SEDIMENT EXCLUSION AT RIVER INTAKES

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Summary

The problem of handling sediment that complicates the process of withdrawing water for human needs is addressed. Practical solutions based on analysis of sediment characteristics and flow behavior, are presented. These involve hydraulic structures associated with the intake works that are designed to divert, exclude or remove sediment from the water being abstracted. Examples of various types of engineering designs based on hydraulic principle are given. Recommendations are made regarding the control and avoidance of sediment problems at intakes by preventive measures.

1. Introduction

The extraction of water from rivers is one of the most ancient human activities in the field of hydraulic engineering. Nevertheless, the design of an intake structure in a natural river still belongs to the most delicate tasks even in our days. Problems arise

mainly from the fact that in natural rivers besides the water also a considerable amount of sediment is transported. Therefore, the designers of intake structures repeatedly find themselves confronted with the problem of how to take the water out of the river while leaving the sediment behind. In developing countries construction and operation of river intakes deserve particular attention as the natural conditions in the rivers are usually more complex and at the same time less well documented than in industrialized areas.

2. Sediment Transport In Rivers

The sediment which is transported in rivers originates from soil erosion caused by wind and water with heat and frost being significant assisting forces. Sediment transported in a river can have various sources:

- the catchment (sheet-, rill-, and gully-erosion)
- the tributaries
- bed erosion
- bank erosion including landslides and falling rocks

Sediment transport can take place in various forms, according to the hydraulic conditions provided by the flow, and according to the properties of the sediment. *Bed load* and *suspended load* are only rough and ready, but inaccurate, classifications of the phenomena taking place in the river. There is no clearly defined separation point between the two kinds of motion in nature.

The distinction results from the fact that for analytical consideration two entirely different theoretical approaches have been found practicable. In reality there is no sharp demarcation line between sediment motion as *bed load* and as *suspended load*.

Analytical description of sediment transport is difficult even when restricted to idealized one-dimensional considerations. In the vicinity of an intake structure, however, the flow is far from being one-dimensional. The complex three-dimensional flow pattern makes a strictly theoretical analytical treatment of the behavior of the sediment a nearly irresolvable task.

Consequently, for intake design hydraulic model test*ing* is applied extensively as an appropriate substitute for deficiencies in theoretical approaches, and as a readily accepted way out from an obvious dilemma. Empirical techniques based on observations have become standard practice.

The sediment transported by the river flow is usually not uniformly distributed. Transport rate and grain size distribution vary with the flow depth as well as the channel width. The sediment distribution with depth is dependent on flow characteristics and sediment properties: the coarser the sediment and/or lower the flow intensity, the higher the rate of bed load transported and the lower the amount of sediment in suspension.

These well-known phenomena influence the design of sediment-controlled intake structures. From experience, it is much easier to prevent the intrusion of bed load sediment than of suspended sediment.

The first step towards sediment control at an intake, therefore, should be to modify the sediment distribution of the approaching flow in the river so as to increase the sediment concentration in the fluid layers close to the bed. This can be achieved by applying appropriate river training measures capable of decreasing the flow velocity and of suppressing turbulence.

3. River Intakes

Water extraction from rivers may serve various purposes. The water may be intended for drinking, for irrigation, for power generation or for industrial processes, but regardless of what purpose has to be served, it is only the water that is wanted. The sediment brought in by the flow is not desired and is an unfortunate and troublesome side-effect. Ever since humans have started to extract water from rivers, the question of how to handle sediment problems has been one of the main concerns of the intake designers. According to hydraulic principles, there are four distinct intake types.

- lateral intake
- frontal intake
- bottom intake
- suction intake

Relating to sediment control, a somewhat different classification seems to be more appropriate. With respect to the mechanism of sediment transport, the problem in question can be divided into two categories:

- control of bed load
- control of suspended load

In the following section, various principles and techniques of sediment control will be introduced, their special features explained, their strengths and weaknesses discussedand their suitability for application in developing countries evaluated.

4. Control of Bed Load at River Intakes

The separation from the water of sediment moving close to the bed is somewhat easier to handle than the exclusion of sediment in suspension. There are numerous methods and techniques available. Regardless of how different they may appear at first sight, all are based on a single principle, namely the application of a horizontal divider, separating the upper layers containing mostly pure water from the sediment-laden lower layers. A comprehensive description of a large number of methods and techniques of this kind is given in his monograph by Scheuerlein.

Although the sediment control techniques considered in the above paragraph can be traced back to a common basic principle, they differ widely in some other respects. Three major groups can be identified:

- sediment rejection
- sediment extraction

- sediment ejection

4.1. Sediment Rejection

The principle of sediment rejection is shown in Figure 1. While the upper layers of the flow are allowed to enter the intake, the lower layers are kept from entering the intake and conveyed towards downstream with the remaining river flow. For this method, various kinds of submerged sills and bars are used to keep the sediment from entering the intake. In many cases also advantage is taken of the occurrence of natural secondary currents providing favorable flow patterns in the vicinity of the intake (for instance, at the outside of bends where the flow close to the bed tends to move away from the intake).

When favorable natural flow patterns are lacking, very often auxiliary measures are applied as, for instance, spur dikes, floating pontoons, training walls, cantilever sills, etc. as given by Scheuerlein in the cited source.

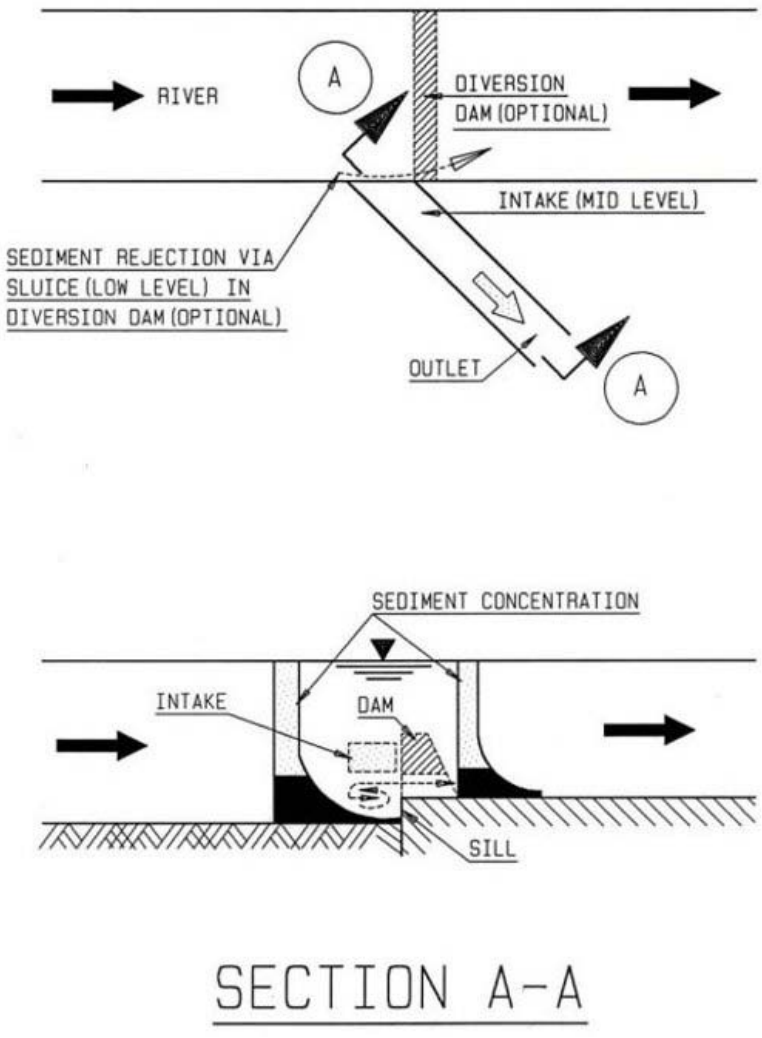

Figure 1. Sediment Rejection

The principle of sediment rejection can also be applied when the intake is not combined with a diversion dam. With proper design, the sediment rejection technique can allow for diversion up to 50 per cent of the total river flow without encountering bed load problems at the intake. For optimum efficiency, the design should always be verified by means of hydraulic model tests.

In developing countries, the principle of sediment rejection at intakes is the most frequently applied technique of sediment control. However, in many cases the performance is inefficient due to poor design and improper operation.

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Bibliography

Bouvard M. (1992). *Mobile Barrages and Intakes on Sediment Transporting Rivers*, 297 pp. Rotterdam, Brookfield: Balkema. (Originally a 1984 IAHR-publication in French, Paris: Edition Eyrolles 54). [An engineering monograph on the practice of water abstraction from sediment carrying streams. A good overview of a relevant aspect of sustainable hydraulic design].

Mashauri D.A. (1988). "Towards Clean Water: Removal of Suspended Solids by Vortex Basins," The Tanzania Engineering Journal, April. [A popular article on the subject].

Mtalo F. and Hashim O.B. (1991). "Removal of Sediments From Canals Using Vortex Tube Ejectors", African Journal of Science and Technology, Series A Technology, October. [Another state-of-the-art article].

Scheuerlein H. (1984). "Design of Water Intakes for Sediment-Laden Rivers" (in German: *Die Wasserentname aus geschiebeführenden Flüssen*), Berlin: Ernst & Sohn. [A comprehensive description of a large number of methods and techniques of sediment exclusion by means of a horizontal diversion type of intake].

Scheuerlein H. and Mtalo F. (1993). "Sediment Control at River Intakes", in *Water, the Lifeblood of Africa*, Victoria Falls, Zimbabwe: Proceedings I.A.H.R. African Regional Division Symposium, July, pp. 13.1-13.8. [The original paper on which this chapter is based].

Biographical Sketches

Helmut Scheuerlein is full Professor and Director of the Water Resources Institute and Hydraulics Laboratory, University of Innsbruck, Innsbruck, Austria. He obtained his Engineering Degree in Civil Engineering at the University of Technology, Munich, Germany in the Department of Civil Engineering in 1961.

From 1961 to 1974 he was first Research Assistant for 2 years at the Institute of Hydraulic Engineering and Water Resources at the same university; and for three years thereafter he was Research Associate at Obernach Hydraulics Laboratory, Munich, Germany. In 1968 he received the degree Doctor in Hydraulic Engineering, and for six years thereafter Dr Scheuerlein was Senior Engineer and Deputy Director at Obernach Hydraulics Laboratory, Munich, Germany. From 1974 - 1976 Dr. Scheuerlein was active as expert for the UNDP, Tehran, Iran, Ministry of Power, in Hydraulic Engineering and Water Resources

Research and advisor to Tehran Hydraulics Laboratory.

From 1976-1993 Dr. Scheuerlein was again stationed at his former Hydraulics Laboratory in Munich at the University of Munich, as Senior Engineer and Deputy Director, where he also obtained the degree Dr. Ing. Habil in1983 and the Professorship of Hydraulic Engineering and Water Resources in 1990.

From 1993 to the present, Prof. Scheuerlein is a full professor and head of the Water Resources Institute, University of Innsbruck, Innsbruck, Austria and also Director of the Innsbruck Hydraulic Laboratory.

Professor Scheuerlein teaches university courses in water resources planning and related fields, supervises research and hydraulic model testing, and is actively consulting on water resources development projects. He participates as faculty member in knowledge transfer, training of graduates and engineers from developing countries, and carries out joint research projects with the University of Dar es Salaam in Tanzania. He also co-operates with scientific institutions in Egypt, Indonesia, Peru, Iran, and China and evaluates knowledge transfer projects in Africa and Asia. He supervises joint research and acts as external examiner for M.Sc. courses in various African countries.

Prof. Dr. Scheuerlein is member of several Austrian and German Water Resources and Engineering Associations, the ASCE, the ICOLD Committee on Sedimentation of Reservoirs. He is Chairman of Division III on Geophysical Hydraulics of the IAHR, and a member of the International Nile Basin Association (INBA). He has produced 80 scientific publications and 80 project reports, one textbook on diversion dams (in German) and is editor of three conference proceedings. His language capabilities are excellent in German and English and fair in French, Spanish and Persian.

Felix Mtalo is head of the Department of Water (Civil Engineering) in the College of Engineering, University of Dar es Salaam, Dar es Salaam, Tanzania. He has taken the initiative to develop what has been the early beginnings of a Water Section in the then Department of Civil Engineering, to the present status as named above. He is busily and enthusiastically involved in water matters in Central Africa, has contributed to research and has publications in water engineering, specifically sediment transport and exclusion.