Problem 01

1. Comparison of Upstream Depth

Based on u/s depth, flow can be calculated as:

$$Q = (\frac{2}{3})^{\frac{3}{2}} B\sqrt{g} H^{\frac{3}{2}}$$

Putting $Q = 0.2\ m^3/s$, obtained u/s depth above the crest is:

$$0.2 = \left(\frac{2}{3}\right)^{\frac{3}{2}} \times 1 \times \sqrt{9.81} \times H^{\frac{3}{2}}$$

$$=>\ H = 0.24\ m$$

The same can be obtained from HEC-RAS model using:

$$H = \text{W.S. Elev (at RS } 1000) - \text{Weir Crest Elevation}$$

For model built using inline structure:

$$H = 0.81 - 0.54 = 0.27$$

And for model built using cross section:

$$H = 0.78 - 0.54 = 0.24$$

2. Comparison of Critical Depth

Analytical critical depth:

$$y_c = \left(\frac{Q^2}{gB^2}\right)^{1/3}$$

$$=> y_c = \left(\frac{0.2^2}{9.81 \times 1^2}\right)^{\frac{1}{3}}$$

$$=> y_c = 0.160\ m$$

Critical depth for model built using inline structure was $0.16\ m$ for both RS 1000 and RS 0; however absent directly above the weir.

And for model built using cross section:

At normal channel sections (RS 1000, 625, 375, and 0): $y_c = 0.16\ m$
At hump sections (RS 525, RS 475): $y_c = 0.70 - 0.54 = 0.16\ m$

5. When Downstream Depth is Increased

For both modeling approaches (inline weir and cross section weir), it is observed that when the downstream water depth in the channel is increased, the weir transitions from a free-flowing condition to a submerged condition due to the backwater effect.

Both models are prepared with 7 flow profiles with different d/s water surfaces. Their effects are outlined below:

Profile	Downstream W.S. Elev (RS 0)	Inline Model Upstream W.S. Elev (RS 1000)	Cross-Section Model Upstream W.S. Elev (RS 1000)	Flow Status
PF 1	0.57 m	0.81 m	0.78 m	Free Flow
PF 2	0.62 m	0.81 m	0.78 m	Free Flow
PF 3	0.67 m	0.81 m	0.78 m	Free Flow
PF 4	0.72 m	0.81 m	0.78 m	Free Flow
PF 5	0.77 m	0.81 m	0.79 m	Submerged
PF 6	0.87 m	0.88 m	0.88 m	Submerged
PF 7	0.97 m	0.98 m	0.97 m	Submerged

6. Discussion

A broad-crested rectangular weir was simulated in HEC-RAS using both inline structure and cross-sectional modeling approaches under the given boundary conditions and by increasing downstream depths.

It is observed that the cross-sectional model produced an upstream water surface elevation of 0.78 m, which perfectly matched the analytical upstream depth of 0.24 m when 0.54 m hump height was subtracted. Meanwhile, the inline structure model predicted a slightly higher upstream water surface elevation of 0.81 m, producing a head of 0.27 m above the crest.

Both the cross-sectional and inline model produced critical depth of 0.16 m at RS 1000 (u/s) and RS 0 (d/s) matching analytical critical depth. The cross-sectional model explicitly computes a critical water surface elevation of 0.70 m directly over the hump (0.54 m), perfectly matching the analytical critical depth of 0.16 m above the channel bed. On the other hand, the inline structure model left the critical depth calculations absent at this upstream cross-section.

Both modeling approaches show an identical upstream Froude number of 0.09 at RS 1000 and a downstream Froude number of 0.15 at the channel exit, which confirms subcritical conditions across the channel. However, the cross-sectional model uniquely captures the supercritical transition over the weir, where the Froude number approaches 0.97 at RS 525 and briefly shifts to a supercritical state of 1.01 at RS 475, validating that critical flow control physically occurs on top of the hump.

Under increasing downstream depths, both modeling approaches successfully simulate the backwater effect that forces upstream water levels to rise. The cross-sectional model reacts to this sooner, showing a clear upstream water surface rise when the downstream boundary reaches around 0.77 m. The inline structure model holds it longer, only triggering an upstream rise when the downstream boundary hits around 0.87 m.

Problem 2

04. Discussion

A steady-flow simulation was conducted for a 1000-meter-long trapezoidal channel with a design discharge of 194 m^3/s to analyze the hydraulic impacts of an inline weir structure positioned at River Station (RS) 490. The system was evaluated under a uniform longitudinal bed slope of 0.044 m/m.

At the upstream boundary (RS 1000), the steep channel gradient forces the incoming flow into a supercritical regime, characterized by a shallow water depth of 0.24 m and a Froude number of 6.66. This high-velocity condition is sustained downstream through the reach until RS 600, where the flow maintains a supercritical Froude number of 2.46.

As the flow approaches the inline structure obstruction, it undergoes a hydraulic transition. Between RS 600 and RS 500, the water abruptly decelerates, transitioning into a deep subcritical state where the flow depth increases to 3.98 m and the Froude number drops to 0.09. It marks the formation of a hydraulic jump upstream of the weir, serving to dissipate kinetic energy before the control structure.

The flow subsequently discharges over the inline weir and passes through critical flow conditions at RS 400, as indicated by a Froude number of 1.01 and a water surface elevation of -15.57 m. Past this control section, the steep bed slope causes the water to rapidly re-accelerate into a supercritical state, reaching a peak Froude number of 4.58 at RS 300.

Between RS 200 and the exit at RS 0, the water depth settles between 0.43 m and 0.55 m, while the Froude number approaches a steady state of 2.17.