Hard Coastal Structures

Principles, Design, and Hydrodynamic Performance of the Defended Shoreline.

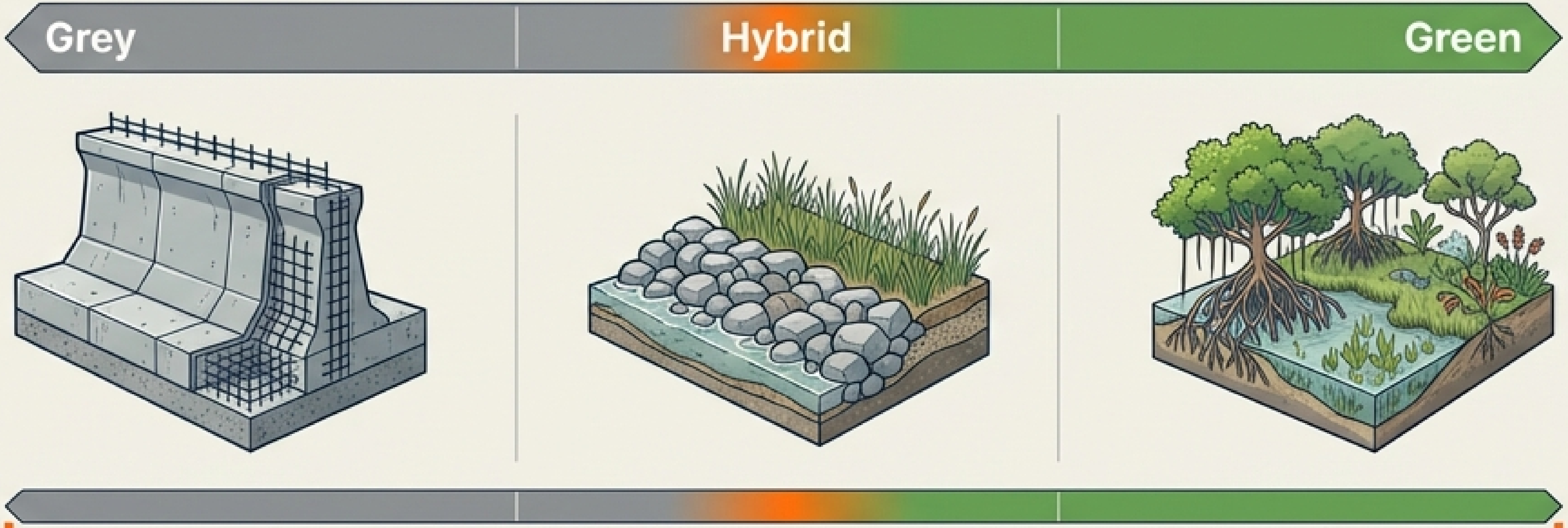
Producer Note

ENGINEERING HANDBOOK / VOL VI.
// LOADS - STRUCTURE - RESPONSE

The Strategy: Hold the Line

The Driver: Hard infrastructure is deployed where failure is not an option. It protects critical urban density, economic assets, and heritage sites from erosion and flooding. The philosophy is static resistance.

The Coastal Protection Continuum



Hard Structure

Function: Resist Forces
Adaptability: Low
Ecological Value: Low

Hybrid

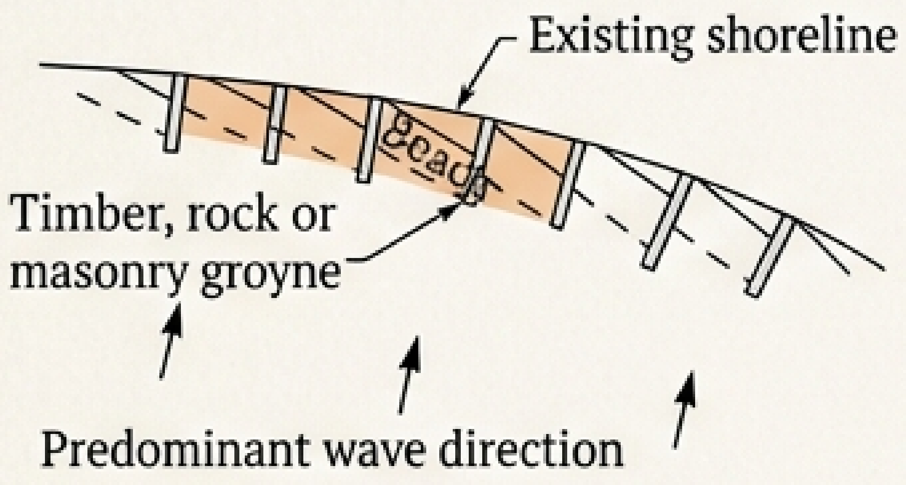
Function: Dampen & Retain
Adaptability: Medium

Nature-Based

Function: Work with Nature
Adaptability: High
Ecological Value: High

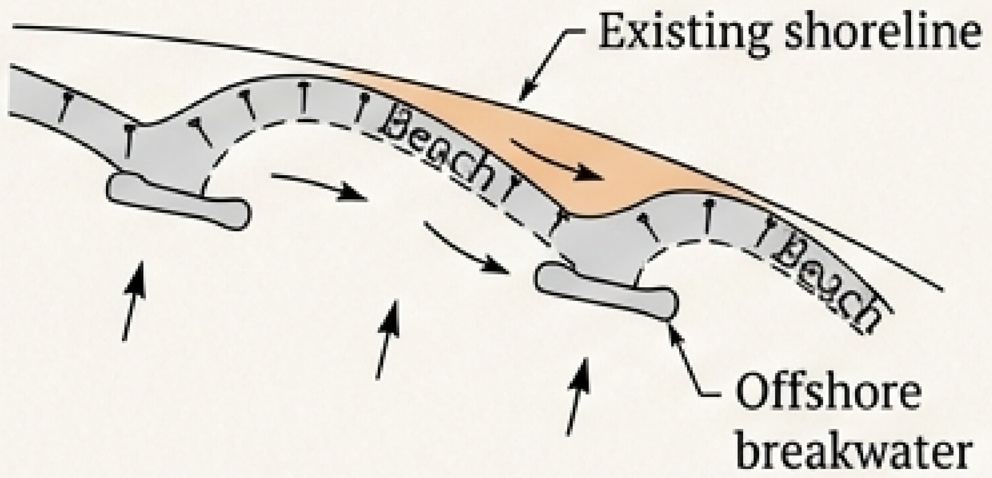
The Toolbox: Engineering Solutions

Groins



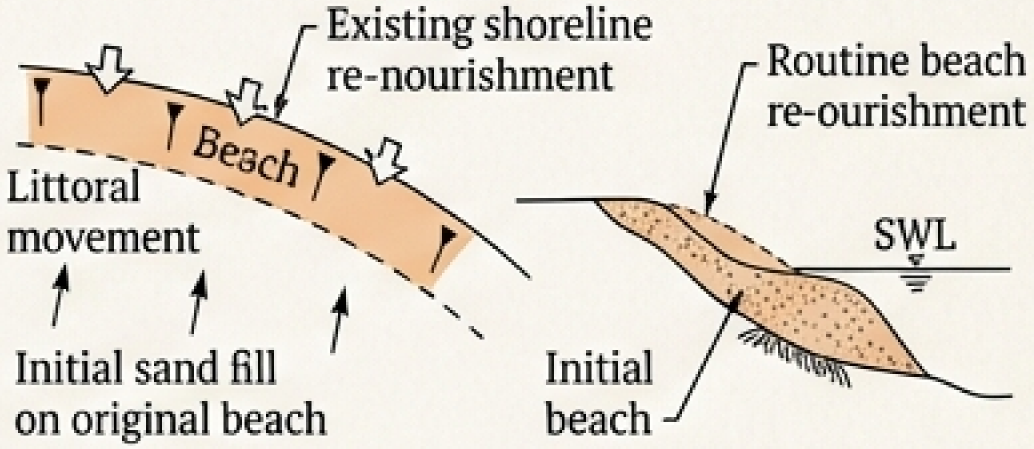
Perpendicular. Interrupts transport.

Offshore Breakwaters



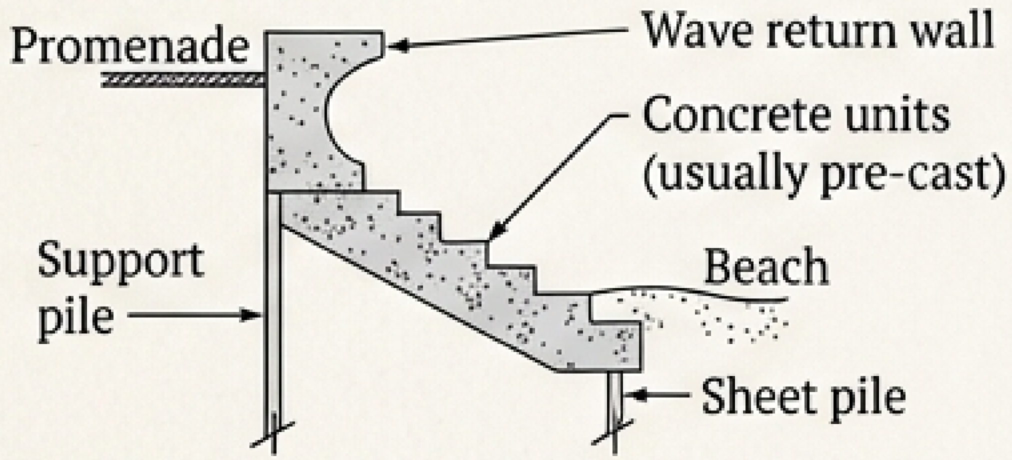
Parallel (Offshore). Reduces wave energy.

Beach Nourishment



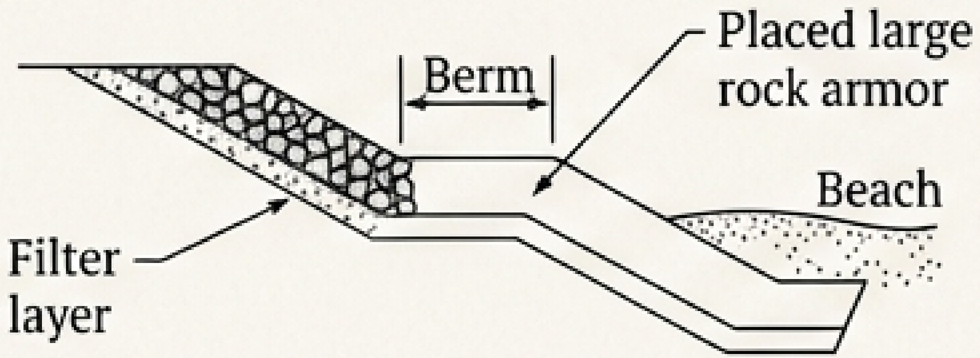
Soft Intervention. Artificial fill.

Stepped Sea Wall



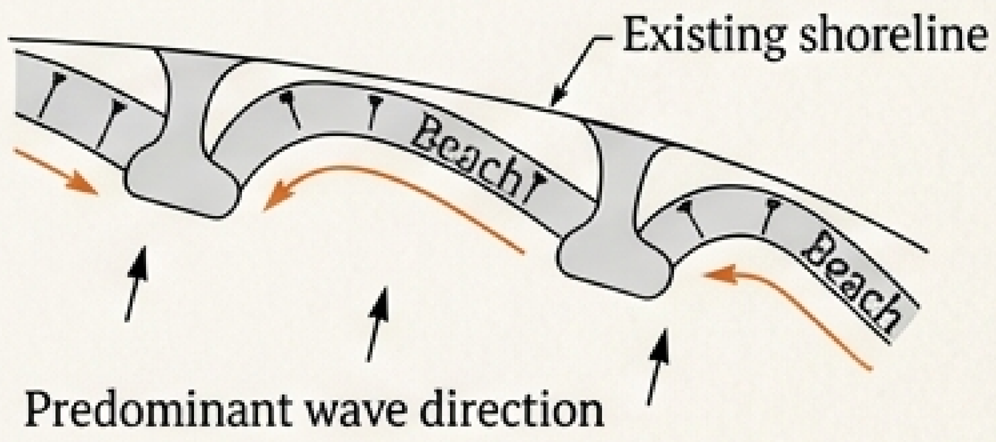
Parallel (Onshore). Resists impact.

Rip-rap Revetment



Parallel (Onshore). Dissipates energy.

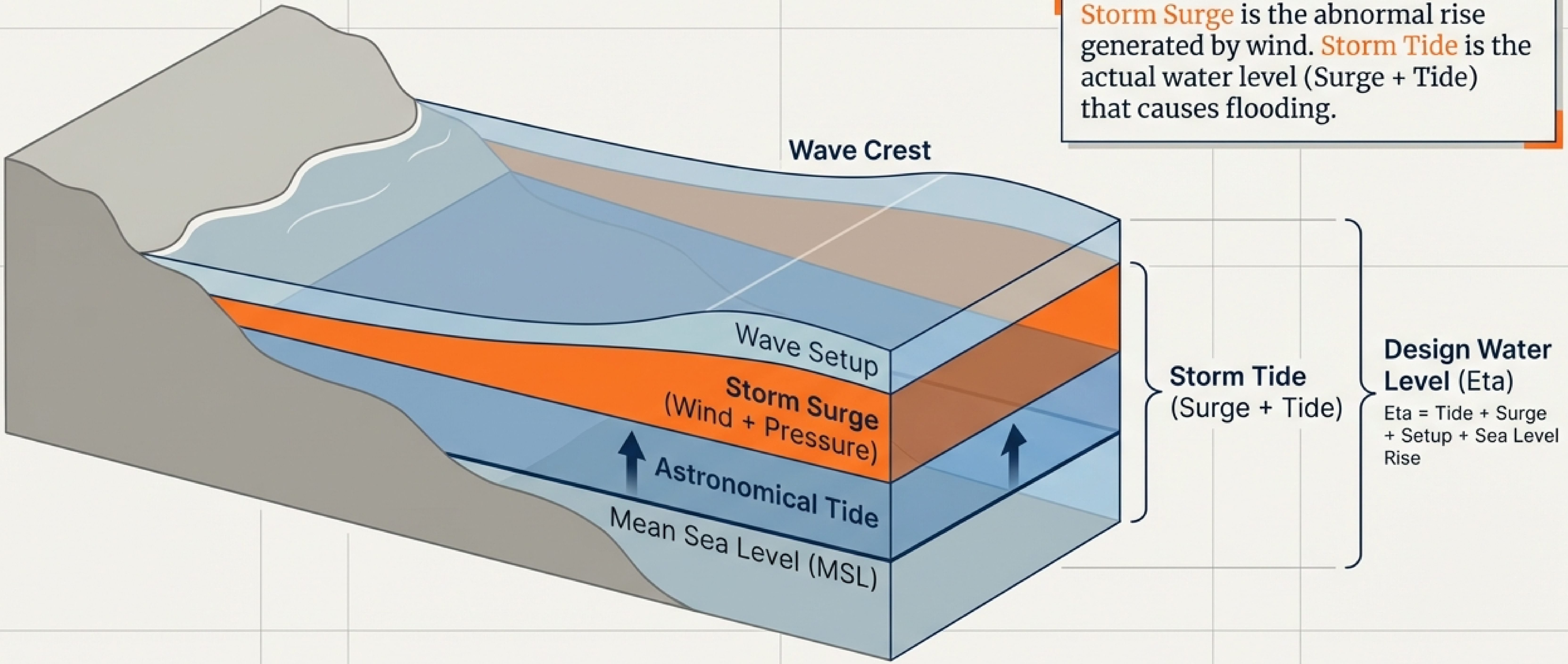
Artificial Headland



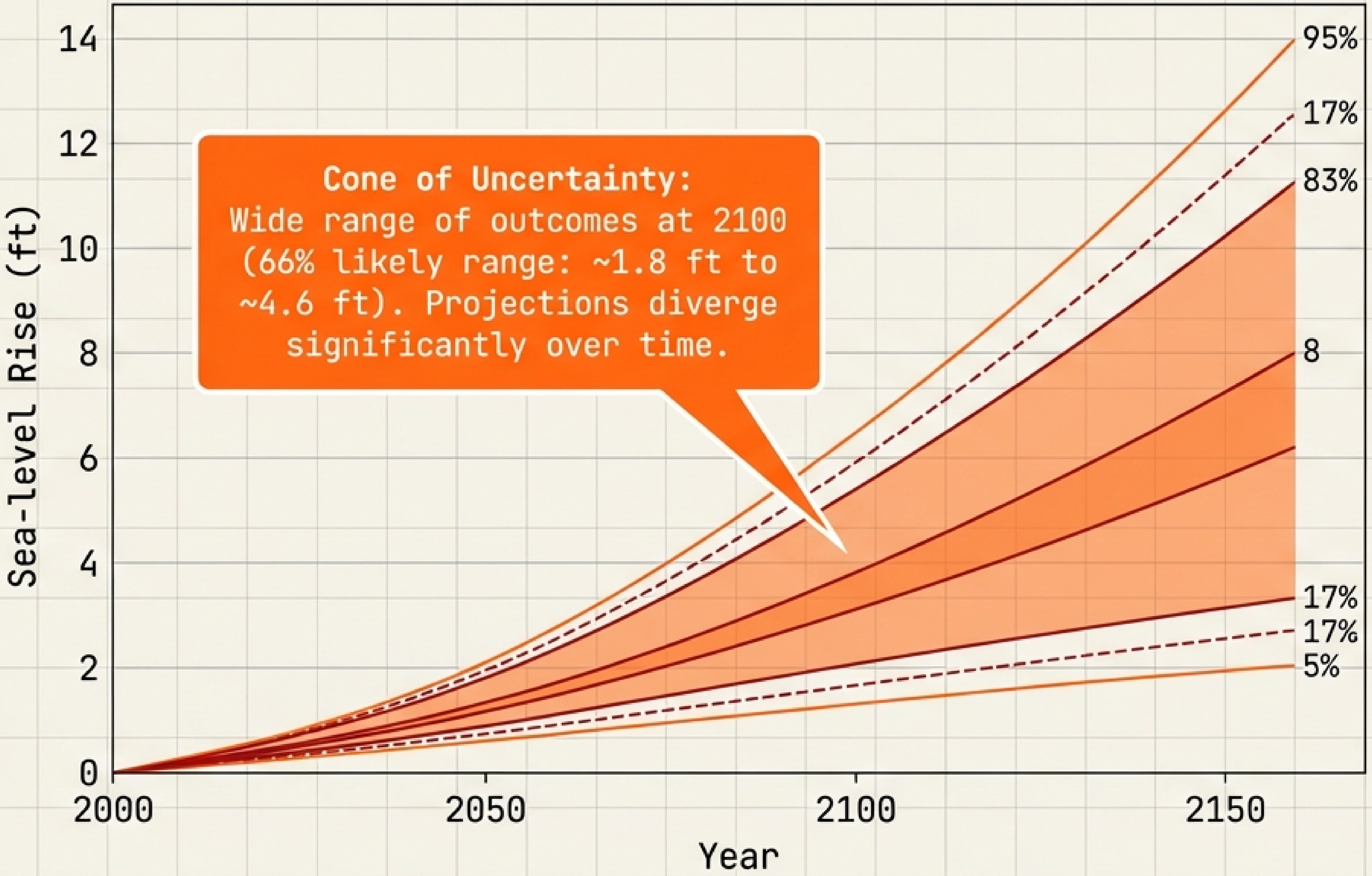
Composite. Stabilizes bays.

The Threat Environment: Total Water Level

Storm Surge is the abnormal rise generated by wind. Storm Tide is the actual water level (Surge + Tide) that causes flooding.



Time-Dependent Variables: Sea Level Rise (SLR)



Design Life & Uncertainty

Hard structures are often designed for 50-100 year lifespans. The Design Water Level is not static; it increases over the structure's life due to rising sea levels.

Return Periods (Tr)
Critical Barriers = 100-200 yrs; Seawalls = 50 yrs.

Hydrodynamics: Wave Transformation

Design Wave Height at Toe:

$$H_d = K_s * K_r * H_0$$

K_s = Shoaling Coefficient
K_r = Refraction Coefficient

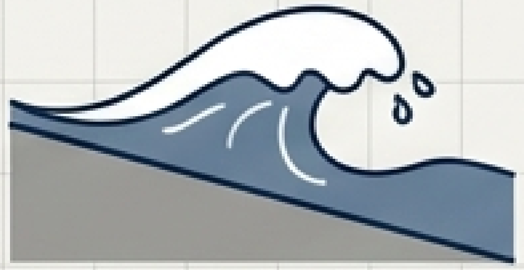
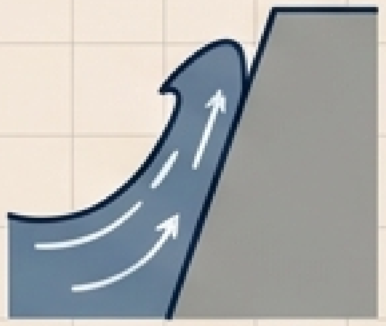
As waves feel the bottom, velocity decreases and height increases. The wave that hits the wall (Hd) is different from the deep water wave (H0).

Wave-Structure Interaction: The Breaker Parameter

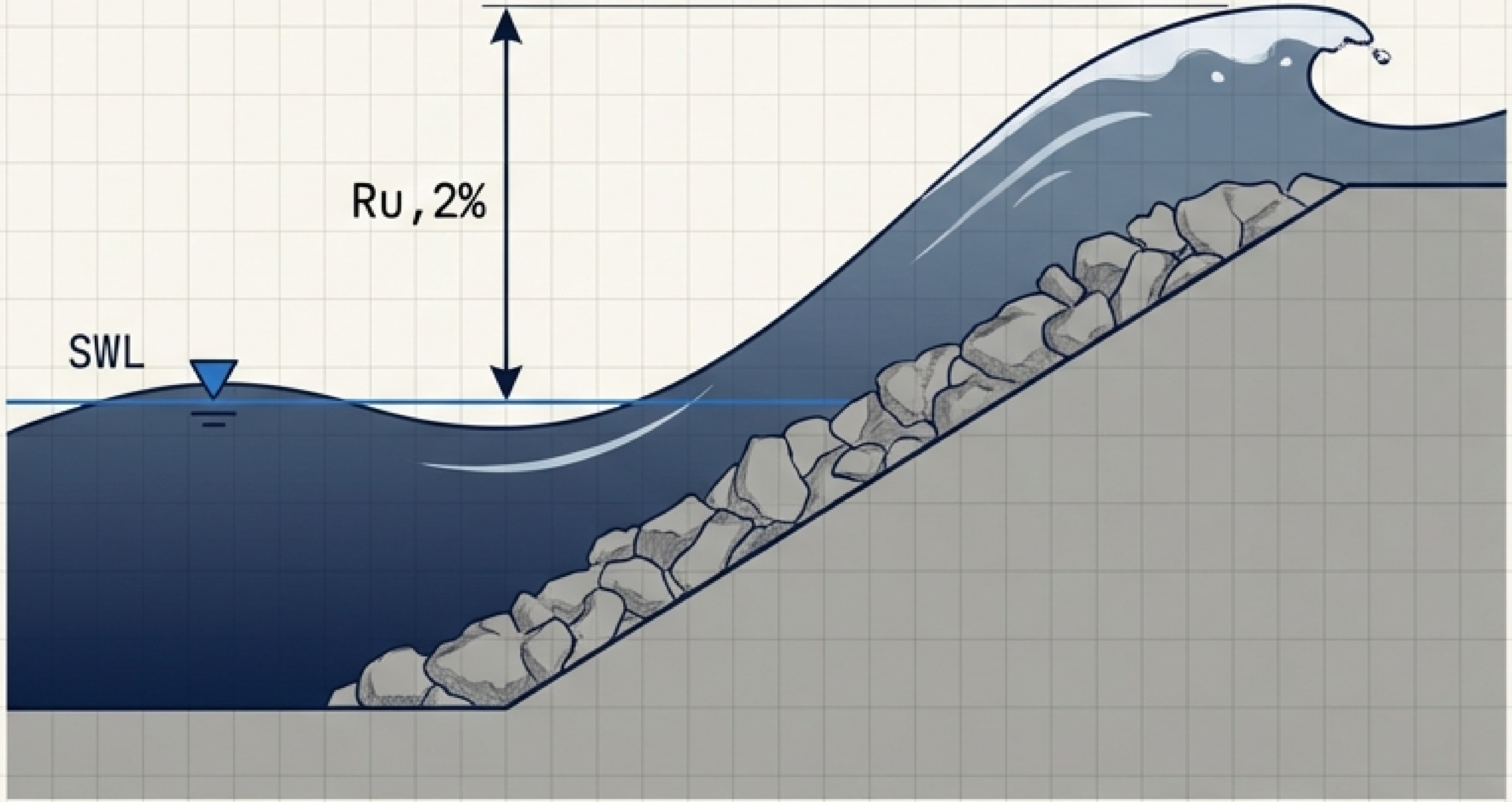
$$X_i = \frac{\tan(\alpha)}{\sqrt{H/L_0}}$$

$\tan(\alpha)$ = Structure Slope $H/L0$ = Wave Steepness

Typical for Hard Structures

Spilling	Plunging	Surging / Reflecting
$Xi < 0.5$	$0.5 < Xi < 3.3$	$Xi > 3.3$
		
Gentle Slope.	Max Impact Pressure.	Max Run-up.

Design Calculation 1: Wave Run-up (Ru)



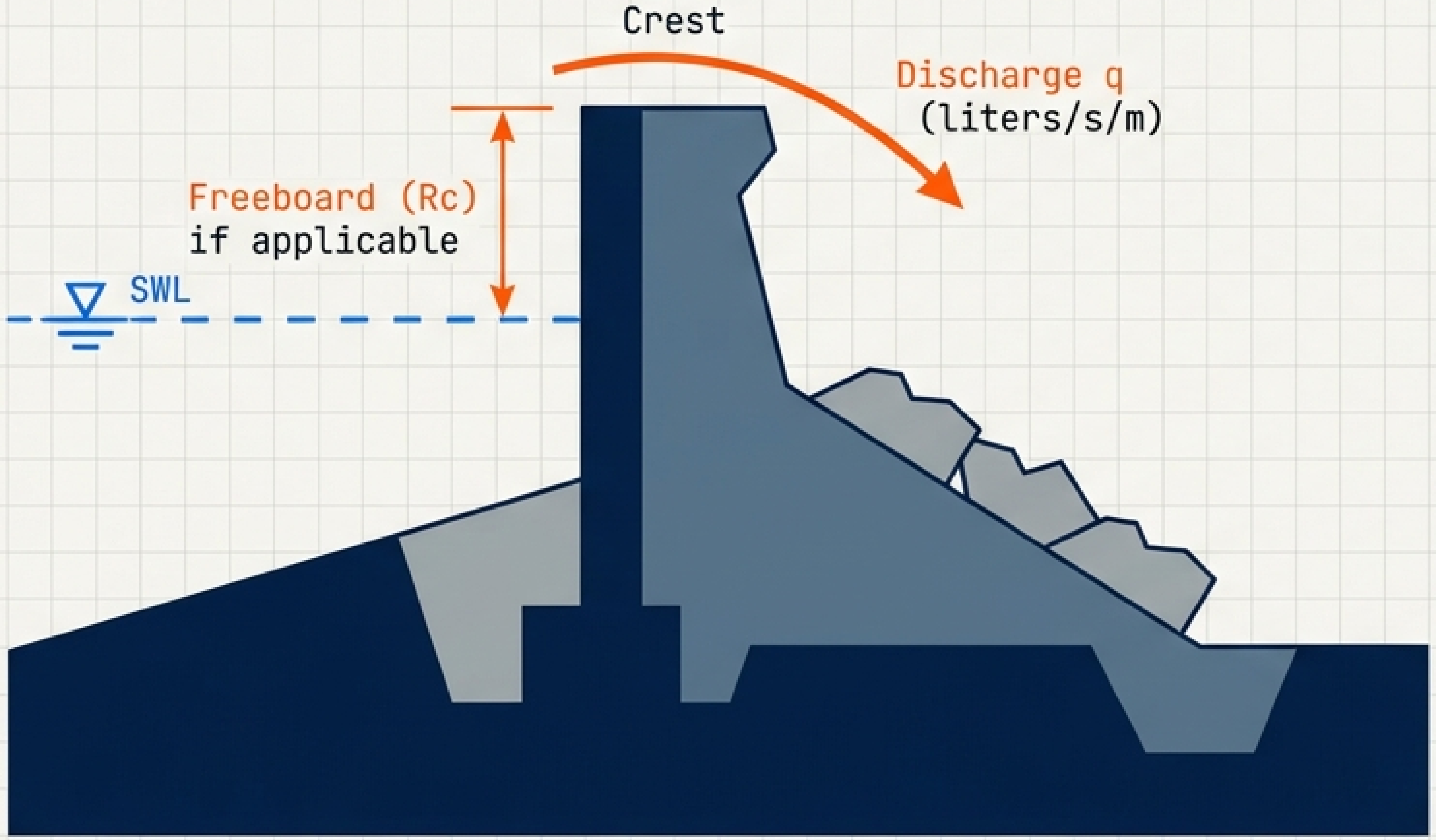
Based on definition sketch for coastal dikes and seawalls.

The Roughness Factor (gamma$_f$)

ENGINEERING NOTE

Roughness is the engineer's lever. Using rock armor introduces turbulence, dissipating energy and reducing the required wall height by ~45%.

Design Calculation 2: Overtopping (q)



Sensitivity Analysis

The overtopping formula contains an exponential term based on Freeboard (Rc).

Small changes in wall height = Exponential changes in safety.

Increasing Rc by just 0.5m can reduce discharge by an order of magnitude.

Based on EuroTop Manual Guidelines.

Case Study: Design Challenge

Project: Perimeter Defense Revetment

Design Inputs (Given Data)

Wave Height (Hm0): 3.0 meters

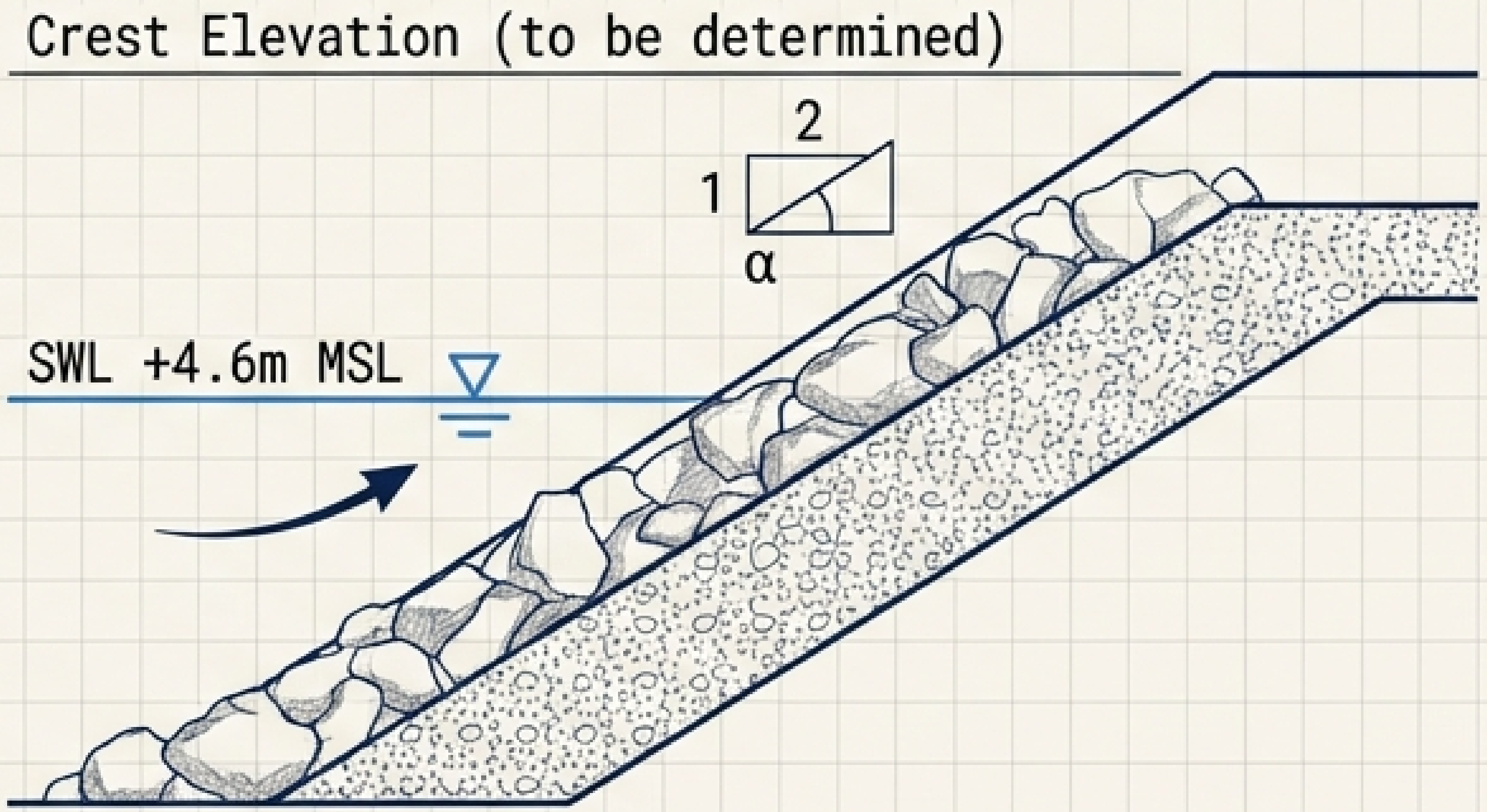
Wave Period (T): 7.0 seconds

Structure Slope: 1:2 (tan alpha = 0.5)

Material: Double-layer Rock Armor (Roughness gamma_f = 0.55)

Design Water Level: +4.6m MSL (Includes Tide + Surge + SLR)

Objective: Determine required Crest Elevation.



Based on definition sketch for coastal dikes and seawalls.

Step 1: Characterizing the Wave

Calculate Wavelength (L0)

JetBrains Rono

$$L0 = \frac{g * T^2}{2pi}$$

$$1.56 * 7.0^2 = 76.5 \text{ m}$$

Calculate Steepness

JetBrains Rono

$$\frac{H}{L0} = \frac{3.0}{76.5} = 0.039$$

Calculate Breaker Parameter (Xi)

JetBrains Rono

$$Xi = \frac{0.5}{\sqrt{0.039}}$$

Xi = 2.53

Xi > 2.0 impiies Surging / Non-Breaking waves. This determines the formula for Step 2.

Based on definition sketch for coastal dikes and seawalls.

Step 2: Calculating Run-up

The Math

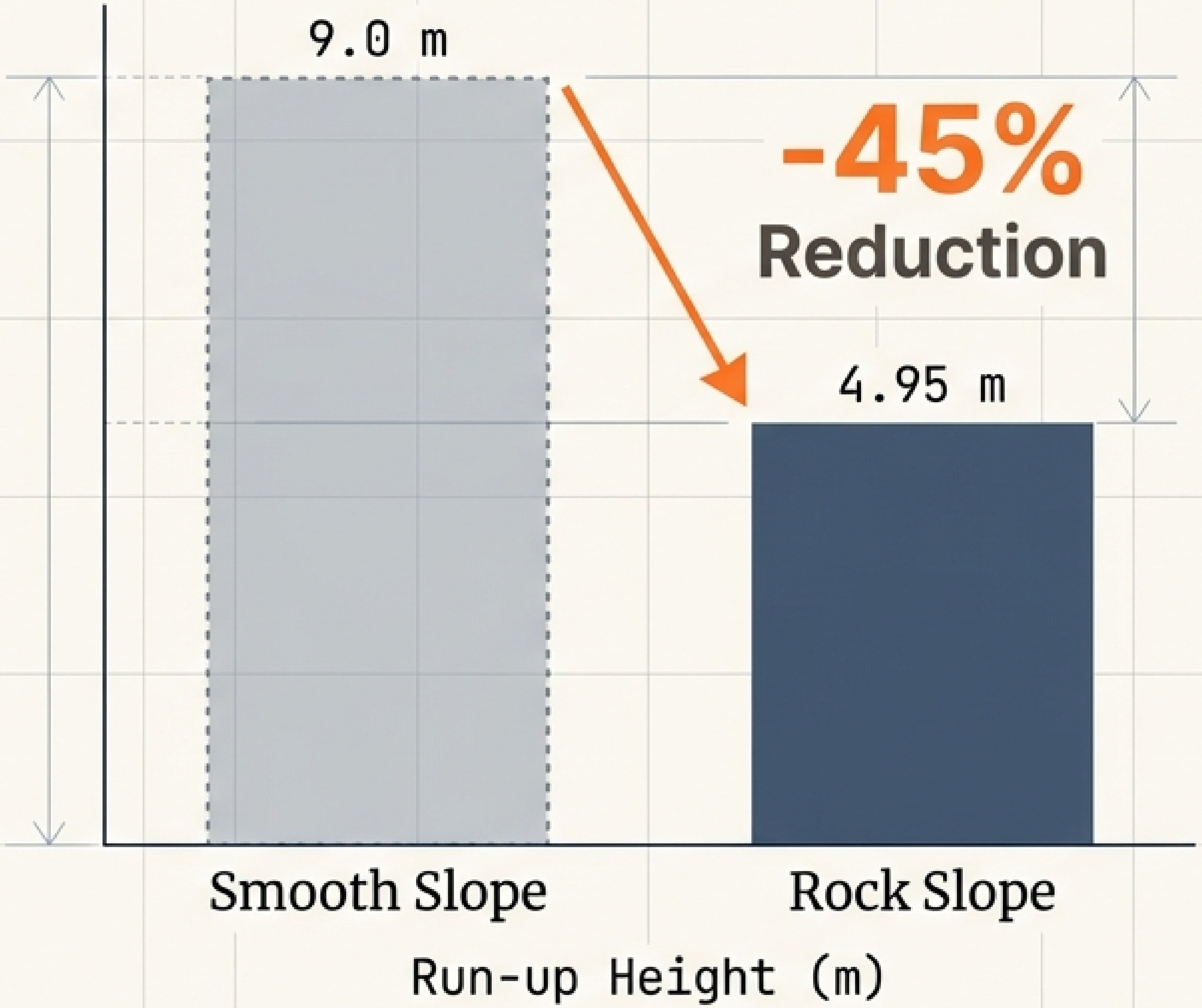
- Base Run-up for Non-Breaking Wave = 3.0 (Maximum Cap).
- Roughness Factor (gamma_f) = 0.55.

`Equation: Ru = 3.0 * 0.55 * H`

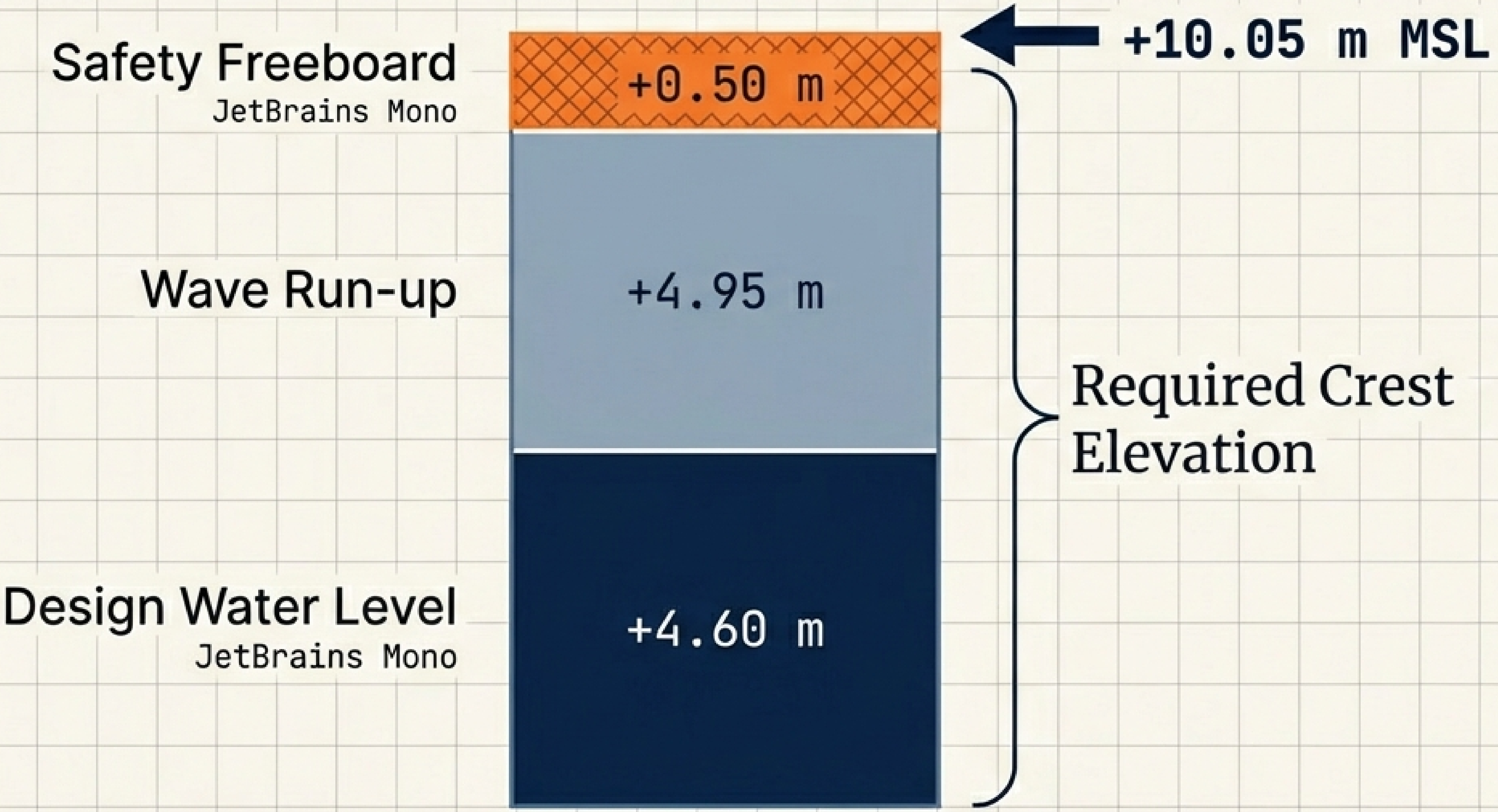
- `Calculation: 1.65 * 3.0m`

Result: $R_{u,2\%} = 4.95$ m

Effect of Armor



Step 3: Setting Crest Elevation



The structure must be built to 10.05m above Mean Sea Level to safely contain the run-up.

Step 4: Verification (Overtopping)

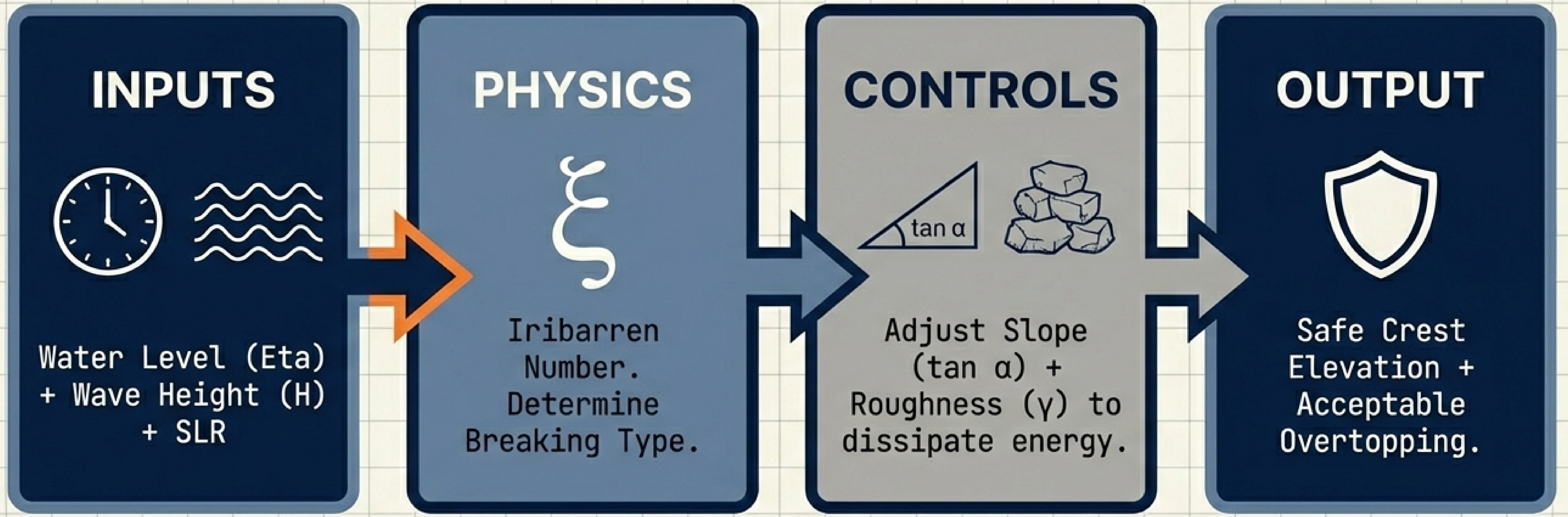
Safety Check: Mean Discharge (q)

Available Freeboard (Rc) Merriweather	10.05m - 4.6m = 5.45m JetBrains Mono
Formula Merriweather	EuroTop Non-Breaking Exponential JetBrains Mono
Calculated Discharge Merriweather	3.9 Liters / sec / m JetBrains Mono

VERDICT: ACCEPTABLE.

3.9 L/s/m is within splash tolerance for a rock revetment. The design is safe.

Summary: The Engineering Cycle



Hard structures resist force through mass and geometry. Successs lies in accurate load prediction and energy dissipation.