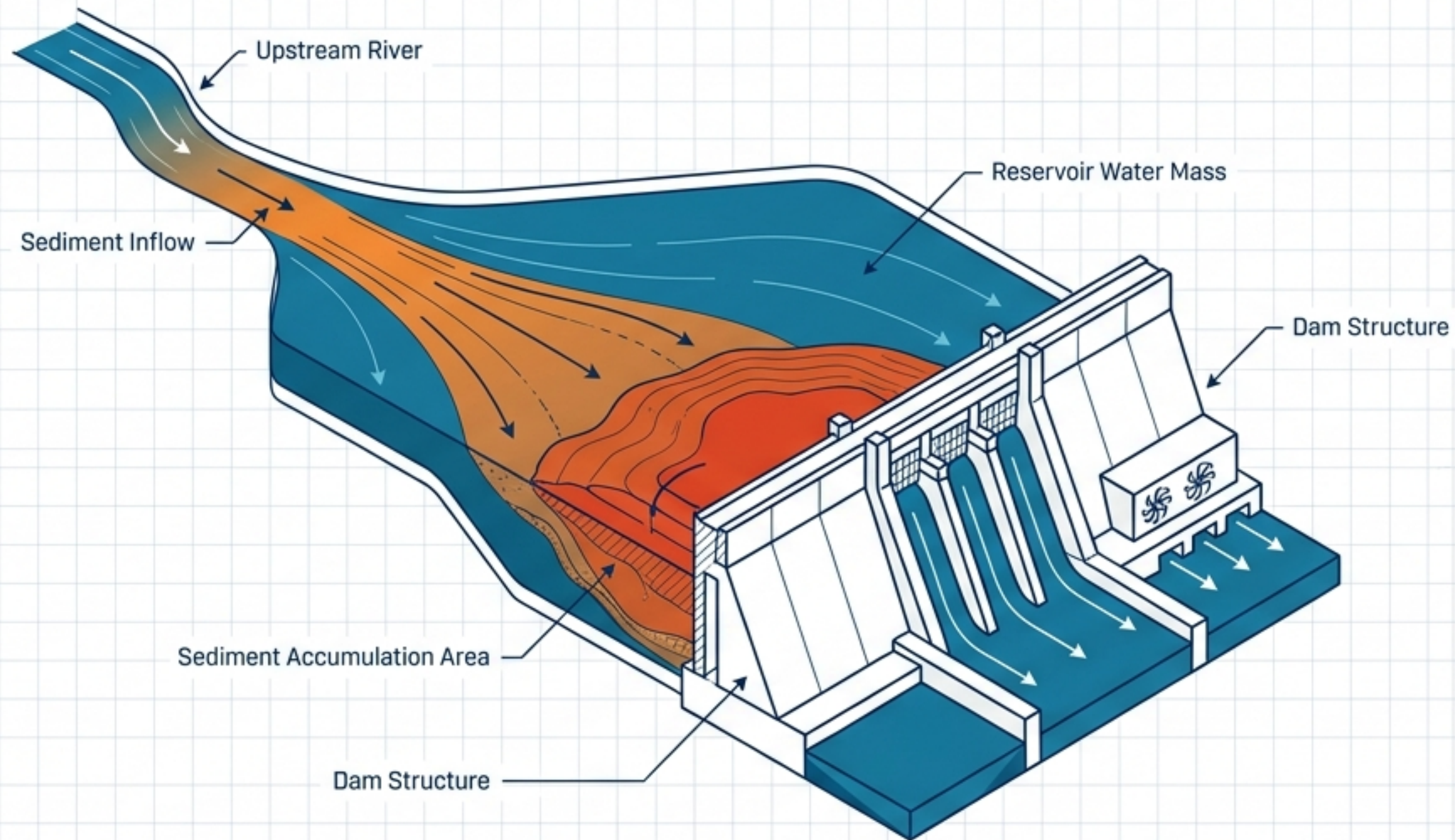


Reservoir Sedimentation & Management

From Trapping to Sustainable Operation



THE TICKING CLOCK OF GLOBAL WATER SECURITY

~0.5–1%

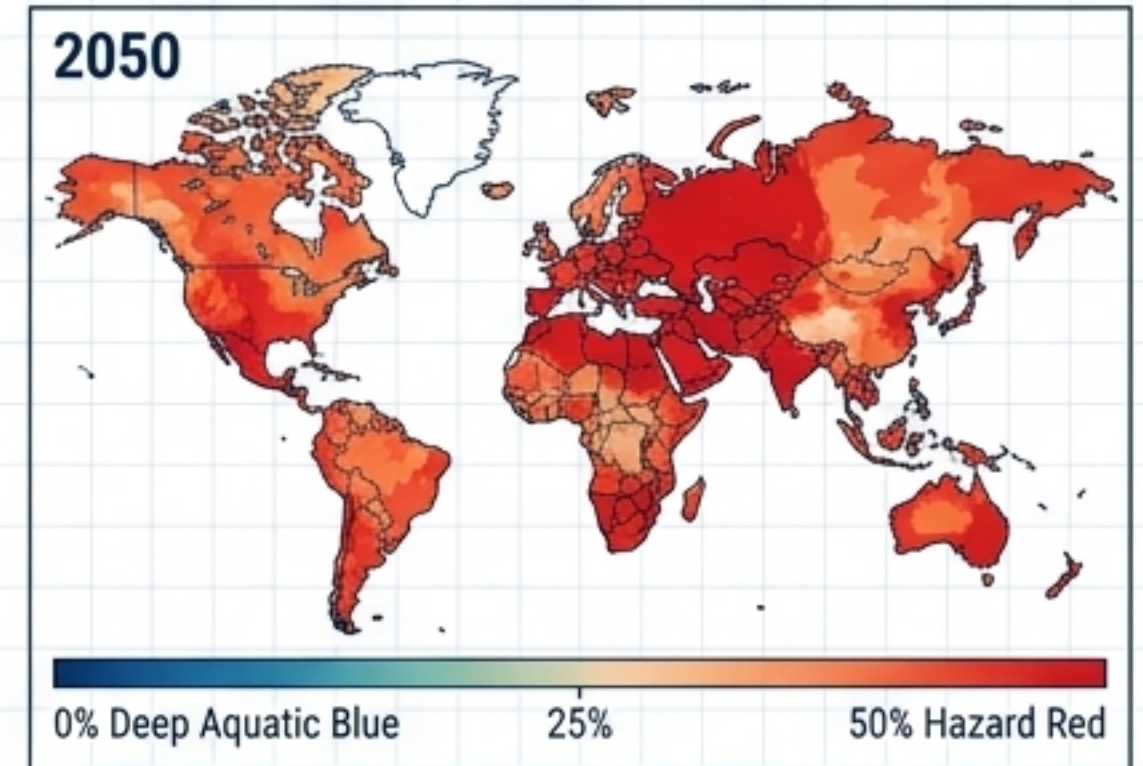
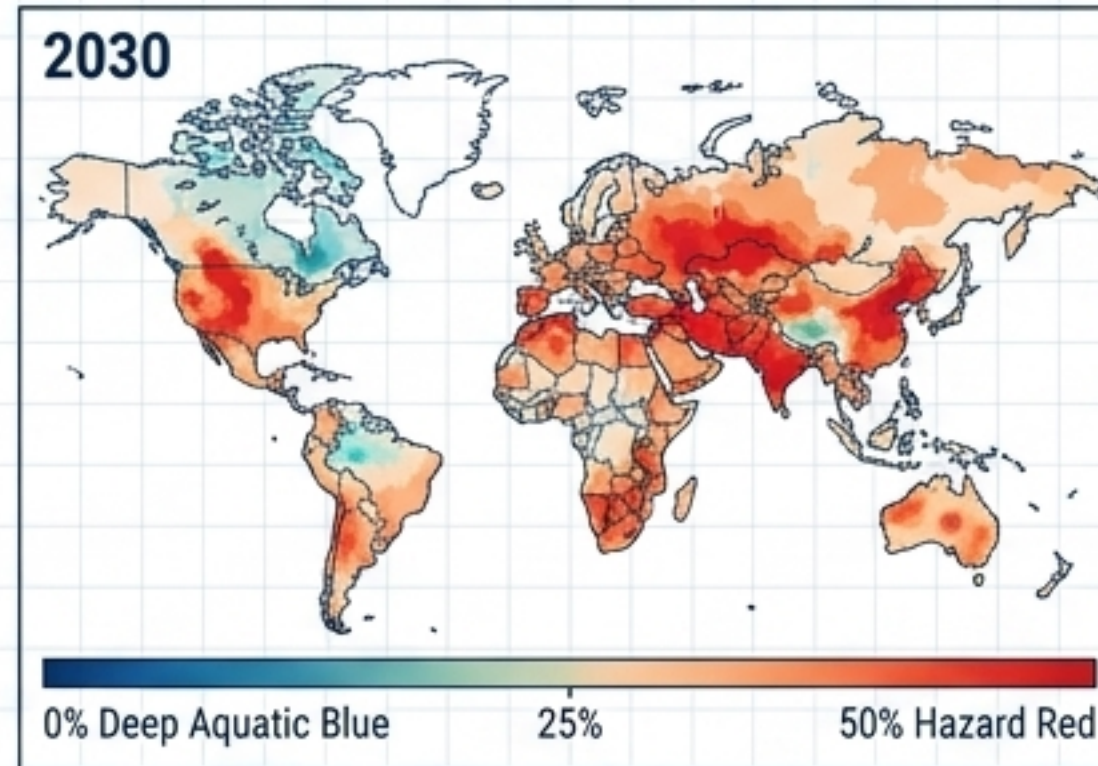
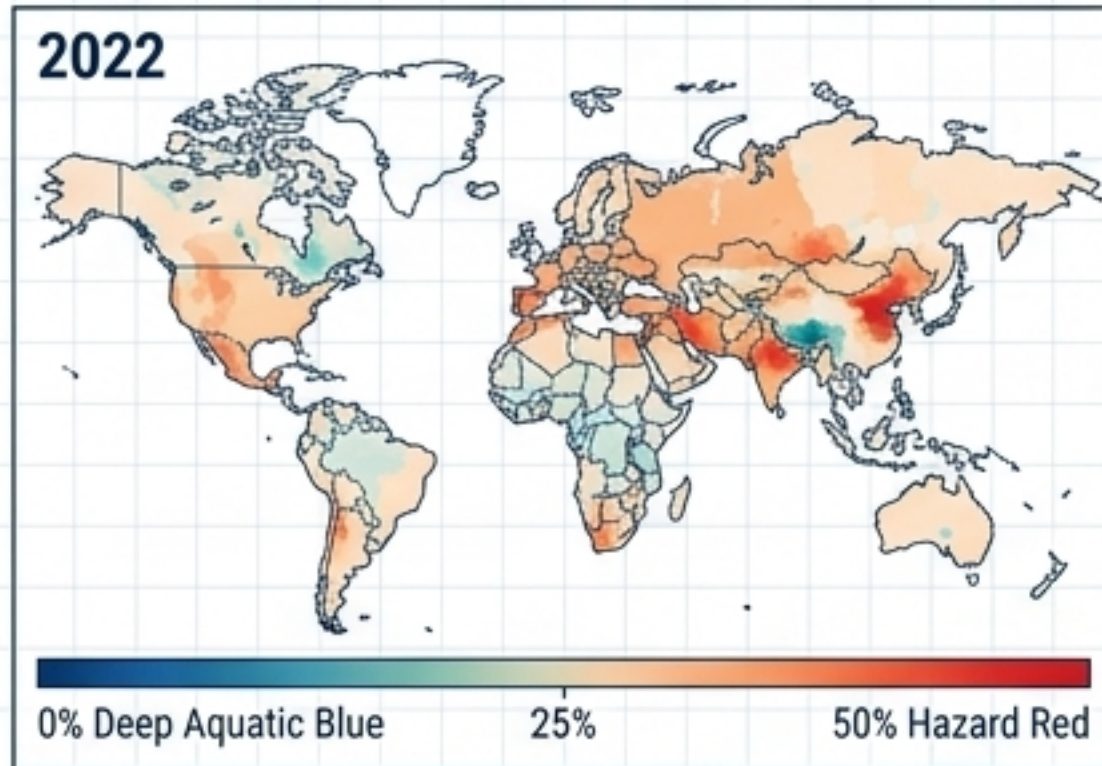
Annual global storage
loss rate

13–19%

Estimated initial storage
capacity lost to date

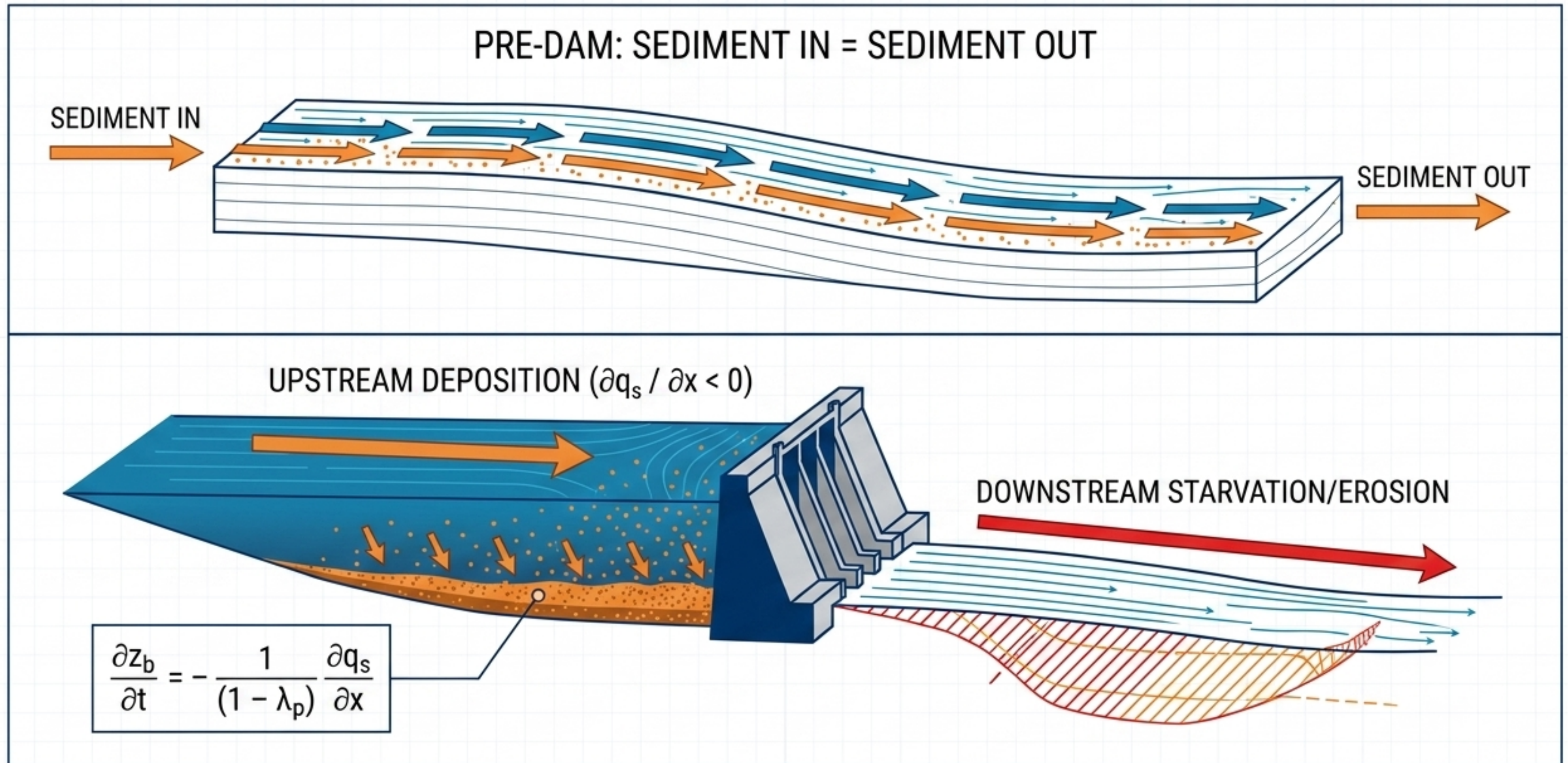
26%

Total global capacity projected
to be lost by 2050



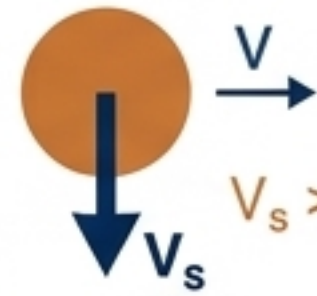
The world's reservoirs are losing their most critical asset—volume—threatening long-term water supply, hydropower generation, and flood attenuation.

DISRUPTION OF SEDIMENT CONTINUITY



The Physics of Deposition: Spatial Sorting

Settling Velocity (V_s) vs. Flow Velocity (V)

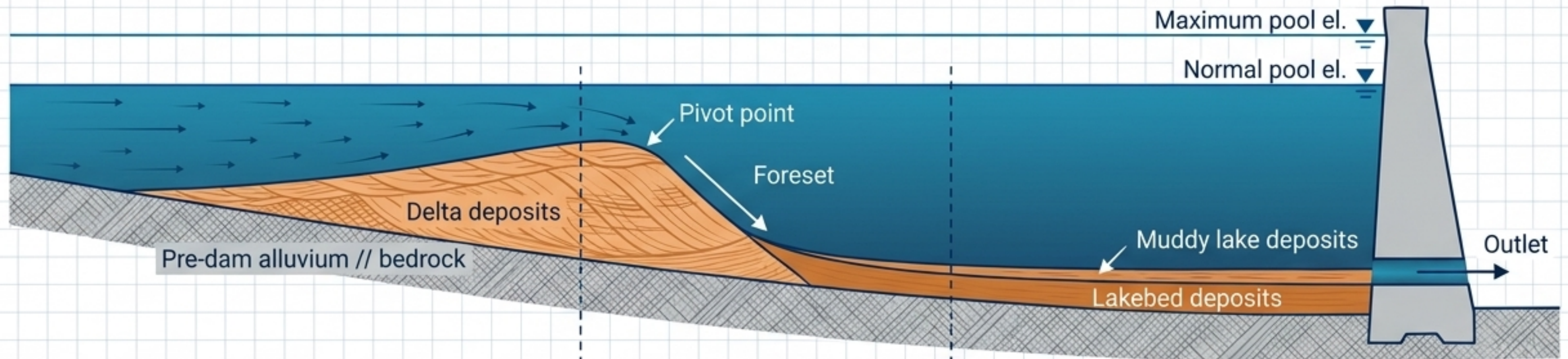


$V_s > V \rightarrow$ Deposition



$V_s < V \rightarrow$ Transport

Explains why fine particles travel all the way to the dam face.

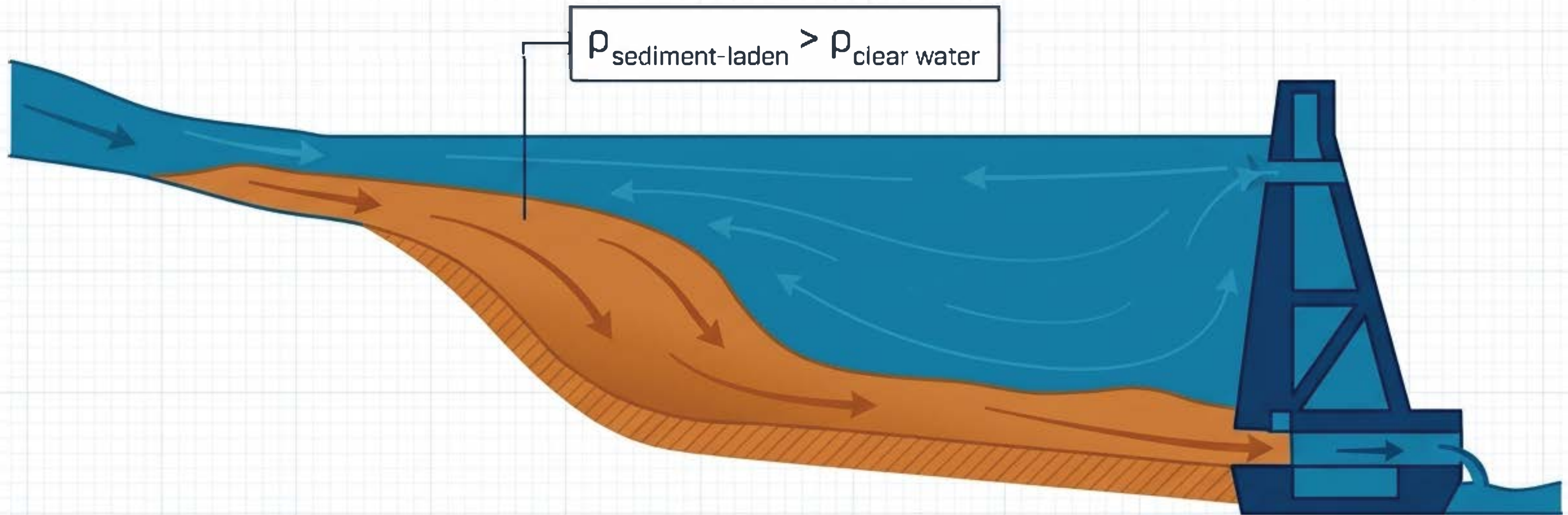


Zone 1: Topset/Delta
Coarse bedload drops instantly as velocity drops.

Zone 2: Foreset/Pivot Point.
The advancing face of the delta.

Zone 3: Bottomset/Lakebed.
Fine sediments settling out.

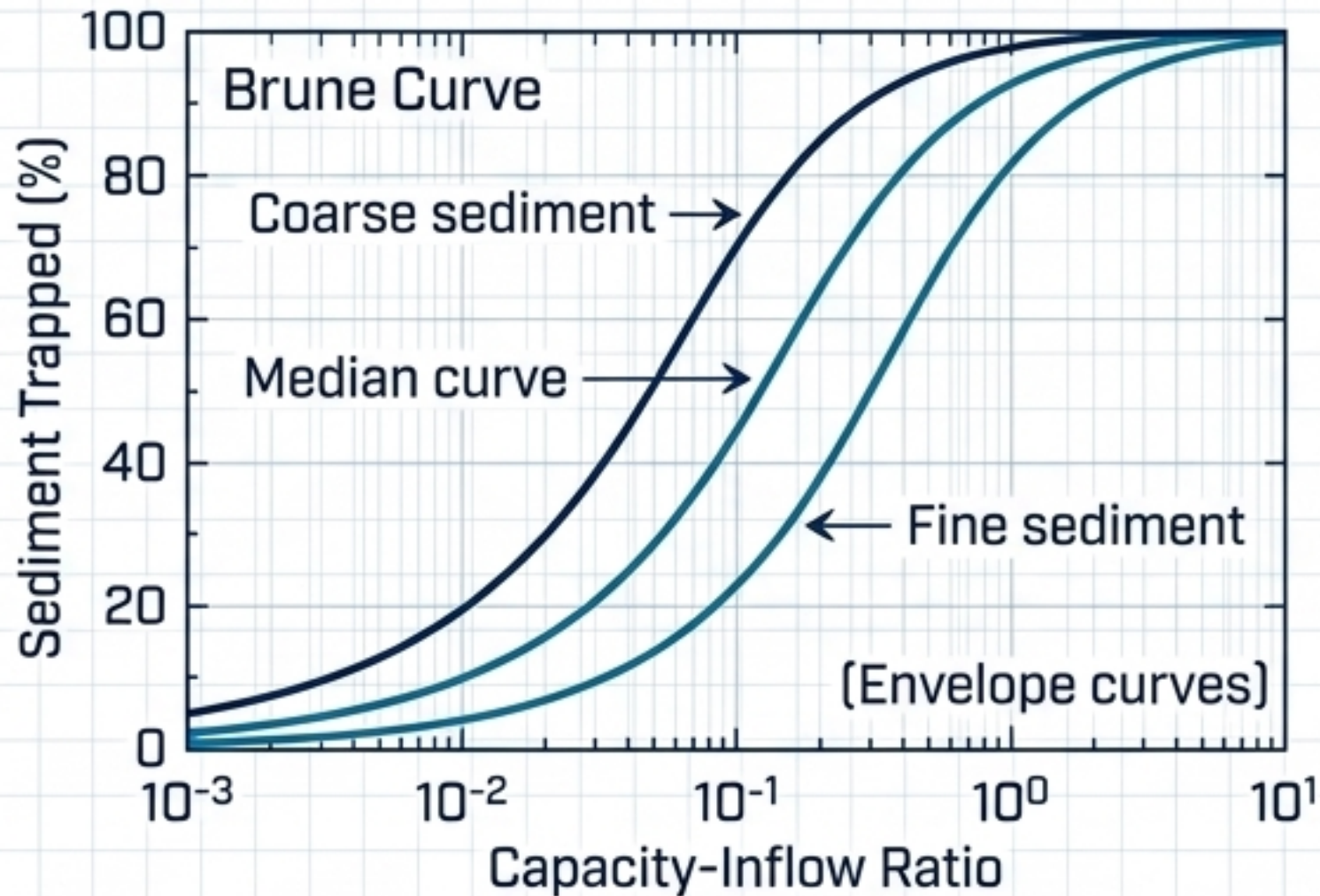
THE HIDDEN THREAT: DENSITY & TURBIDITY CURRENTS



Turbidity currents bypass standard settling zones, **transporting highly concentrated** fine sediments directly to the dam, significantly reducing trapping efficiency estimates and threatening bottom infrastructure.

Calculating Trap Efficiency (TE): Brune vs. Modern Models

The Baseline

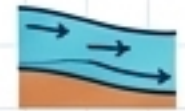


$$TE = \frac{\text{Sediment Retained}}{\text{Sediment Inflow}}$$

Modern Limitations

Diagnostic

- Brune assumes steady conditions.



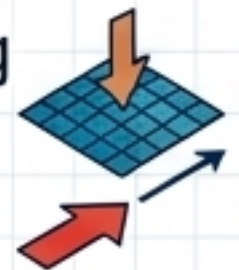
- Ignores:



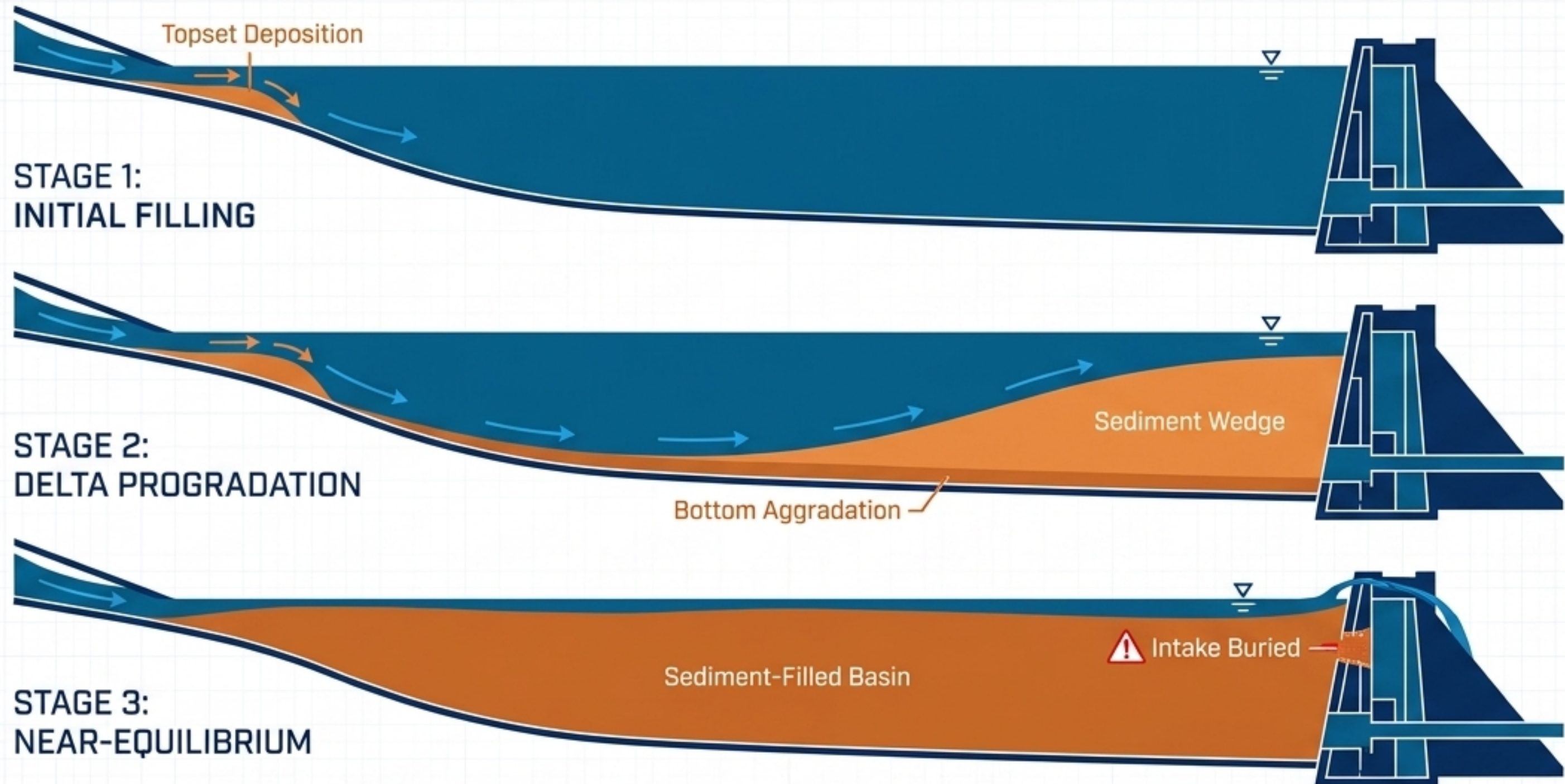
Density currents,
operational changes,
sediment heterogeneity.



Modern extensions require event-based 2D/3D modeling (e.g., Delft3D, TELEMAC) to account for unsteady flood pulses and adaptation lengths.



TEMPORAL EVOLUTION: THE DECADAL DEATH OF A RESERVOIR

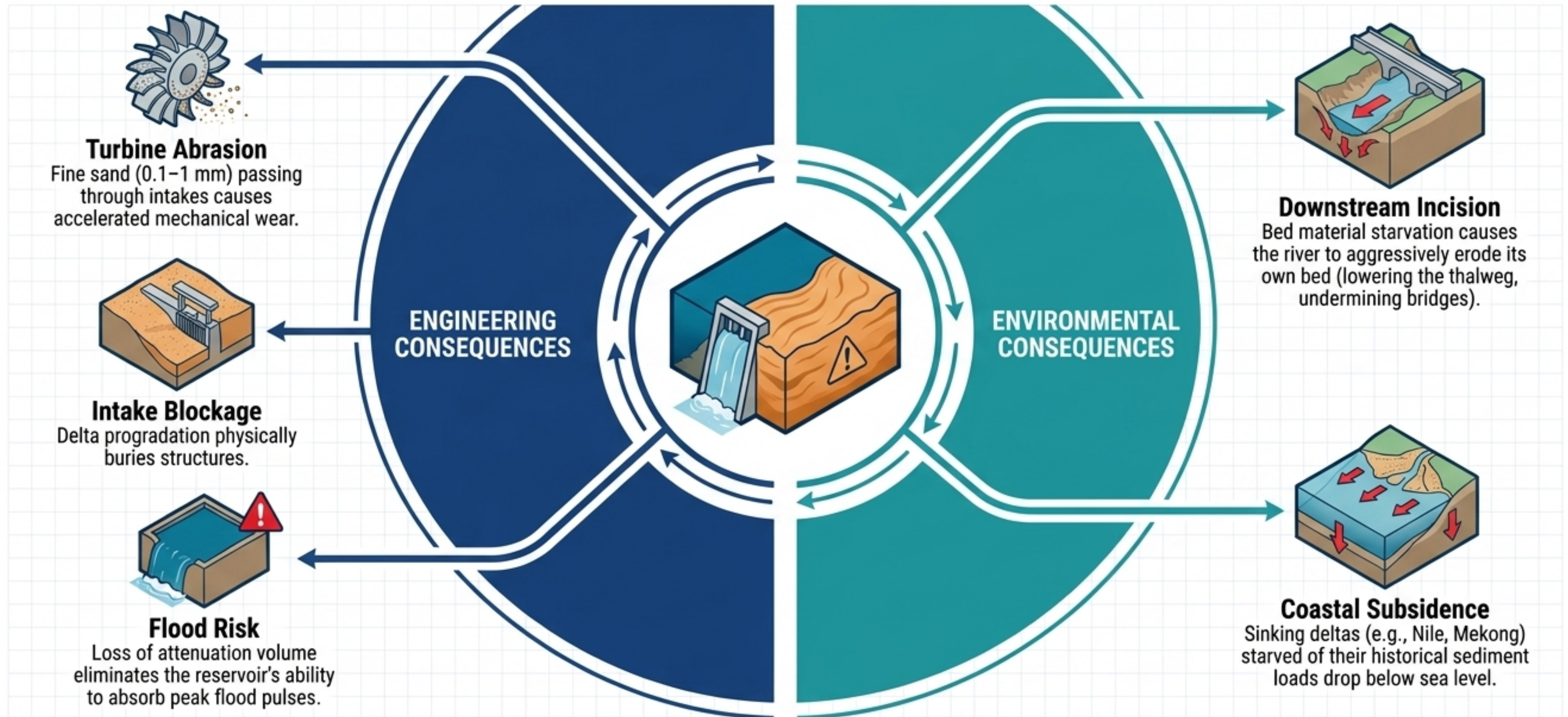


DESIGN LIFE & STORAGE LOSS





- Design life is typically reached when 50% of active storage is lost.

$$V(t) = V_0 - \int (Q_s * T_E) dt$$

SYSTEM-WIDE CONSEQUENCES OF IMBALANCE

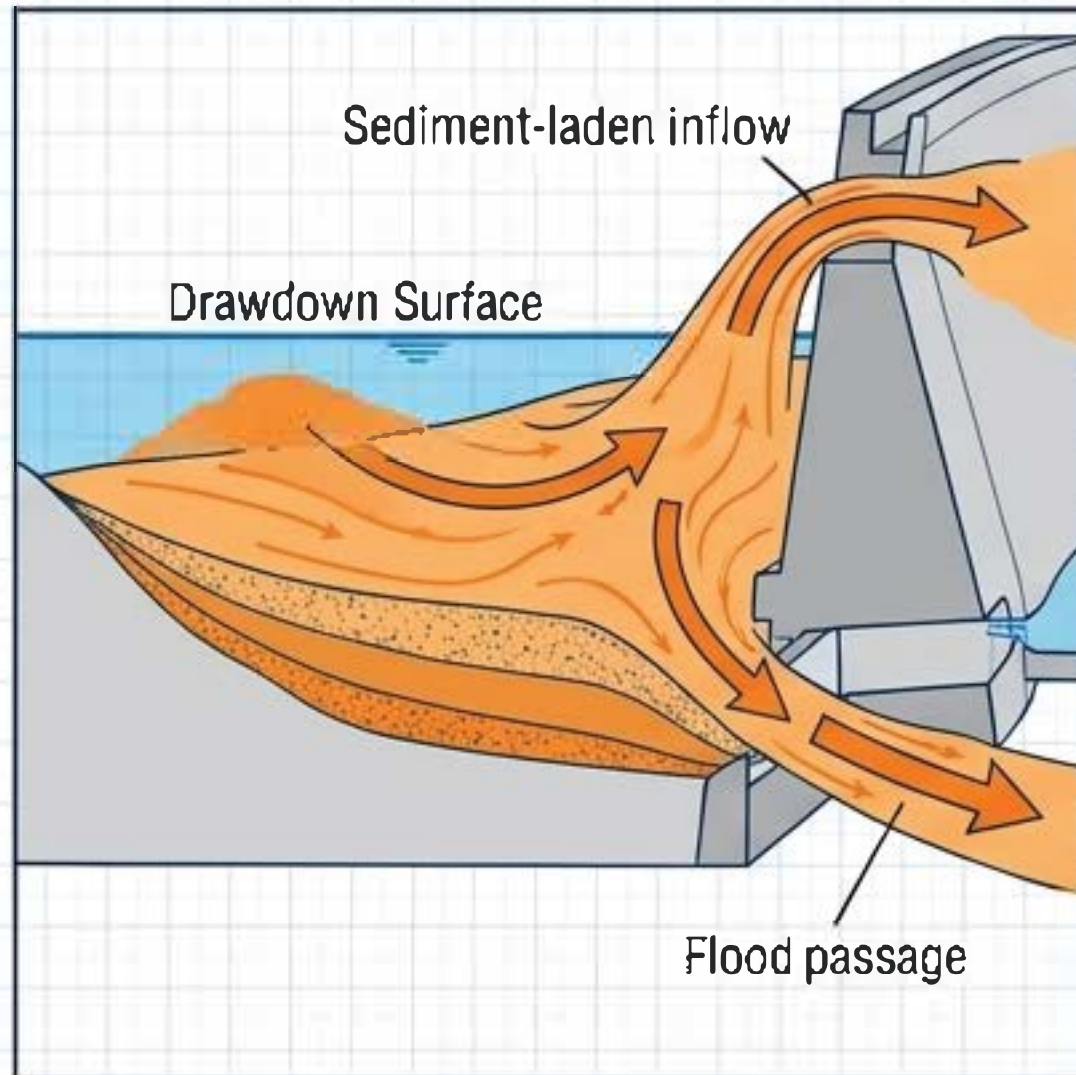


THE 4 MANAGEMENT STRATEGIES: SYNTHESIS MATRIX

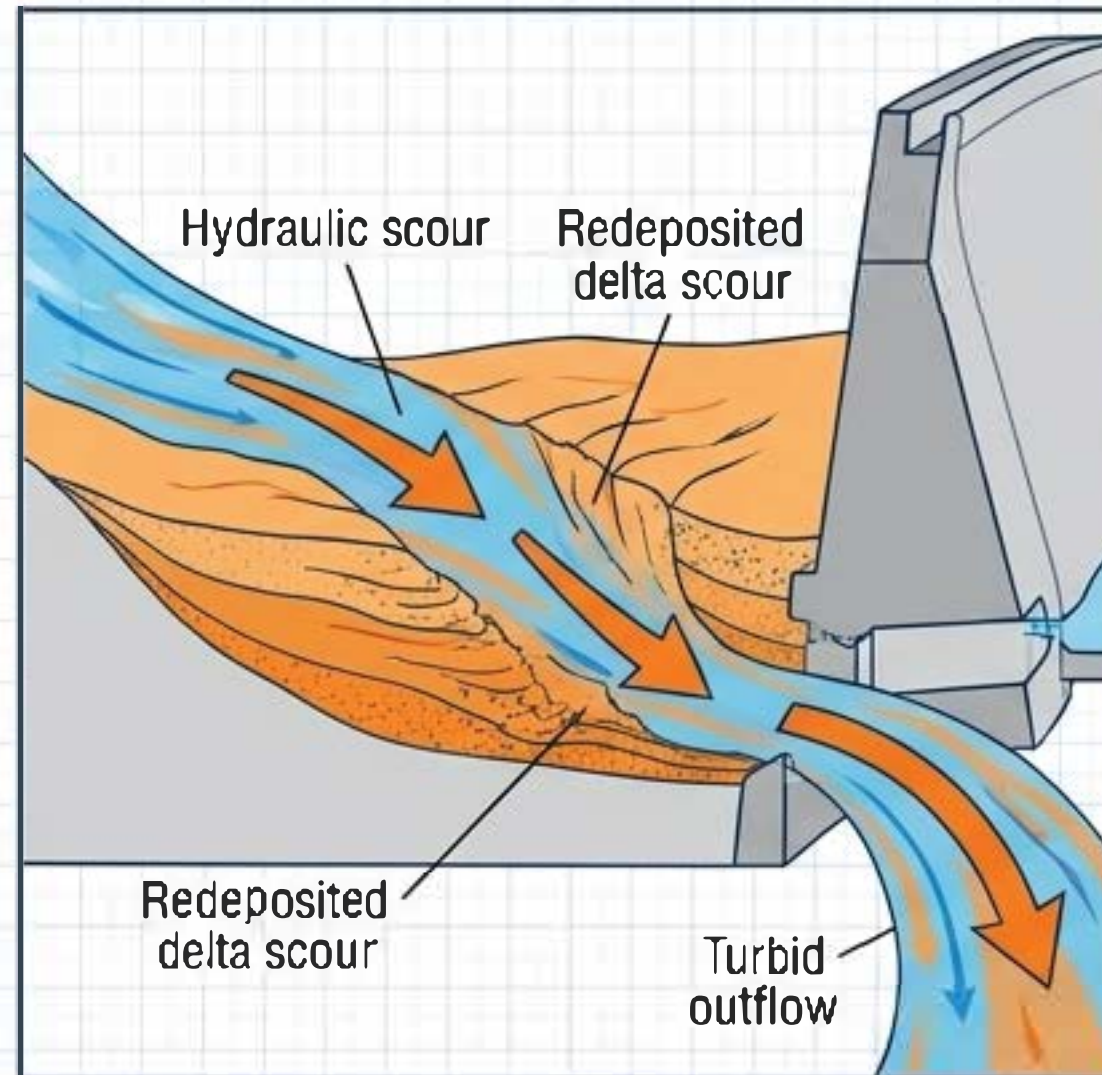
<h2>1. REDUCE INFLOW</h2> <p>(Watershed Management)</p> 	<h2>2. ROUTE SEDIMENTS</h2> <p>(Minimize Deposition)</p> 	<h2>3. REMOVE DEPOSITS</h2> <p>(Physical Extraction)</p> 	<h2>4. ADAPT</h2> <p>(Do not improve balance)</p> 
<ul style="list-style-type: none">• Soil conservation, check dams, revegetation.• Reduces sheet/rill erosion by 50-80%.	<ul style="list-style-type: none">• Bypass tunnels, flood sluicing, density current venting.• Maintain continuity during flood pulses.	<ul style="list-style-type: none">• Hydraulic flushing, mechanical dredging.• Highly Costly: ~\$5-15/m³	<ul style="list-style-type: none">• Raise dam height, modify intakes, reallocate to dead storage.• Only delays the inevitable.

OPERATIONAL MECHANICS: ROUTING VS. REMOVAL

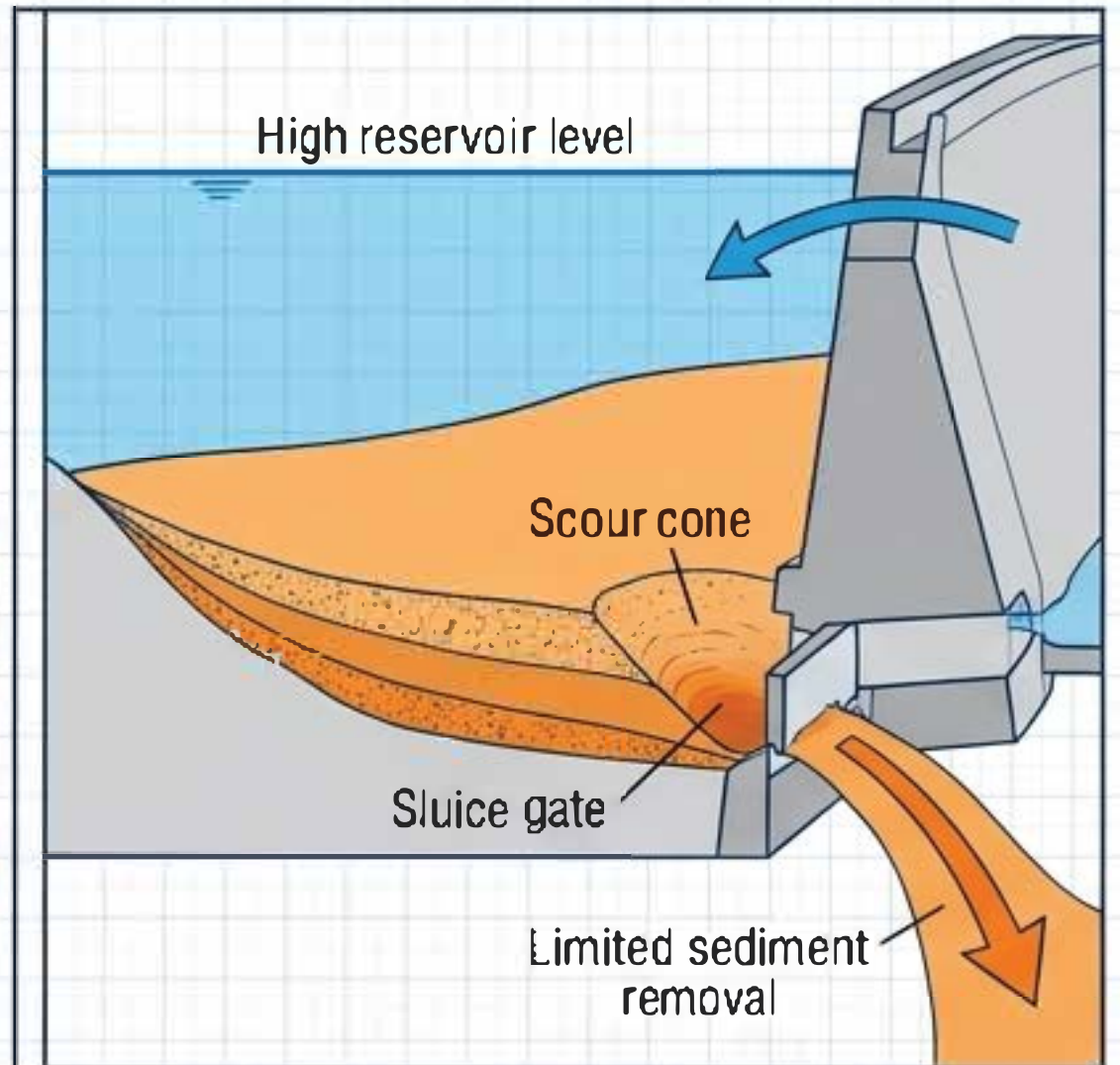
DRAWDOWN SLUICING
(ROUTING)



EMPTY FLUSHING
(REMOVAL)



PRESSURE FLUSHING
(REMOVAL)

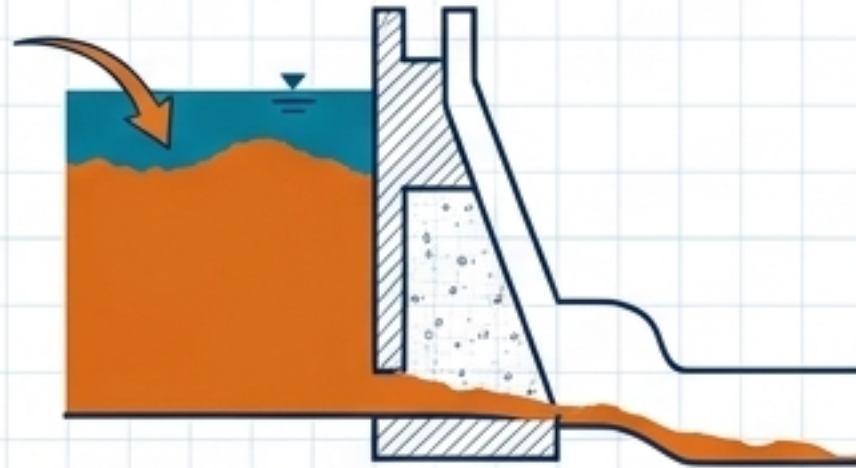


FLUSHING REMOVES EXISTING DEPOSITS; SLUICING PREVENTS DEPOSITION DURING FLOODS.

THE PARADIGM SHIFT: LIVING WITH SEDIMENT

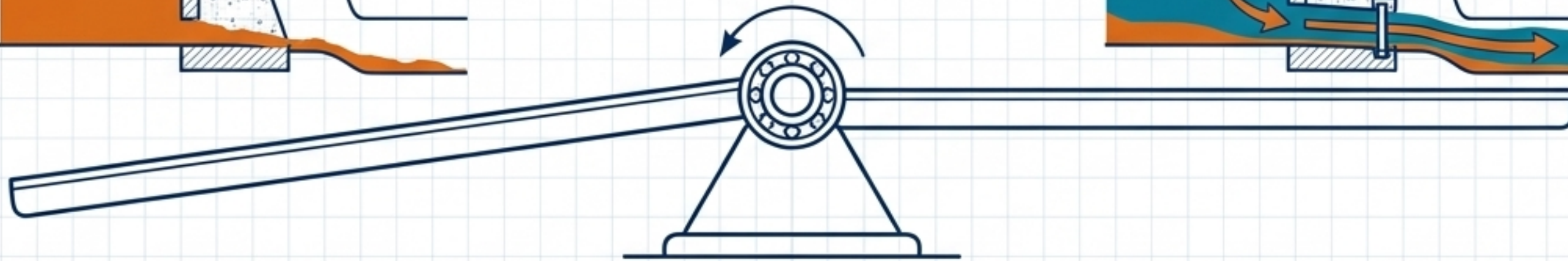
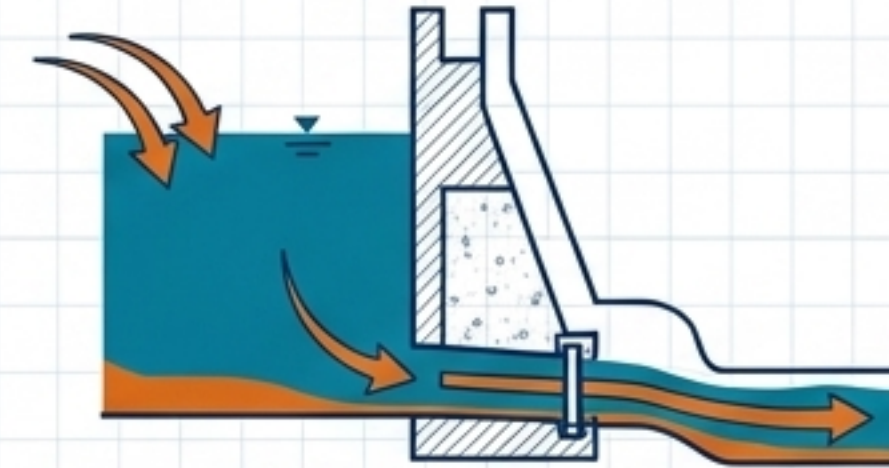
The Old Paradigm: Maximize Storage

- Temporary Imbalance
- Expects Sediment Outflow = 0
- Inevitable infrastructure death



The New Paradigm: Sustainable Balance

- Sediment Continuity
- Integrates routing, removal, & watershed management
- Long-term Sediment Outflow \approx Inflow

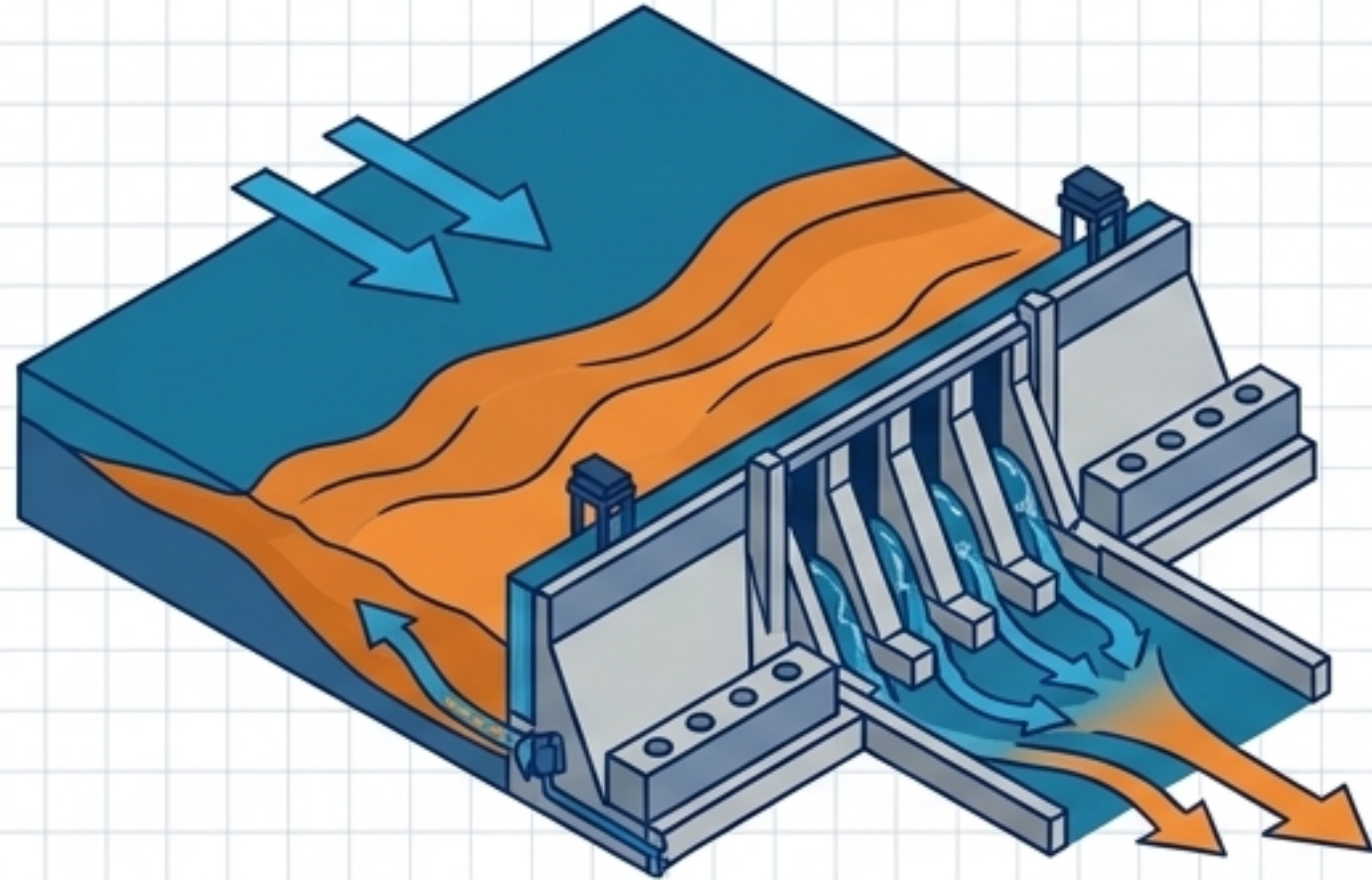


Key Metric Box

The Operational Target: Maintain **Trap Efficiency (TE) < 50–60%** to allow sufficient sediment pass-through, preserving both reservoir volume and downstream morphology.

SCALE IS IRRELEVANT: UNIVERSAL SEDIMENT PHYSICS

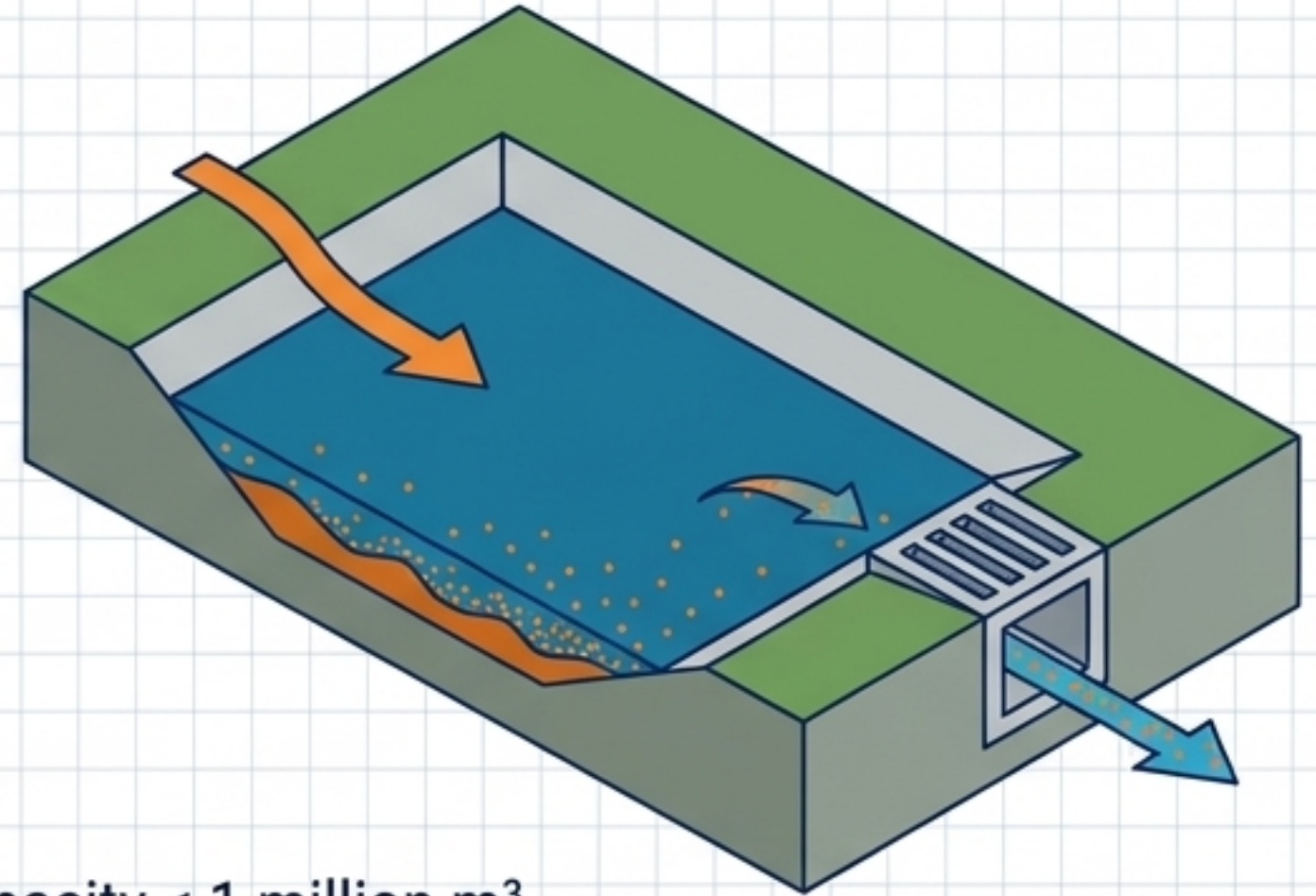
MACRO: THREE GORGES DAM, CHINA



185m height, 39.3 km³ capacity.

- Pre-dam load: ~491 Mt/yr.
- Retention rate: ~86%.
- Management: Extensive seasonal drawdown operations to scour tail deposits before flood seasons.

MICRO: SUBURBAN STORMWATER BASINS

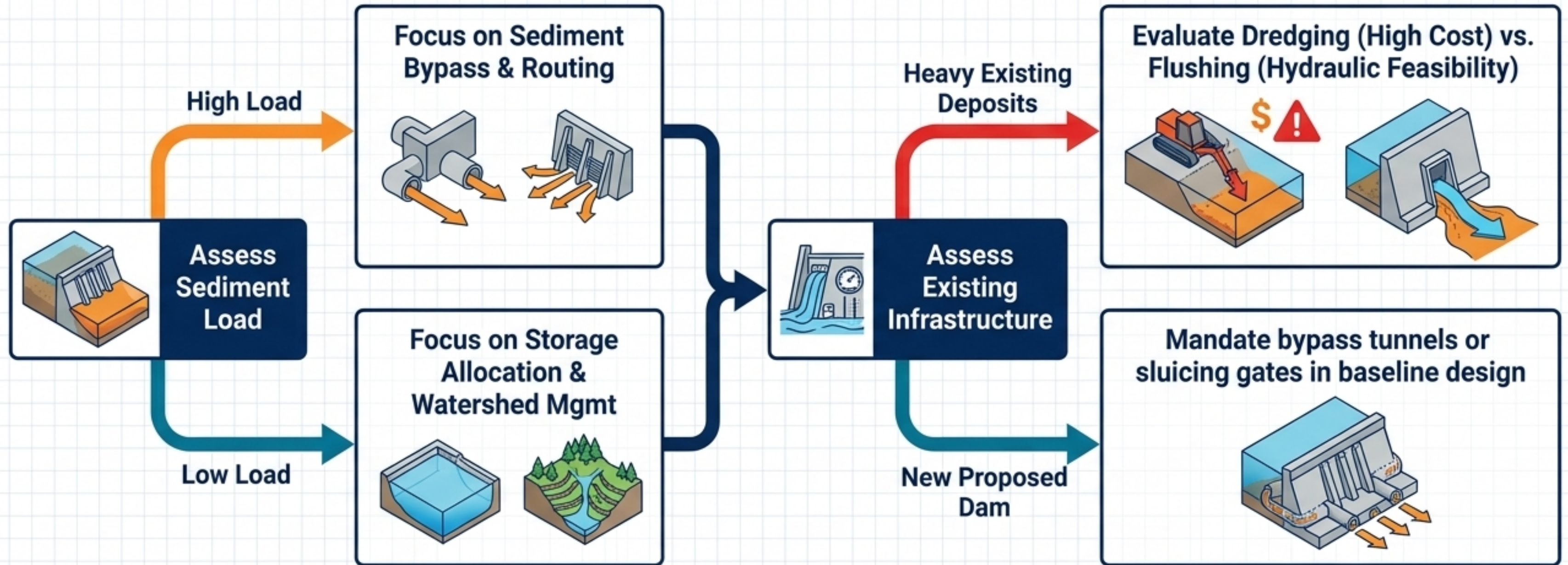


Capacity < 1 million m³.

- Rapid filling: 50% capacity lost in 20-30 years.
- Management: Mandated dead storage design (10-20% volume set aside) and enforced periodic mechanical dredging.

Whether managing 491 million tons a year or a 1-acre suburban detention pond, the disruption of sediment continuity requires active intervention.

THE DESIGN & DECISION FRAMEWORK



Maintaining long-term reservoir storage is a continuous management decision, not a static design.