Critical Depth

SPEAKER Bob Holmes: Okay. In this particular section, we're gonna talk about some various relationships between critical depth and something we call the "unit flow", and also the critical velocity. Now, from our previous section, we're able to derive that the critical velocity is equal to the square root of the acceleration of gravity times the critical depth. Now, we're gonna define something we call the "unit discharge", which is basically the discharge through a 1-foot width of cross section. So instead of having an entire cross section where we would have a flow rate equal to Q--capital Q--we're gonna talk about unit flow rate or unit discharge, and that would be what we would have--it's abbreviated small letter "q," and that's the flow through 1-foot wide section of the cross section. Now, if we multiply the critical depth and that 1-foot wide section times the critical velocity, we have the unit discharge. That is the square root of "g" times the cubed value of the critical depth.

A note, the critical depth or the unit discharge is only dependent upon the critical depth in this particular case. This implies that if you can force critical flow, you can compute the unit discharge, "Q". This is the basis for many of our critical depth flumes. As I noted in earlier lectures such as flumes as the Parshall flume or a broad-crested weir, we're forcing the flow through critical depth and therefore we have a unique relationship between the stage and the volumetric discharge.

Now, if we combine equations--remember we had that the specific energy is equal to the depth plus the velocity head and we assume that our critical velocity is equal to the square root of "g" times the critical depth, we can pull those together, substitute the value of "g" times the critical depth under the square root sign and we can come up with a value that says that the minimum value for this specific energy is equal to three halves the critical depth.

Now, if unity--that would be assuming that our value for the Coriolis coefficient is equal to 1. Now, if we cannot assume that that Coriolis coefficient is 1 or unity, we have a different equation for our Froude number. The Froude number is equal to the mean velocity divided by the square root of the acceleration of gravity times the critical depth or times the depth in this particular case, divided by the alpha value, which is the Coriolis coefficient.

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Now, in flow throughout the various rivers and streams that you will work in, you're gonna have flow going from subcritical to supercritical and vice versa in many of your open channels. Now if it occurs rapidly over a very short distance, this is something that we call rapidly varied flow. Hydraulic drops and hydraulic jumps are two examples of this type of rapidly varied flow.

Now, let's talk quickly about a hydraulic drop. That's where the flow goes from subcritical to supercritical. You might think of Niagara Falls, that's a hydraulic drop. Although extreme, you basically have the flow coming from subcritical going over the precipice and then it becomes obviously supercritical as it falls through. And most of the cases, we don't have that particular type of rapid drop like that. It's more gradual where you'll have the slopes changed from subcritical slope to a supercritical slope forcing the flow from the upstream to the downstream part to be supercritical. This abrupt change in the channel slope or cross section also causes an inverse or reverse curve for the water surface profile at this location. And we're gonna talk about water surface profiles in a later lecture.

At this point where we had the hydraulic drop, not only are we going through critical depth, but we're also indicating that the specific energy is a minimum. We're going to show you a particular graphic later on in this particular lesson that will demonstrate what happens with the specific energy curve when we go through various parts of the flow.

Now, the free overfall, which I talked to you about like Niagara Falls, is a special case of this hydraulic drop. Now, the critical depth should be a minimum at this free overfall because it has curvilinear flow through this particular section. Our specific energy assumptions are not exactly valid all the time in this particular situation, though. We found that at the brink of these overfalls that the depth actually at the brink is the critical depth divided by 1.4. So we go through the minimum value of the specific energy a little bit upstream of where we have our critical depth. And so right at the drop itself, we have a value that's a little bit smaller than the actual critical depth. We find that the critical depth is actually 1.4 times this depth at the brink. Now, the critical depth location is located a distance three to four times the critical depth upstream from the brink.

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Let’s switch gears a little bit and talk about a hydraulic jump. Many of you have seen it but you may have not known what you were looking at, or you may not have known that we call it a hydraulic jump. Hydraulic jump occurs when you go from supercritical to subcritical flow, and it occurs very abruptly. This is often the case these hydraulic jumps are occurring downstream of a sluice where you're allowing water to come out from under a sluice gate on a very flat slope. The energy that it comes out at, that slope is not able to maintain that particular flow and so as it gets downstream, all of a sudden it will go through a hydraulic jump.

We have various types of hydraulic jumps. We can have an undular jump which occurs when the flow is only slightly supercritical, the flow transitions to supercritical over a series of undulations. More importantly--more directly are easier to define is something we call a direct jump which where you have--is where you have highly supercritical flow and it changes depth very quick and very rapidly in a short distance of time. And you can see that graphic on your slide. We will also show that to you in the flume.

At this point, that concludes our lesson, and we will proceed to another flume demonstration with some additional graphics and then we will encourage you to work the problems in Lesson 11.