Inspecting an Open Channel Water Measuring System

All irrigation measurement and delivery systems deteriorate over time. Careful observation and inspection is needed to see the deterioration and make corrections. Deterioration in canals and ditches is easy to see (trees and weeds growing in the canal or ditch, seepage, blowouts, etc.), but deterioration in the measuring system may not be as obvious to the user, especially users who are always working with measuring system. After all, "it has always worked fine in the past." Water users and providers are often surprised to find that their water measurements are not accurate due to deterioration. Regular and careful inspections are necessary. Inspections also reveal changing delivery needs that require other types of measuring devices and reveal other possible errors of operation.

Why worry about accuracy? – Because accurate measurement helps maintain accurate water delivery and protection of water rights. Weirs and flumes are the most common methods of measuring water, but each type has its individual requirements. What suits for weirs may (or may not) suit requirements for a flume, but what suits for a flume will not suit requirements for a weir.

<u>How sharp-crested weirs operate</u>

The water surface is lower at the weir blade than it is upstream from a weir (Figure 1). The difference in elevation between the two circled points on the surface of the approach flow is called the velocity head and represents the potential required to produce the increase in velocity between the points. In general, the approaching flow should be tranquil, a fully developed flow in long, straight channels with mild slopes, free of close curves, projections, and waves.

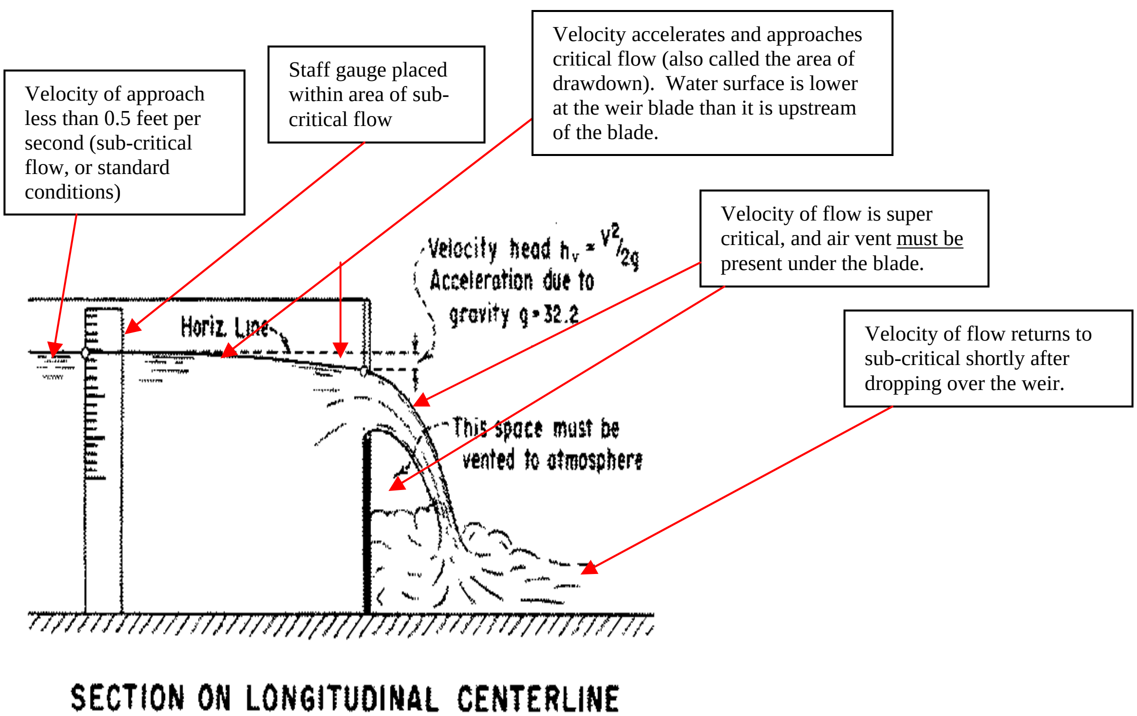
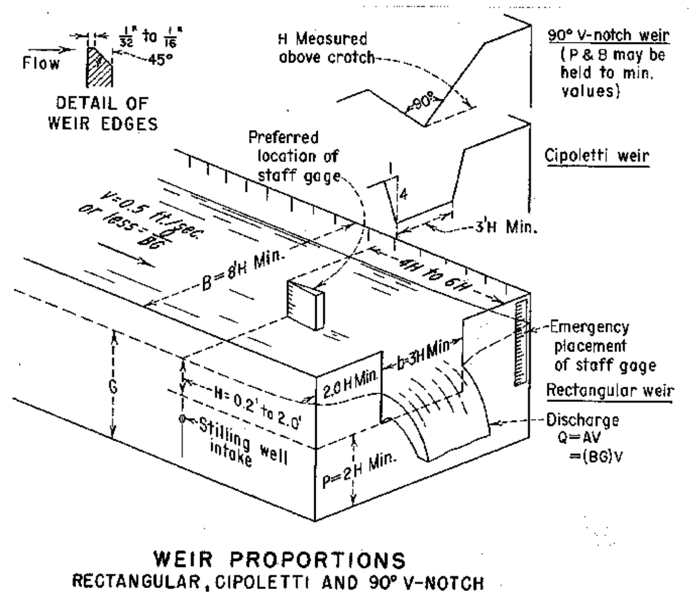


Figure 1. Profile of how water flows properly over a weir for accurate measurement

A drop in water surface of 0.1 ft common just upstream from a weir represents an increase in velocity of 0.8 ft/s. If the head on the weir is measured too close to the weir, the head measurement can be up to 0.1 ft too small. For a weir 6 ft long, with a head of 0.45 ft, a discharge of 7 ft^3/s is indicated. If the head measurement is too close to the weir so that the head is reduced by 0.1 ft, a discharge of 5 ft^3/s would be indicated. That difference amounts to an error of about 35 percent based on the reported discharge.

Weirs must be constructed with certain proportions to ensure accurate measurement (Figure 2). Maintaining those proportions will ensure that measurements are as accurate as possible under normal operating conditions. That means that approach velocities are sub-critical, approach critical flow as water approaches the weir, attains super-critical flow as water passes over the weir, and returns to sub-critical after water drops through the weir. Figure 3 shows weirs with proper approach flow and proper drop over the weir.



H = depth of water passing over the weir blade, where H is measured above the weir blade
b = length of weir crest, which should be 3 times the maximum depth of water to flow over the weir blade
B = the width of the approach channel before the weir blade; 8 times the maximum head is optimum
P = height of the top of the weir blade above the bottom of the weir pool

The staff gauge should be in the center of pool back of the weir blade at least 4 times the maximum depth of water to flow over the weir blade, or if on the side in a quiet part of the pool and outside where the water begins accelerating through the weir blade (the area where drawdown in the pool begins)

Figure 2. Proportions in sharp-crested weirs for obtaining accurate measurement.

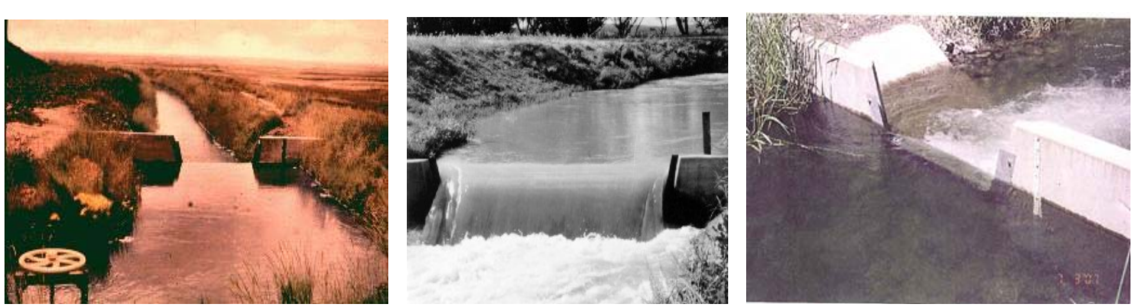


Figure 3. Approach flow on these weirs is as it should be for accurate measurement

Causes of incorrect operation and measurement of a weir

Standard weir tables do not compensate for excessive velocity of water through the weir. Velocity faster than 0.5 feet per second **before** the water is to begin accelerating in velocity (increasing from 0.5 feet per second to 0.8 feet per second, about 4 lengths of maximum head behind the weir blade, see Figure 1) will result in delivering more water than is measured. Causes of excessive velocity head include inadequate pool depth upstream from the weir, deposits in the upstream pool, and poor lateral velocity distribution upstream from the weir.

Figures 4 and 5 show conditions which causes poor distribution of flow and result in inaccurate measurements. The high velocity, turbulent stream is approaching the weir at a considerable angle. The high velocity approach flow and the waves on the surface cause errors in measurement and the standard rating table for the weir in question will not be within an acceptable range of error.

Figure 4. Build-up of sediment behind a weir reduces the depth of the weir pool. Water cannot be slowed down enough to allow controlled drop of water over the weir

Figure 5. Vegetation and buildup of sediments behind the weir result in no measurement being able to be made

The presence of water surface boils, eddies, or fast currents, is reason to suspect the accuracy of the measuring device (Figure 6). A bend or angle in the channel just upstream from the measuring device or a rapid expansion in the flow section will result in error due to turbulence and uneven flow through the measuring device.

Figure 6. Example of poor approach flow conditions upstream from weir. The first shows the channel as not being straight or a pool calm, and both situations show that the velocity of water is too fast for accurate measurement

<u>Exit Flow Conditions</u>

Exit flow conditions can cause as much flow measurement error as approach flow problems, but those conditions are not encountered as often in practice. Sharp-crested weirs should discharge freely rather than submerged. However, a weir operated near submergence may not affect the discharge as much as the possible lack of ventilation under the nappe shown in Figure 1. A submerged weir is shown in Figure 7.

Figure 7. Example of a submerged weir where backwater below the weir prevents the water from falling properly over the weir blade

<u>Indications that a weir is operating properly in a weir pool, at the weir, and below a weir</u>

Figure 8 shows the areas to inspect to determine if conditions in the weir pool upstream of the weir are o.k.

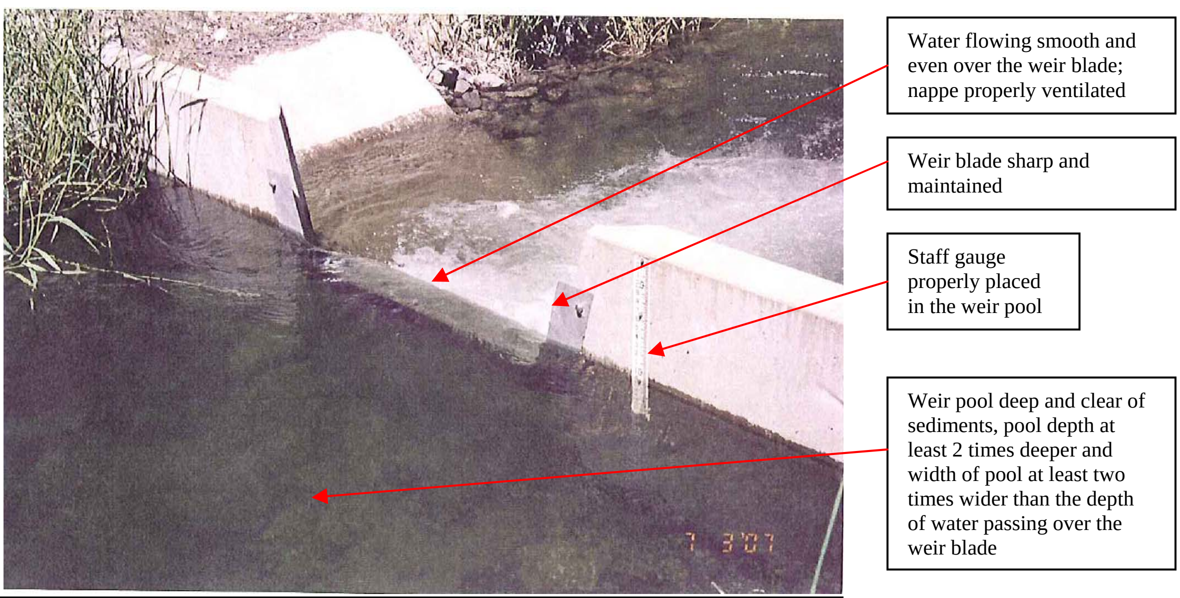


Figure 8. Conditions for a properly maintained and operating weir

<u>Conditions below the weir pool that indicate the weir is operating properly</u>

One of the main indicators below a weir pool is the presence of what is called a hydraulic jump. A hydraulic jump occurs when the velocity of the water reduces from super-critical as it passes over the weir to sub-critical velocity as water flow returns to normal flow in the ditch or canal and is indicated by (Figures 9 and 10). A hydraulic jump indicates that the weir is not submerged.

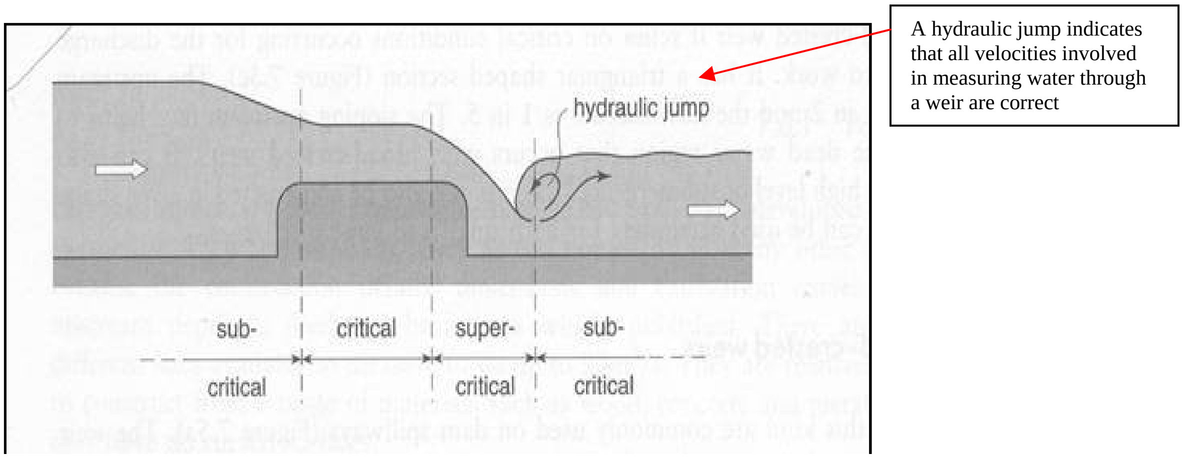


Figure 9. A hydraulic jump indicates that conditions below a weir (or flume) are correct

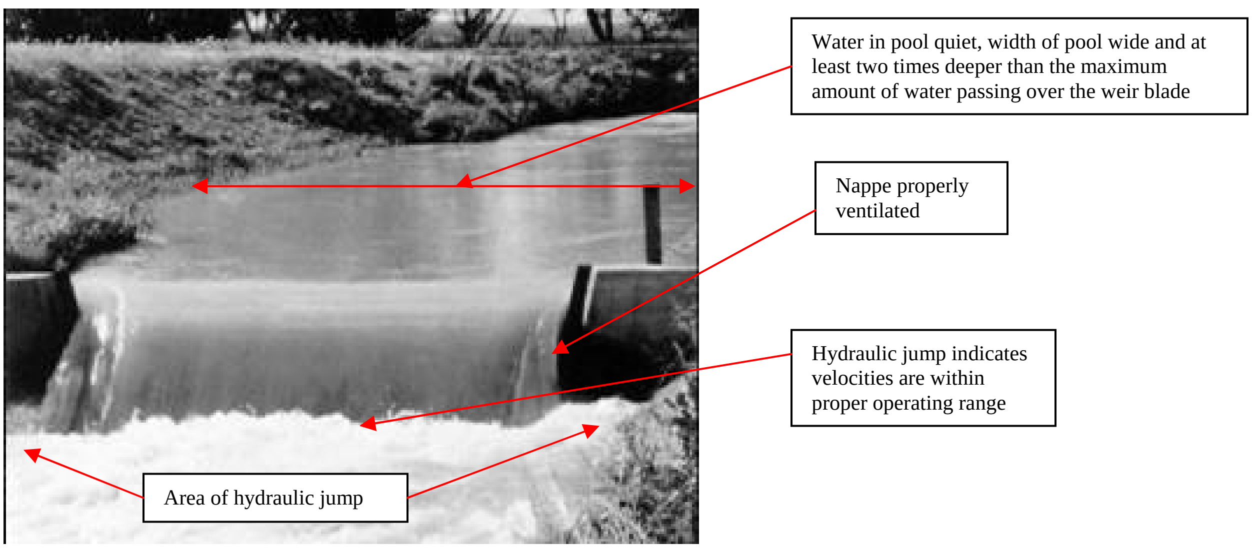


Figure 10 shows conditions in the weir pool, nappe ventilated, and hydraulic jump

Indications that long-throated ramp flumes and Parshall flumes are operating properly

The head loss on a flume is less than about one-fourth of that needed to operate a sharp-crested weir having the same control width, and in some long-throated flumes, may be as low as one-tenth. Convergence at the entrance tends to improve velocity distribution of approach flow and the passage of floating debris.

Examining long-throated ramp flumes

Examining a long-throated ramp flume to find out if it is working properly is relatively simple. Figure 11 shows what the profile of flow looks like in a long-throated ramp flume that is operating properly. Occasionally, a flume is set too low, and backwater submerges the throat excessively, which can introduce extremely large errors in discharge measurement. The only remedy is to raise the flume, unless some local obstruction downstream can be removed to reduce the backwater.

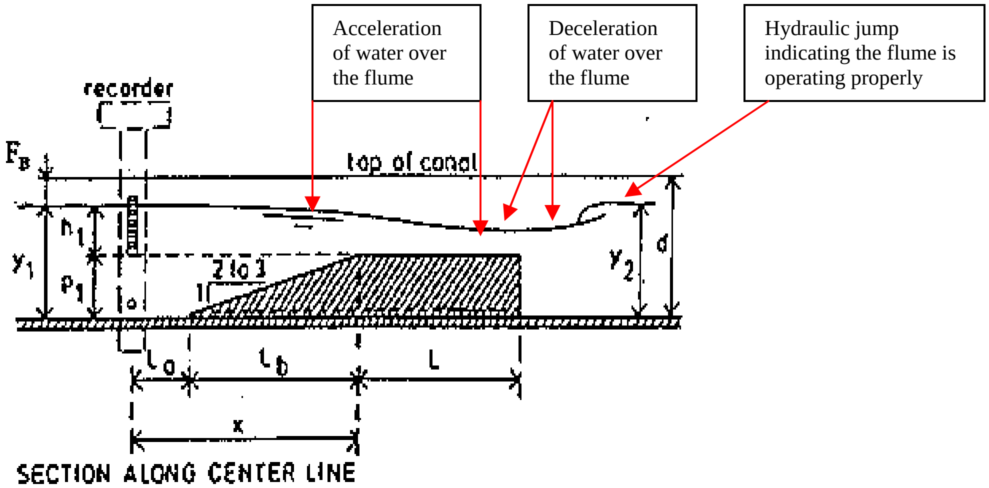


Figure 11. Profile of a long-throated ramp flume showing the profile of water before, during, and after passing over the flume

To determine if a small long-throated ramp flume is properly installed, a carpenter's level can be used to determine if the ramp flume is level along its length and on its width (Figure 12, below). If it is not level both ways, then discharge will have either have to be recalculated, stream gauging measurements made to develop a rating curve, or the flume reset. A properly operating will have the hydraulic jump should be even across its profile.

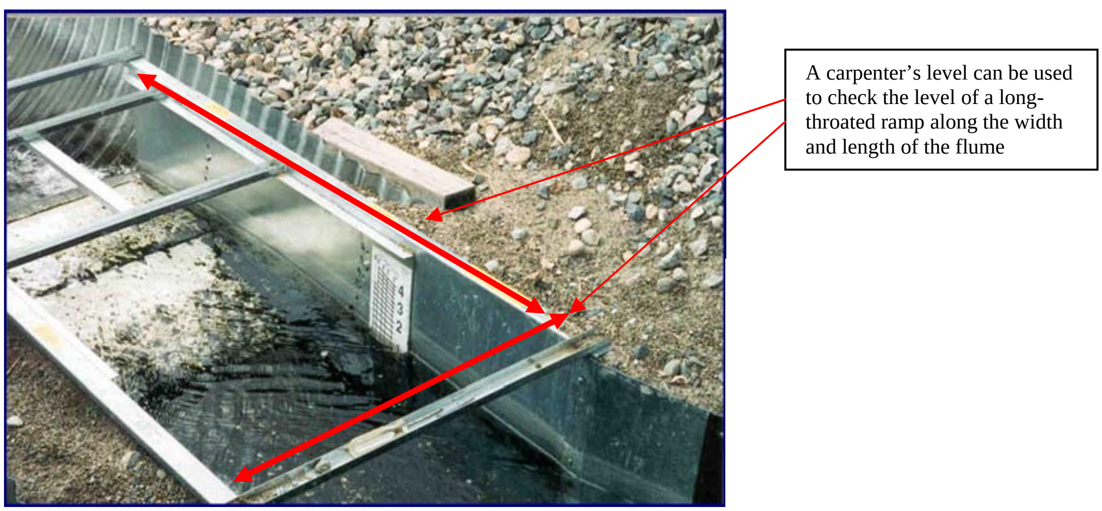


Figure 12. Use a carpenter's level to make sure a ramp flume is level at its length and width

<u>Presence of a hydraulic jump on flumes</u>

While a hydraulic jump is not nearly as pronounced on flumes as on sharp-crested weirs, a hydraulic jump on flumes is still an indication if conditions of flow through the flume are correct. Figure 13 shows a hydraulic jump on a long-throated ramp flume. Figure 15 shows the hydraulic jump on Parshall flumes.

A hydraulic jump should be detectable on all sizes of ramp flumes. Figure 13 (below) shows the hydraulic jump below a long-throated ramp flume that is about the only visible indication that a ramp flume is operating properly when water is flowing over the flume. If a hydraulic jump is not present, the flume is submerged and an accurate measurement cannot be made.

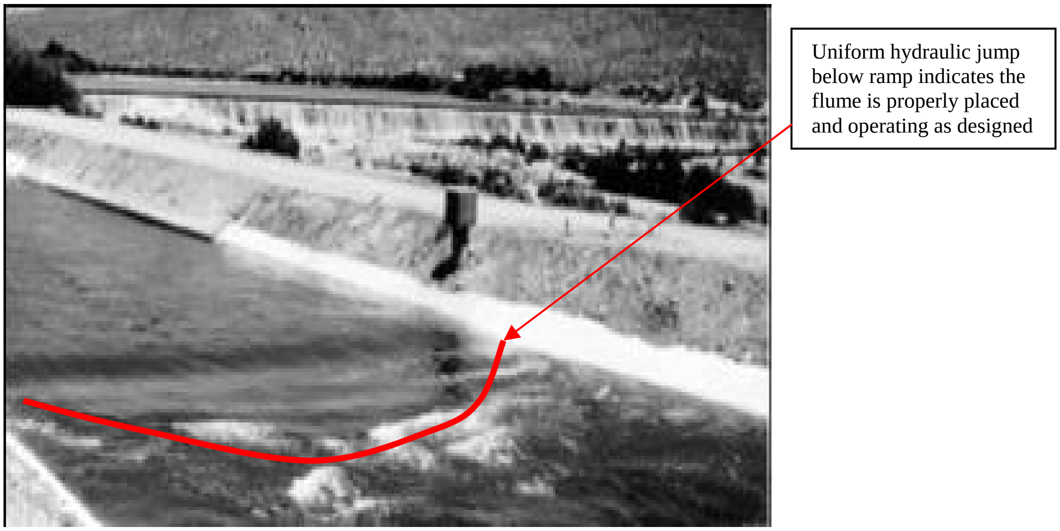


Figure 13. Uniform hydraulic jump below a ramp flume that indicates the long-throated ramp flume is operating as designed

An inspection of the ramp flume built in place (Figure 14) can also be made when the canal is dry by using surveying equipment to determine proper slope of the ramp, the length of the ramp on top, and whether or not the ramp is level.

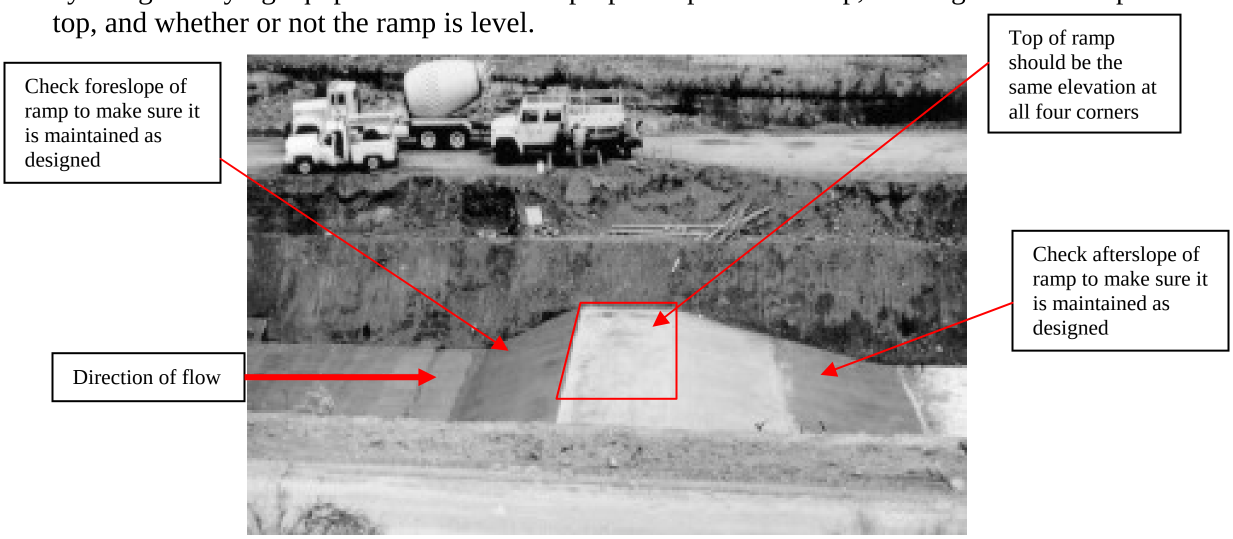


Figure 14. Concrete ramp flume built in place showing the areas to inspect to determine if a ramp flume can still functions as designed or if a new rating curve needs to be calculated

<u>Examining Parshall flumes</u>

Examining a Parshall flume (Figure 15) to determine if it functions properly is similar to inspecting a long-throated ramp flume. Parshall flumes require precise angles. Most Parschall flumes are now pre-built and on-site construction is not necessary. A pre-built Parshall flume is desirable over building one in-place because the angles needed on a Parshall flume are built-in.

Similar to the long-throated ramp flume, the four corners of the bottom of the throat of a Parshall flume need to be at the same elevations in order for the flume to ensure correct measurements are taken.

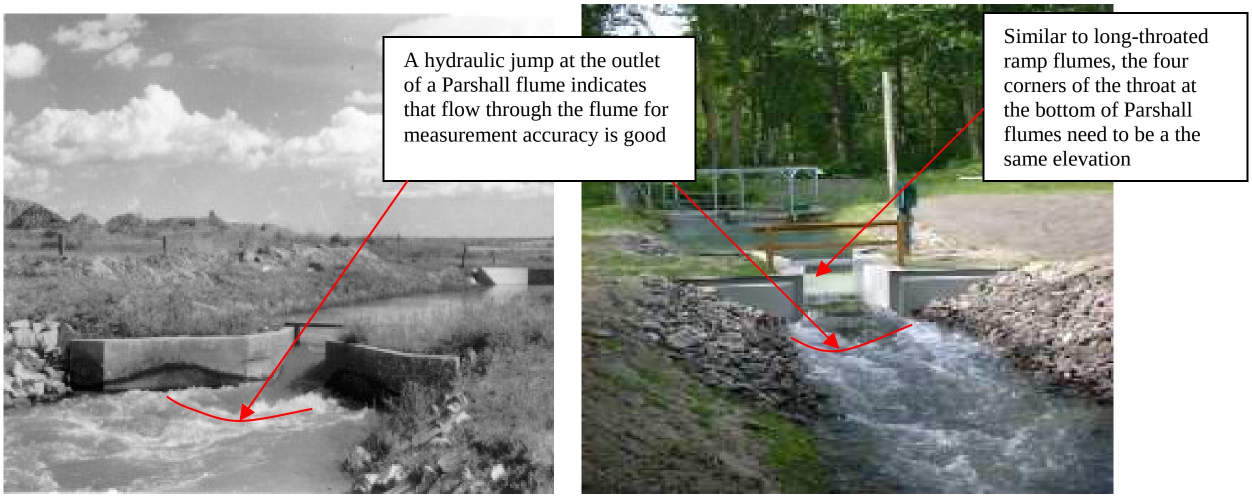


Figure 15. Parshall flumes showing the hydraulic jump and where to measure the throat to determine if all four corners of the bottom of the throat are at the same elevation