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Using "Residual Depths" to Monitor Pool Depths Independently of Discharge

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Fishery managers are focusing more and more attention on pools to protect and enhance fish habitat in streams. Pools are vital components of fish habitat in streams, especially for larger fish,¹ because their great depth offers protection from predators. Pools can be highly sensitive to disturbance of watersheds and riparian areas^{2,3} and can be enhanced by introducing woody debris, boulders, or artificial structures in streams.⁴ Improving strategies to protect pool habitat ultimately depends on unbiased, quantitative methods for monitoring changes in pool dimensions. Comparisons of pool dimensions either between streams or in one stream over time can be confounded, however, by differences in stream discharge, which strongly affect water depth.

To surmount this problem, a method for measuring pool depth independently of variations caused by discharge has been developed by using the concept of "residual depth."⁵ Residual depth is the difference in depth or bed elevation between a pool and the downstream riffle crest (fig. 1). Residual depth is measured by sounding or surveying a pool with tape, rod, and (optionally) an engineer's level and subtracting the depth or elevation of the riffle crest from those in the pool. Data can be plotted as profiles or used to draw residual-depth contours on a map. The method is simple and unbiased, and can be adapted to measure pool length, area, and volume. Residual pool dimensions can represent low flow conditions that are important for summer rearing habitats of fish.

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As vital components of habitat for stream fishes, pools are often monitored to follow the effects of enhancement projects and natural stream processes. Variations of water depth with discharge, however, can complicate monitoring changes in the depth and volume of pools. To subtract the effect of discharge on depth in pools, residual depths can be measured. Residual depth is the difference in depth or bed elevation between a pool and the downstream riffle crest. Residual pool depth or volume can be measured at wadable flows by using only a tape and graduated sounding rod. Residual dimensions represent extreme low-flow conditions, which often determine the capacity of streams to produce fish. The measurement of residual depth is an unbiased way to easily distinguish pools from other reaches. Its application is illustrated by a case study on a stream in northern California.

Retrieval Terms: fish habitat monitoring, pools, stream channel surveys, stream enhancement evaluation

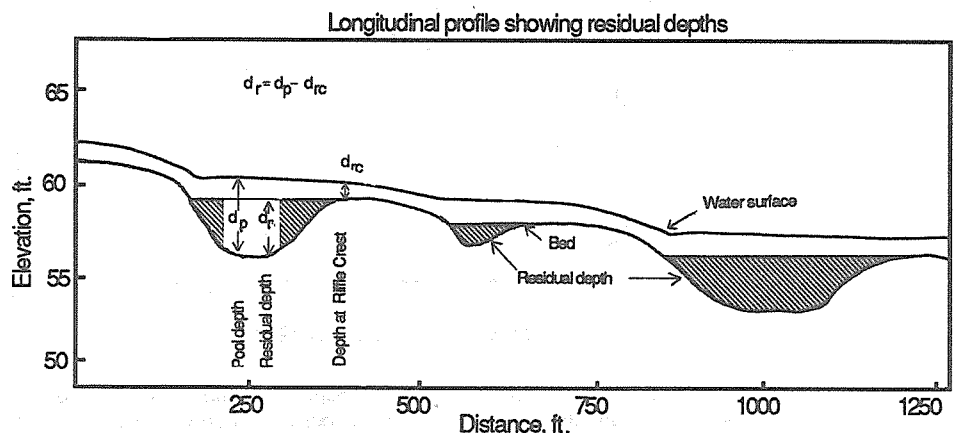


Figure 1—A longitudinal profile of a reach of stream, showing the method for measuring residual depths.

RESIDUAL DEPTH

Water depths in pools depend on both the depth of the depression in the stream bed and the discharge at the time of measurement. How can comparable measurements of pool depth be made without having to measure at equal discharges?

Say, for example, mean depth in a pool was measured as 1.1 ft one summer before placing a rock deflector to increase scour. During the following summer, pool depth is remeasured. Did depth increase or decrease? If depth were measured the second time at Q_a (fig. 2), an observer that was unaware of differences in discharge would conclude that the deflector had increased depth to 2.5 ft; if instead depth were measured at Q_b , the observer would conclude that depth had decreased to 0.8 ft. Repeated measurements of pool depth and discharge before and after treatment would show the true change in pool depth at a given discharge, but this method would be time-consuming and demand a certain schedule of measurement.

"Residual depth" is independent of discharge and need only be measured once before and once after treatment in order to detect changes. Residual depth is the depth that, if flow were reduced to zero, water would fill pools just up to their lips that are located at riffle crests downstream. Depths

in pools would then correspond to residual values. Thus residual depths represent extreme low flow conditions, which can limit a stream's capacity to support fish populations. The method also provides an unbiased way to easily distinguish pools from other reach types: pools are simply reaches having residual depths greater than zero.

METHODS

Pool frequency and the residual depth and length of pools in a vertical plane running down the channel can be measured quickly by using the following procedure. It should be done during low flow when the water surface over pools is nearly horizontal. Materials needed include a tape, rod, and notebook.

1. To measure distances between residual depth measurements, stretch a tape along the thalweg (zone of greatest depth) or the centerline of the channel. Thalweg distances give the real distance between depth measurements, but such distances from point to point along the stream channel can vary from year to year because of their wandering. Centerline distances give distances along the channel as a whole and vary little from year to year. Particularly in channels with bends, however, centerline distances do not necessarily equal the dis-

tances between depth measurements in the thalweg and thus can introduce error in measurement of residual depths averaged over the reach. In any case, use consistent measures of distance.

2. At distances measured along the tape, note reach type (pool, riffle, run, etc.) and measure depths in the thalweg (deepest thread of the channel). Be certain to measure the distance and depth at riffle crests.

3. To compute residual depths, subtract depth at riffle crests from depths in upstream pools. Mean or maximum residual depths or the entire frequency distribution of residual depth can then be easily determined.

Assuming that the rod is held reasonably vertical the primary sources of error in measuring depth are due to failure to locate the thalweg and the roughness of the bed. I estimate probable error in depth measurement to be approximately twice the median diameter of bed particles. The percent error decreases with increasing ratio of depth to bed particle size. I estimate error in measurement of thalweg distance to be approximately 2 percent. These values for error are estimated from experience and not experimentation. Error probably varies with operator, and stream conditions.

If the water surface over a pool slopes downstream appreciably, residual depths will be over-measured by the method outlined above, which is based on the assumption that the water surface over pools is horizontal. The error created by this assumption would nearly always be negligible during low flows. For instance, if the water surface over a 100-ft-long pool slopes 0.5 percent (a steep slope for low flow), the average error in measuring residual pool depths will equal 0.25 ft. If the error in using this assumption is unacceptable, however, a longitudinal profile of the stream bed can be surveyed by using an engineer's level. After plotting the longitudinal profile, residual depths are measured from horizontal lines extending upstream from riffle crests (fig. 1).

Given that the elevation of the downstream riffle crest sets the size of the residual pool, any dimension—depth, length, area, or volume—can be measured from a planimetric map having depth contours. Residual pool volume, for example, is the difference between total pool volume and the portion of pool volume higher in elevation than the downstream riffle crest.

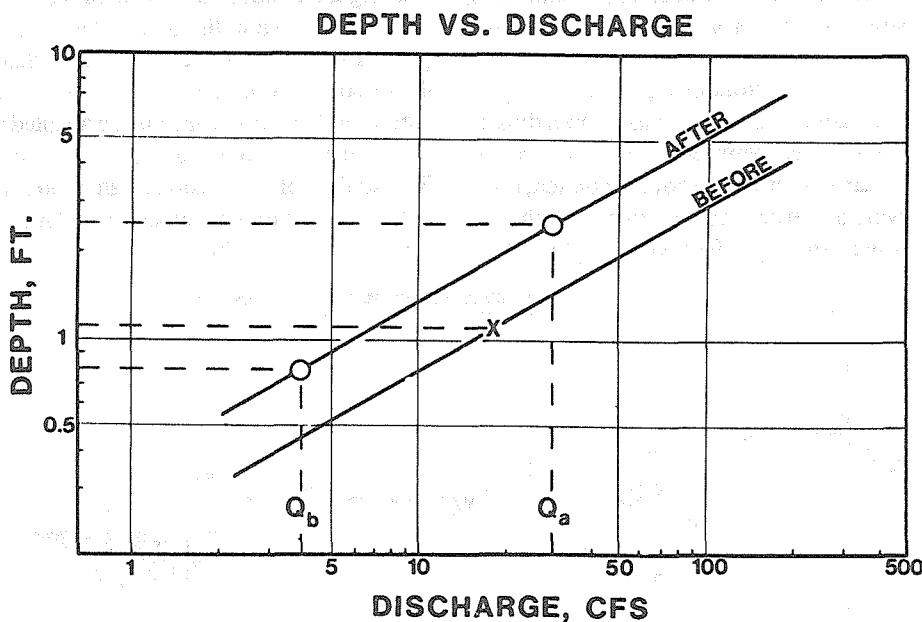


Figure 2—Variation of depth in a pool with discharge before and after a structure was added to increase scour. Depth was measured once before treatment ("X"). An increase or de-

crease in depth after treatment ("o") would be indicated, depending on whether depth were measured at Q_a or Q_b .

APPLICATION

To illustrate how this method can be used, I describe below its application in evaluating a stream enhancement project by Six Rivers National Forest. The Forest placed three boulder clusters, five gabion weirs, and six bankside deflectors in Red Cap Creek, near Orleans, California, during the summer of 1982 to scour pools and provide cover for juvenile steelhead trout and chinook salmon (fig. 3). We surveyed a longitudinal profile of the streambed and water surface down the thalweg of the channel before the structures were placed (fig. 4). We repeated the survey the next summer after a flood in December caused noticeable channel changes in reaches both with and without structures. Residual depths of all pools, including seven which were not influenced by the structures, were measured from the profiles.

We compared maximum residual pool depths measured before and after the struc-

tures were placed (fig. 5), as well as inspected the stream, to judge the effectiveness of the structures to scour pools. Residual depth in pools without structures decreased. Some boulders in riffles and fast runs at locations 7 and 9 (fig. 3), were either buried, moved out of the reach, or left too high on the channel bed to be effective. Others in fast reaches, such as at locations 7 and 8, caused little scour. However, most deflectors and boulder clusters survived the winter and scoured pools. Deflectors such as 2 and 11, that were built along pre-existing pools, scoured the deepest pools, although the pool along structure 9, which was partially destroyed and buried, decreased in depth. Deflector 5 produced little scour, probably because it lay behind a bedrock projection, and deflector 13 became isolated from the thalweg.

Considered as a whole, the project seems to have preserved pool depth during an interval of decreasing pool depth, de-

spite some failures of individual structures. With error estimated at ± 0.6 ft (twice median bed particle size), eight structures increased residual depth significantly, five caused no change, and one resulted in a decrease in depth (fig. 5). Of the pools without structures, two showed no significant change and five showed a decrease in residual depth. Total pool depth cumulated longitudinally remained essentially unchanged. Although only structure 11 created a pool as deep as the major natural pools, the structures increased pool numbers from 11 to 20.

This method allowed us to quickly and conveniently monitor the effects of structures on pools. The entire project took a total of 3 days to survey the profiles and 2 days to analyze the data. This method was also used to detect changes in pools associated with removing woody debris from small streams in Alaska.⁶

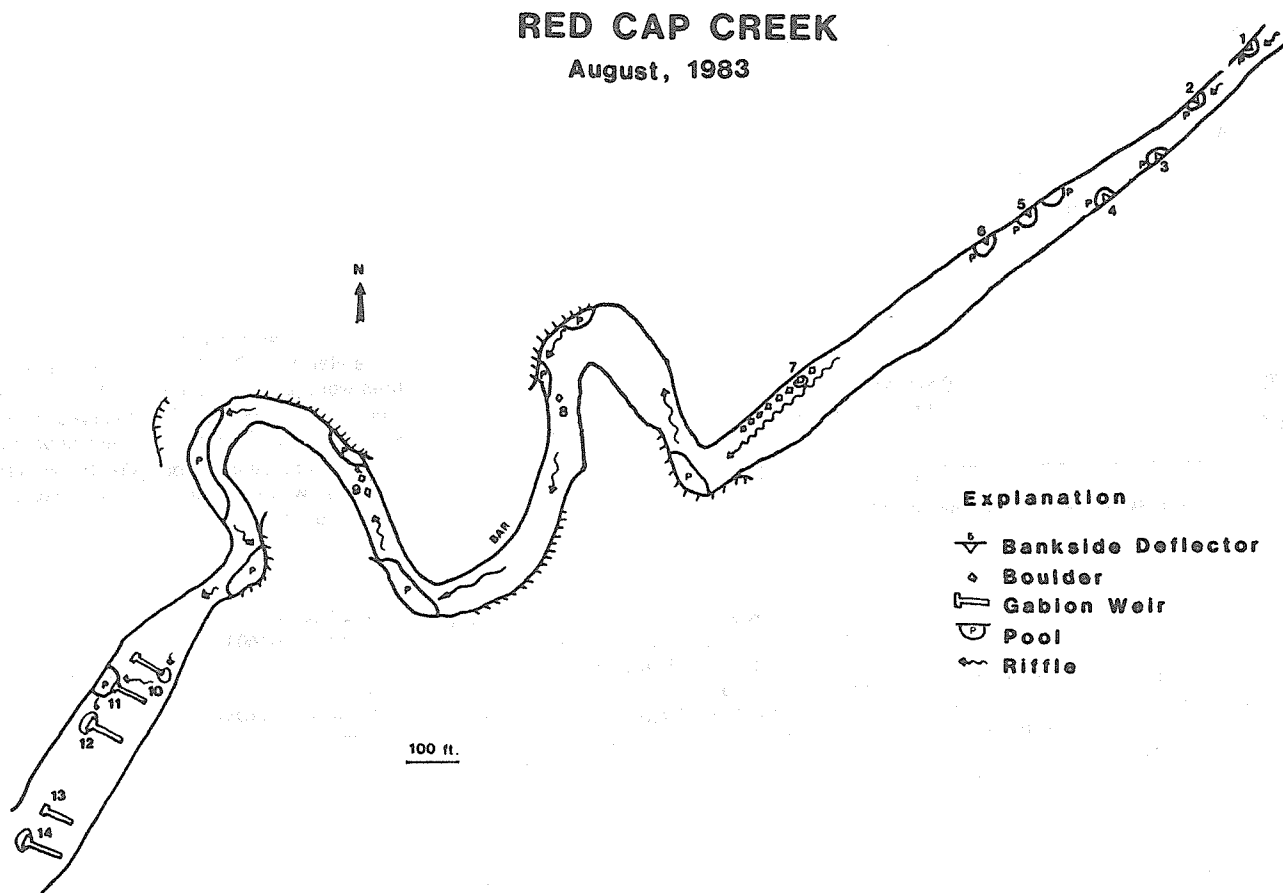


Figure 3—A reach of Red Cap Creek near Orleans, California, was used to apply measurements of residual depth to monitor pools.

Artificial structures are identified by number (1-14).

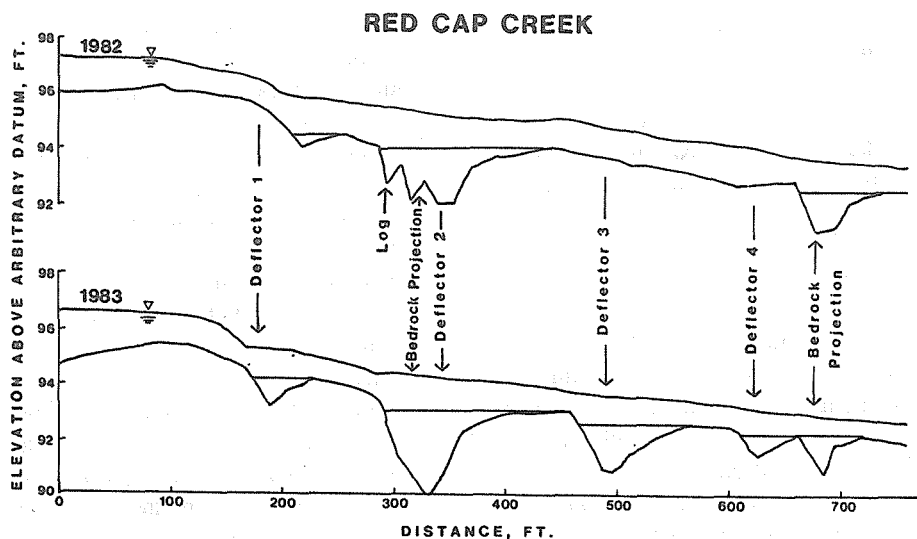


Figure 4—Longitudinal thalweg profiles of a portion of the Red Cap Creek study reach, showing the water surface, stream bed, the location of deflectors placed in the channel to cause scour, and horizontal lines drawn upstream from riffle crests to measure residual depths of pools.

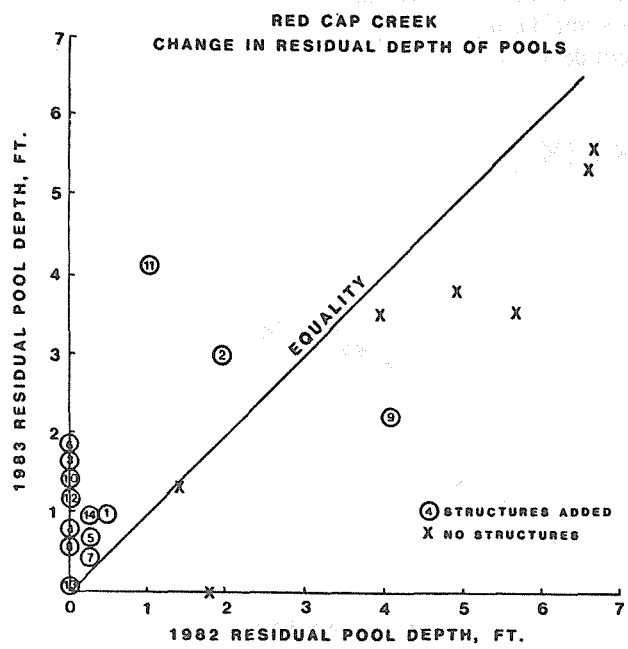


Figure 5—Changes in residual depths of pools in the Red Cap Creek study reach after structures were added in summer 1982, to increase scour. Numbers identify structures shown in figure 3. Points falling below the line of equality show a decrease in residual depth; those falling above show an increase. New pools formed around structures plot along the ordinate.

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END NOTES AND REFERENCES

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