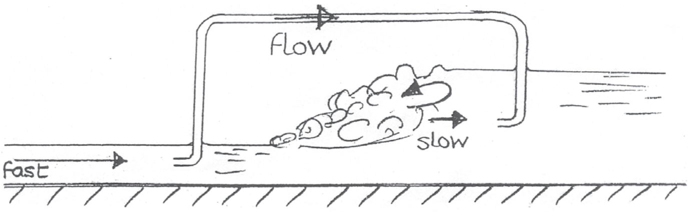


Figure 7(a)

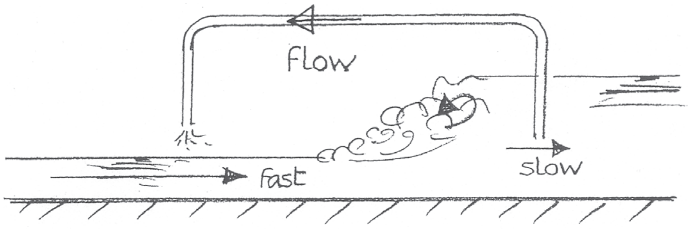


Figure 7(b).

starts to get deeper and slower and move towards the state of less energy (and critical flow). It cannot continue to gradually increase its depth right up to the critical state because then it would have minimum energy and would not be able to flow anywhere (nowhere has less energy) unless the channel bed level became lower.

At a place in the channel where the fast flow and the natural, deep, slow flow satisfy a precise requirement then the flow jumps from one state to the other and misses out the non admissible critical flow state altogether. This is the hydraulic jump which involves a great loss of flow energy because the water is thrown around very vigorously and the energy required to do this is taken from the energy in the upstream flow. A swimmer in the hydraulic jump is also thrown around vigorously.

The swimmer in the hydraulic jump

An important thing to understand is why the swimmer is caught and held by the hydraulic jump. Since there is a large energy loss in the jump the downstream energy is less than the upstream energy and the swimmer should fall downstream through this energy difference, just like falling down stairs!

Unfortunately the swimmer's movement is controlled by only a part of the energy; he floats on the surface of the water and it is the height energy that controls his movement. This part of the total energy increases as he goes downstream and the decrease of it in the upstream direction throws the swimmer back in that direction. It is the total energy (= height and speed energy taken together) which decreases suddenly in the downstream direction at the hydraulic jump. If this difference in the total energy could be made to influence the swimmer's movements then he would, undoubtedly, move downstream through the jump.

These effects can be readily demonstrated in the laboratory by using either the total energy difference across a jump to push water through a pipe spanning the jump, as in Fig 7(a), or by using only the height energy difference to do the same thing, as in Fig 7(b). In the first case the water flows downstream through the pipe and in the second case it flows upstream (at first sight giving us perpetual motion).

Designing for safe hydraulic jumps

Besides the main current in the stream, moving in the downstream direction, there is a secondary current which helps to hold the swimmer in the jump. This is the flow that rotates in the vertical plane about a horizontal axis and which usually appears at the front of the jump, causing the towback current on the surface. In many cases it is this alone which prevents the swimmer's escaping the hydraulic jump and which, especially, is not appreciated by the novice canoeist as the acute danger that it is.

Obviously there are two things required in order to overcome the holding properties of the hydraulic jump:

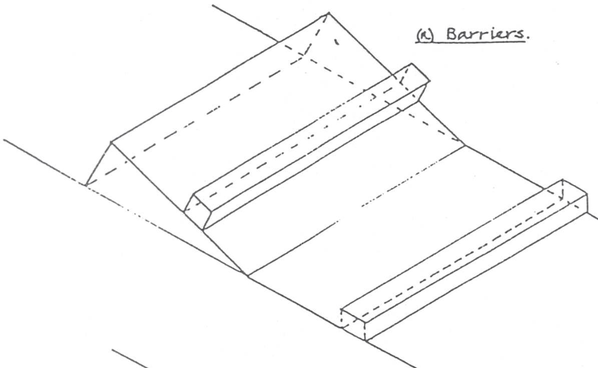
(a) The jump must be made more flat.

(b) The submerged jet of fast flowing water in the downstream zone must be brought to the surface so that no towback current appears.

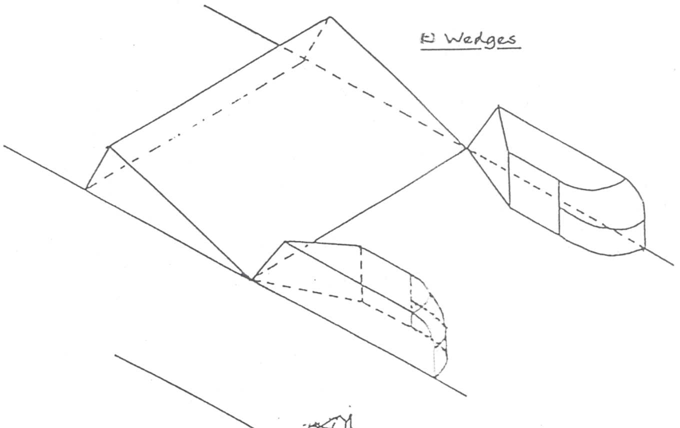
These objectives can be met if the shallow fast flow upstream of the jump is caused to ride over a deep layer of slow moving or stationary flow (a separated flow). There have been various successes at doing this, including the entry gate to the artificial canoe slalom course at Holme Pierrepont, designed by the undersigned. Some of the ideas tested in arriving at that final design are shown in Fig 8.

One method which is carefully investigated is worthy of particular mention, in conclusion. This is the use of flexible roughness on the downstream slope of a triangular profile weir. This appears to cause rapid thickening of a boundary layer of slow flow on the face of the weir with the fast flow riding on top of this boundary layer and being forced to the surface. The flow then behaves approximately as required in the two objectives stated above.

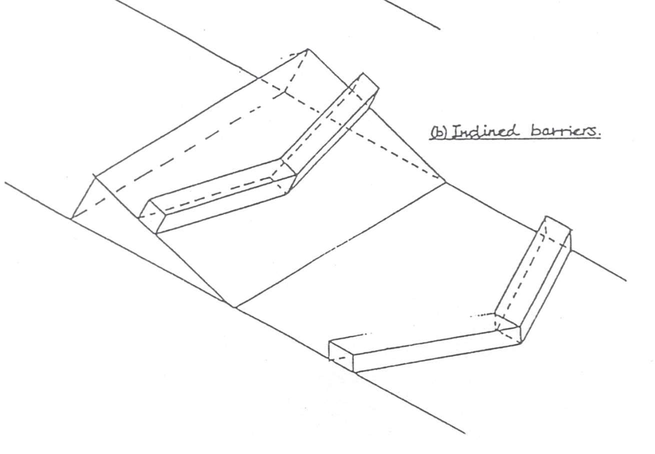
Dr George Parr *was formerly of the Department of Civil Engineering, Nottingham University, and was formerly a C2 member of the British wild water racing team, later becoming WWR chairman.*



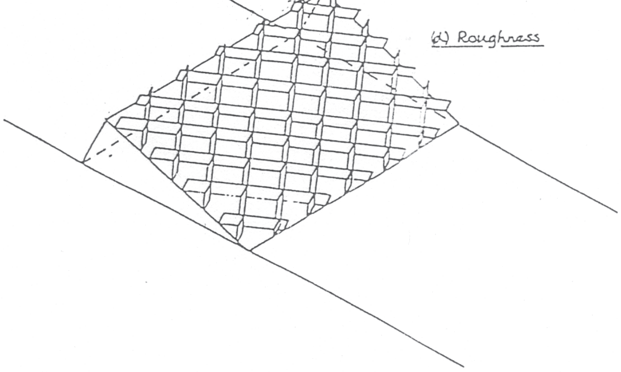
(a) Barriers.



(c) Wedges



(b) Inclined barriers.



(d) Roughness