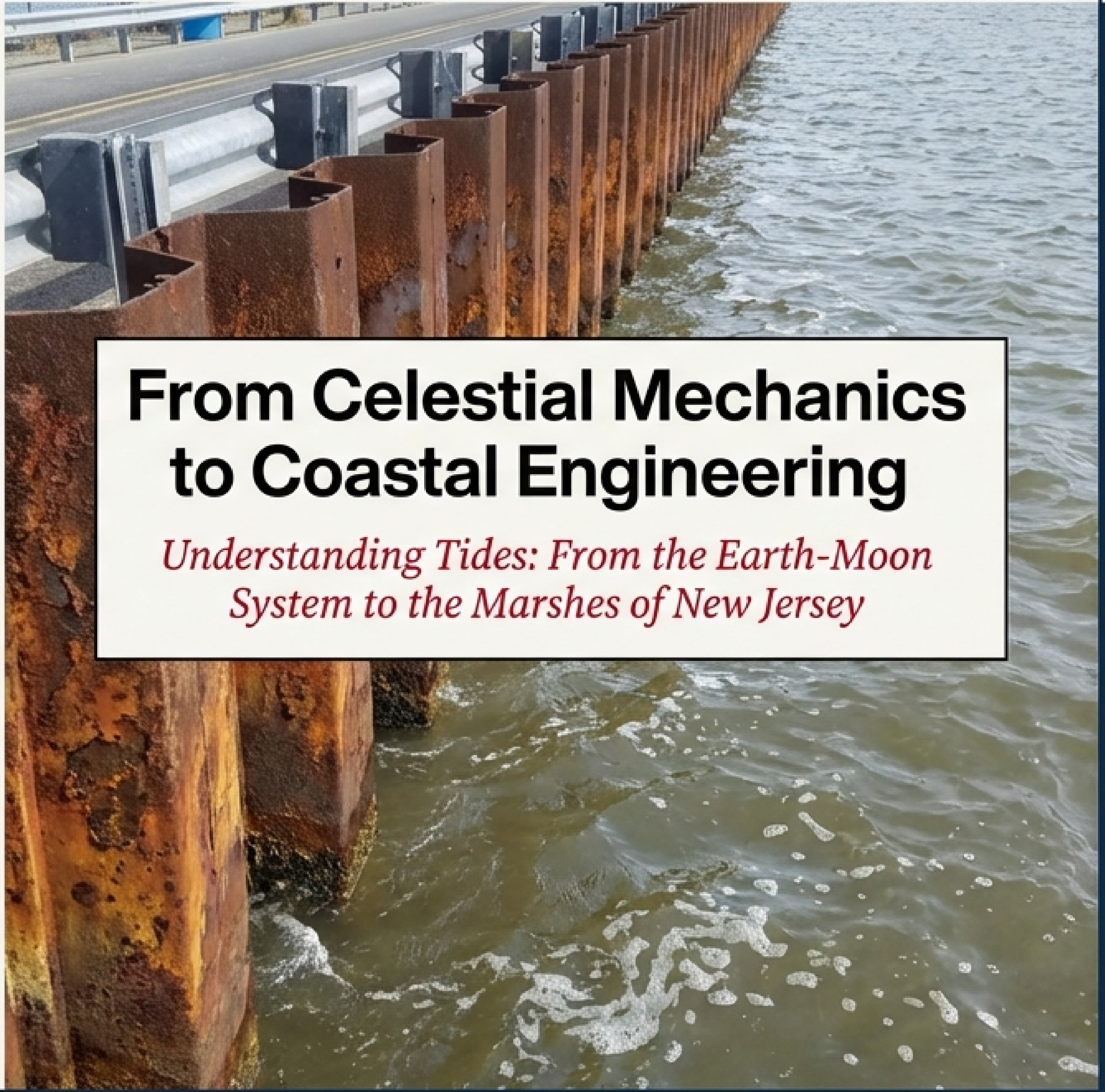
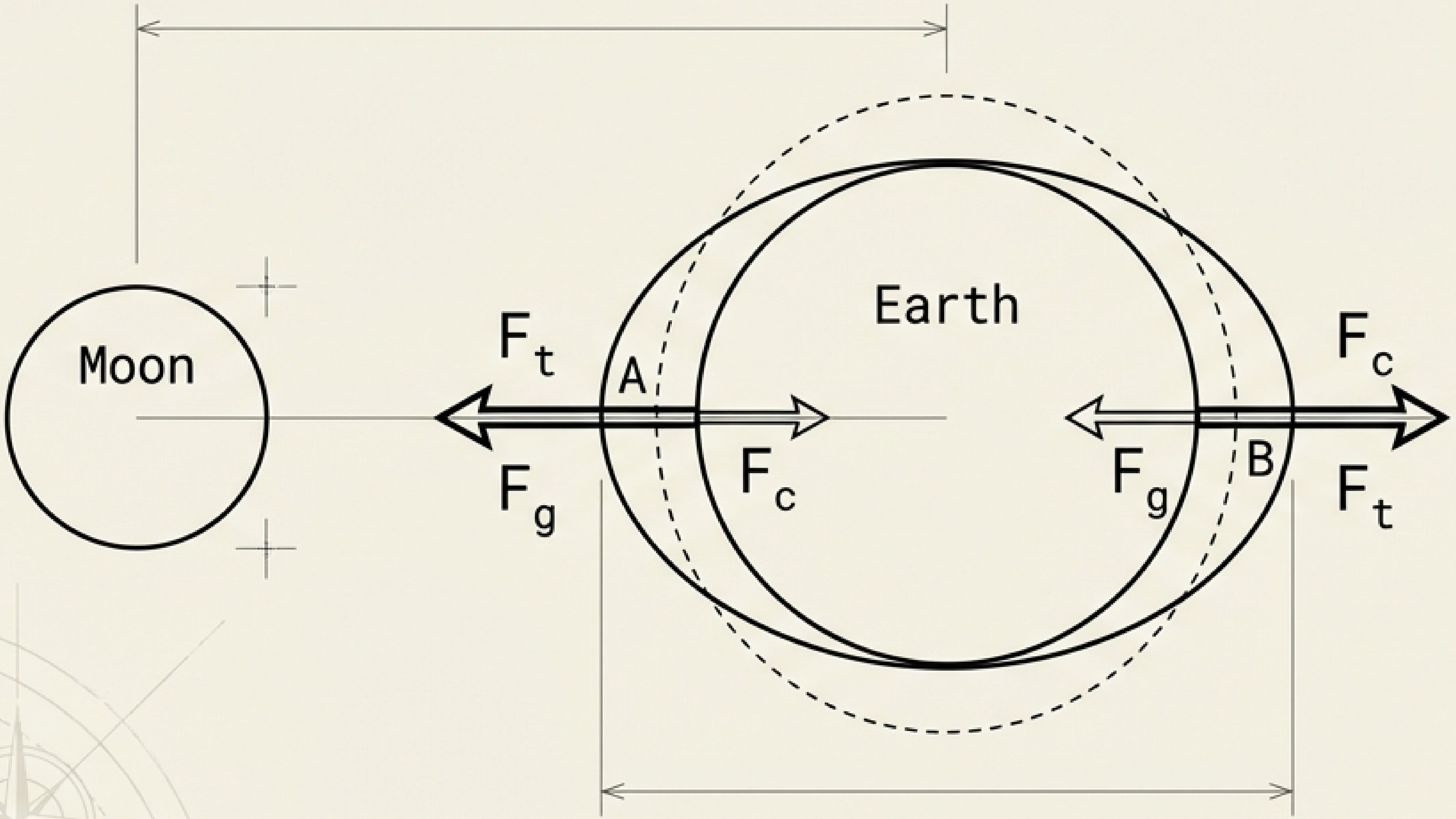


From Celestial Mechanics to Coastal Engineering

Understanding Tides: From the Earth-Moon System to the Marshes of New Jersey

The Balance of Forces

Gravity vs. Centrifugal Motion



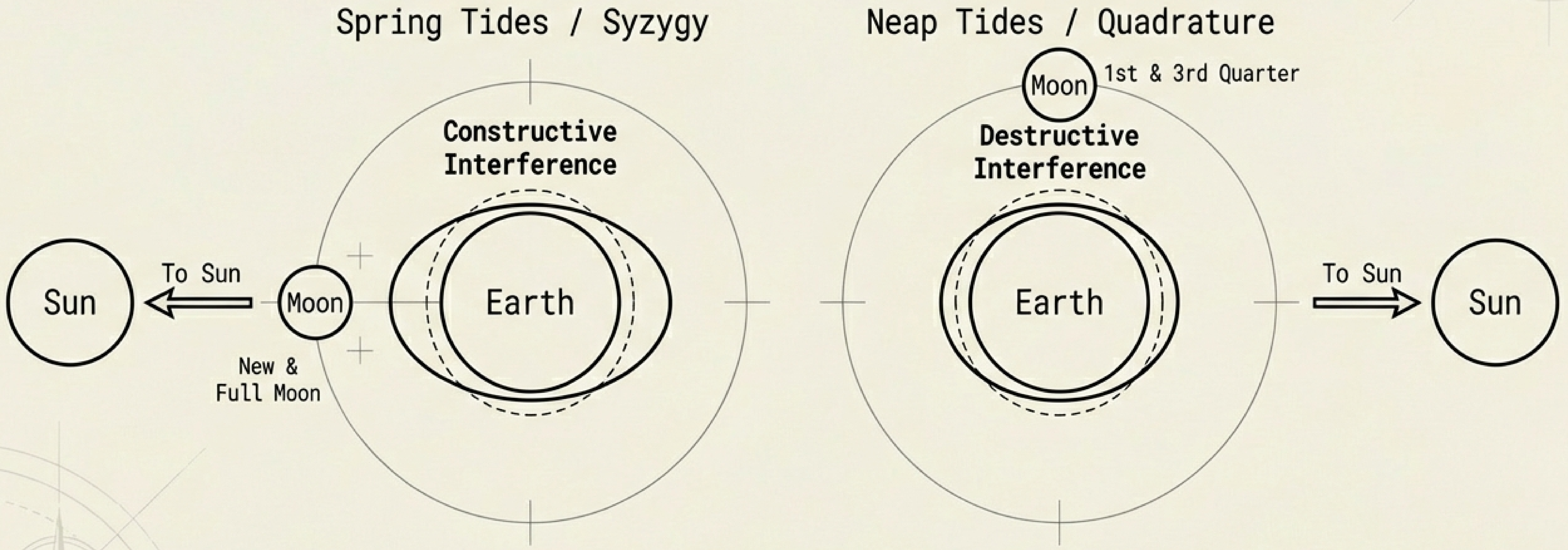
Gravitational Force (F_g):
The Moon's gravity pulls water toward it. At Point A, F_g exceeds centrifugal force, creating a bulge toward the moon.

Centrifugal Force (F_c):
Resulting from the Earth's revolution around the barycenter. At Point B, F_c exceeds gravity, throwing water outward.

The Result (F_t):
Two opposing tidal bulges. Tides are not just a 'pull'; they are a result of the system's rotation.

Solar Influence and Interference

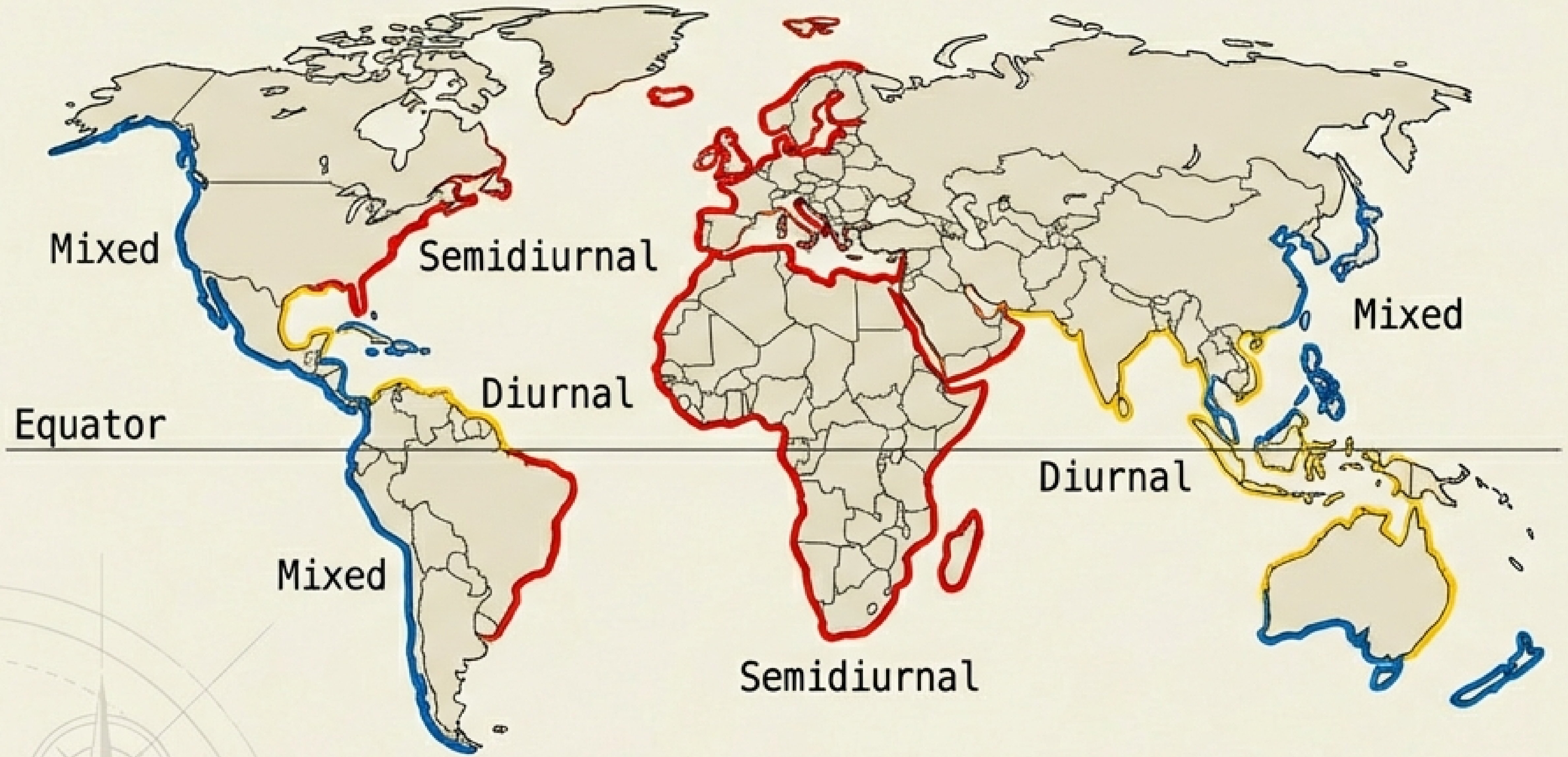
Constructive vs. Destructive Patterns



Spring Tides: Sun and Moon align, amplifying gravitational pull. Maximum tidal range.
Neap Tides: Sun and Moon at right angles, cancelling forces. Minimum tidal range.

Global Variance

Why Tides Don't Follow a Single Clock



Semidiurnal:
2 equal highs/lows per day.

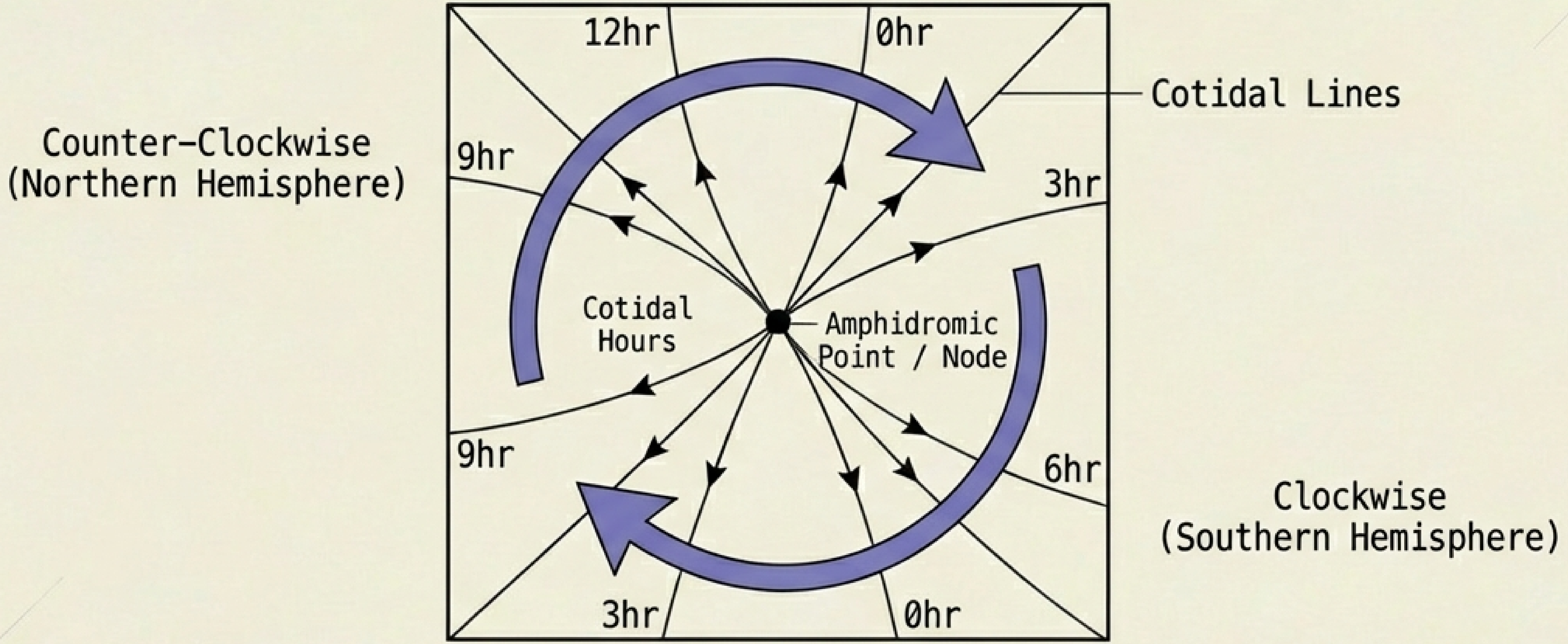
Diurnal:
1 high/low per day.

Mixed:
2 unequal highs/lows.

The Cause:
Landmasses block the ideal wave. Basin geometry filters frequencies (M2, S2, K1, O1) differently.

Basin Resonance & Coriolis Effect

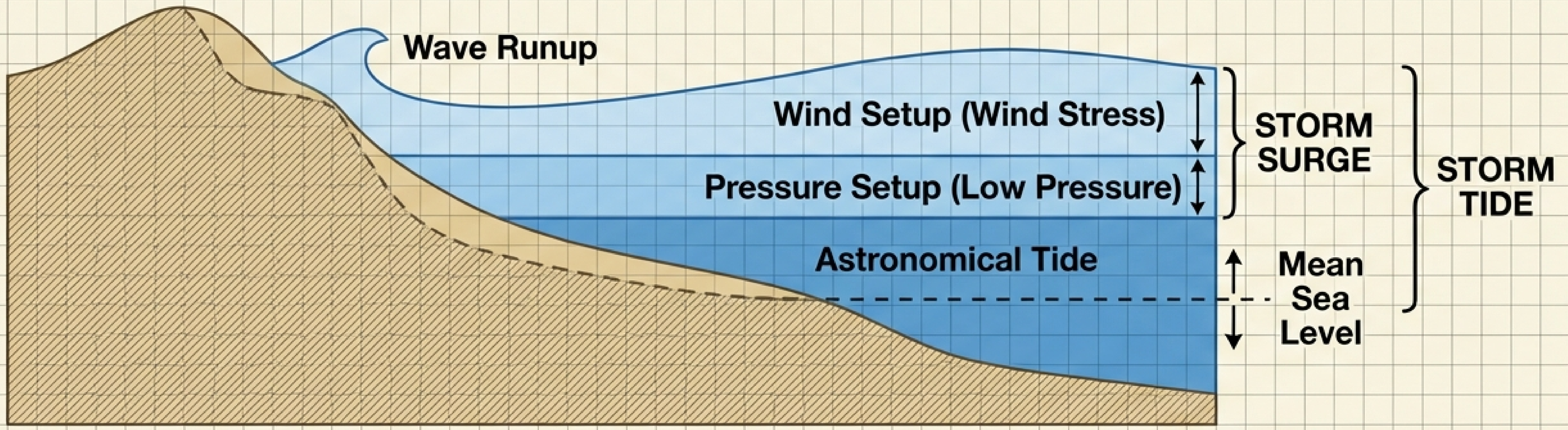
The 'Sloshing' Factor



- **Resonance:** Every basin has a natural period of oscillation. If tidal forcing matches this period, tides amplify.
- **Amphidromic Points:** Tidal crests rotate around nodes where the range is zero. This causes high tide to arrive at different times along a single coastline.

The Unpredictable Variable: Storm Surge

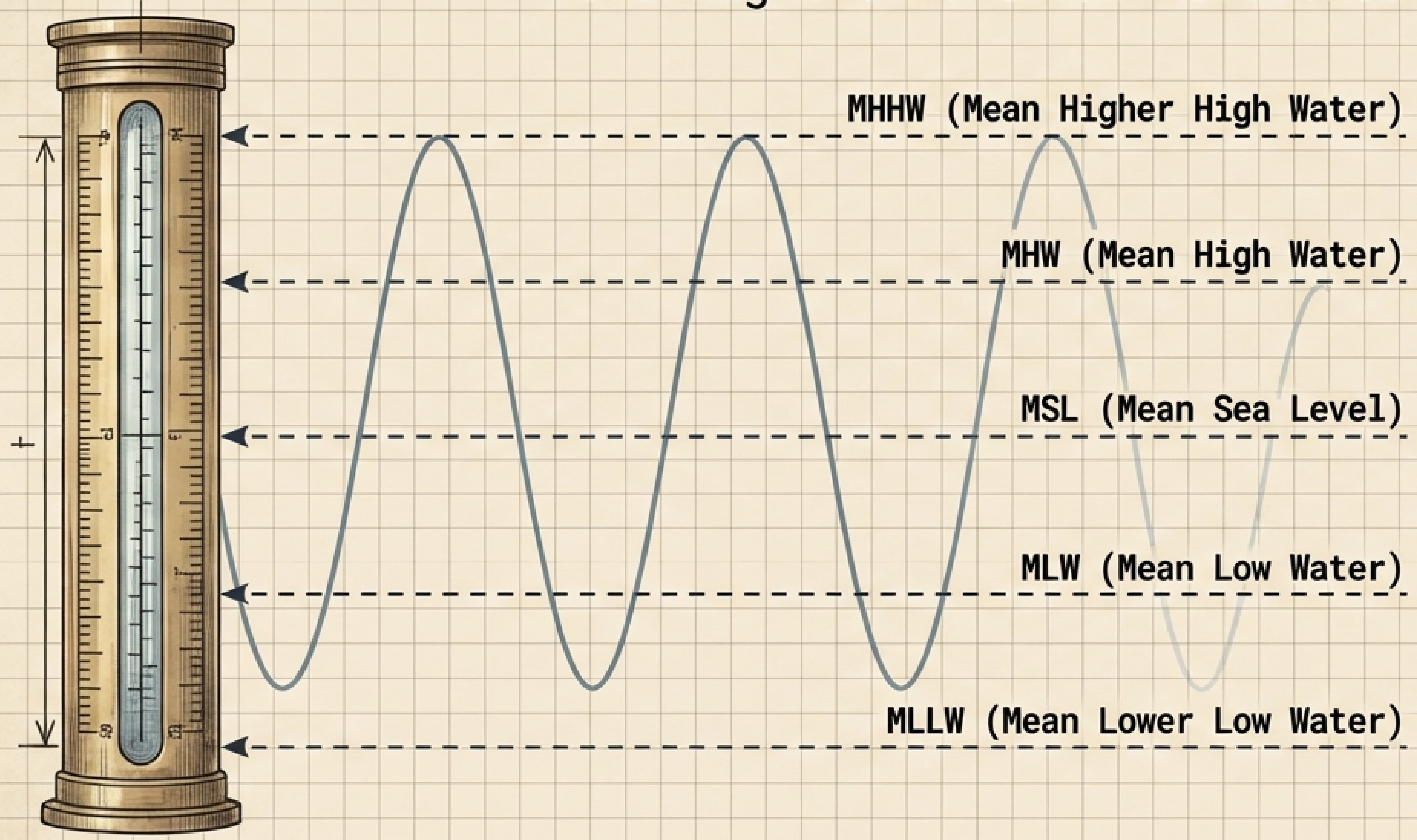
Meteorological vs. Astronomical



Safety depends on distinguishing the predictable gravitational tide from the stochastic meteorological surge.

The Engineer's Ruler: Tidal Datums

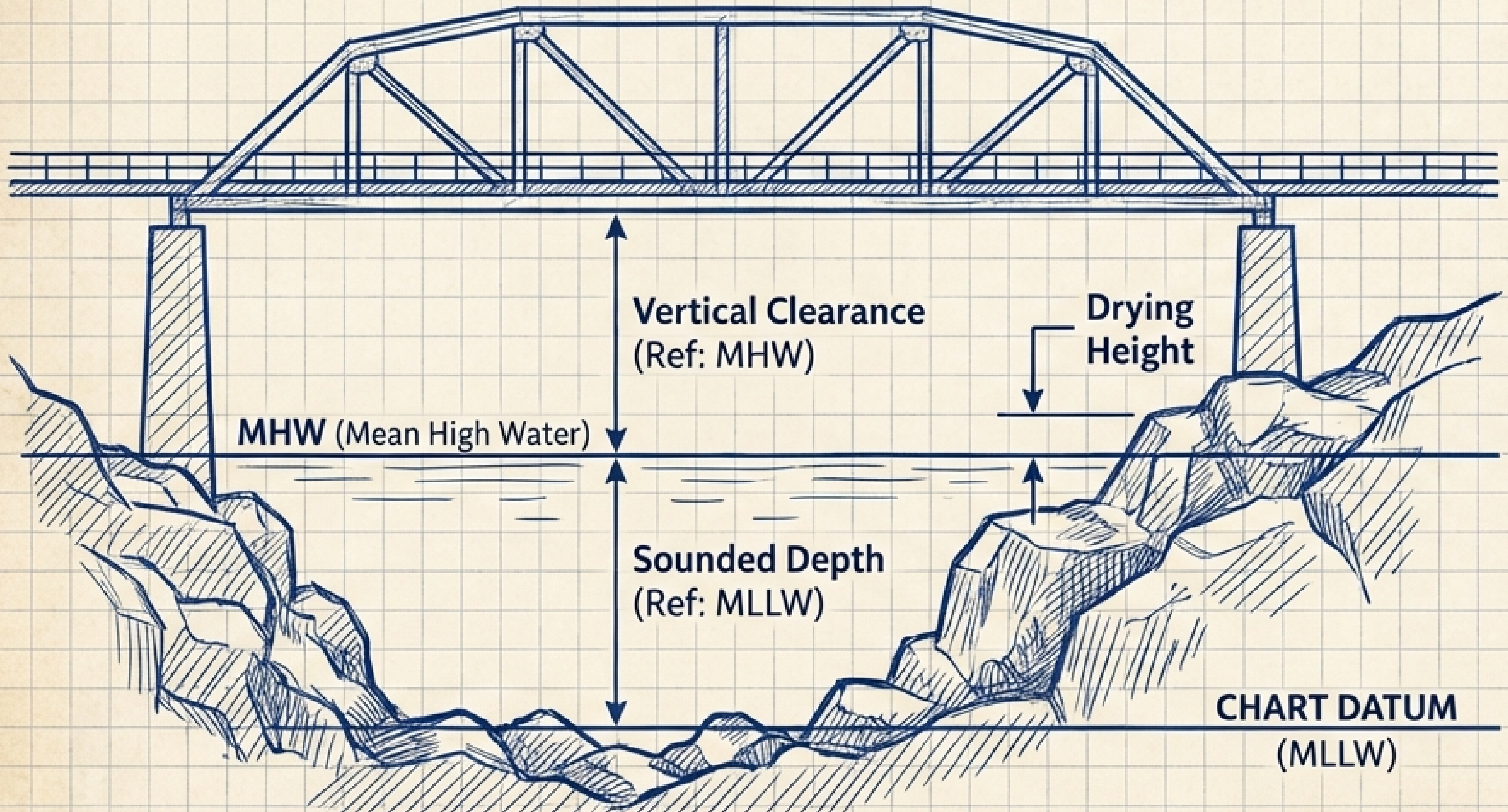
Defining the Vertical Reference



- **The 19-Year Average:** Datums are averages taken over the Metonic Cycle (18.6 years) to account for lunar node variations.
- **MLLW:** The standard reference for US navigation charts.
- **MHHW:** Often the reference for flood protection heights.

Datums in Practice: Charts vs. Surveys

The Critical Difference in Zero



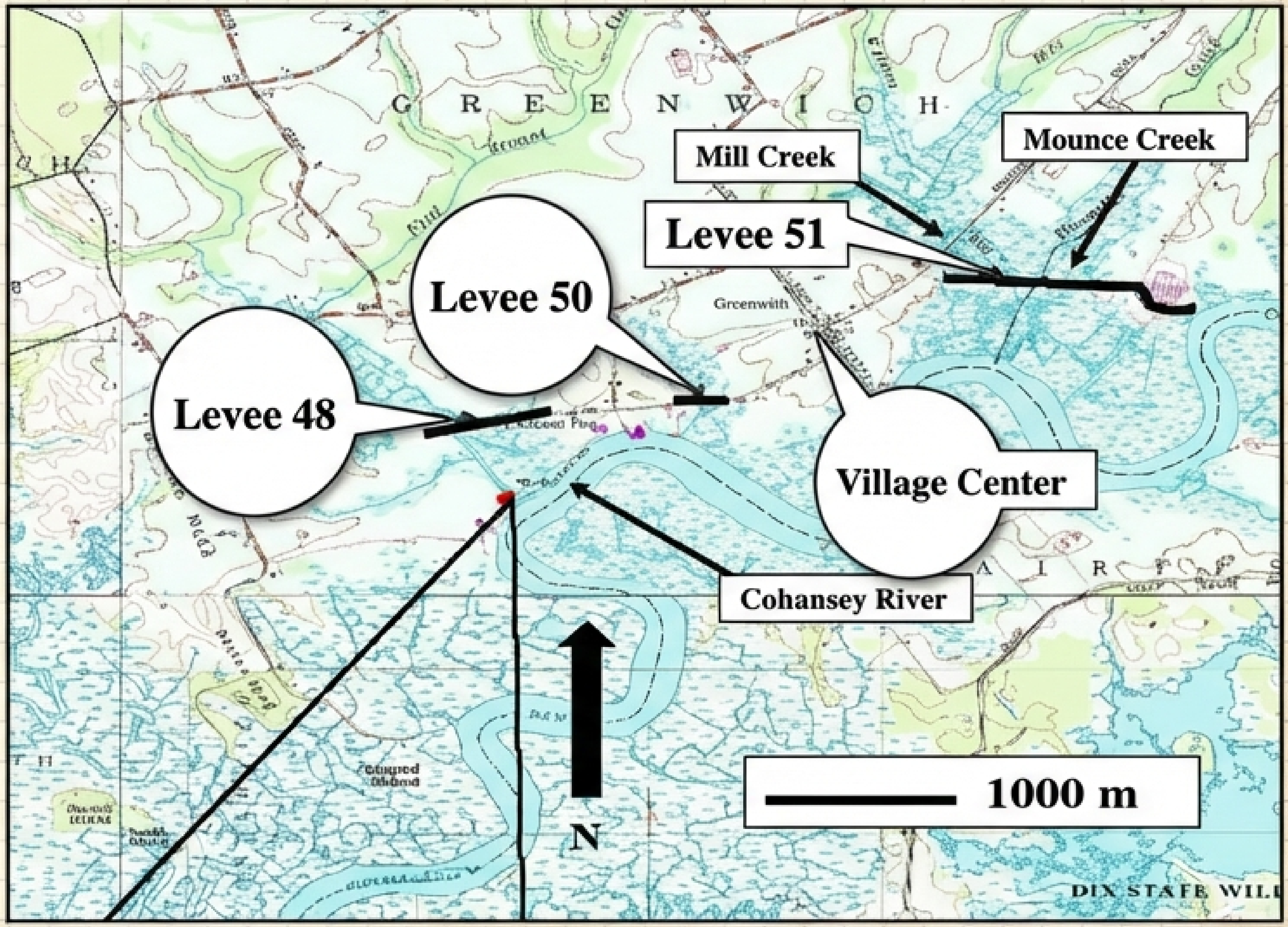
- **Chart Datum (CD):** Based on MLLW. Conservative for ship safety (depth).
- **Land Survey Datum:** Based on Geodetic vertical. Used for construction.
- **Risk:** Confusing these datums can lead to bridge collisions or levee overtopping.

Case Study I: Greenwich, New Jersey

Conflict: Flood Control vs. Ecosystem

Context: Historic village relying on earthen levees.

Problem: Levees restrict tidal flow, turning dynamic salt marshes into stagnant basins dominated by invasive *Phragmites*.



Infrastructure at the Breaking Point

Inspection Date: October 7, 2017

High Water Event

Structural Corrosion

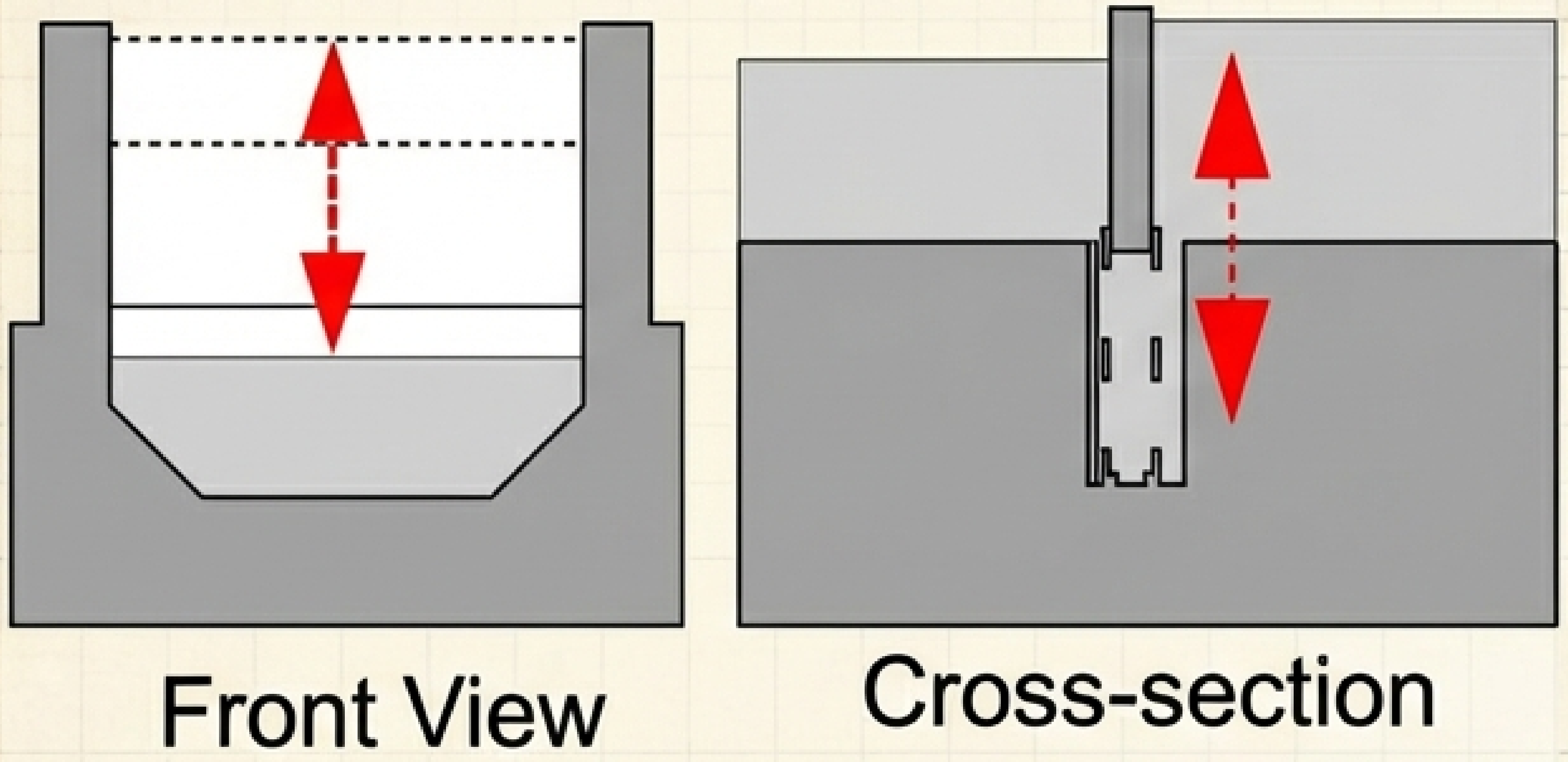
Barrier Failure

High tides push water levels dangerously close to road surfaces. The physical deterioration of sheet piles necessitates immediate engineering intervention.

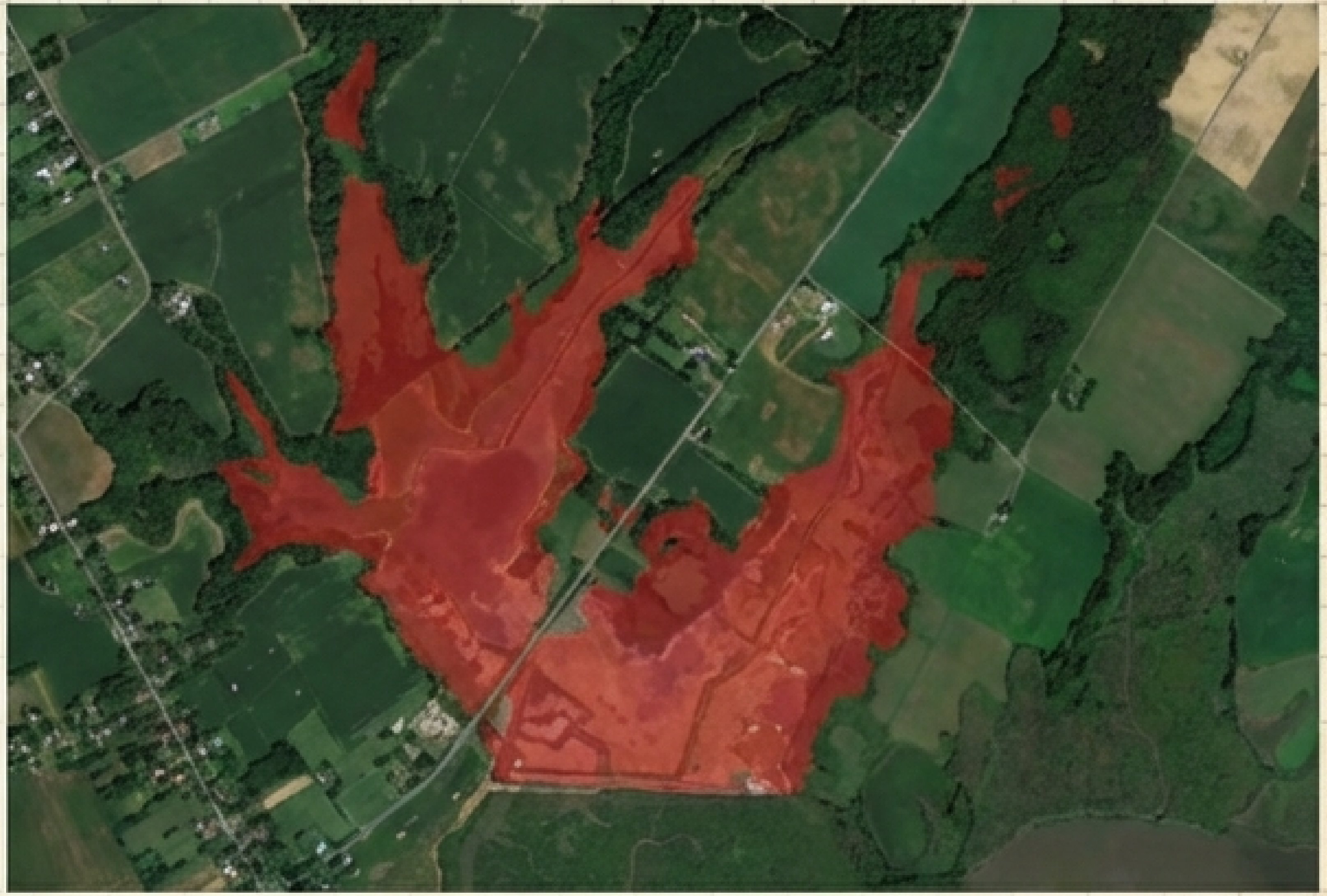
The Solution: Vertical Lift Gates

Restoring Flow & Protecting Assets.

Adjustable Tidal Exchange



(adapted from IAGEE 2)



Projected Marsh Restoration Area
(adapted from MAGE-3)

Restoration: 226 Hectares | **Ecosystem Value:** $2.39M / year | **Benefit:** Flood Resilience + Salinity Restore

Case Study II: Linden, New Jersey

Marshes Creek in an Industrial Landscape

The Context: Heavy Industry, Residential (Tremley), and Critical Infrastructure.

The Challenge: Managing flood risk in a dense, impermeable environment where water has nowhere to go.

The Choke Point

Restricted Conveyance & Sedimentation

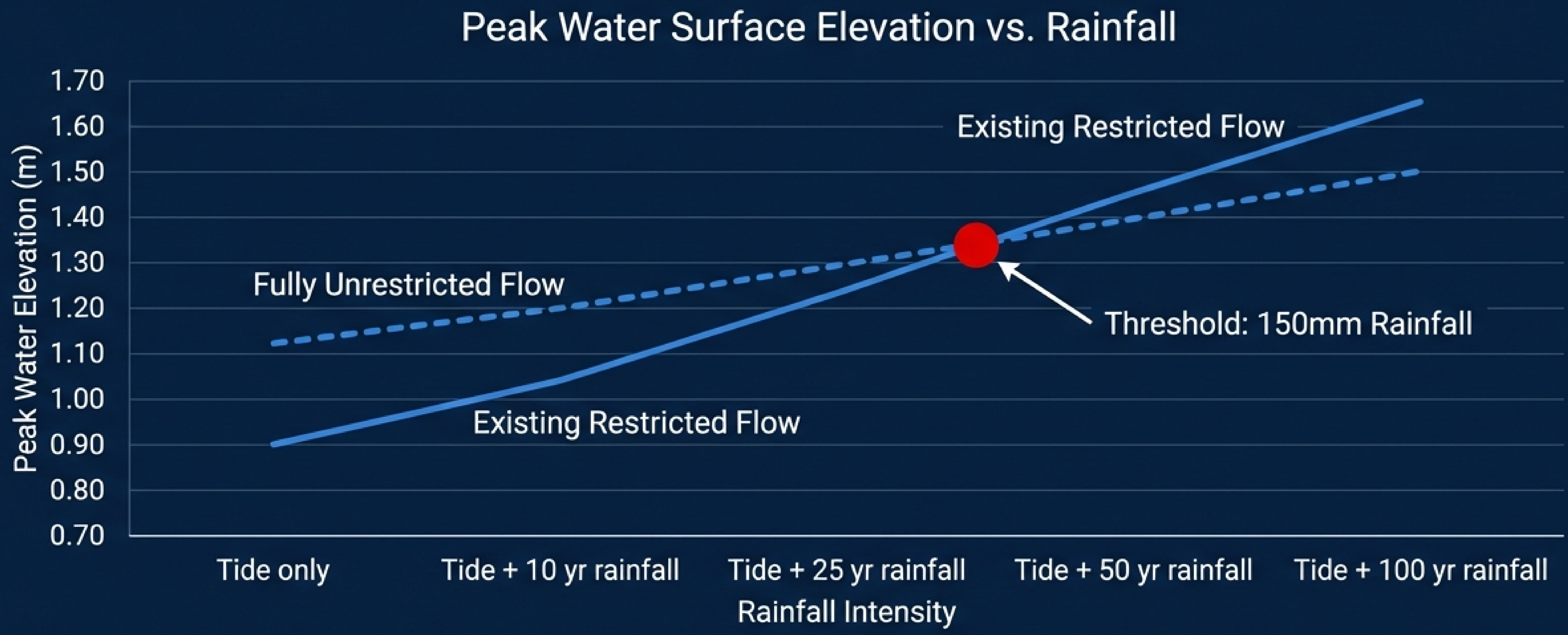
Undersized Culvert

Sediment Deposition

Mechanism of Failure: undersized culverts restrict tidal exchange. This slows water velocity, causing sediment to drop out of suspension and further clog the channel.

The Critical Threshold: Tides vs. Rainfall

ASCE Model Findings



Counter-Intuitive Finding: Restoration *lowers* flood risk during normal rain (better drainage) but *increases* risk if rainfall exceeds 150mm (tide + rain volume).

Summary: Engineering in a Dynamic System

Source: Tides are generated by immutable cosmic forces.

Measurement: Precise datums (MHW, MLLW) anchor liquid dynamics to static designs.

Application: Resilience requires balancing these forces with local ecology and hydrology.

Conclusion: We cannot stop the tides, but we can design to live with them.