Flow Over Weirs: Broad-Crested Weirs

SPEAKER Charles Berenbrock: Welcome to Lesson 18, flow over weirs. In this section, we'll be discussing flow over weirs.

A weir is an obstruction in a channel that causes water to back up behind it and to flow over it. Basically, a weir forces water to flow through critical. Thus, it simplifies the calculations or the determination of discharge. A weir usually has an opening or a notch. Weirs are quite simple. They're really cheap to make or buy. They're a common device to measure flow in channels especially in irrigation ditches. If the edge of the weir is quite thin or beveled and it comes up to a sharp point, it causes the water to spring and to be clear of the weir on the downstream side. When this happens, this is called the sharp-crested weir. A weir may behave as a sharp-crested or a broad-crested depending on the depth of flow over it.

The sheet of water flowing over the weir crest is called a nappe. If there's air below the nappe, the discharge is considered free or critical. If there's flow over the nap--in other words, it's not ventilated then and the flow is considered submerged or drowned. You'll see a lot of this terminology in text or in textbooks. If the downstream water surface elevation--and we call that WSE--is above the weir crest, the flow rate through the weir will be appreciably affected.

This is a photograph of a weir, and it's of a sharp-crested weir. Notice that it has a sharp point. It produces a nappe. There's air below the nappe. And the shape of the water below the nappe [underside] is the same shape as an ogee spillway. This is just an introduction to tell you more about weirs.

In the following, we'll discuss about the hydraulics of a broad-crested weir that usually has a long notch and you can see the long notch in this illustration. And we denote that by the variable called "L."Usually, Section 1 is placed upstream, sufficiently far enough upstream, so that the effects from other broad-crested weir do not affect the flow around the cross-section—I mean, around Section 1. Section 2 is located at the upstream end of the broad-crested weir. And then Section 3 is located at the downstream end of the weir. Again, weirs force the water to go through critical. And in this case, for broad-crested weirs, the critical is on the downstream at Cross-section 3 and

you can see the red lying around D_c. Denote that as critical depth. Also notes some other variables. The broad-crested weir height is denoted by "P." H_1 is the height of water above the broad-crested weir at Section 1 (h_1) plus the velocity head at Section 1 ($v_1^2/2g$).

If we write the energy equation between Section 1 and 3, the following equation results where we have the velocity head at Cross-section 1 which is alpha1 (α_1) times v sub-1 squared (v_1^2) divided by 2g plus h_1. Now, h_1 is the depth of water at Cross-section 1 above the weir. It [the quantity on the left hand side of the equation] is equal to the critical velocity squared divided by 2g--sometimes we denote this as a critical velocity head--and then we add the critical depth to it, D_c. Also, we have to add in the friction losses between Sections 1 and 2, and also between 2 and 3, and then we also have to denote the losses due to the entrance losses from the weir itself. And we denote that as "h_e." Because the velocity at Section 1 is usually small or quite small, so we'll set v_1 equal to zero, then we can say that our friction head between Sections 1 and 2 is also quite small or zero. Usually, the length of the weir is usually small and if we do–so L equals zero. And if we do that, then we can say that our friction head from 2 to 3 is also quite small.

Now, h_e is our entrance losses or the energy losses due to the contraction of flow over the weir. And it's approximated as usual and you can see the following equation. Because our velocity at Cross-section 1 is quite small, the velocity head at Section 1 can go to zero. So our entrance loss, h_e, is equal to k_e times the critical velocity squared over 2g. Now, we've substituted this expression end and rearranged the energy equation. It results in H_1 equal critical depth plus our critical velocity head times the quantity of 1 plus k_e.

Remember from previous lessons that the critical depth, D_c, again for rectangular channel is related to the total specific energy and velocity as the following equation shows where D_c, the critical depth, is equal to two-thirds (2/3) times the critical energy and it can also equal two times the critical velocity squared over 2g. And then it equals two-thirds our total head which is the water depth above the broad-crested weir plus the velocity head at Cross-section 1. Now if we substitute this expression and re-arrange the energy equation, the energy equation yields, v_c, is equal to the square root of 2 times g divided by 3 times the quantity of 1 plus k_e times H_1 to the one-half power. Now to attain discharge, we just multiply both sides of that equation by area or by

the width of the broad-crested weir times the critical depth. And when we do that, the following expression results.

Now we are going let ”C”, the contraction ratio, represent two-thirds times the square root of 2g divided by 3 times the quantity of 1 plus k_e. And when we replace ”C” into the equation, discharge equals C, our contraction ratio times “b” the width, times H_1 to the three halves power. Remember that “C” is the contraction ratio. If C is only a function of k_e, then C will equal two-thirds times the square root of 2 times g divided by 3 times the quantity 1 plus k_e. However, if “C” is a function of other variables besides just k_e, then C becomes C equals C prime (C’), then you can multiply it by k_r, k_s, and other loss terms. And then k prime--I mean, C prime (C’) is equal to two-thirds times the square root of 2g divided by 3 times the quantity of 1 plus k_e.

This is a graph showing the variation of “C” with slopes over the upstream face of the broad-crested weir. You can see as the slope of the upstream face increases, let’s say from one-half versus one to two versus one in that diagram, “C” becomes larger. And the lower diagram shows what the upstream face is for the broad-crested weir.

k_e generally ranges from 0 to 5.5. The C will vary from 3.09 to 2.52. A k_e that equals zero represents a very smooth opening and then C would equal 3.09. And then our contraction ratio, h over L, would become small. Now, remember L is the length of our broad-crested weir and h is the wider depth at Cross-section 1 above the weir. When k_e is equal to 0.5, it represents a sharp non-streamlined opening, then C would equal 2.52 and the contraction ratio would be quite large. When your contraction ratio is grater than 1, it behaves more like a sharp-crested weir.