Sedimentation and its Challenges for Operation and Maintenance of Hydraulic Structures using SHARC Software- A Case Study of Eastern Intake in Dez Diversion Dam in Iran

M.R. Mansoujian, N. Hedayat, M. Mashal, H, Kiamanesh

Abstract**—**Analytical investigation of the sedimentation processes in the river engineering and hydraulic structures is of vital importance as this can affect water supply for the cultivating lands in the command area. The reason being that gradual sediment formation behind the reservoir can reduce the nominal capacity of these dams. The aim of the present paper is to analytically investigate sedimentation process along the river course and behind the storage reservoirs in general and the Eastern Intake of the Dez Diversion weir in particular using the SHARC software. Results of the model indicated the water level at 115.97m whereas the real time measurement from the river cross section was 115.98 m which suggests a significantly close relation between them. The average transported sediment load in the river was measured at 0.25mm , from which it can be concluded that nearly 100% of the suspended loads in river are moving which suggests no sediment settling but indicates that almost all sediment loads enters into the intake. It was further showed the average sediment diameter entering the intake to be 0.293 mm which in turn suggests that about 85% of suspended sediments in the river entre the intake. Comparison of the results from the SHARC model with those obtained form the SSIIM software suggests quite similar outputs but distinguishing the SHARC model as more appropriate for the analysis of simpler problems than other model.

Keywords—SHARC, Eastern Intake, Dez Diversion Weir.

I. Introduction

SEDIMENTATION is emerging as important considerations in hydraulics engineering. Its importance relates the ways in which it might affect the flow behavior along river stream and the operation of hydraulic structures constructed along it. One of such structures is diversion weir which is primarily designed to divert the flow into the water intake feeding the irrigation and drainage canals which in turn operate to supply the water requirements of croplands under its command [1]. The run-offs in their process of moving on the soil surface transport considerable volume of sediment particles into the streams. This is due to erosion phenomenon which ultimately causes precipitation of much of these loads behind the dams and as such, makes it possible for their entry into the water intakes and irrigation canals. It is this hydraulic reality which concerns the engineers because of the effects in which they might have on the operation and maintenance of these vital structures.

The presence of sediment loads behind the Dez diversion weir and subsequent emergence of the sediment island upstream of it [8]-[9], not only causes serious challenges for the operational efficiency of these structures but also change the hydraulic gradient and divert the flow towards the western intake while elevating the river bed at the eastern intake and subsequent difficulties in water abstraction [10]. Given the above considerations, this paper aims to analytically study the sedimentation processes and the ways in which these might affect the operation and behavior of these hydraulic structures in general, and the Eastern water intake of the Dez Diversion Weir in particular.

II. Materials and Methods

Dez diversion weir is situated 36 km downstream of the Dez hydro-electrical dam and 6km downstream of Regulating dam south of Dezful, a city surrounded by a 120,000 ha of the command area. It is designed to divert and supply annual water requirements of about 3.5 MM^3 which is fed into its two Eastern and Western Canals [1]-[10]. The diversion structure is designed to incorporate Ogee shape concrete discharge structure of 394m long having 4m height from the river bed at 116.5 m altitude from the see level, operating freely. Its hydraulic features include two sludge gates one on the western side incorporating two arc gates having a dimension of 15×4m equipped with electrically operated gates and 750 m3/sec and another in the eastern side having 850m^3/sec incorporating 8 slide gates ,also electrically-operated gates.

There are two water intakes, one constructed on western side of the weir with a capacity to feed a 157 m3/sec at a 200 angle and another at the Eastern side having a 93 m^3/sec with a 90^0 intake angle. It is design to operate at a maximum flooding discharge of 6000 m^3/sec [1]-[2].

Researcher, Islamic Azad University, Dehloran Branch, Iran. (e-mail: Rezamansoujian@yahoo.com).
Associate professors, Islamic Azad University, Dezful, Iran.
(e-mail: n.hedayat@yahoo.com).
Assis. professors, Aburihan college University of Tehran, Iran.
Assis. professors, Islamic Azad University, Dezful Branch, Iran.

The methodology involved collection of filed data along the river course stretching about 1.4 km between the Diversion Weir and the Old Dezful Bridge upstream complemented by further data observed in the Dezful Hydrometric Station. These data on hydraulic behavior and sedimentation processes were analyzed considering the two water intakes and the hydraulic features of the diversion weir using the SHARC software. The crucial data requirement to model the experiment included the river discharge and diverted flow towards the eastern water intake, river cross-section, suspended sediment particles, and bed-load particles. Results from calibration of the model were compared with the observational data to enhance the reliability of the results.

A. Data for the simulation model

This paper used two methods to estimate the Manning roughness co-efficient, Lacy and Simons and Albertson (fig. 1.2). This was needed to find out which of these two methods would have an output closer to measured water level at specified river cross-section. The appropriate roughness co-efficient was used to run the intake model (fig. 5).

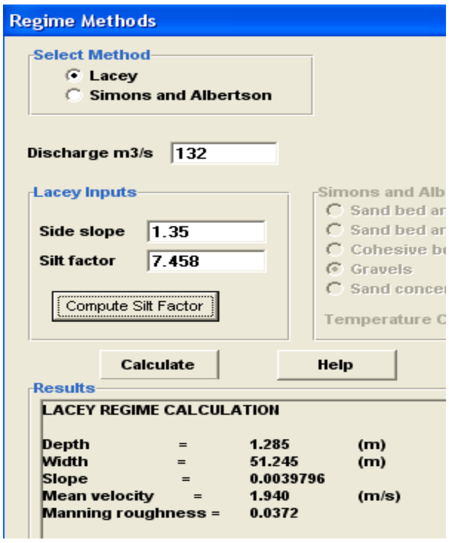


Fig. 1 Methods of estimating the Manning roughness co-efficient

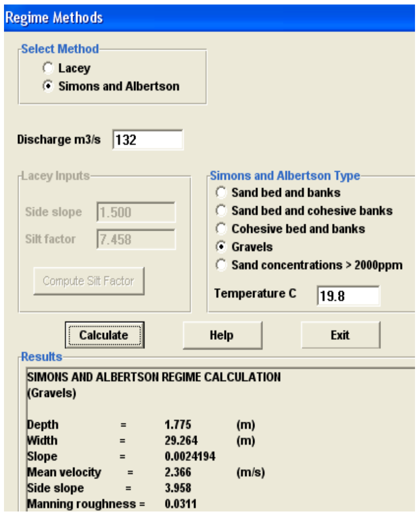


Fig. 2 Methods of estimating the Manning roughness co-efficient

B. Sand transport prediction

From the six methods that can be used by the software to predict the amount of sediment transport (Table 1), Yang model was selected to run the intake model [3] (fig. 3).

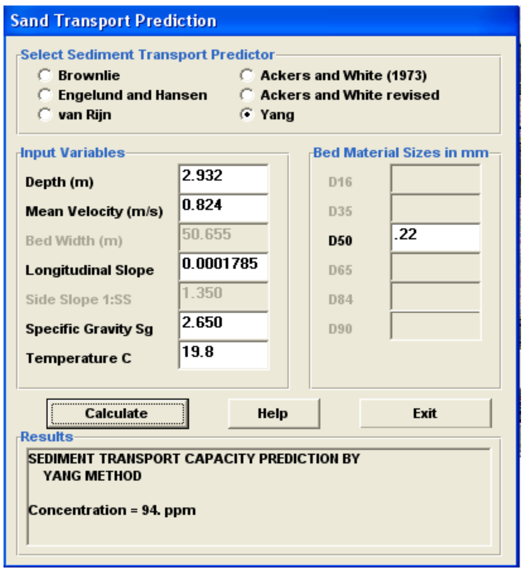


Fig. 3- Example of estimating sediment transport capacity prediction by Yang method

TABLE I
ESTIMATING SEDIMENT CONCENTRATION USING VARIOUS METHODS BY THE SHARC SOFTWARE

Yang	Ackers and White revised	Ackers and White (1973)	Van Rijn	Engelund and Hansen	Brownlie	Method
94	220	208	144	228	160	Concentration (PPM)

C. Estimation of the suspended loads

Westrich and Jurashek method can be used to estimate sediment transport concentrates but only for the lined canals where little or no sediments can be settled. For the purpose of this study Arora, Raju and Garde method was selected as this as research elsewhere [3] suggest was found to be more appropriate for the unlined streams like the Dez River. The silt transport capacity concentration was predicted at 122 ppm (fig. 4).

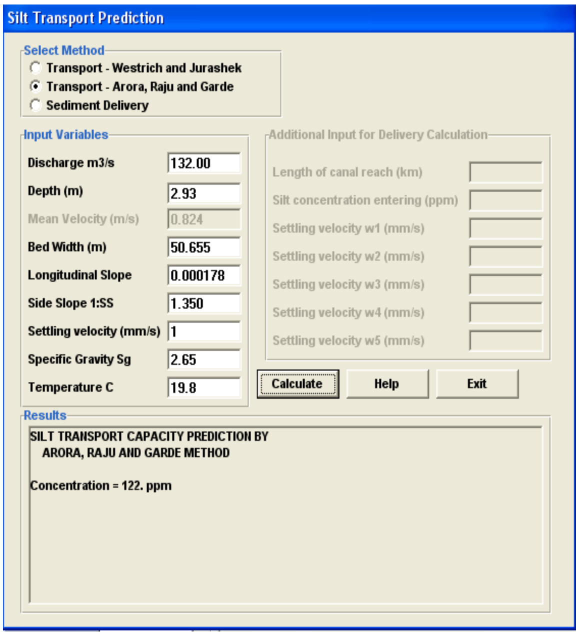


Fig. 4 Estimating suspended load concentrate by Arora, Raju and Garde

D. Determining hydraulic characteristics of the Eastern Intake

Various hydraulic parameters (i.e., river discharge, water level gradient, Manning roughness co-efficient, water temperature, sand particle specific gravity and estimated sand transported concentration) were provided by the software in order to simulate the eastern intake structure model (fig. 5).

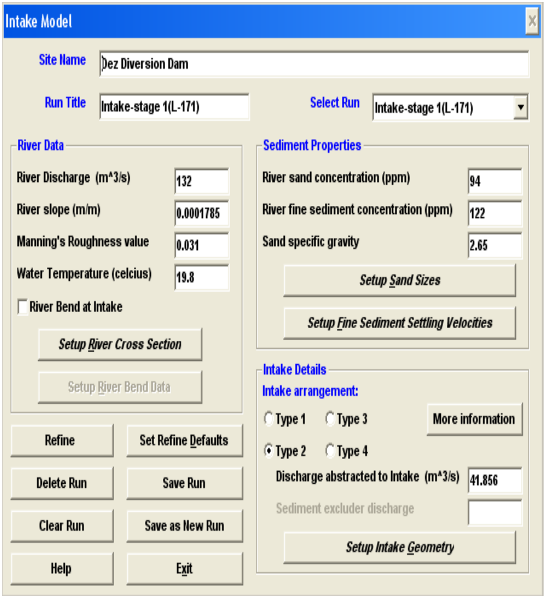


Fig. 5 Running the model

E. Equations

The methodology followed by Simons and Albertson (1963) was based on available data on a databank of few North American rivers. In order to provide a systematic methodology for their theoretical model, they classified five types as follows [5]:

Type1- Sand bed and banks
Type2- Sand bed and cohesive banks
Type3- Cohesive bed and banks
Type4- Gravel
Type5- sand concentrations > 2000 ppm

Typical equations used by Simons and Albertson in their study are as follows

$$B = 0/9\,P \quad , \quad P = K_1 Q^{1/2}$$

$$R = K_2 Q^{0/26} \quad , \quad S_\circ = \frac{1}{R^2}\left(\frac{V}{K_3}\right)^{1/n}$$

$$y_n = \begin{cases} 1/21\,R & , \quad R < 2/1\,m \\ 0/61 + 0/93\,R & , \quad R > 2/1\,m \end{cases}$$

These constant values depend on the type of canals, i.e., for the type 2 canals the following constants can be used: [5]

n=0.33 K_1=4.71 K_2=0.484 K_3=10.81

Yang and Mollinos used the principle of the disturbed flow showed that the following relation between the total sediment volume and the flow strength should be established as shown bellow:

$$\log C_T = M + N \log \frac{VS}{w_x}$$

Where M and N are without dimension and depend on the flow and sediment characteristics. Yang provided a formula for rivers with sandy bed and particle sizes diameters less than 2 mm as follows:

$$\log C_T = 5.435 - 0.286\log\frac{w_s D_s}{\gamma} - 0.4571\log\frac{u^\bullet}{w_s} + \left(1.799 - 0.409\log\frac{w_s D_s}{\gamma} - 0.314\log\frac{u^\bullet}{w_s}\right).\log\left(\frac{VS}{w_s} - \frac{V_c S}{w_s}\right)$$

Where Cr is total sediment transport (ppm). Yang (1984) provided another equation for rivers with sandy bed having particle size between 2-10 mm as follows [6]:

$$\log C_\tau = 6.681 - 0.633\log\frac{w_s D_s}{V} - 4.816\log\frac{u^\bullet}{w_s} + \left(2.784 - 0.3051\log\frac{w_s D_s}{V} - 0.282\log\frac{u^\bullet}{w_s}\right).\log\left(\frac{V.S}{w_s} - \frac{V_c.S}{w_s}\right)$$

III. Results and Discussions

Results (fig. 6) showed that the SHARC software estimated the water level at 115.97 m, whereas the actual observed water level at the river cross-section was 115.98m [2]. This shows no significant statistical difference between the model and the observed data which indicates a close proximity of the two sets of data along the river reach where the study was conducted and various research studies [8]-[9], have also reported similar results.

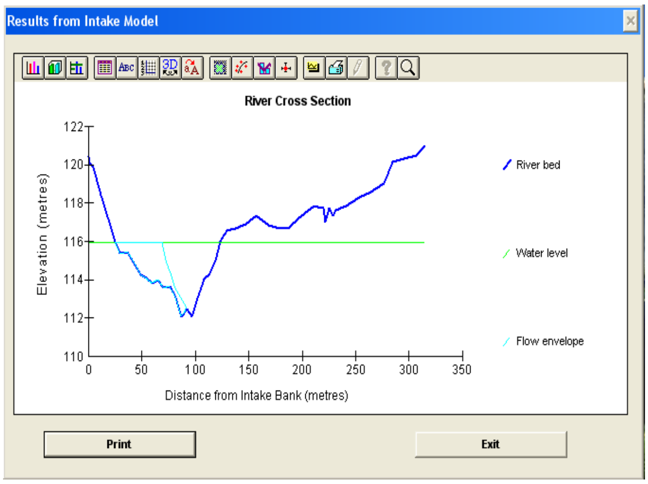


Fig. 6 Modeled cross-section in the software

Results (fig. 7) further estimated the average sediment particle size in river (d50) at 0.25 mm. From these findings, it can be deducted that almost all suspended loads in the river stream were moving. That in turn suggests no significant sedimentation along this river reach. However, it suggests that a great majority of the suspended loads were moving into the Eastern water intake, which research elsewhere [9] has substantiated. It has also estimated the annual sediment load entry into that intake structure at about 150 tons. This was shown under circumstances where the software estimated median sand size diameter entering the intake structure at 0.293 mm (fig. 8). Comparison of the data obtained by the model with the set of the observed data from the intake structure suggest the entry of approximately 85% of the volumetric suspended sediment loads into the Eastern water intake structure.

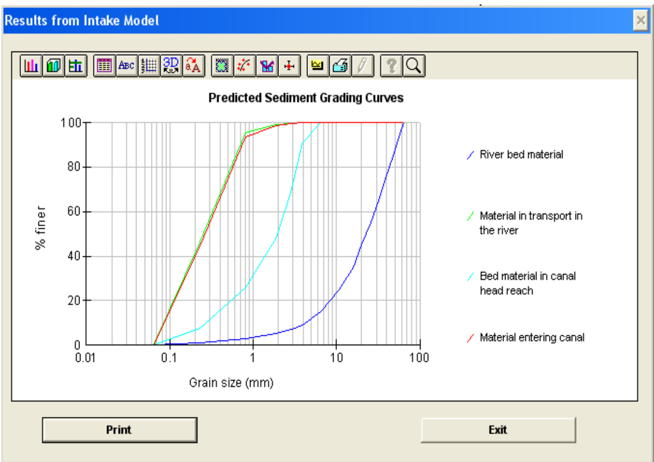
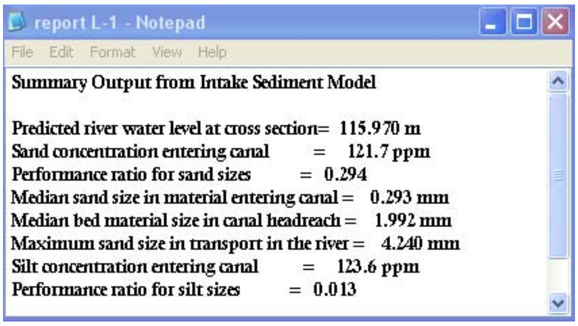


Fig. 7 Sediment transport grading in the river that entering the canals



Summary Output from Intake Sediment Model

Predicted river water level at cross section= 115.970 m
Sand concentration entering canal = 121.7 ppm
Performance ratio for sand sizes = 0.294
Median sand size in material entering canal = 0.293 mm
Median bed material size in canal headreach = 1.992 mm
Maximum sand size in transport in the river = 4.240 mm
Silt concentration entering canal = 123.6 ppm
Performance ratio for silt sizes = 0.013

Fig. 8 The output of the intake with a discharge of 41.856 m3 /sec

It can be deducted from other research findings [4]- [9]-[10] that firstly the SHARC software is an appropriate analytical tool for studying the sedimentation process behind the hydraulic structures such as the diversion dams . It was also found that such software can potentially be used for feasibility studies as well efficient managing the operation and maintenance of the hydraulic structures. Secondly, application of this software in river engineering projects would make it possible to simulate the entry of the sediment loads into the water intake structures. Simulation model of the sediment transport as was investigated in this study, calls for incorporation of a new design configuration that embodies a sediment basin adjacent to and immediately close to the Eastern intake. Incorporation of such structure is expected to trap considerable volume of the transported loads and as such, eliminate or reduce the undesirable consequences that [8] have reported to be the major cause for concern in a foreseeable future if systematic measure are not taken by the stakeholders. The operational efficiency of hydraulic structures that were designed to supply water requirements of cropland in the command area would improve. This in turn would ensure the sustainability of hydraulic structures as the vital water supply systems of the Dez irrigation and drainage schemes. These is particularly crucial during dry seasons which research [1] have shown not only to make it a challenge for the water agencies to satisfy the water requirements of the croplands but also to incur considerable economic loss due to reduction of the crop yield of the farmers.

By comparing the result of present model with those obtained by SSIIM [7] suggests that although there is a clear proximity between these two sets of data, the SHARC software nonetheless could easily be applied for the simple problems. The SSIIM software on the other hand could only be applied for more complex problems in river engineering, particularly for determining the 3D flow pattern with high precision. The application of this would depend on prevailing conditions which the project has to be implemented.

The study also found that the slow flow velocity around the eastern intake structure has caused gradual precipitation of sediment particles in the area. This has led to increased river bed level, which in turn, had exacerbated water abstraction in that vicinity. Inappropriate intake angle (90^0) has also made an undesirable impact on functional efficiency of the intake structure. The present hydraulic conditions around the eastern water intake structure have also altered the hydraulic gradient towards western intake. The present design feature of the eastern intake structure having a 90^0 angle has shown to be no longer suitable for what has emerged as serious challenges for the operation and maintenance regimes , as research studies [1]-[8]-[9]-[10] have already indicated. The study has further highlighted recent shifts in the flow behavior that has led to considerable morphological changes that in turn poses various problems. The emergence of the sediment island immediately upstream of water intake structures has disrupted the establish river regime that has become the main source of sediment load transport towards the western bank. This phenomenon has shifted the sediment loads into the intake structure and from which into the main canal. Sediment load transport of such description is a potential challenge for the water conveyance and distribution system of the Karkheh flood plain, a 'fertile production paradise' which this study considers as the food-production bastion and grain silo of Greater Dezful, the water supply for its cropland is undoubtedly important not only socio-economically and politically but also environmentally [1].

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