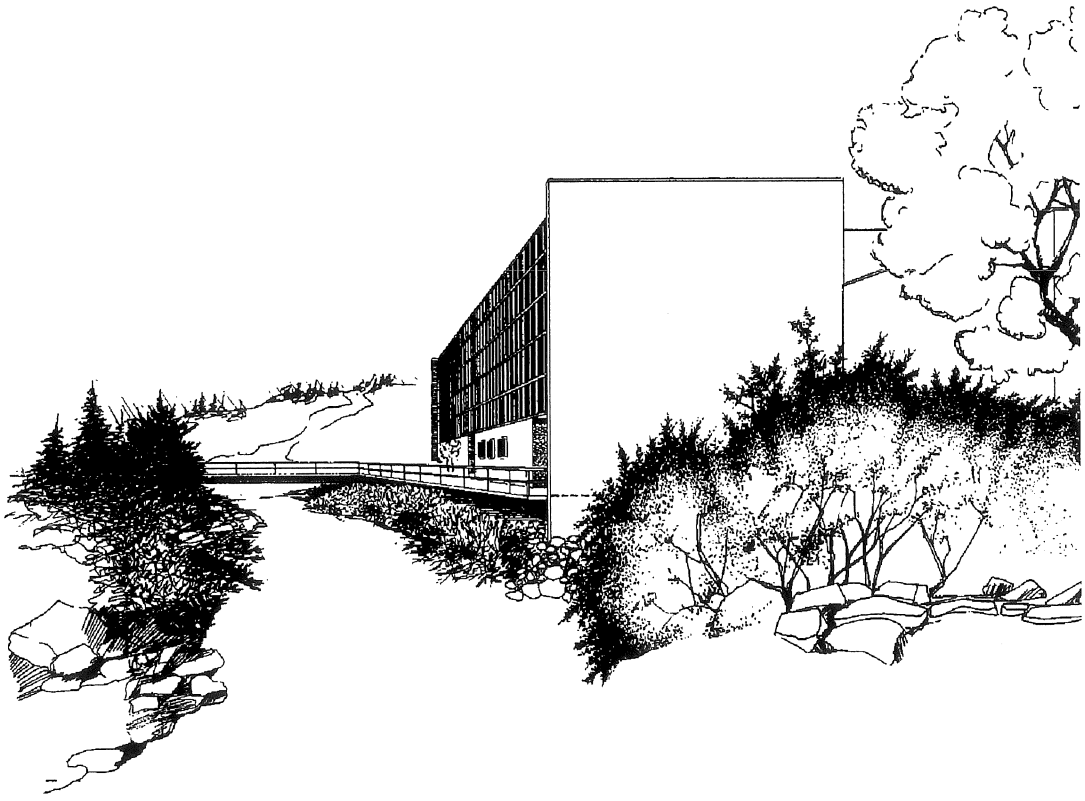
EVALUATION OF FLOW MEASUREMENT ACCURACIES AT PIUTE DAM

Prepared for the

Sevier River Water Users Association

April 2007



UTAH WATER RESEARCH LABORATORY

Utah State University
Logan, Utah

Report No. 1759

EVALUATION OF FLOW MEASUREMENT ACCURACIES AT PIUTE DAM

Submitted to the:

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Introduction

On March 8, 2007, Steven Barfuss and Jeremy Jensen from Utah State University, visited the Sevier River gauging stations at both Clear Creek and Piute Dam. These were both USGS gauging stations in the past, but were turned over to the Sevier River Water Users Association in 1995 and 2003, respectively. This brief summary report describes the observations and physical measurements made at these sites and includes recommendations for improving flow measurement accuracies.

Several problems found at the Clear Creek gauging station will greatly affect its ability to accurately monitor flows in the Sevier River. This gauging station has a Campbell Scientific data logger with radio telemetry. The data transmitted from the station is posted on the Sevier River Water Users Association website. Although a calibration of the Clear Creek gauging station was planned during the site visit, this station was not calibrated due to the presence of ice in the gauging station.

Ray Owens, the Sevier River Water Commissioner, stated that the Clear Creek gauging station is not normally used for flow measurement, but only as an indicator of when water released from Piute Dam reaches the valley. Inside the gauge station, the float was frozen in a block of ice, causing it to perpetually read about 1.2 feet. From information on the Sevier River Water Users Association website, the float appears to have been frozen at around 20 cfs for much of January and February and part of March 2007. The outside staff gauge was buried in sediment to about 2.1 feet. Ray also expressed concerns that the intake pipe for the gauging station might be filling with sediment. It was apparent that the Clear Creek gauging station was in ill repair and, even after the ice melts, that errors in flow measurement are probable at this site.

Piute Dam

The Sevier River gauging station below Piute Dam measures flow rates over a two-stage weir that is 70 feet long. The two stages of the weir have a vertical offset of 6.875 inches. The upper stage of the weir is 50 feet long and is located on the right abutment looking downstream and the lower stage is 20 feet long. Figure 1 shows a cross section of the weir.

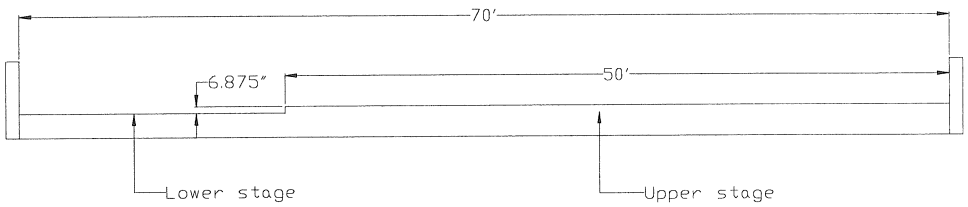

Figure 1: Piute Dam weir cross-section (looking downstream)

Gauge readings from this station are sent to the gate house at the dam, where the weir flow rate (the flow being released from the dam) is calculated using an algorithm

developed by the USBR. The flow and gauge readings are both posted on the Sevier River Water Users Association website hourly.

While observing the flow over the weir at the Piute Dam gauging station, it was apparent that the nappe of the weir experiences varying aerated conditions as the flow rate changes. Under some flow conditions, large rocks just downstream of the weir break the nappe and partially aerate the flow over portions of the weir, while other parts of the weir are not aerated. Figure 2 shows an example of this occurring. In addition, Figure 3 shows that the air vents originally installed in the sidewalls immediately downstream of the weir are located too far downstream from the weir to aerate the nappe. A properly designed weir will provide sufficient aeration to the underside of the nappe to stabilize the flow for all flow conditions. It is important to maintain a stable weir nappe, since the head upstream of the weir is directly related to the weir aeration. Typically, for the same flow rate over the weir, a non-aerated nappe will have a lower and less stable approaching water surface (head) than will an aerated nappe.

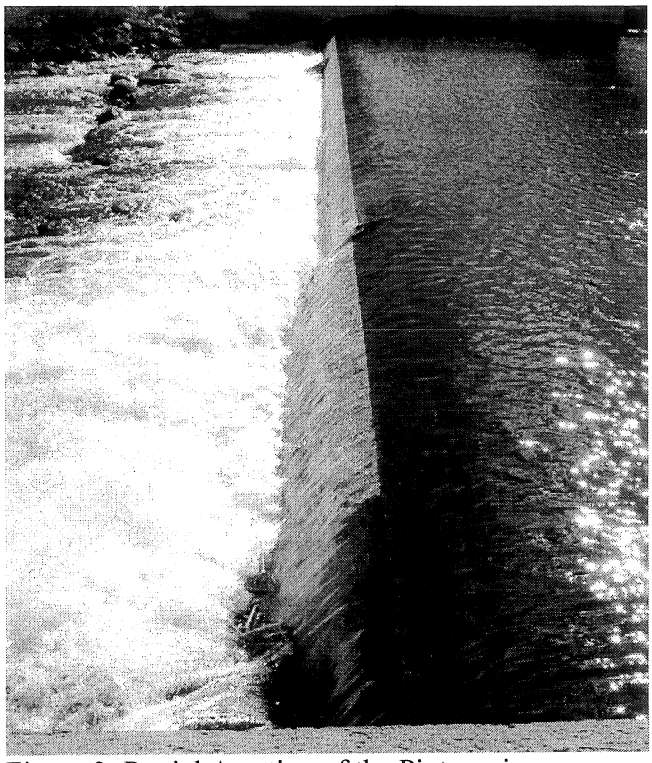

Figure 2: Partial Aeration of the Piute weir

Figure 3: Air vent in side wall located above the weir nappe

During the March 8th 2007 site visit, velocity and depth measurements were taken from a bridge located about 22 feet upstream of the weir at two different flow rates. These measurements of water depth and velocity were taken with a Marsh-McBirney electromagnetic flow meter on a scaled bridge rod. Measurements were taken every two feet beginning on the west bank moving east after the river had reached a steady state condition (about an hour after changing the flow through the dam). Staff gauge readings from the abutment wall of the river and from the staff gauge shack were taken and the indicated flow rate at the gate house on the dam was recorded for each flow condition. The trapezoidal method was used to calculate the flow over the entire weir.

A surveyor's transit was used to measure the weir elevation in reference to the staff gauges and the height of the offset between the upper and lower section of the weir. The offset height was also verified using a tape measure at the conclusion of the field tests when all flow from the dam was stopped. At the no-flow condition, the relative position of the gauge in relation to the weir crest was also verified using the static water surface. The results of the reference measurements can be seen in Figure 4. From these measurements, it was found that the offset between the two stages of the weir is actually 6.875 inches, or 0.573 feet, instead of the nominal 6 inches used previously.

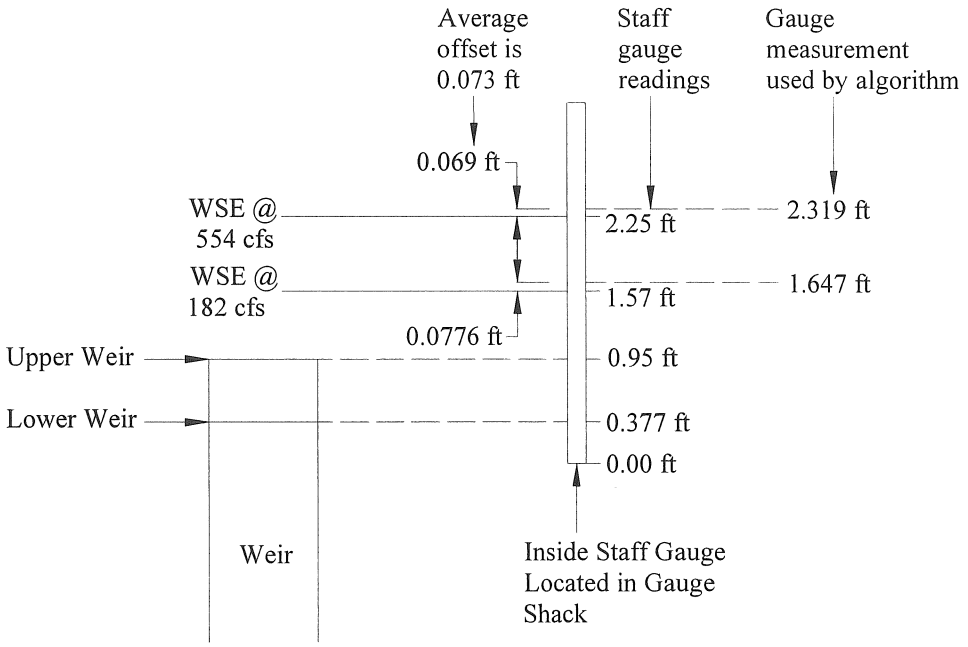

Figure 4: Gauge measurements

Data Analysis

An analysis of the data collected at Piute Dam gave some insight into existing problems and possible solutions that can be recommended. Ray Owens stated that ten feet were added to the gauge readings used by the data logger. For the purpose of this analysis and to provide a common datum for data comparisons, ten feet were subtracted from all gauge readings used by the data logger. From Figure 4, it can be seen that there is a consistent positive offset in the gauge measurement used by the algorithm (as recorded by the data logger) and the actual water surface measurements made during the field tests. The weir was calibrated at two flow rates, and the difference between the actual water level and that recorded by the data logger for each flow was averaged and found to have an offset of 0.073 feet.

It was also found that a gauge reading of zero on the inside staff gauge (the gauge where the data logger records water surface elevations) does not correspond with zero on the weir, as seen in Figure 4. The actual zero on the weir registers 0.377 feet on the inside staff gauge. For analysis purposes, the sum of these offsets (0.073 feet plus 0.377 feet) was subtracted from the gauge readings recorded by the data logger and will be referred to as the actual water depth over the weir.

USU report # 1741 describes using a physical model at the Utah Water Research Laboratory to determine the appropriate rating curve for the weir under both aerated and non-aerated conditions and with and without sediment on the upstream side of the weir.

By using the actual water depth over the weir versus flow for both the non-aerated physical model with sedimentation (the modeled condition that most closely simulates the prototype weir), and using the data from the field calibrations performed on March 8, 2007 by USU personnel and previous to this date by Ray Owens, a curve fit was performed and a new flow algorithm was developed. Equation 1 was developed using the model data to fill in the gaps between field calibrations. Through analysis of the fit curves used for the equations, a head of 1.25 times the height of the offset in the weir was chosen as the breakpoint to allow for continuity between Equation 1 and Equation 2. For all flows below this point, Equation 1 should be used. For all flows equal to or greater than 1.25 times the height of the offset in the weir (6.875 inches), Equation 2 should be used. Q equals flow in cubic feet per second and H is the actual water depth over the lower weir in feet.

$$Q = 436.6 * H^5 - 433.6 * H^4 + 112.8 * H^3 + 67.08 * H^2 - 1.293 * H \quad (1)$$

$$Q = 277.9 * H^2 - 278.3 * H + 100.6 \quad (2)$$

Figure 5 compares the existing USBR algorithm the new algorithm from the equations above and the prototype calibrations at the actual water depth over the lower weir. The physical model results are not shown in Figure 5. The illustrated USBR algorithm in Figure 5 includes adjustments to the head measurement so that the indicated gauge readings have a common datum. As seen in the figure, the flow calculated by the current USBR algorithm is smaller than that calculated by the new algorithm. As indicated by the field tests and as seen in the schematic of Figure 4 and in Figure 5, the head recorded by the data logger and used by the current USBR algorithm to calculate flow rate indicates a head that is higher than actual for a given flow rate. Therefore, at a given head, a larger-than-desired flow rate is normally being released from the dam when using the existing USBR algorithm. Percent errors in the flow rate are indicated on Figure 5 for a given head.

As an example of the magnitude of the error, the flows and gauge readings on the Sevier River Water Users Association website during July 2006 were compared with the new algorithm including the above corrections. During this month, over 2000 acre-feet more water was released than supposed. Even though the instantaneous difference in the curves of Figure 5 may not seem significant at first glance, a large total amount of water is lost when flow volume errors are summed over time.

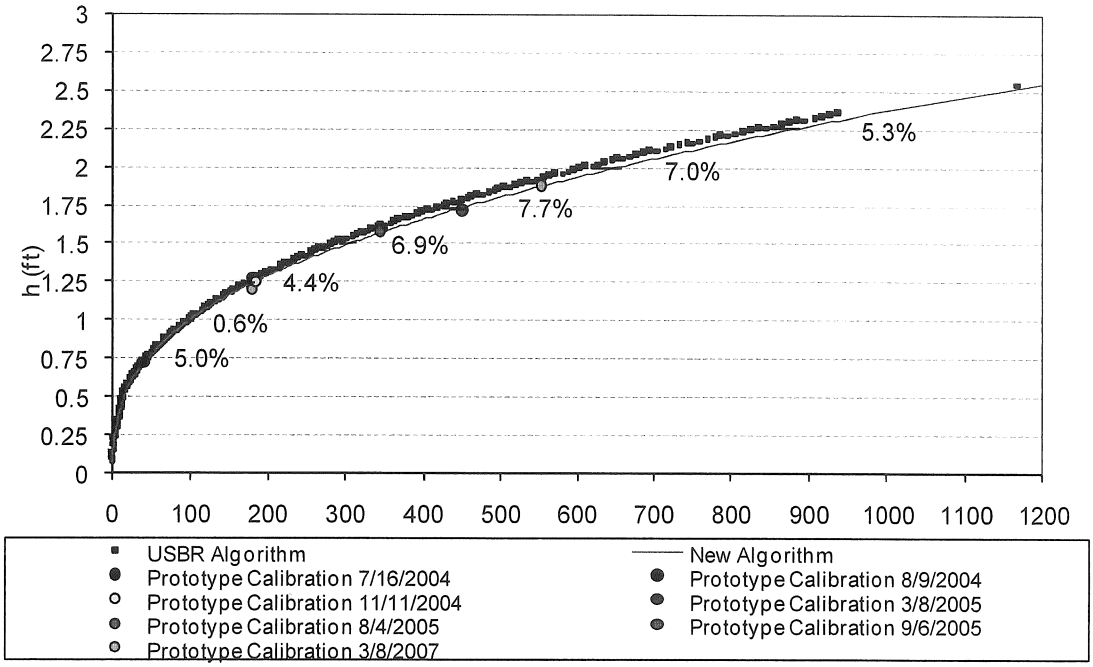

Figure 5: Algorithm comparison

It is suggested that the algorithm in the data logger at Piute Dam be changed to match more closely the available calibration data. The new proposed algorithm is based upon head measurements from the data logger in its current condition. If adjustments are ever made to the data logger, then a new algorithm will need to be developed.

It is also suggested that necessary maintenance be performed on the Clear Creek gauge so that it operates properly and can be used to measure the actual flow. This will allow for more accurate measurement of the flow in the Sevier River and for better water resource management.