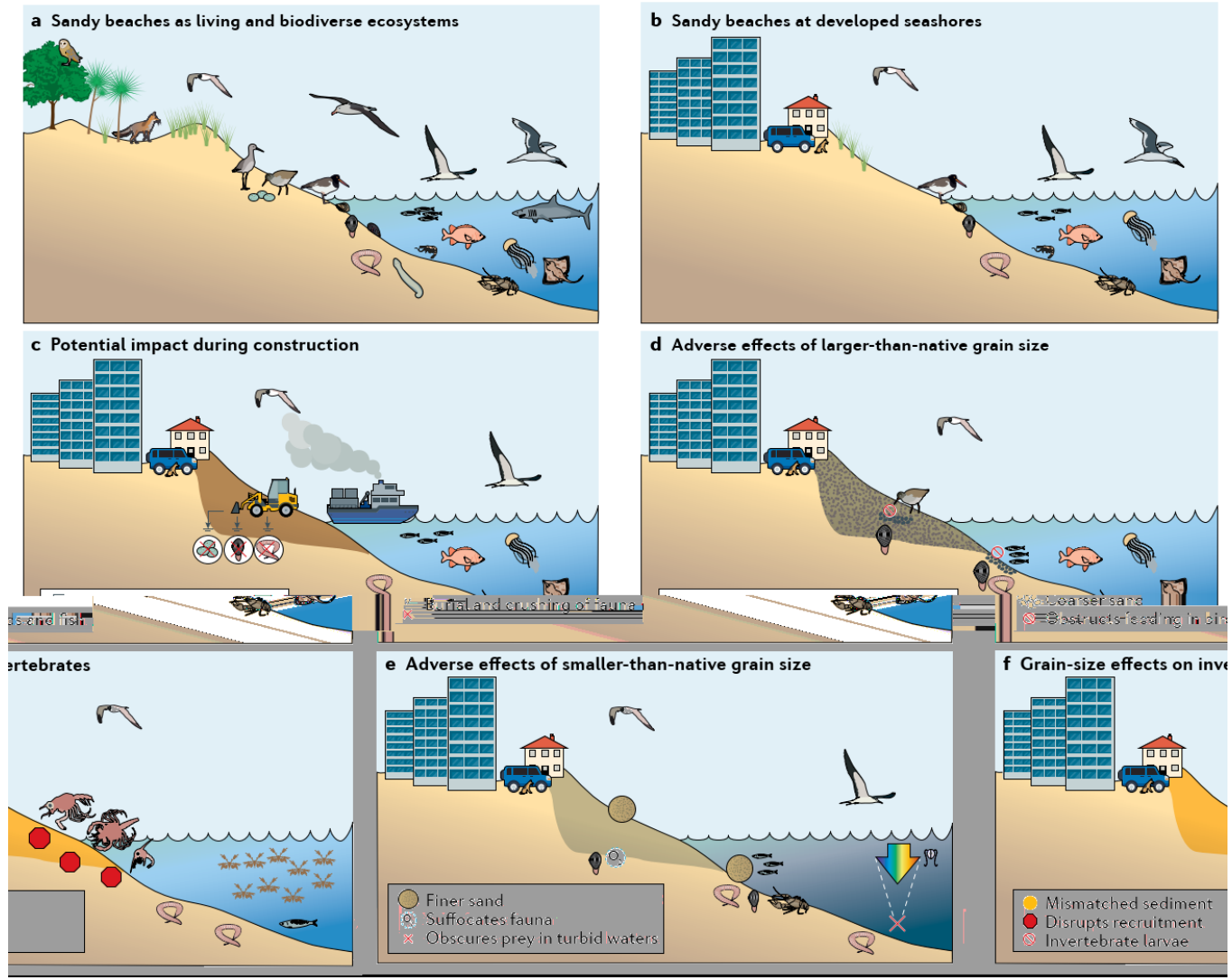
Recreation

- Growth of the dunes and expansion of the coastline: space for recreation has increased
- Dry beach width temporarily increases after beach nourishments, but on average the beach width has not changed
- Risk of damage to infrastructure has decreased
- 26% increase in beach buildings since the 1990’s

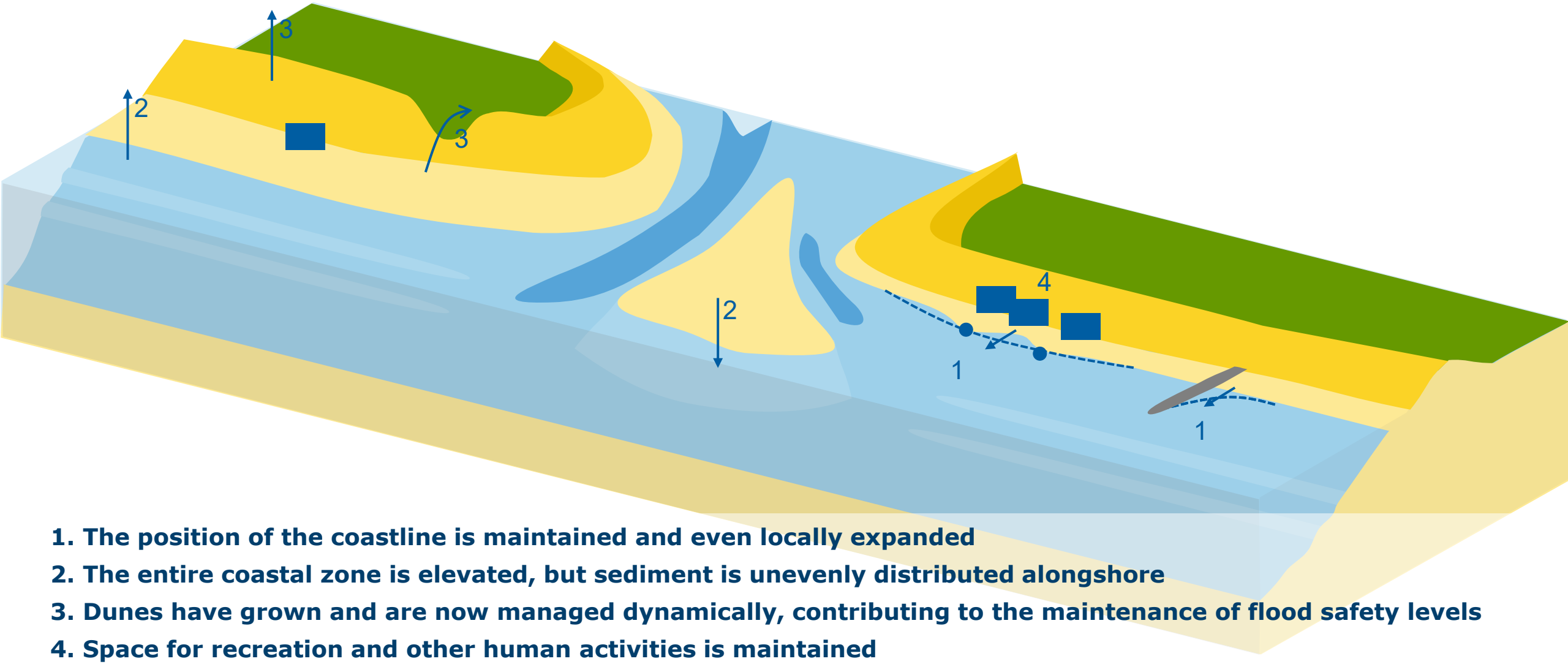


Ecology

- Nourishments contribute to the maintenance of habitats
- They are also disruptive, but ecology in the nearshore is used to disruptions and can often recover. Damage is often temporarily and local



Adverse effects of nourishments – De Schipper e.a. 2021



1. The position of the coastline is maintained and even locally expanded
2. The entire coastal zone is elevated, but sediment is unevenly distributed alongshore
3. Dunes have grown and are now managed dynamically, contributing to the maintenance of flood safety levels
4. Space for recreation and other human activities is maintained

Success of the policy

Effective

Structural erosion was stopped; decrease in % Reference coastline (BKL) exceedings

Efficient

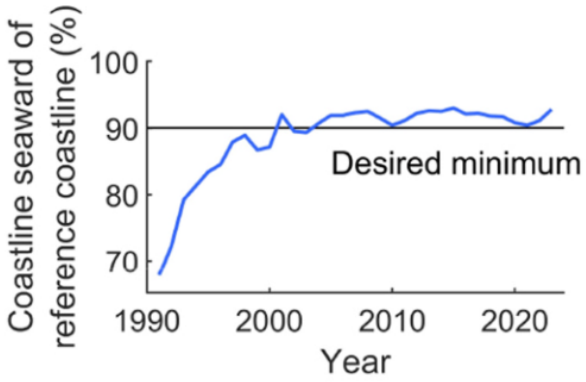
Decrease of beach nourishments; increase of shoreface nourishments

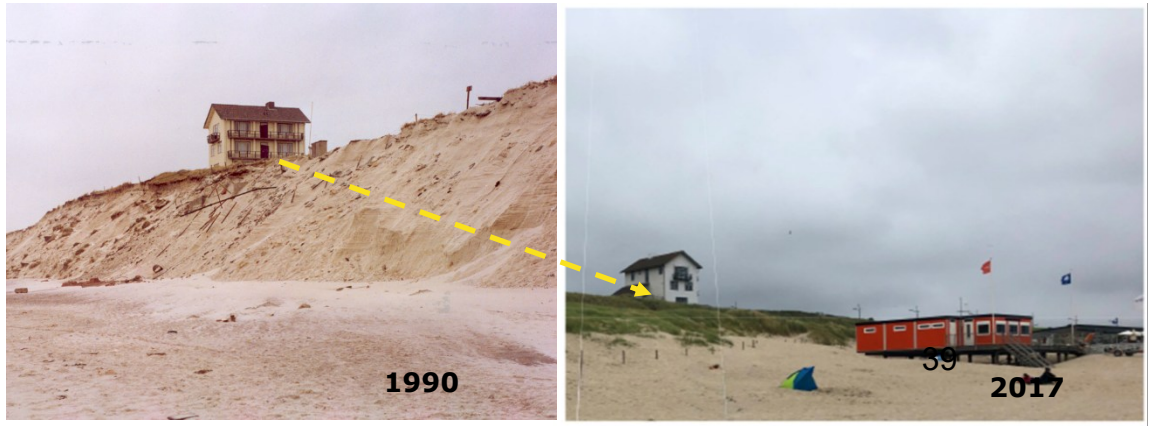
Adaptive

Increase of nourishment volume after 2000: we have a system that we can adjust to the sea level rise

Integrated

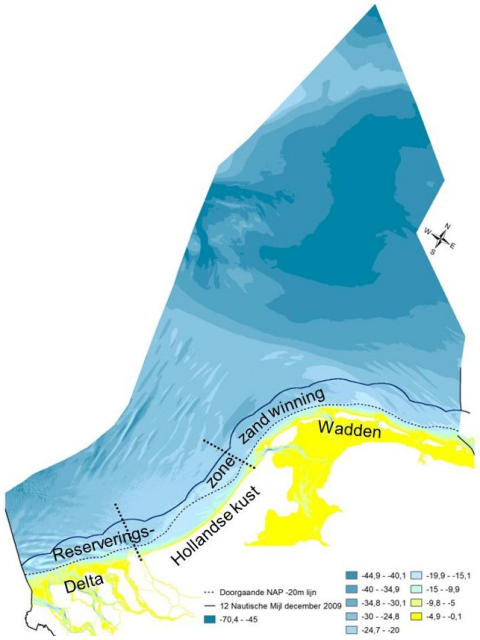
Conservation of coastal functions

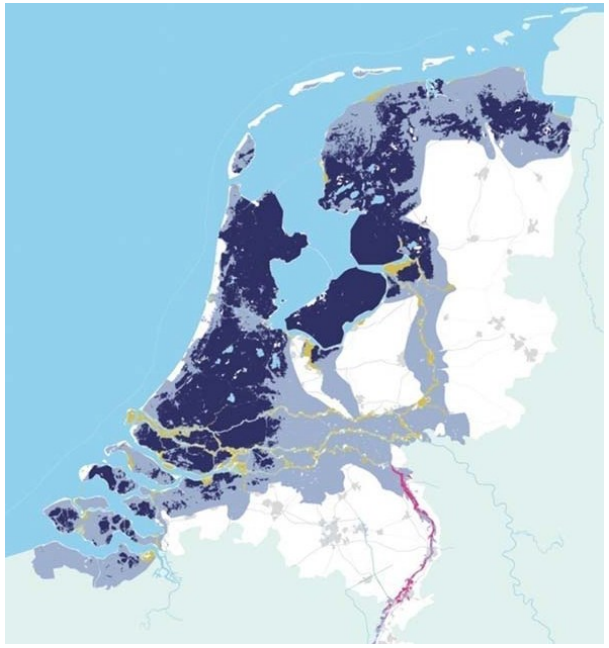


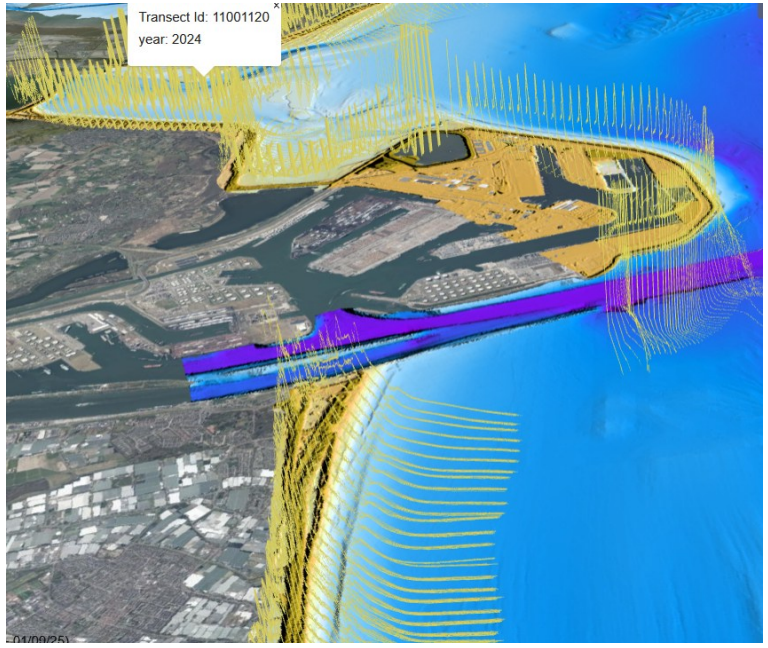


Preconditions for this policy

1. Sand availability
2. Coastal protection is organized on a national level
3. Extensive monitoring program







Principles, Outcomes and Framework

NNBF Performance

Benefits of NNBF

Take home messages

- When you zoom out, NNBF performance and benefits may become more clear:

  The effect of nourishments can be hard to distinguish on a transect level, but is very clear on a national or state level

- At the strategic level, the outcome is the combined effect of all small NNBFs

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Thank you

International collaboration contributes to a more zoomed-out perspective