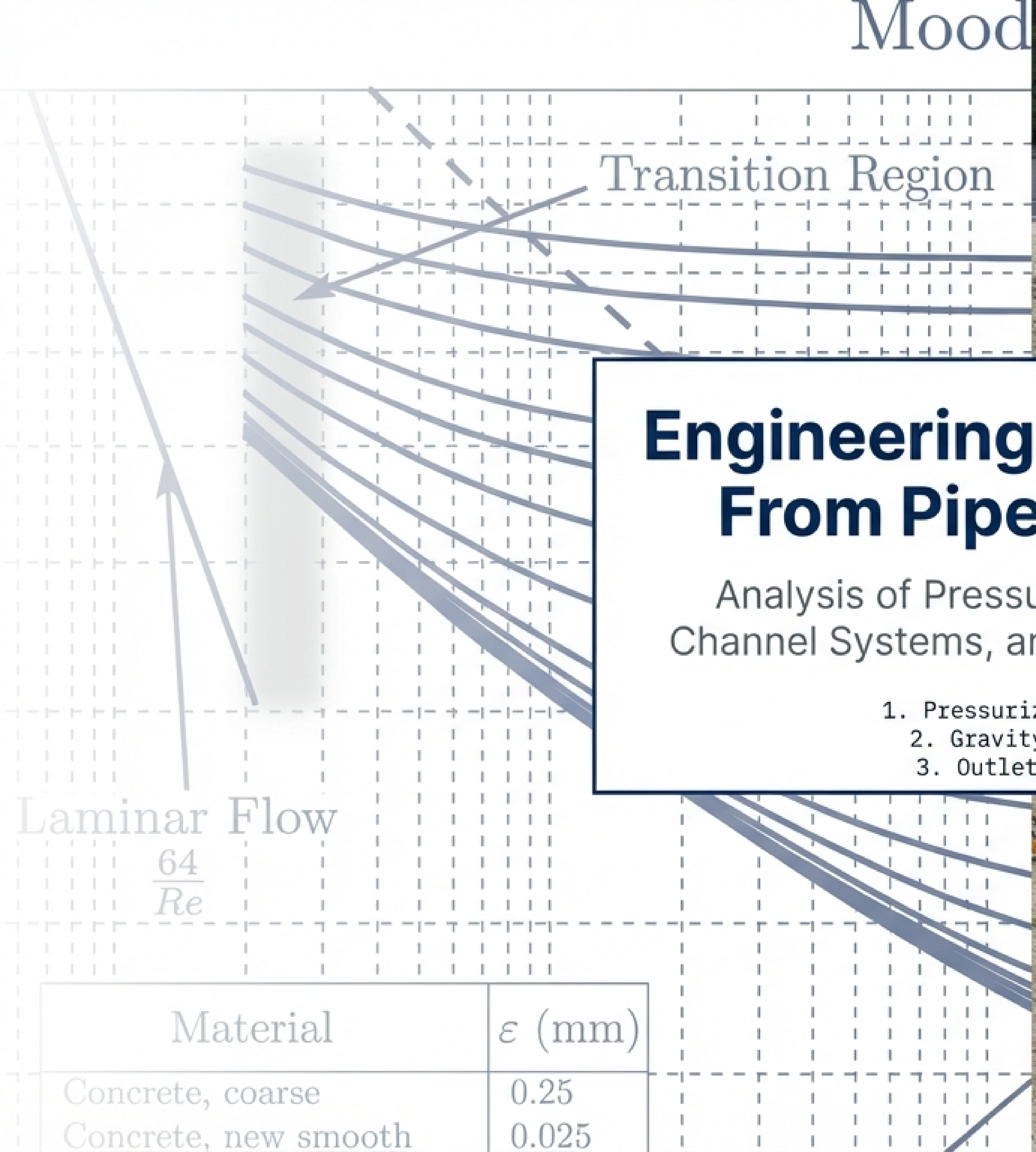
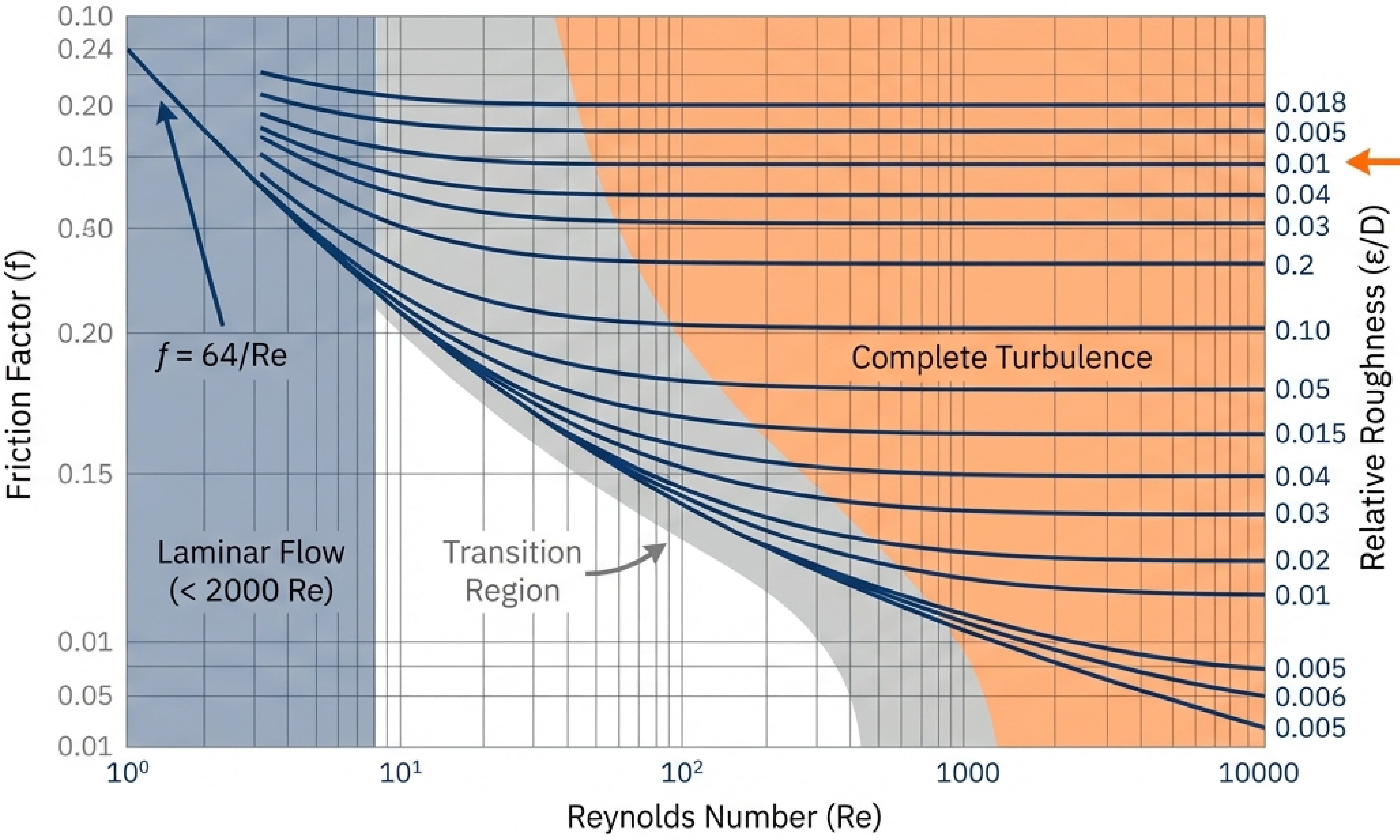


Engineering Hydraulics: From Pipe to Outlet

Analysis of Pressurized Flow, Open Channel Systems, and Outlet Structures

1. Pressurized Systems
2. Gravity Systems
3. Outlet Control

The Physics of Pipe Flow: Friction & Resistance

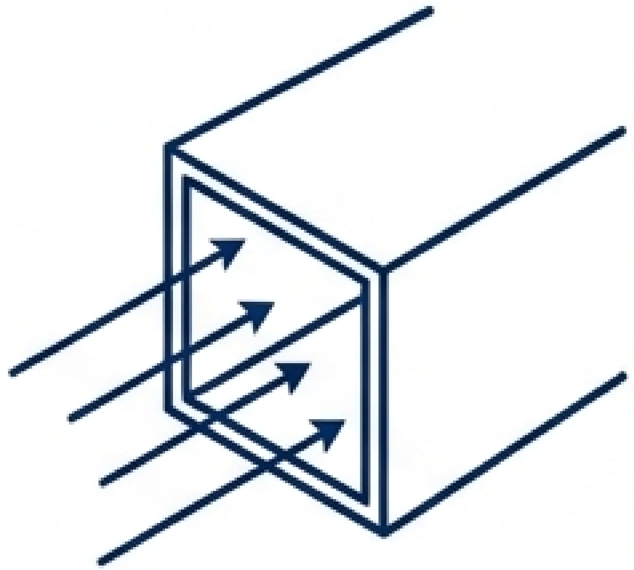
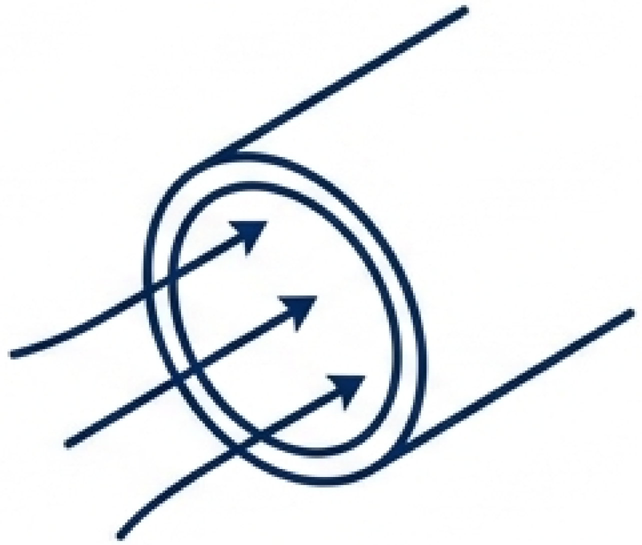
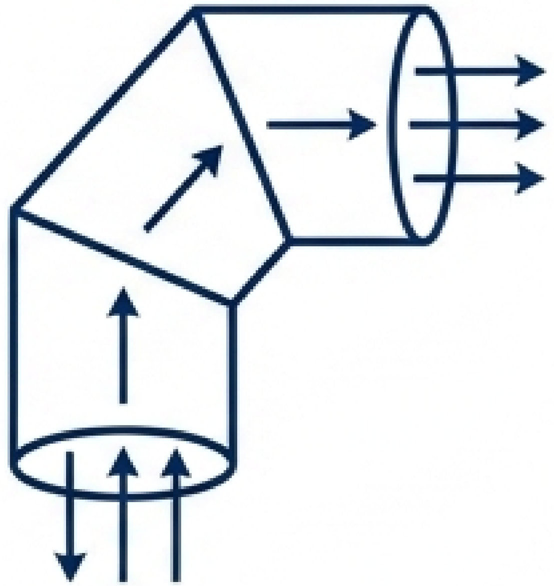
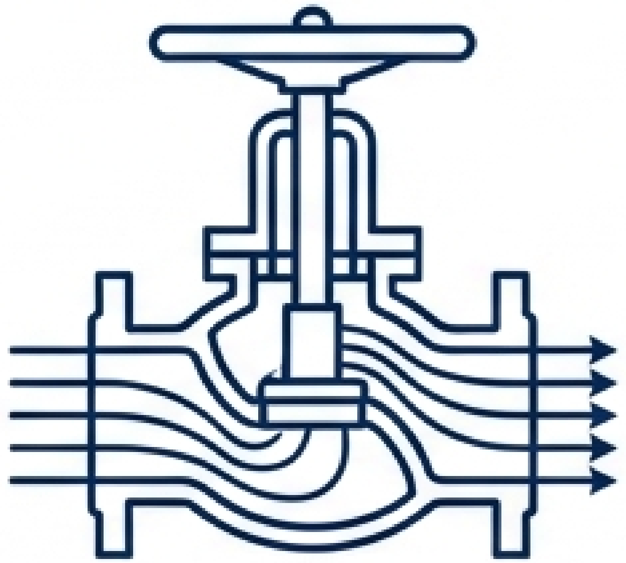


In turbulent flow, friction is driven by material roughness (ε), not fluid viscosity.

$$Re = \frac{\rho V d}{\mu}$$

Local Losses: The Cost of Transitions

$$h_L = K_c \frac{V^2}{2g}$$

			
Square Edge Entrance: K = 0.50 Technical Grey IBM Plex Sans with `IBM Plex Mono`	Well-Rounded Entrance: K = 0.03	90° Miter Bend: K = 1.1	Globe Valve: K = 10.0

Key Insight: Sharp transitions and complex valves act as significant energy sinks compared to smooth fittings.

Adding Energy: Pump Flow Dynamics

Technical Grey
Power Required (kW)

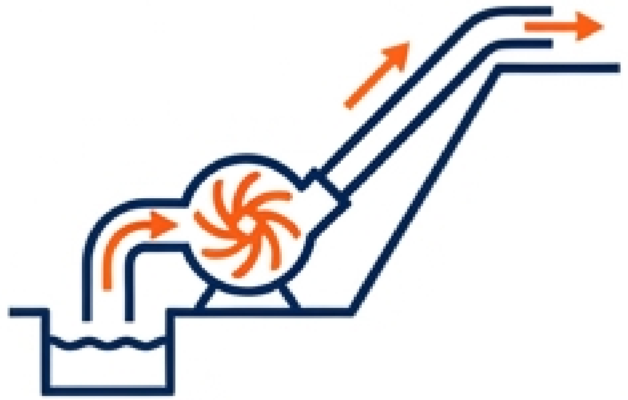
IBM Plex Mono
Dynamic Head (meters) – The energy difference overcoming gravity and friction

$$P = (\gamma\, Q\, H)\, /\, \eta$$

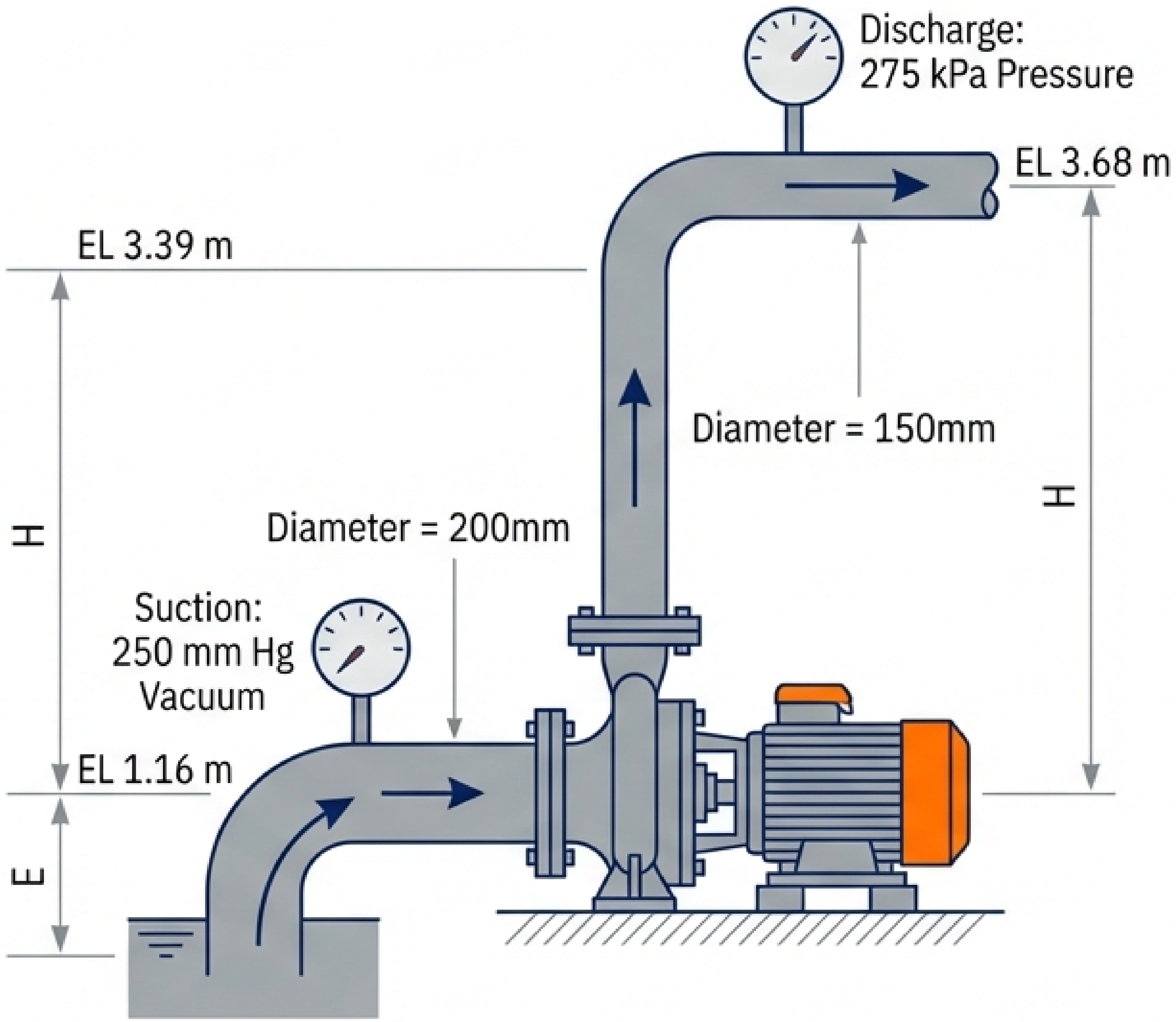
IBM Plex Mono
Specific Weight of Water (9,810 N/m³)

IBM Plex Mono
Flow Rate (m³/s)

IBM Plex Mono
Efficiency (0.0 to 1.0)



Case Study: Calculating Pump Requirements



Problem Statement

Goal: Calculate the power (kW) required to deliver 0.15 m³/s of water.

Unit Conversion

1. Convert Gauge Pressures to Head (meters of water):

$$\text{Discharge Head} = \frac{275{,}000\ \text{Pa}}{9{,}800\ \text{N/m}^3} = 28.1\ \text{m}$$

$$\text{Suction Head} = -250\ \text{mm Hg} \times 13.57\ \text{(s.g.)} = -3.4\ \text{m}$$

NotebookLM

Case Study: Solution & Results

Step 1: Calculate Velocities (Continuity Eq)

$V_{suction}$ = 4.77 m/s
$V_{discharge}$ = 8.48 m/s (Velocity increases as pipe narrows)

Step 2: Apply Energy Equation IBM Plex Sans

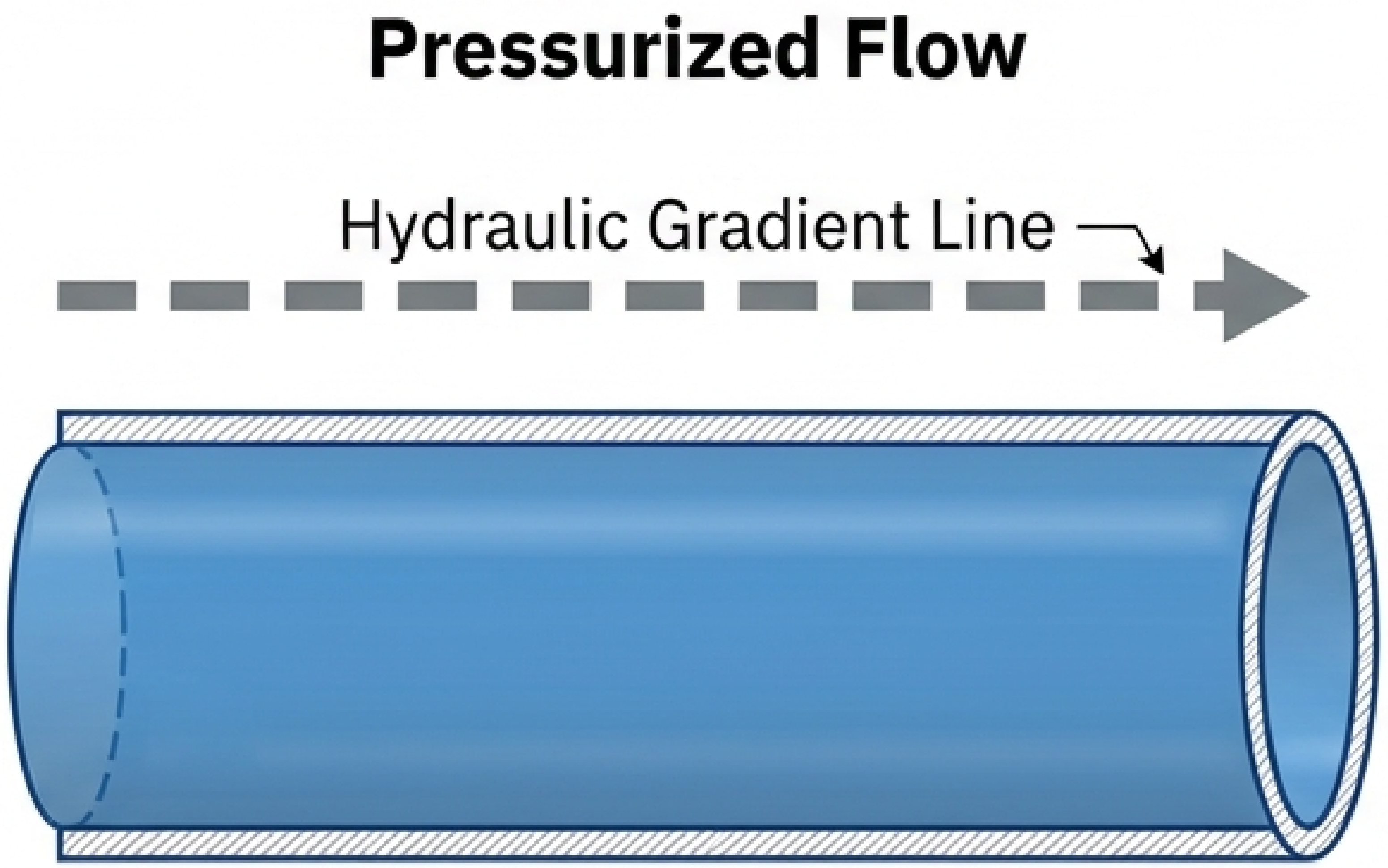
Total Head Increase (E_p) = 37.0 Joules/Newton

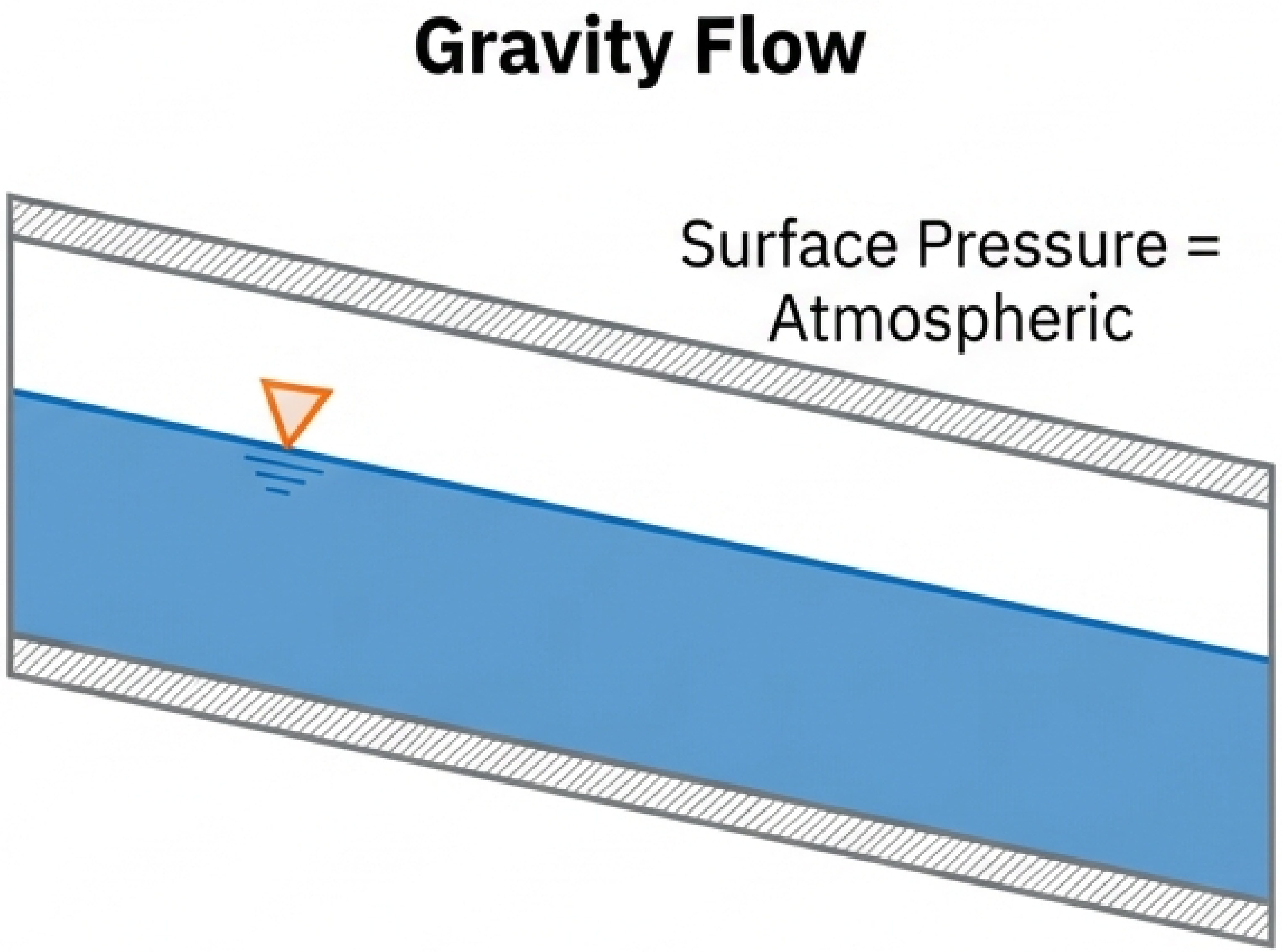
Step 3: Calculate Power IBM Plex Sans

$$P = (0.15 \times 9800 \times 37.0) / 1000 = 54.4\ \text{kW}$$

Phase 2: Open Channel Flow

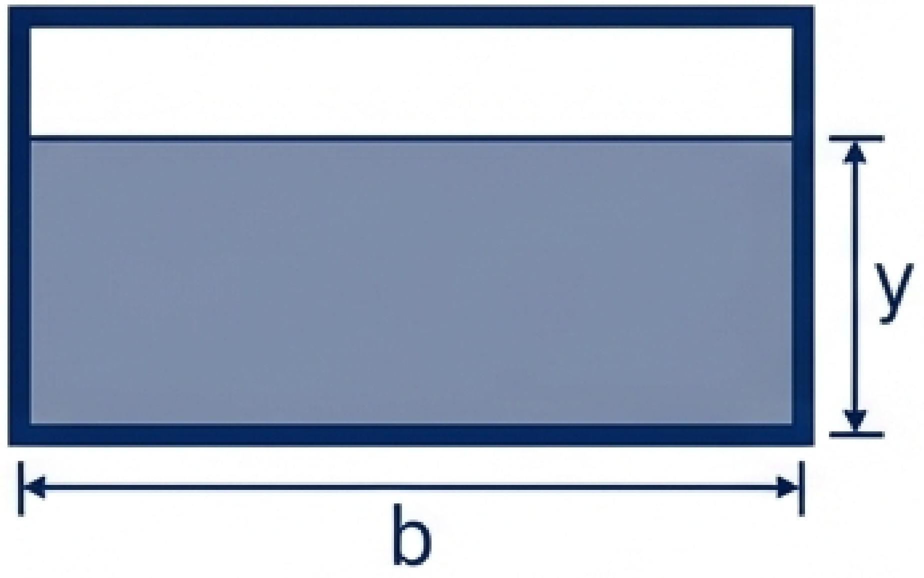
The Critical Difference: The Free Surface

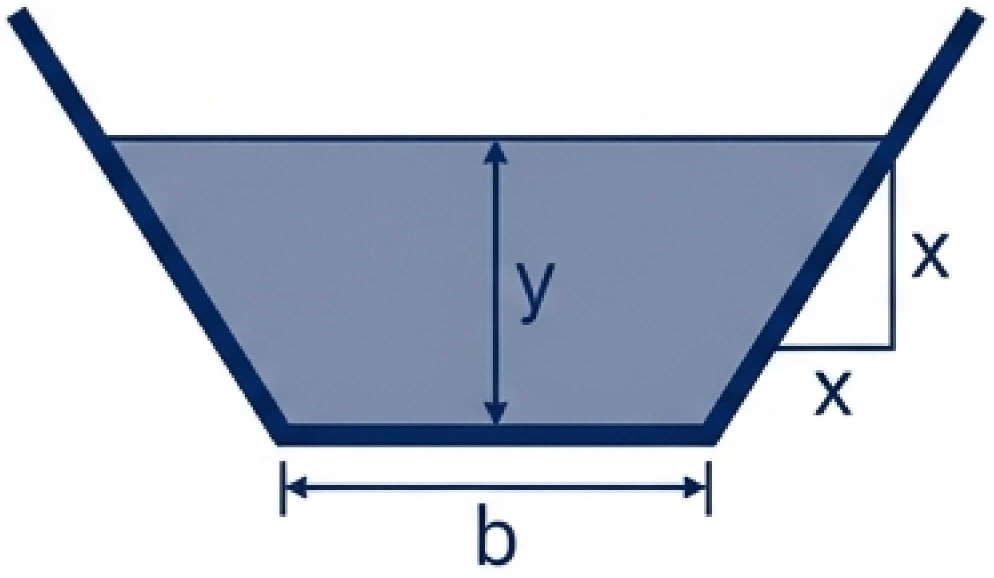


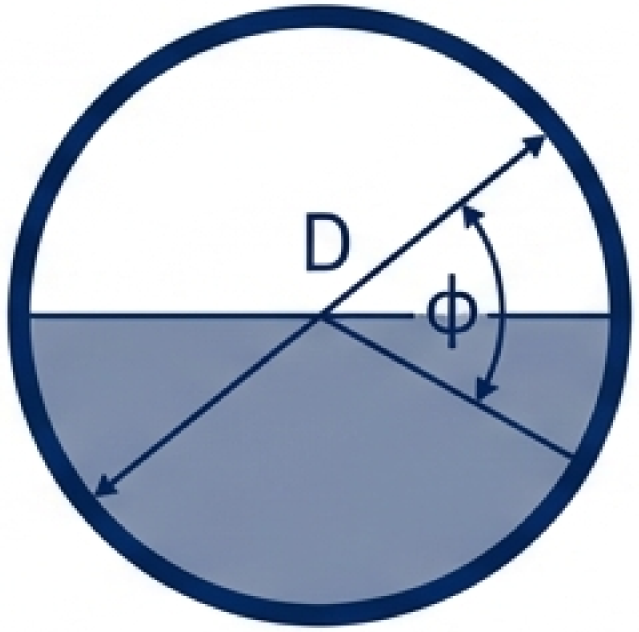


In open channels, water is driven by slope and gravity, not mechanical pressure.

Channel Geometry & Hydraulic Radius





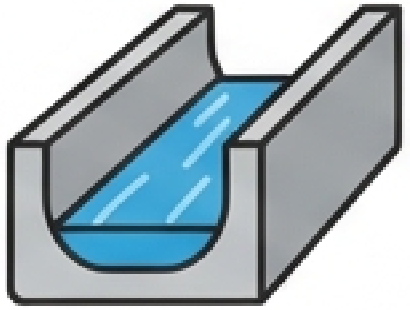


Area (A) $= b \times y$	Area (A) $= (b + xy)y$	Hydraulic Radius (R) $= \frac{A}{P}$
Wetted Perimeter (P) = $b + 2y$	Wetted Perimeter (P) = $= b + 2y\sqrt{(1+x^2)}$	

Hydraulic Radius (R) is the ratio of the cross-sectional area to the length of the surface in contact with the water.

The Manning Equation

$$V = (1/n) \times R^{2/3} \times S^{1/2}$$



Finished Concrete
n = 0.013
(Smooth, Fast)

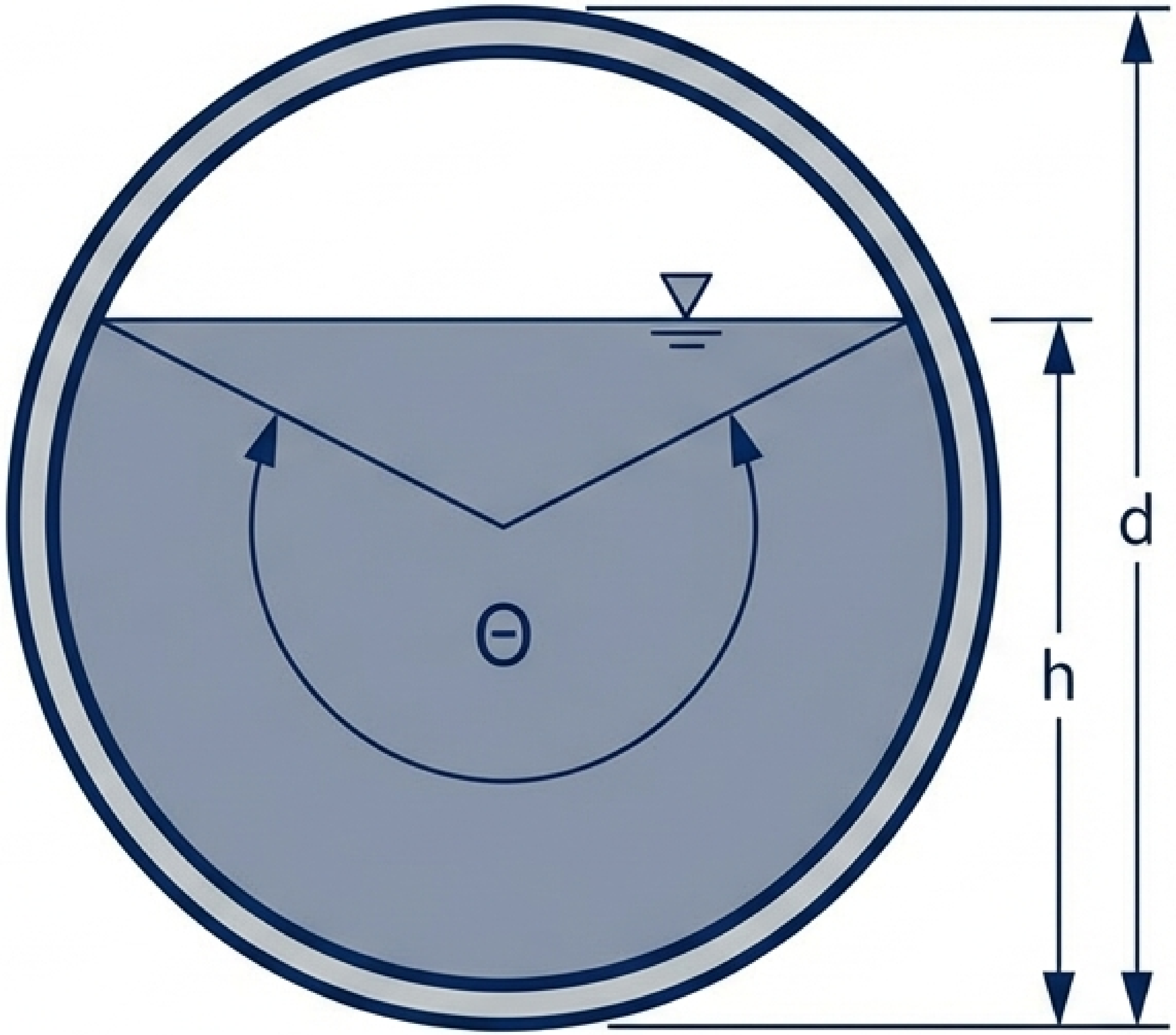
Clean Stream
n = 0.030

Dense Brush/Weeds
n = 0.080
(Rough, Slow)

Spectrum of Roughness

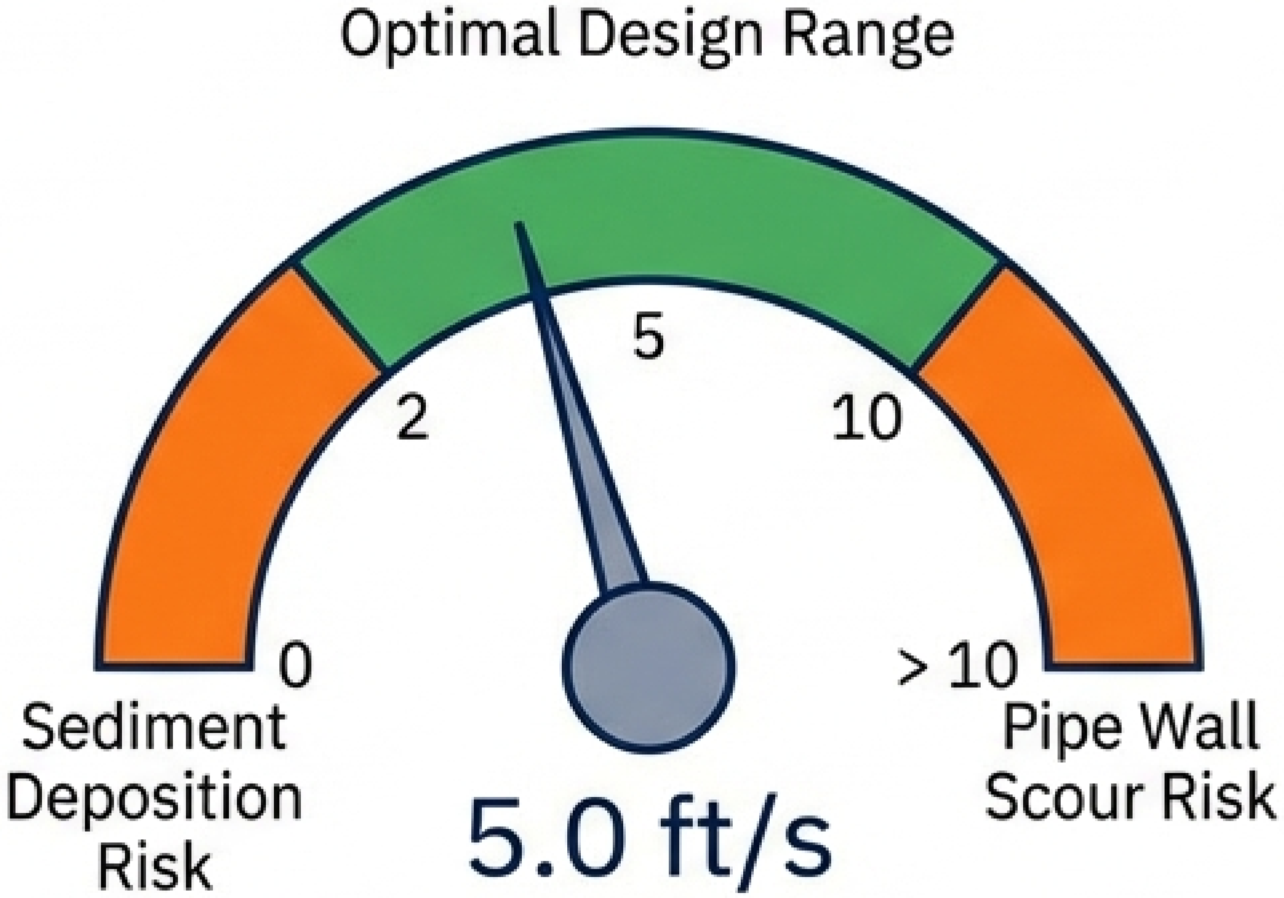
Velocity (V) decreases significantly as vegetation and roughness (n) increase.

Application: Storm Sewer Design



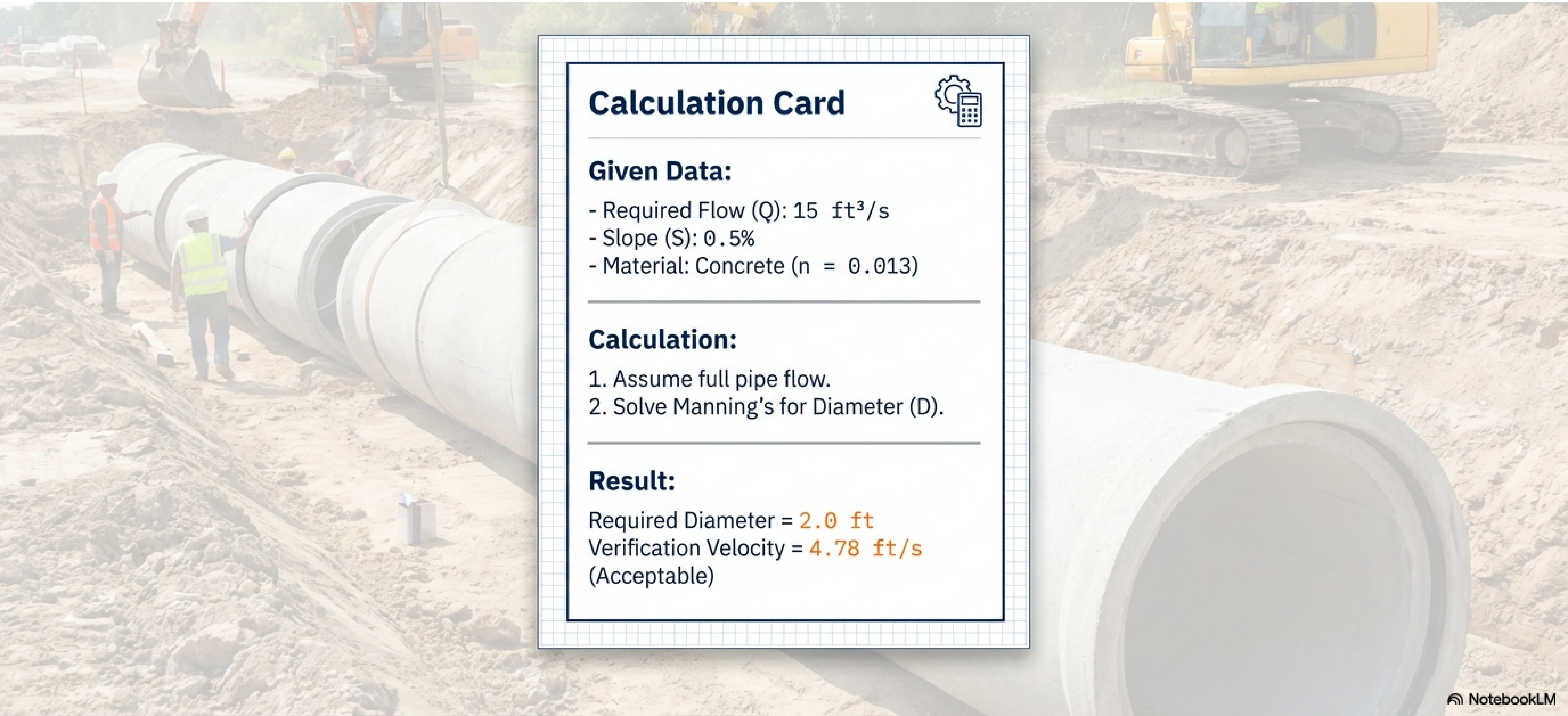
Cross-Section: Circular Storm Sewer

Velocity Design Considerations



Storm sewers act as gravity channels. Design must balance self-cleaning velocity against structural damage.

Worked Example: Sizing a Storm Sewer



Calculation Card

Given Data:

- Required Flow (Q): 15 ft^3/s
- Slope (S): 0.5%
- Material: Concrete ($n = 0.013$)

Calculation:

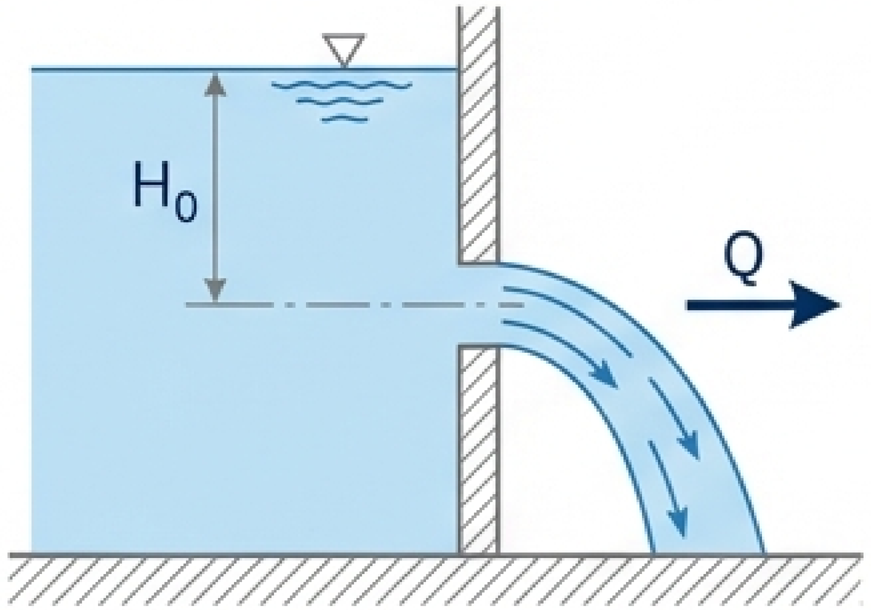
1. Assume full pipe flow.
2. Solve Manning's for Diameter (D).

Result:

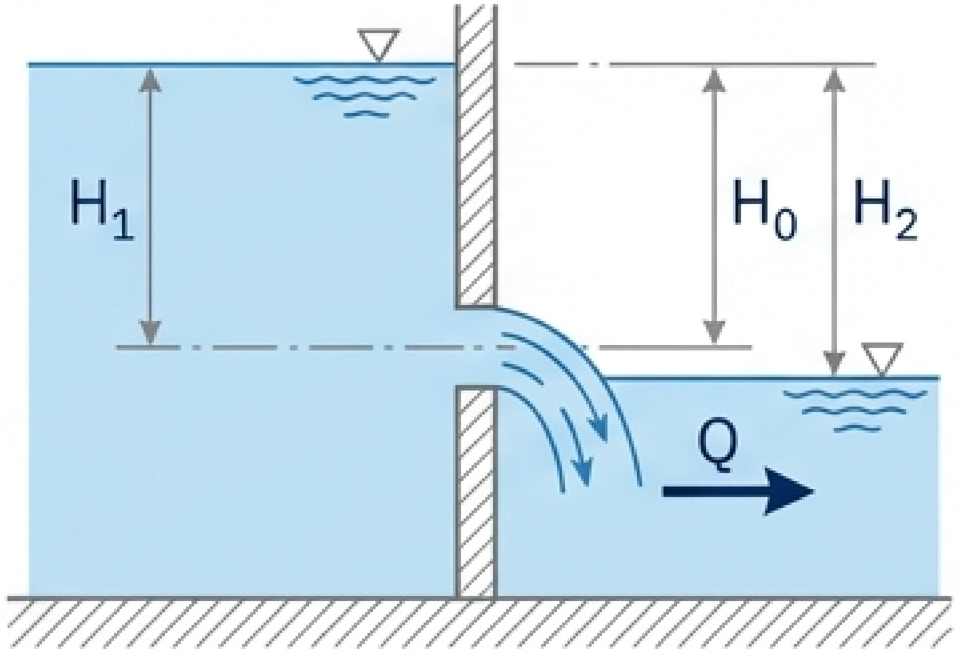
Required Diameter = 2.0 ft
Verification Velocity = 4.78 ft/s
(Acceptable)

Phase 3: Outlet Control — Orifices

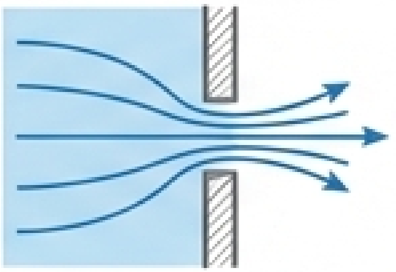
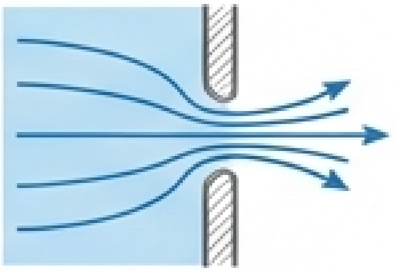
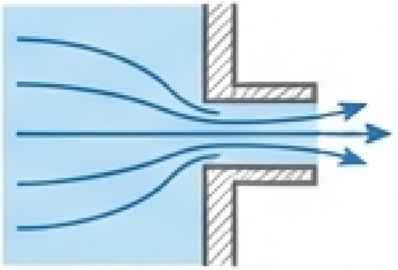
UNSUBMERGED ORIFICE



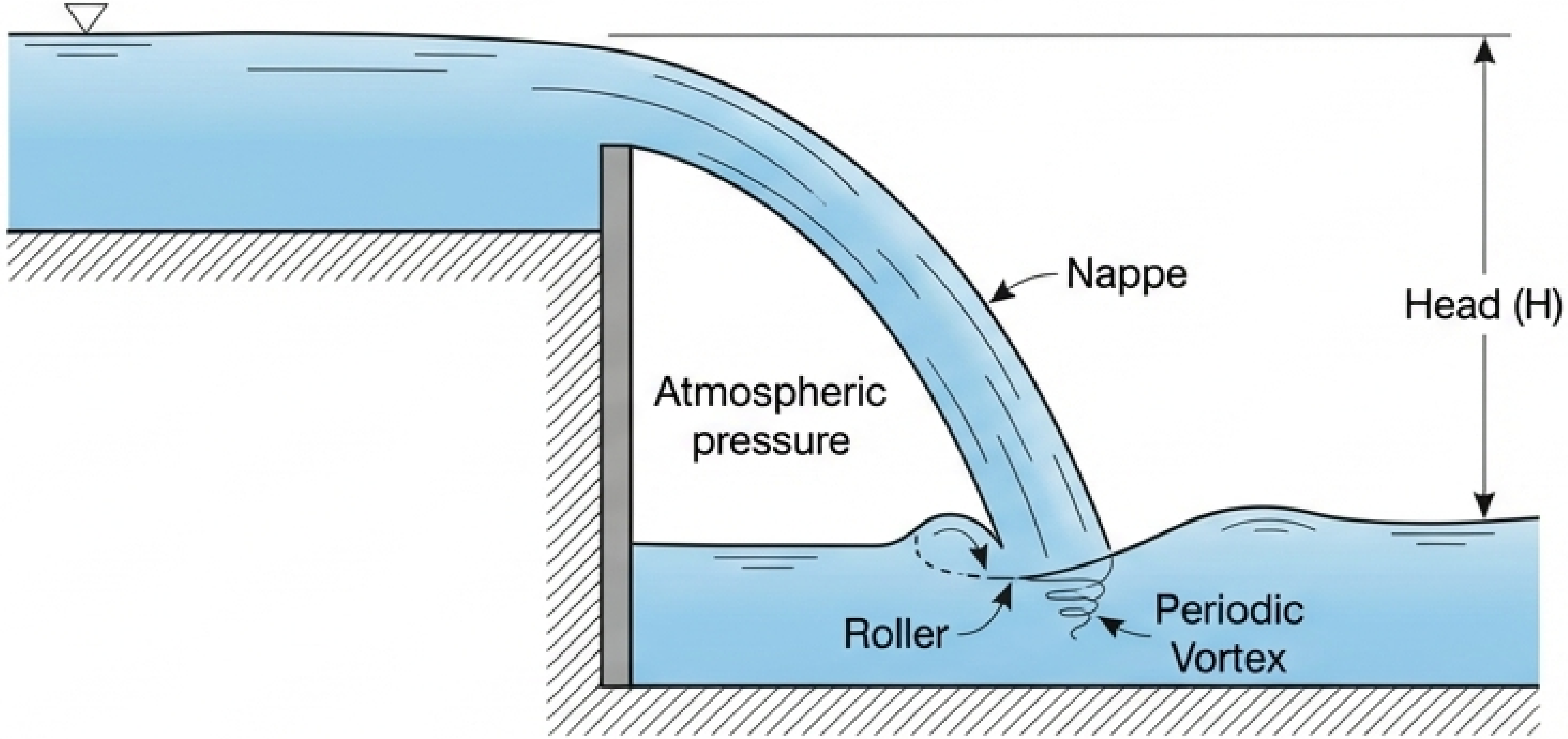
SUBMERGED ORIFICE



Discharge Equation: $Q = C_d \times A \times \sqrt{2gh}$

Discharge Coefficients (C_d)		
Illustration	**Type**	**Coefficient (C)**
	Sharp Edge	C = 0.61
	Rounded Edge	**C = 0.98** **(Most Efficient)**
	Short Tube	C = 0.80

Outlet Control — Weirs



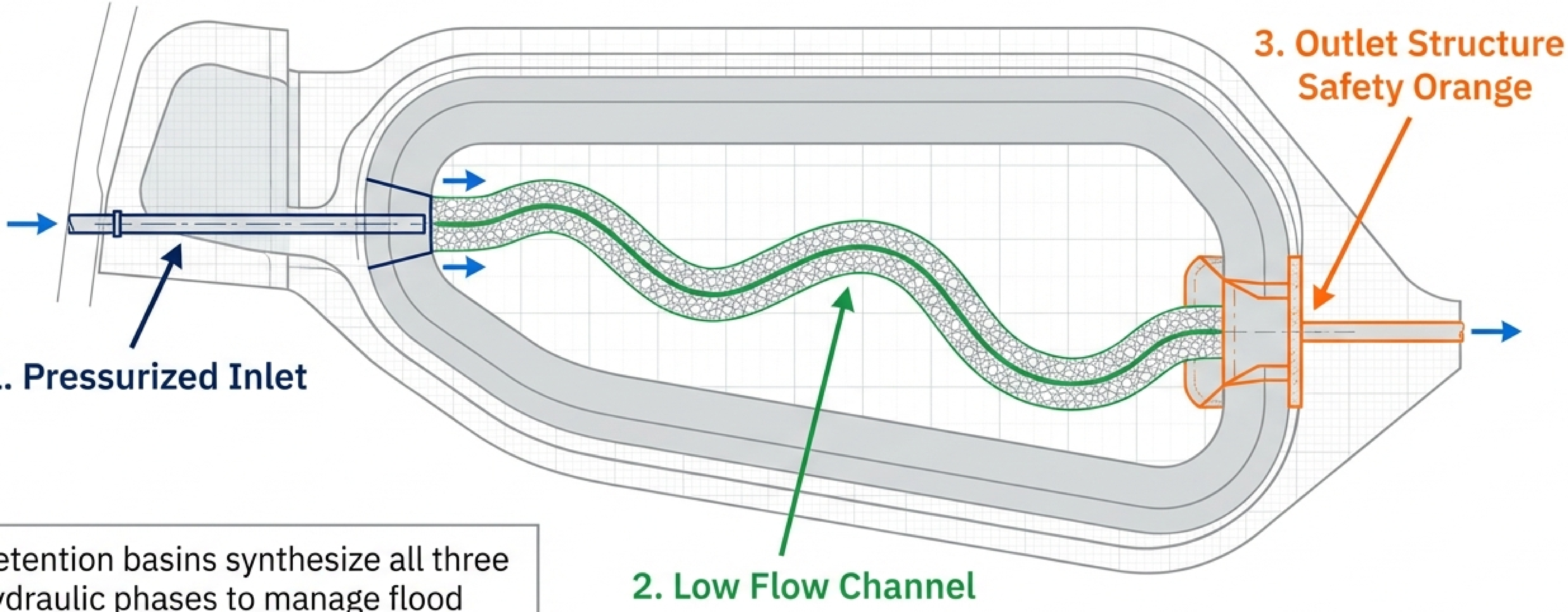
Rectangular Weir Equation:

$$Q = C_w \times \frac{2}{3} \times \sqrt{2g} \times B \times H^{3/2}$$

The Rehbock Formula

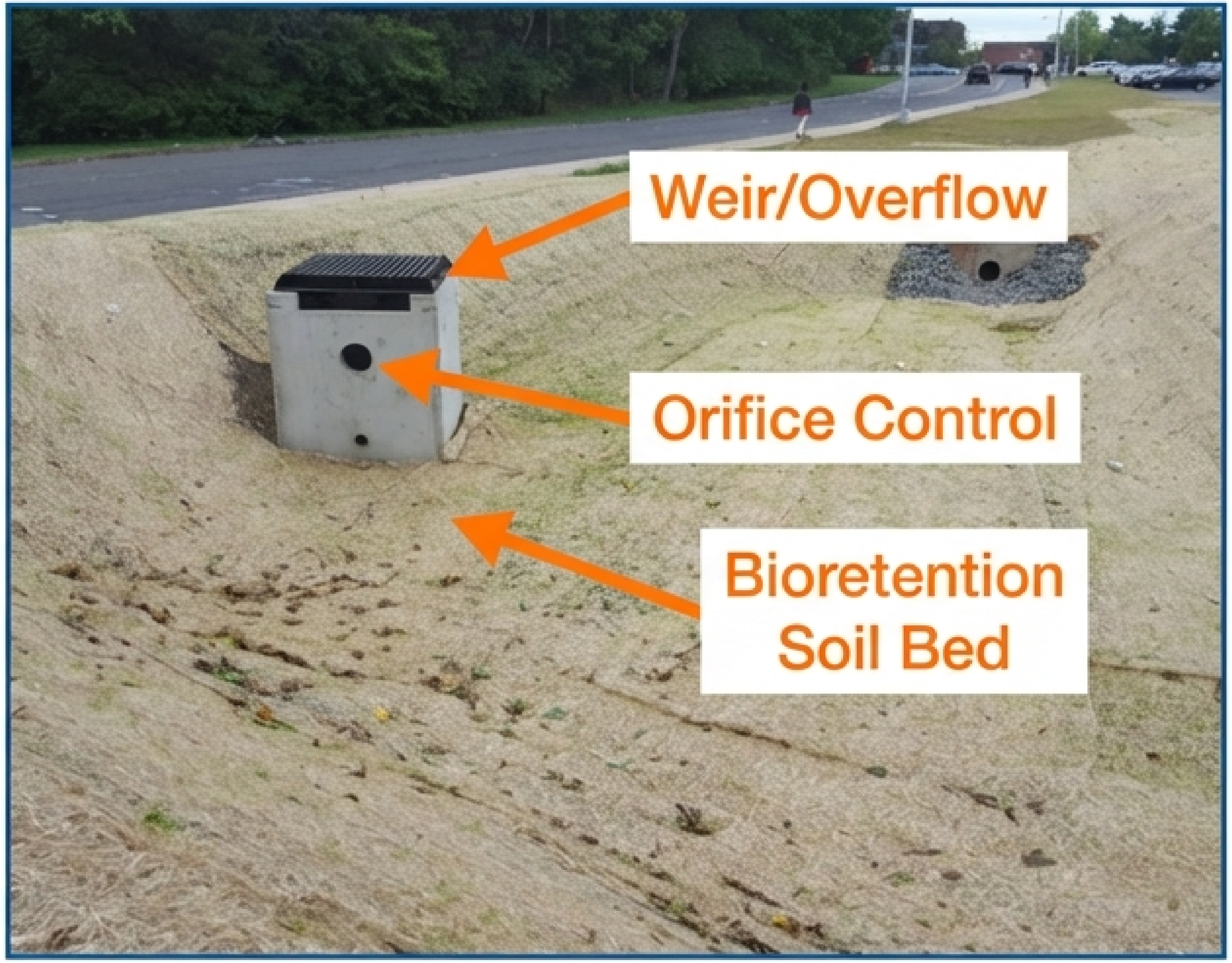
The weir coefficient (Cw) is not constant. It depends on the ratio of Head (H) to Weir Height (P).

Integrated Systems: The Detention Basin



Detention basins synthesize all three hydraulic phases to manage flood peaks and water quality.

Real-World Application: Rutgers Busch Campus



Bioretention system at Brett & Bartholomew Roads, constructed 2016.

REV.	DATE	DWG. NO.
03	11/15/2023	E-301