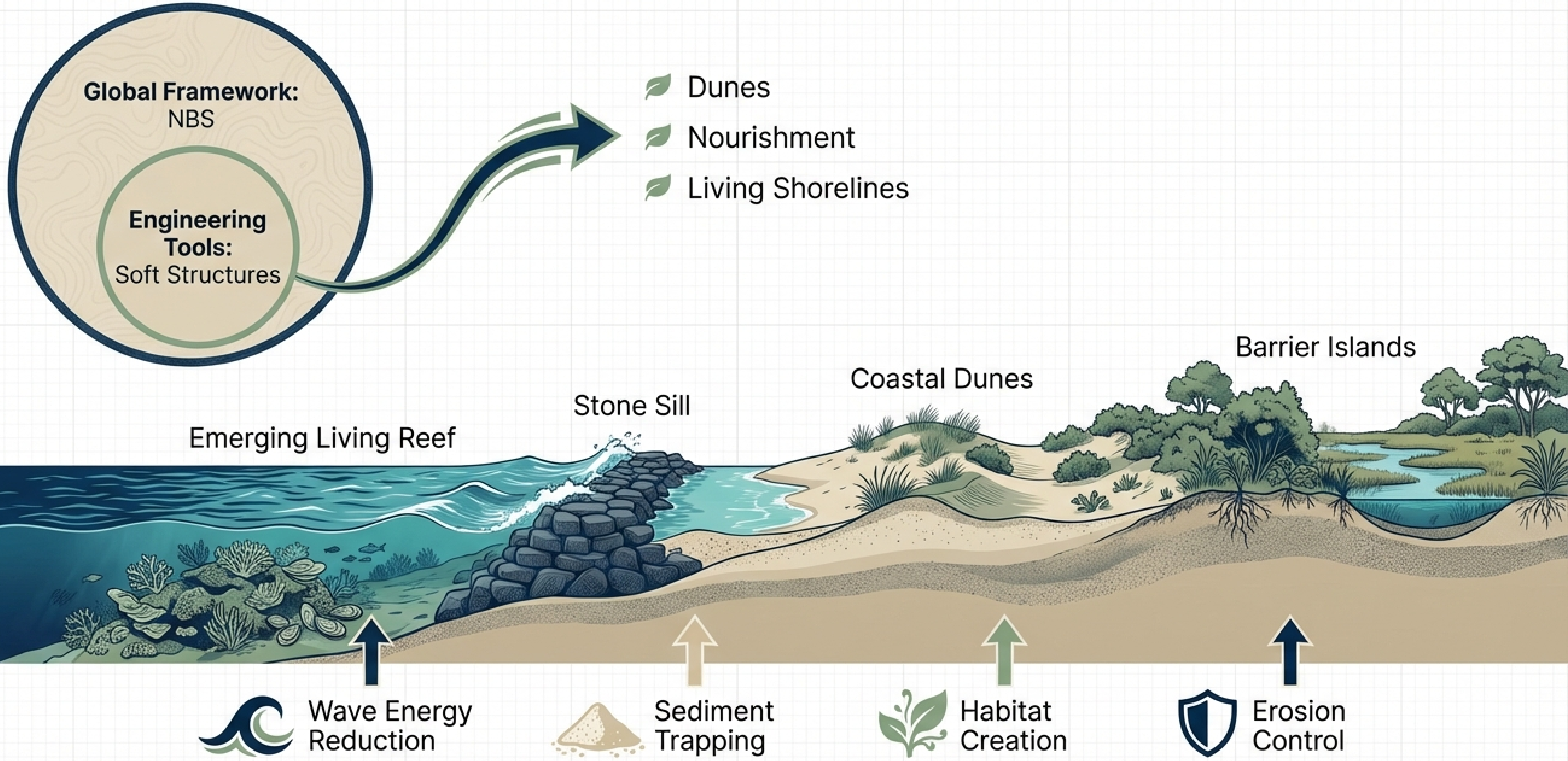
Soft Coastal Structures & Nature-Based Solutions

Principles, Physical Processes, and Engineering Design

Soft/Green coastal structures are the engineering tools used to implement the broader Nature-Based Solutions (NBS) philosophy—working with nature to build long-term resilience.

NotebookLM

The Nature-Based Solutions (NBS) Framework



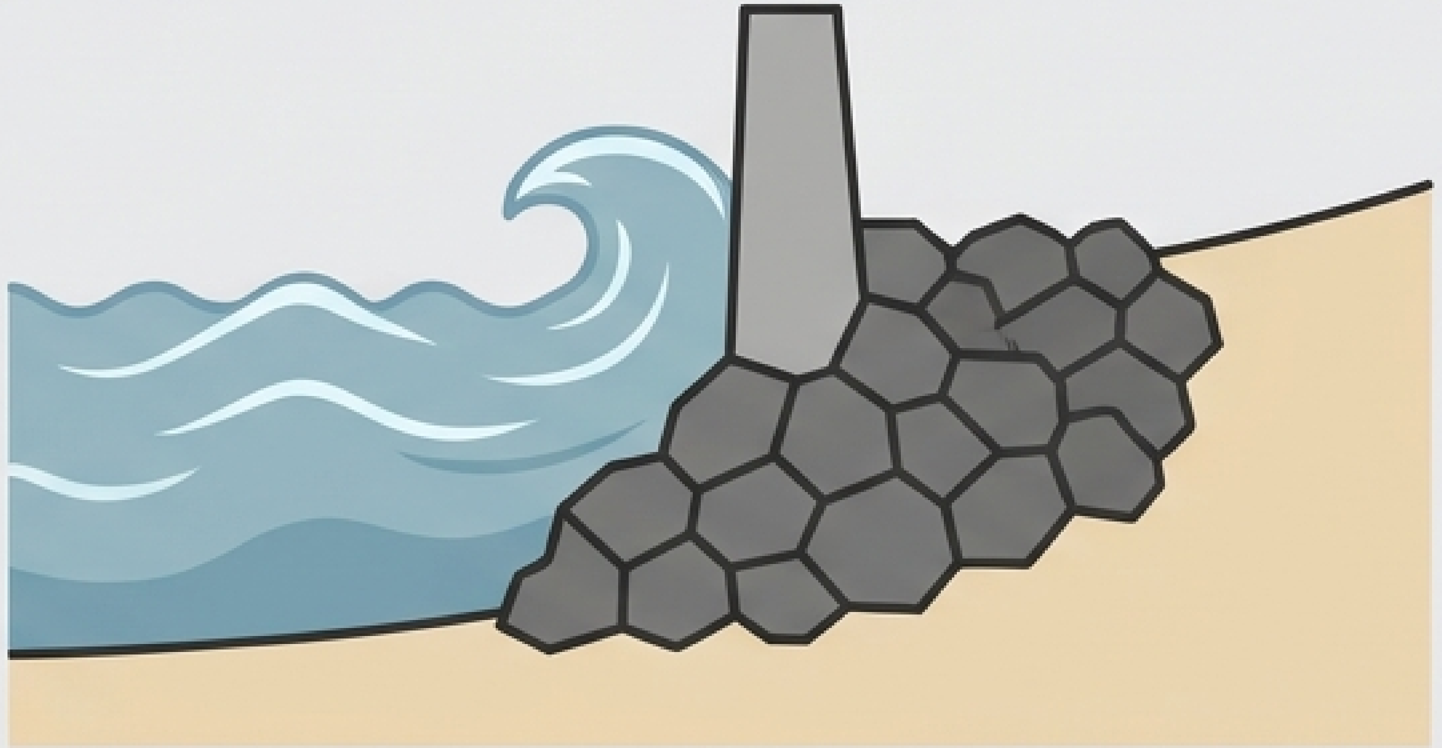
NotebookLM

Comparative Analysis: Soft vs. Hard Structures

Soft (Green / Nature-Based)

- **Material:** Natural (sand, vegetation, reefs)
- **Response:** Dynamic & Adaptive
- **Mechanism:** Dissipates energy (drag, friction)
- **Failure Mode:** Gradual adjustment
- **Co-Benefits:** Habitat, Carbon Storage

Hard (Gray / Engineered)

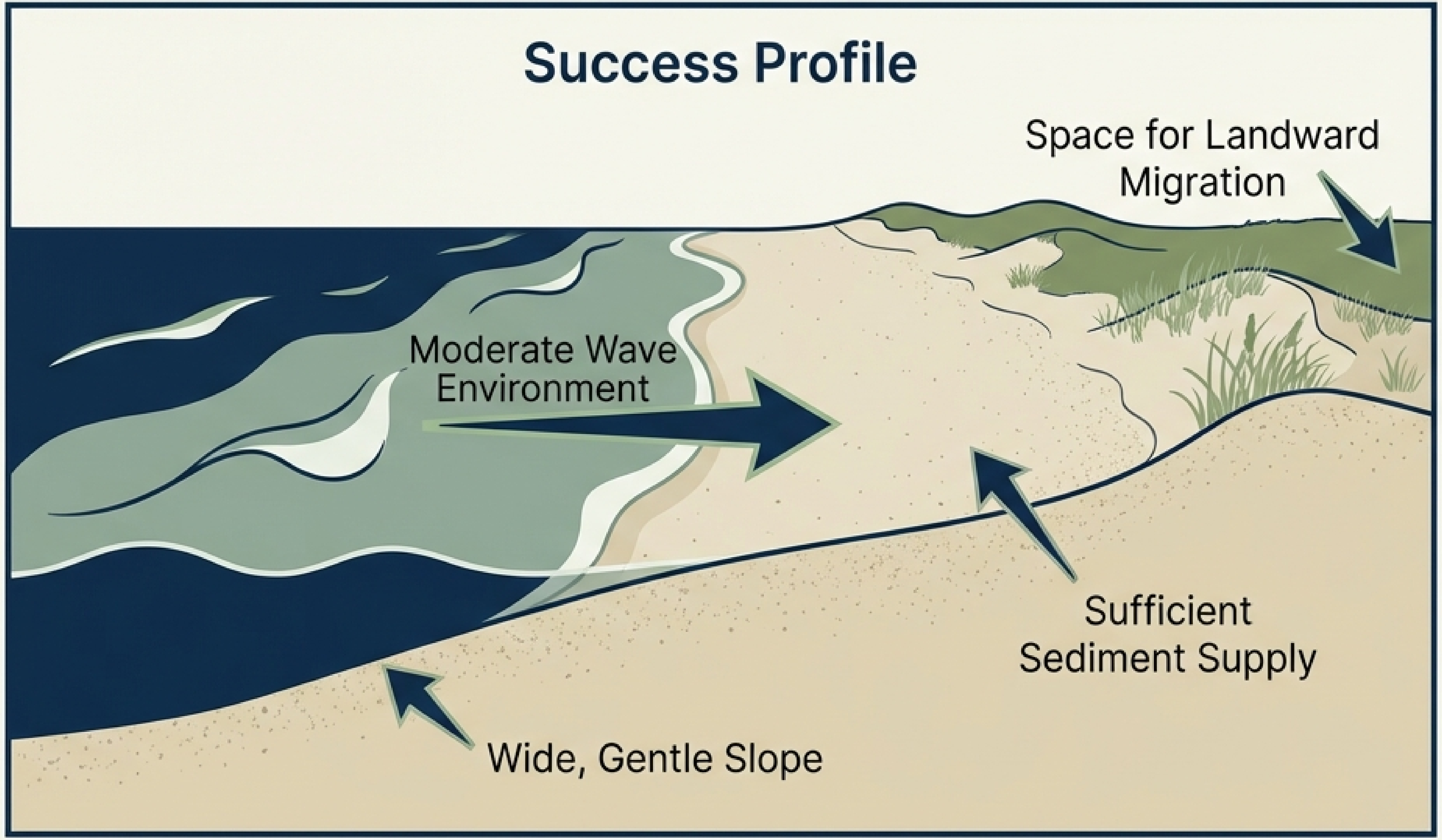


- **Material:** Concrete, Rock, Steel
- **Response:** Rigid & Static
- **Mechanism:** Reflects/Redirects energy
- **Failure Mode:** Sudden/Catastrophic
- **Co-Benefits:** Minimal or Negative

Key Takeaway: Soft structures are process-based; Hard structures are resistance-based.

NotebookLM

Feasibility: When to Go Soft



Warning Box

Failure Conditions (When NOT to use)

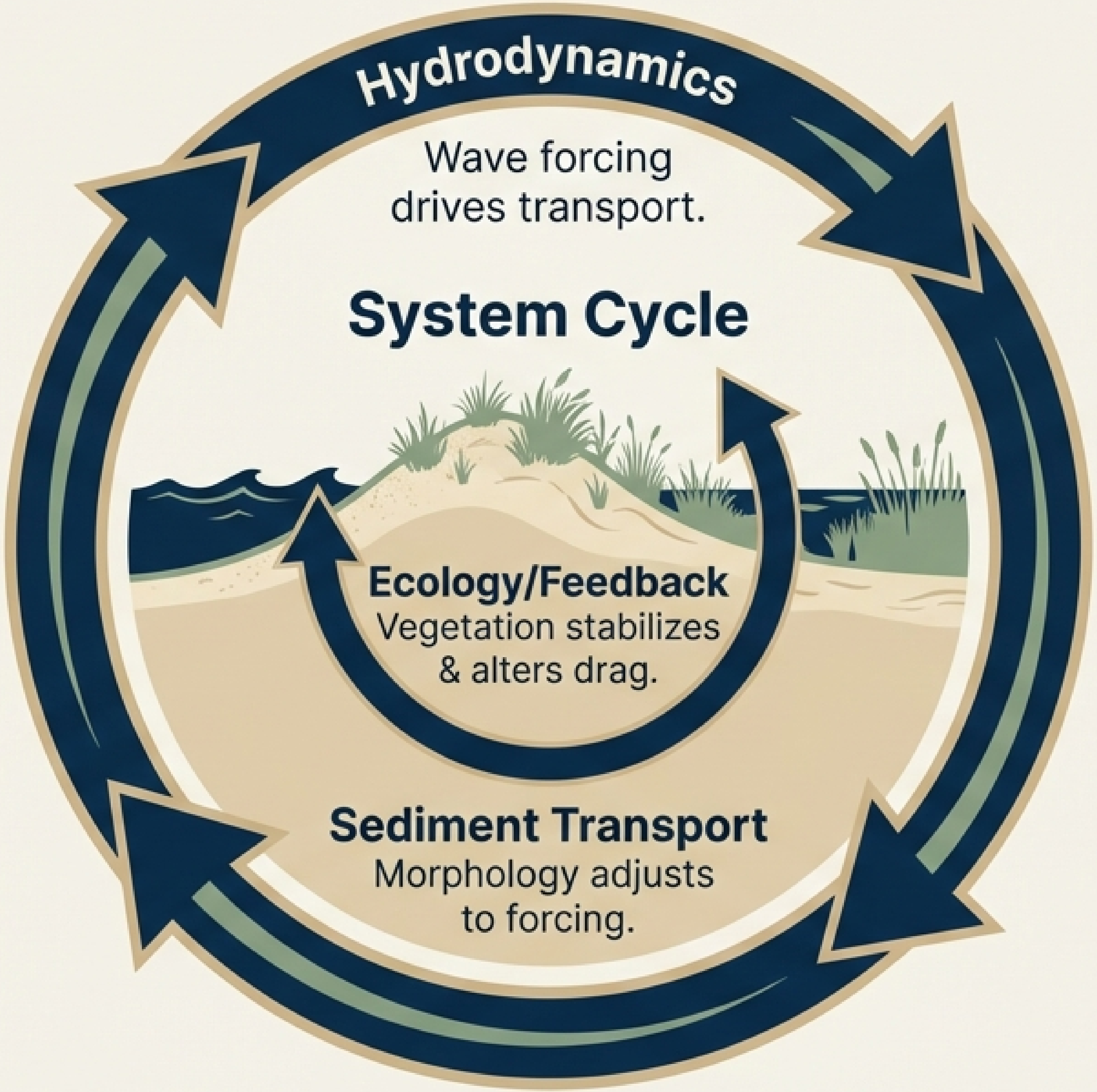
- High-energy open coasts (cyclones/swell)
- Steep nearshore profiles
- Sediment-starved systems
- Critical infrastructure requiring zero overtopping

NotebookLM

The Engine Room: Governing Processes

Pillar
Hydrodynamics
(Waves, Currents, Surge)

Pillar
Ecology
(Vegetation, Biogenic Reefs)

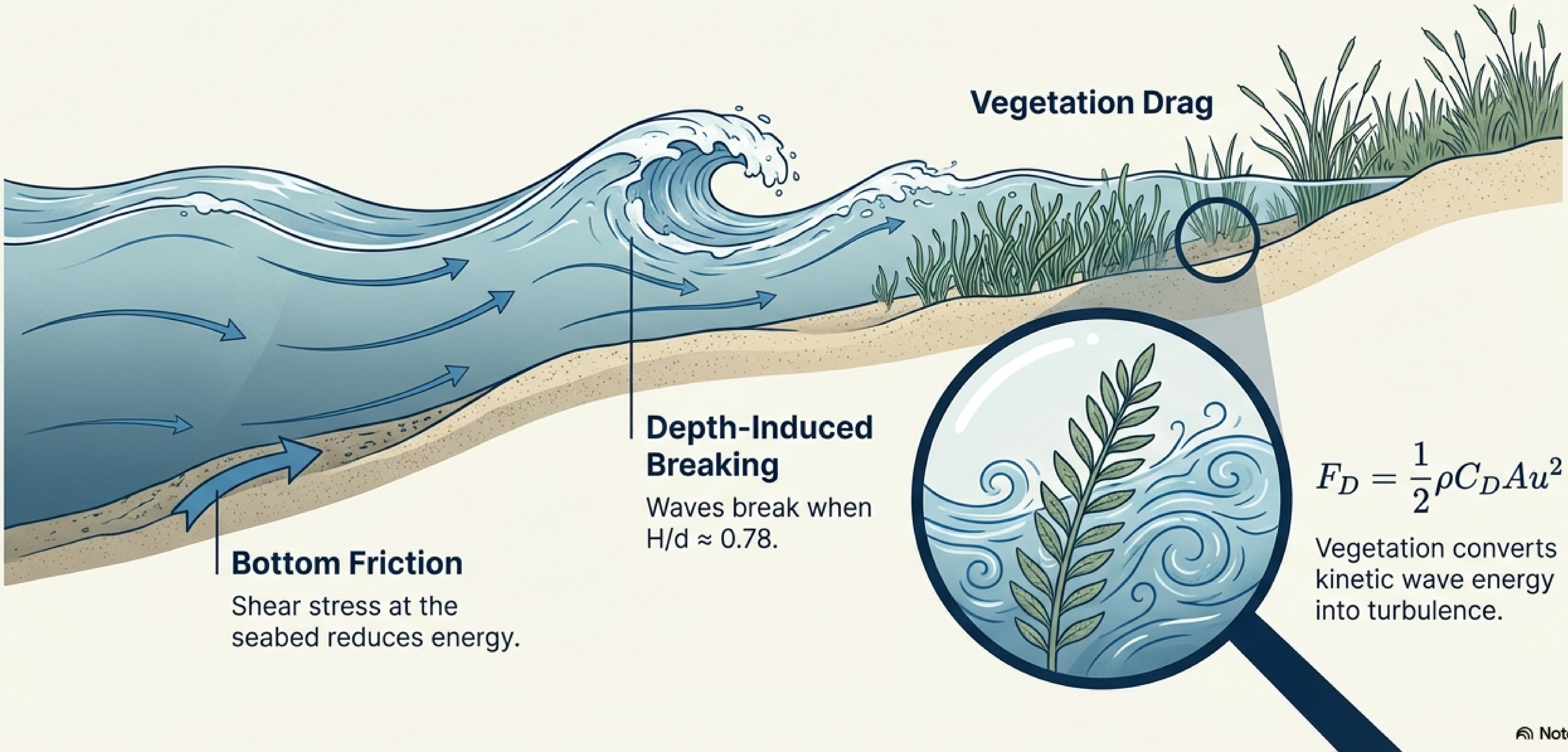


Pillar
Sediment Transport
(Cross-shore, Longshore)

Pillar
Morphodynamics
(Profile adjustment)

NotebookLM

Mechanics of Wave Energy Dissipation



NotebookLM

Technical Naturalism

The Physics of Slope: Surf Similarity & Run-Up

Spilling Breaker ($\xi < 0.4$) | **Plunging Breaker** | **Surging Breaker ($\xi > 2$)**

Spilling Breaker ($\xi < 0.4$) | Plunging Breaker | Surging Breaker ($\xi > 2$)

High Dissipation. Desired for NBS.

High Reflection/Run-up.

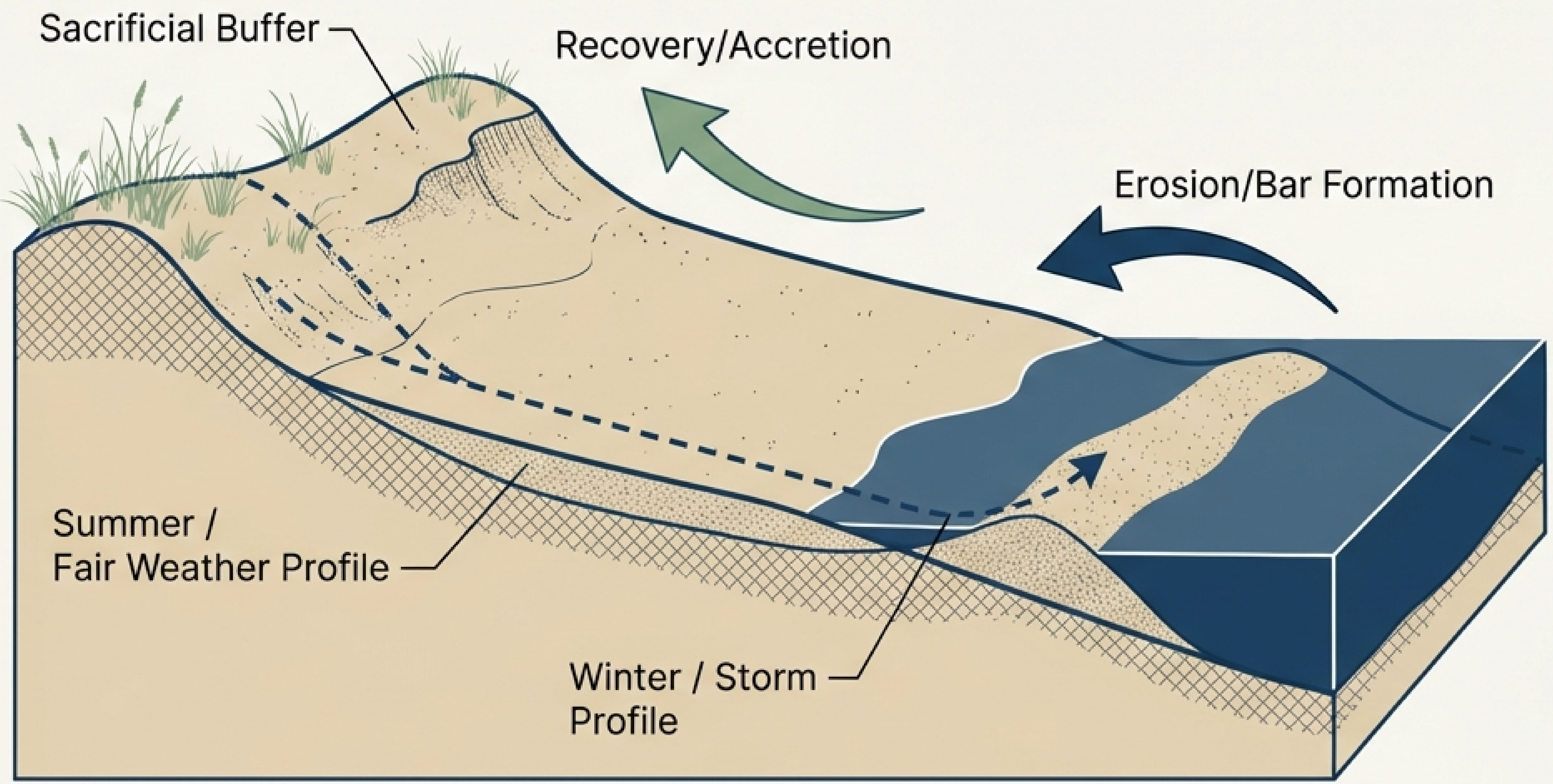
SLOPE STEEPNESS

Surf Similarity Parameter: $\xi = \dfrac{\tan \beta}{\sqrt{H_0/L_0}}$

NBS function by flattening the profile (tan β), converting dangerous surg-surging waves into dissipative spilling breakers.

NotebookLM

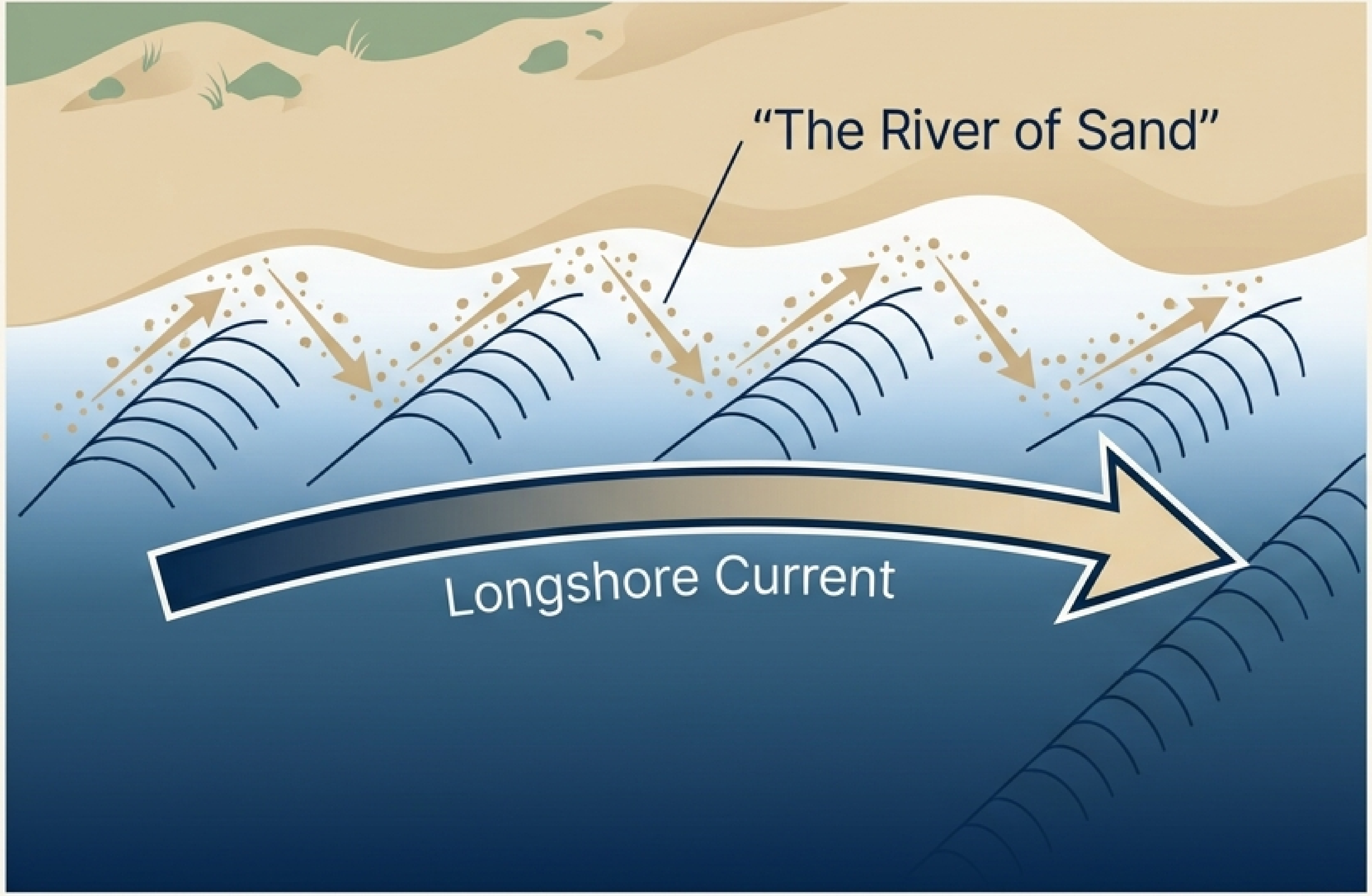
Sedient Transport I: Cross-Shore Dynamics



The Battle of Forces: Storms move sand offshore to trip waves; fair weather moves sand back to rebuild the beach.

NotebookLM

Sediment Transport II: Longshore Drift

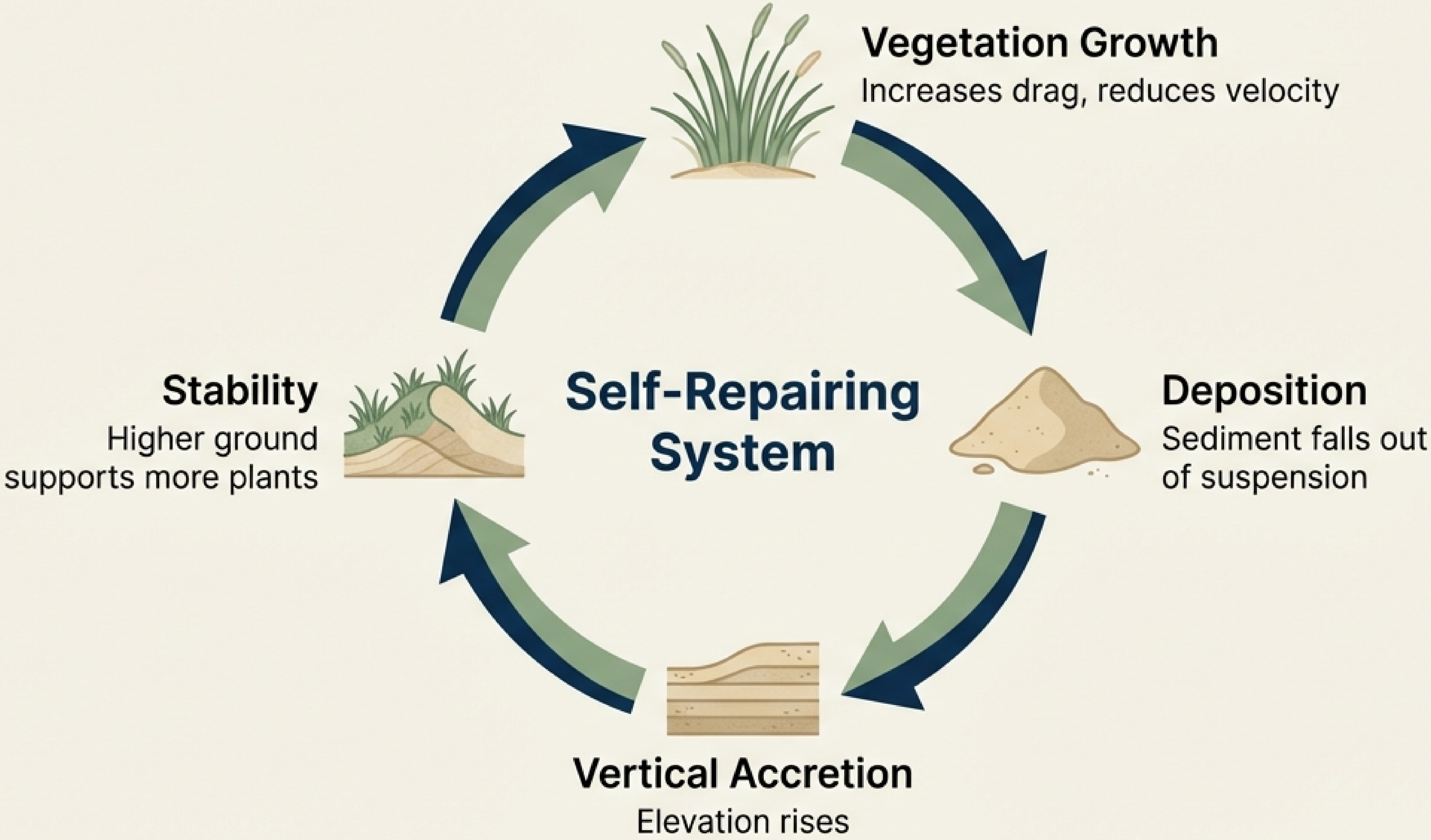


Littoral Drift Dynamics:

- Driven by oblique wave angles.
- Suspended Load vs. Bedload.
- Grain Size Control: Loss rate scales with $1/D_{50}$.
- Engineering Implication: Nourishment is not static; it flows downstream.

NotebookLM

The Multiplier Effect: Eco-Geomorphic Feedbacks



Unlike concrete, NBS grow stronger with sediment supply

NotebookLM

Engineering Application: Beach Nourishment

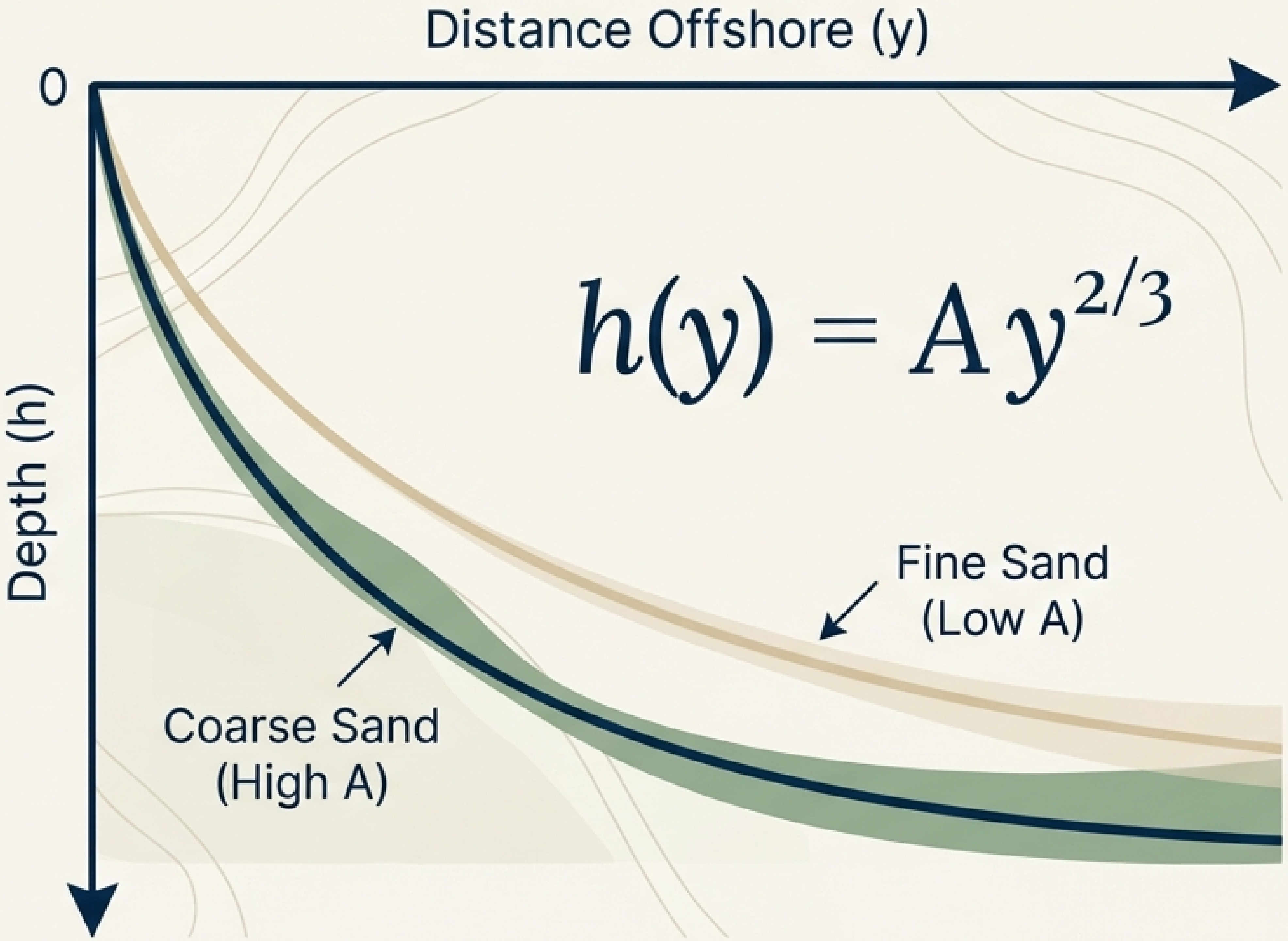
Definition:
A soft engineering structure designed to widen the dissipative buffer (W).

Key Reality:
It is not permanent protection; it is a maintenance strategy.

Methods:
- Dredging & Pumping
- Truck Haul
- Nearshore Feeder Berms

NotebookLM

Design Tool: The Dean Equilibrium Profile

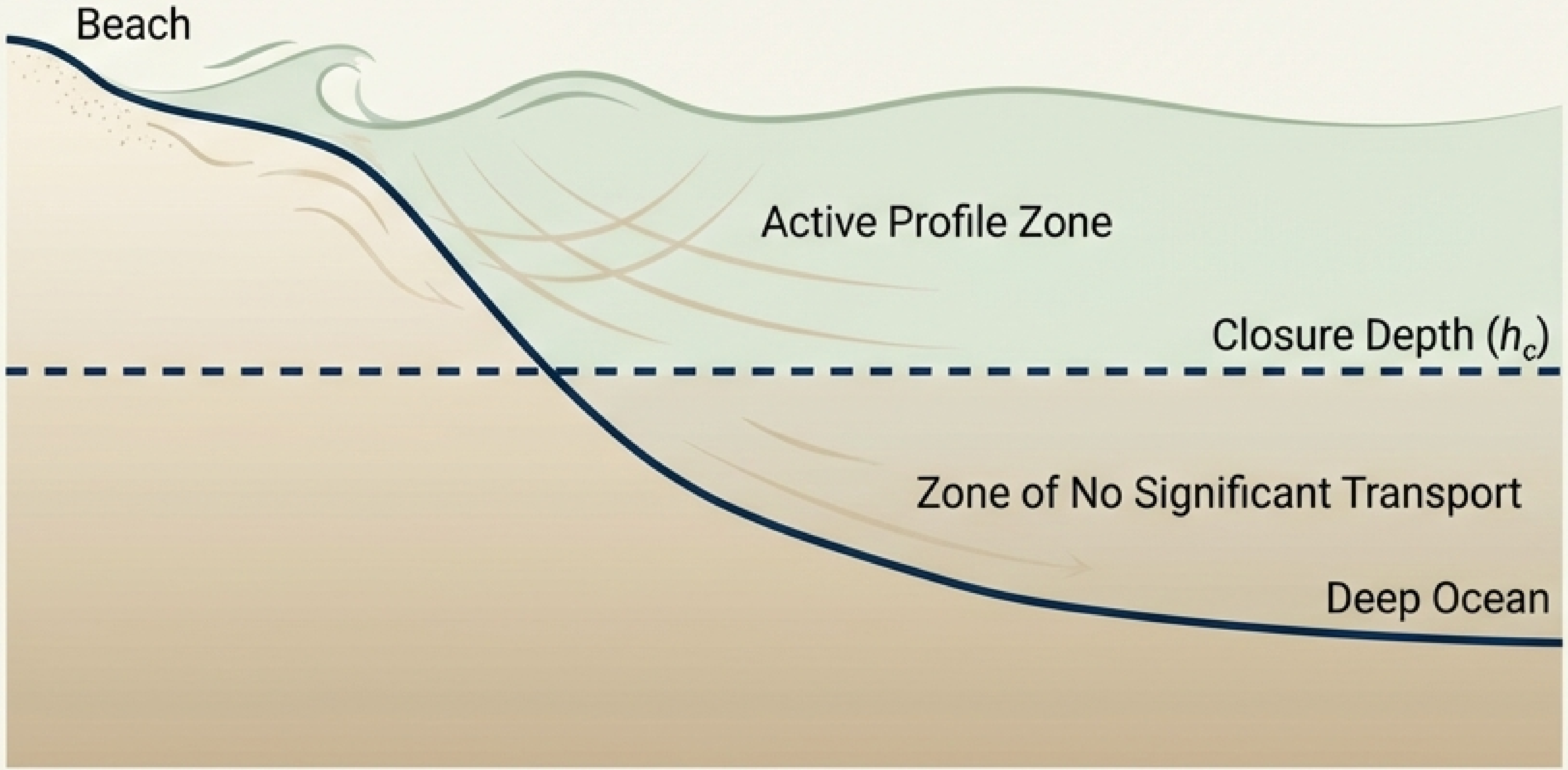


The Law of Beach Shape:

- Nature dictates profile shape based on grain size (D_{50}).
- Engineering Risk: Using sand finer than native = flatter profile = much higher volume required.

NotebookLM

Determining Project Boundaries: Closure Depth (h_c)



Definition: The theoretical depth where the beach profile stops adjusting to surface waves.

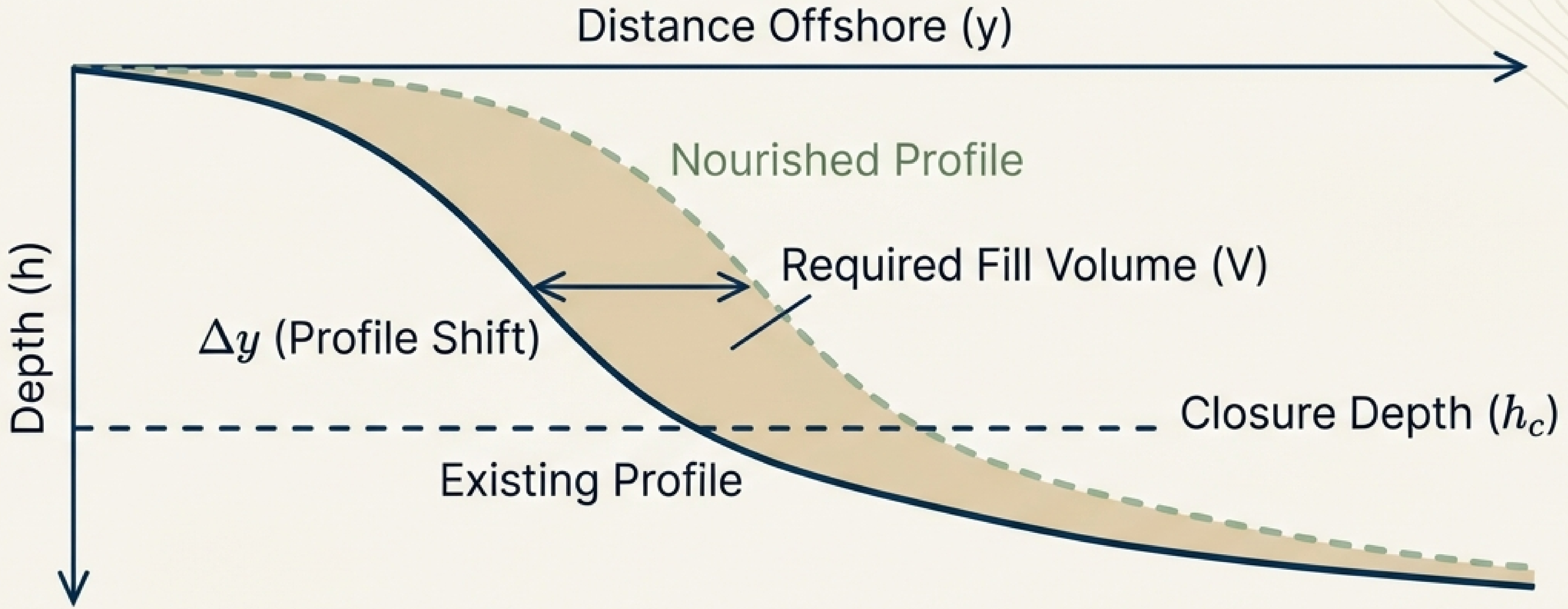
Formula (Hallermeier):

$$h_{\mathrm{c}} \approx 1.6 \times H_{\mathrm{s,annual}}$$

Significance: This is the "bottom line" for volume integration.

NotebookLM

Calculating Volume: The Profile Shift Method

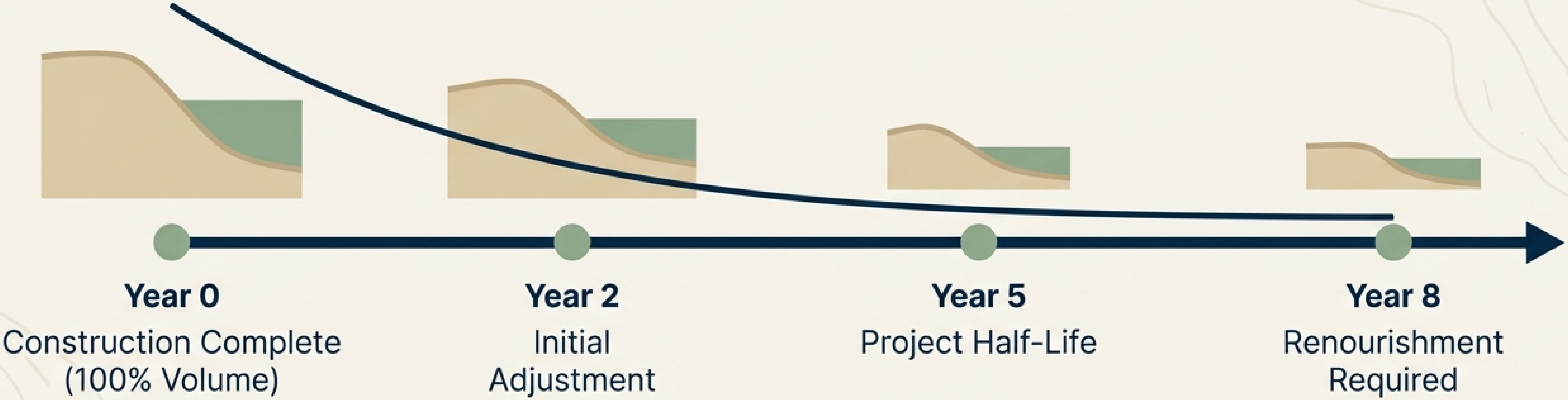


$$V \approx A \frac{3}{5} (h_c + \Delta y)^{5/3} - \text{Native Terms}$$

Note: Volume depends non-linearly on the desired width increase.

NotebookLM

Project Longevity & The Fate of Sand



Factors in Project Life:

- Grain Size: Coarser lasts longer.
- Wave Angle: High drift removes sand faster.
- Equation: $Q_{eff} = (1 - F) Q$ (Interception reduces loss)

Soft structures are living systems requiring ongoing management, not static monuments.

NotebookLM