BED SHEAR STRESS AROUND CYLINDRICAL HABITAT STRUCTURES

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This project is a study of the hydraulics of simple fish habitat structures. These habitat structures are essential for restoring a favorable environment for in-stream species to find shelter and food in adverse flow situations caused by shallow flows. There are a variety of fish habitat structures in use; such as groins, V-weirs, pools, single rock or cluster of rocks (Lowe 1992). Fish habitat structures are currently designed on the basis of empirical relationships and judgment. Natural rocks offer a simple solution to provide shelter and food for fish under adverse flow situations. Rocks provide slower and deeper flow inside their scour holes and the shaded regions provide refuge for fish. The goal of this study is to provide quantitative information to aid in the design of fish habitat structures. A single hemisphere or a group of hemispherical objects have been used to model the flow around habitat structures in previous studies (Shamloo et al 2001; Albers 1997). The mean flow structure and the scour pattern around the objects were studied. Four different flow regimes were identified based on the relative submergence i.e. the ratio of flow depth to object height. Flows around deeply submerged, moderately submerged and slightly submerged objects were studied in addition to one, where the object height was greater than the flow depth.

The long-term objective of the present study is to investigate the turbulent flow field and bed shear stresses around submerged cylindrical objects and to relate the flow structure to the scour pattern in different flow regimes. This paper presents the results of bed shear stress measurements around the objects in different flow regimes on a smooth bed. Bed shear stress magnitudes and directions were measured at fine spatial resolution using a thin yaw-type Preston probe. Cylindrical objects of equal diameter and four heights were tested under similar flow conditions producing four different levels of submergence.

The experimental results clearly depict the location, extent and relative difference in bed shear stress amplification and reduction under different flow regimes. The most intense shearing occurs in the vicinity of the transverse face of the object in all flow regimes. The non-submerged object creates the most significant amplification of bed shear stress over a large area, where the maximum shear stress is about two times that observed for flow around a deeply submerged object. The other two regimes create almost equal amplification of bed shear stress. However, the lateral extent of the region of increased shear stress is larger for the moderately submerged object than for the slightly submerged object. Shear stress fields on the downstream side of the objects give an indication of the relative performance of the objects in developing a shadow from the surrounding high velocity flow for the in-stream species. Moderate or deeply submerged objects would develop a relatively wide closed wake region immediately downstream of the object, but

non-submerged or slightly submerged objects would provide narrow and relatively long near field wake.

It is obvious that for the same flow conditions the bed shear stress would be higher in case of a rough bed compared to the values measured on a smooth bed. However, the smooth bed measurements provide an approximate estimate of the shape and extent of scour. The scouring would likely start on the side face of the cylinders in all flow regimes. It is also likely that for similar flow condition the largest and deepest scour hole would develop in case of the non-submerged cylinder. However, the smallest and the most shallow scour hole would likely occur in the case of the most deeply submerged cylinder. Moderate and slightly submerged cylinder might produce almost equally deep scour hole. Significant downward flow from the upper flow zone on the upstream face of the non-submerged cylinder results in a strong backward flow close to the bed, and hence the horse-shoe vortex system moves up. On the other hand, the faster moving fluid of the upper flow zone passes over the submerged object in the other flow regimes. Thus the reverse flow momentum that causes flow separation on the bed is reduced and the horse-shoe vortex forms closer to the cylinder. The location of the horse-shoe vortex indicates the upstream edge of the scour hole, because the roller created by the horse-shoe vortex loosens the sediment particles from the bed.

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