Assessment of Scour Phenomena in the Weirs' Downstream and Ways to Retrofit and Reduce Scour

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Abstract: **Scour is one of the most important issues related to river and coastal engineering. Meanwhile, dams, as an important structure in supplying water, have a great importance [1]. Weir is one of the most vital components in dam. Failure of many dams is attributed to inefficiency of their weir. Dissipating water jet energy in submerged basins is very complex which depends on various parameters such as water fall speed, fall height, hydraulic and hydrologic factors and downstream bed stones morphology. So, it is necessary to study the parameters affecting scour in weirs' downstream. Accordingly, this paper examines the energy dispersion and dissipation methods to prevent the endangerment of dam structures and weir downstream erosion.**

Keywords**: scour, energy dissipation, submerged basins, sedimentation, energy dispersion.**

I. INTRODUCTION

Although, scour has a long history in the field of hydraulics, due to its condition and complexities as well as lack of a proper relationship to meet all the conditions, it is already of particular interest for researchers in hydraulic and river engineering science. Hydraulic structures which are obstacles to flow, change the flow pattern close to it and results in local scour in the area. The importance of examining scour is evident when the scouring depth is significant, so that the depth reaches the river structure foundation and endanger the stability of the structures or destroy them. The method, usually used to determine the scour depth, is applying empirical relationships or physical models. It should be noted that despite extensive studies to estimate local scour around various hydraulic structures, a general and comprehensive relationship has been presented for calculating the local scour depth around none of river structures. Also, as theoretical and experimental principles of various methods were sometimes different, the calculated local scour is not necessarily the same or close to each other based on different methods.

II. MATERIAL AND METHODS

A. Scour definition:

The erosion of channel bed and edge due to water flow or bed erosion at the downstream of hydraulic structures due to high water flow or turbulent flows and thus eddy currents are called scour [2].

In general, scour is obtained as a result of interaction of forces:

1. The driving force from the flow which operates to separate the particles from the bed.

2. Resisting force caused by the friction and weight of particles which resisted against the particle movement and prevents the separation of particles from the substrate.

A particle starts moving when the force applied by the drag and lift forces, which separate particle from the substrate, prevail the particle resistant force. Local scour of some hydraulic structures downstream shown in figure I.

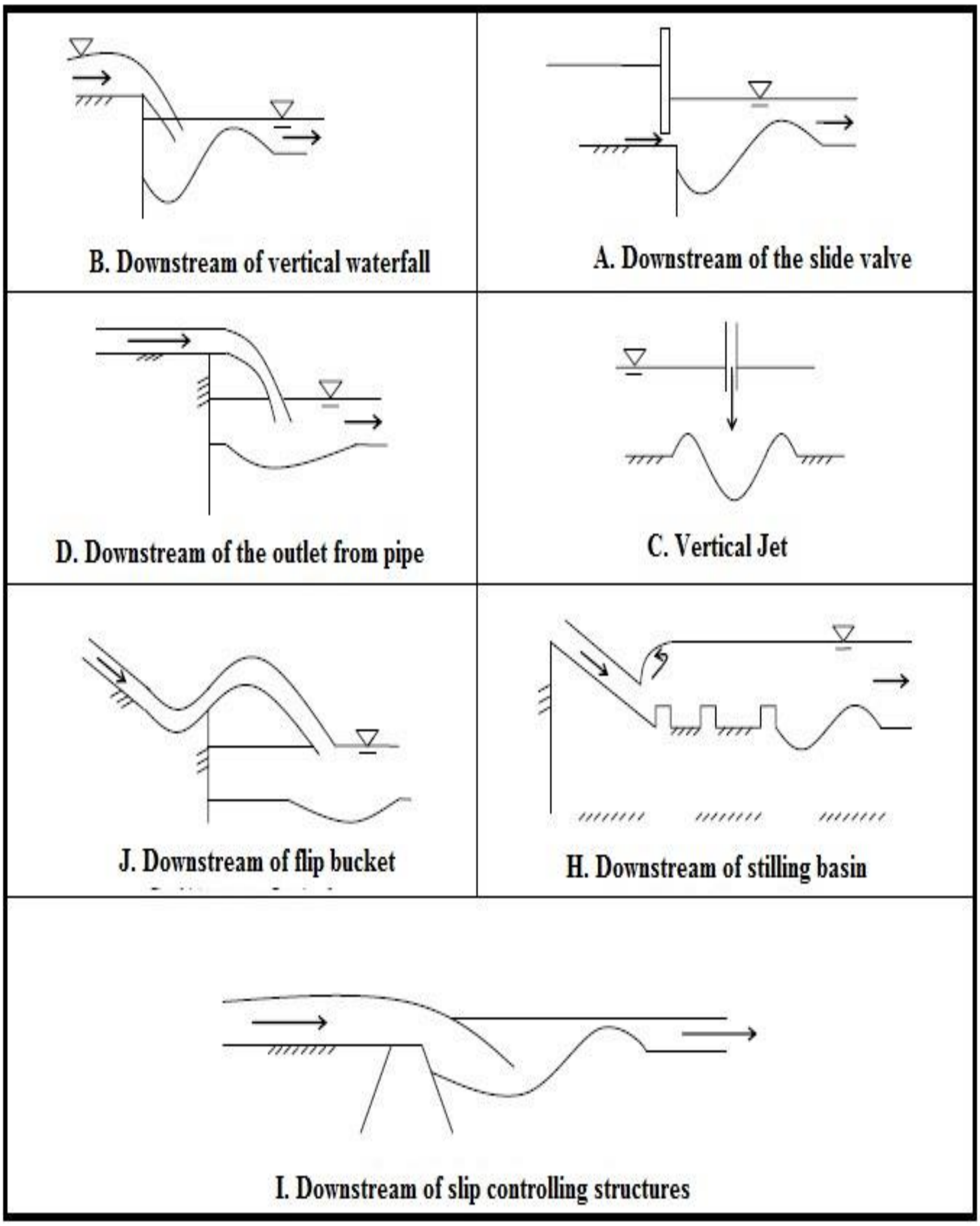

FIGURE I: LOCAL SCOUR OF SOME HYDRAULIC STRUCTURES DOWNSTREAM

B. Scour types:

Scour can be created in different places and under various conditions, including contraction scour, scour at the curves, scour at confluences, but two scour can be defined for bridge bases, including: Local scouring and general scouring [3].

C. Contraction scour:

Presence of cross contraction at the flow increases flow rate and flow erosion power in this location. The scour here is called contraction scour. Contraction scouring is usually the result of limiting river width. For example, the side supports of bridges and bridge piers that are constructed in the middle of the stream reduce the width of channel and therefore result in scouring (figure II).

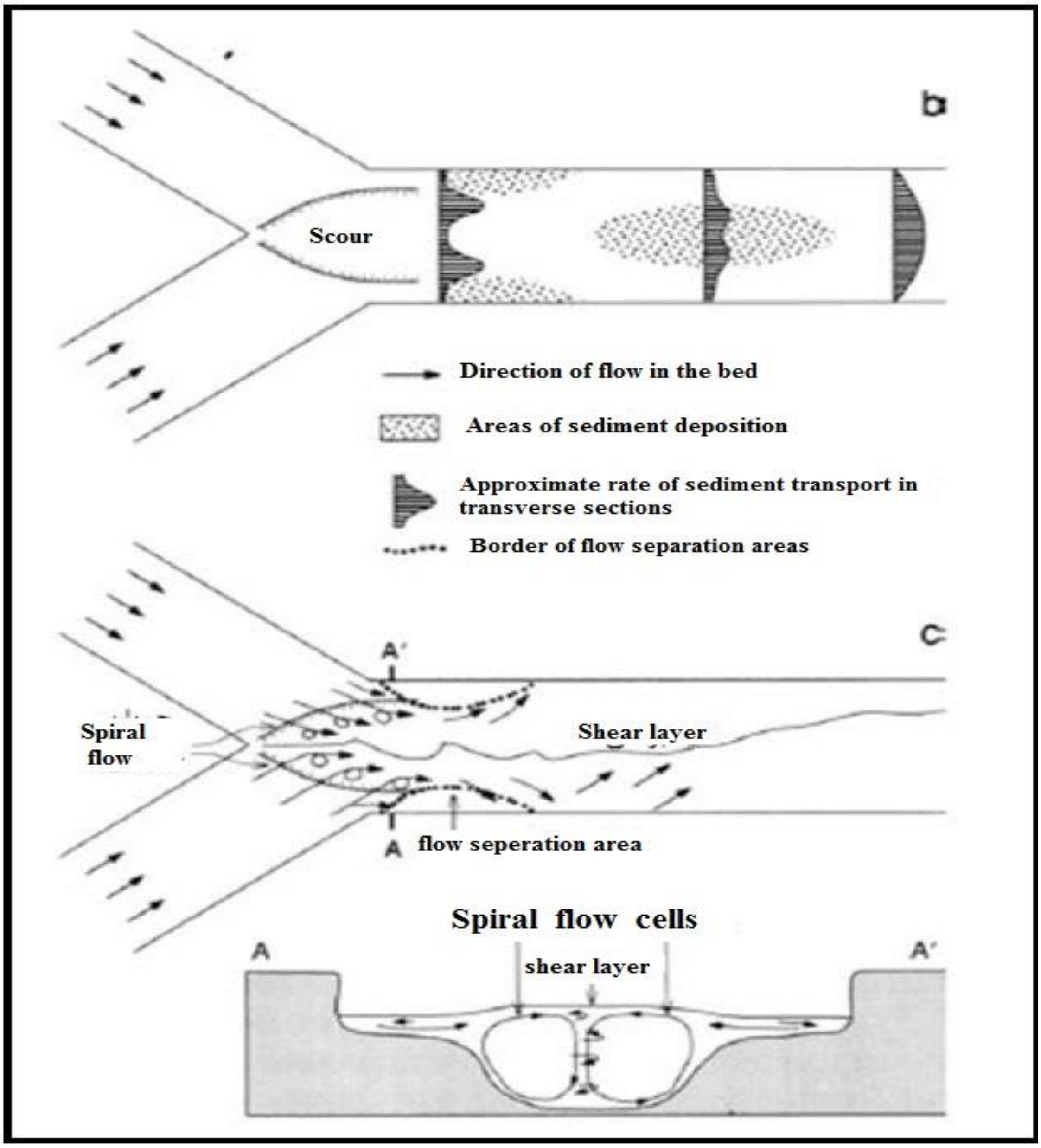

FIGURE II: FLOW PATTERNS, SEDIMENTATION AND EROSION AT THE INTERSECTION OF TWO RIVERS

D. Local scour:

Water structures which change the water flow pattern may cause scour. Because changing the flow characteristics (rate and turbulence) lead to changes in sediment transport capacity which results in imbalance between the actual capacity of sediment transport and the capacity which carries sediment flow. A new balance may finally occur following the hydraulic conditions adapted to scour [4]. The temporal scale of local scour is usually short, but time-dependent scouring process may be significant in the original condition. Local scour occurs wherever the turbulent flow intensity is locally increased [5]. Local scour at the downstream of hydraulic structures such as weirs, chutes, valves etc. is a phenomenon which occurs due to the local velocity more than critical speed (threshold velocity of particle motion). The reasons can be stated as follows:

1. Insufficient energy dissipation
2. Forming unstable hydraulic jump and transferring jump out of the stilling basin bottom
3. The creation of torsional flows at the downstream of hydraulic structures [6].

E. Total scour:

Total scour depth related to a particular structure is obtained from three following scours:

- General scour
- Contraction scour
- Local scour

Bed local balance from each of the above scours is used as the initial conditions, to estimate the other part. Figure (III) shows an example of three parts of total scour.

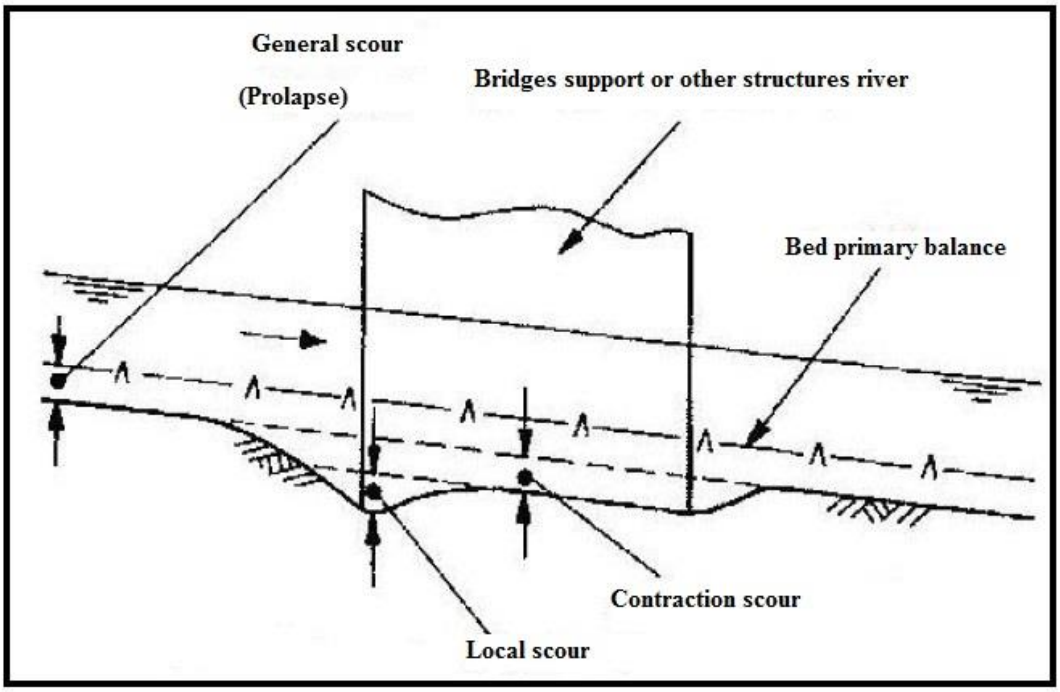

FIGURE III: SCOUR COMPONENTS

F. Scour at the downstream of weirs:

A. Flip weirs:

Flood currents inside the dam reservoirs often result in agitating weirs. The weirs have various types which finally lead to an energy dissipation structure or a certain level. Dissipation structure can be a certain basin or be flowed at the bottom of a natural river [7]. If there is no stilling basin, the flood current could cause scour as a result of jet collision with the river bed. The final shape of scour depends on bed stone place, and cohesionless constructive materials. Generally, studying these scours follow three general goals:

1. No harm to the structure stasis due to structure failure or increasing water drainage
2. No harm to the river floor stasis at the downstream and its wings
3. Forming hills from eroded materials that can increase the shoal level at the downstream of dam.

G. Methods to prevent scouring:

There are several methods to prevent scour as following:

1. Rehabilitation of stilling basin

If the downstream depth is not sufficient for the formation of hydraulic jump in the basin, so that it may be exposed to scour due to the flow conditions of the protective factors against scour, it is necessary to restore stilling basin. Severe scours mostly occur when supercritical water flow exists in stilling basin and hydraulic jump is formed in the downstream channel. To restore the stilling basin, a secondary stilling basin can be built at the downstream of the primary basin or constructing a dam at the downstream to increase the water depth inside the basin. Secondary stilling basin can be made in several ways; the most effective way is to build a new stilling basin from rip rap or concrete

2. Using granulated rip rap

3. Replacement for rip rap materials:

If rehabilitation of stilling basin is not possible and rip rap cannot be used because of issues such as granulation, or cost of transferring to repair scoured parts, some materials will be used as a substitute for it. These include materials such as bags filled with cubic concrete grout and tetragonal concrete blocks which have been used in various projects.

4. Aeration: Johnson examined the decrease in scouring through the jet aeration method and he finally did experiments on the effects of aeration on the ability to scour caused by water jets. Based on the results obtained by him, an aerated jet is much faster dispersed than a conventional jet in the stilling basin, coastal depth required for lack of erosion in the aerated jet is nearly half the depth required in conventional jets with the same discharges.

III. CONCLUSION

Application of submergence basin is as one of the flow energy dissipation methods to reduce scouring and scour at the downstream of weirs can be different depending on the type of weir. In submerged bucket-shaped weirs, because jump length is reduced, these weirs can be used for regions where it is not possible to create stilling basin. Grooved bucket weirs are also sensitive to shoal depth, so that reducing the depth results in surface defects and increasing it results in compression of the outlet jet. As mentioned above, the factors affecting jet scours includes jet energy, angle of impact with the substrate surface, distance between jet formation to bed level, aggregation of sediments in the water and shoal depth. Increasing downstream shoal can reduce the scour. In inclined jets, bubbles dissipate energy of jet to collide with bed materials to reach the water surface, and thus erosion will be reduced. The erosion in deep shoals is more than shallow, because in deep shoals, the force exerted on the air bubbles have more opportunity to dissipate jet energy, but in shallow shoals, energy is dissipated in collisions with bed and aeration is less involved.

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