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DESIGN CRITERIA FOR SETTLING BASINS ON NON-SCARP WATERCOURSES

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Thirteen watercourses along the Nasrana Distributry in Faisalabad district were studied for discharge and sediment load distribution to establish design criteria of settling Basins for efficient desilting of watercourses. The sediment load was found to vary exponentially with discharge and consisted of 83% sand, 12% silt and only 2 to 3% clay. The collected data were used to design settling basins which could entrap 85% of sediments and allow only 15% sediments to enter the fields with irrigation water. A procedure for design of such settling basins has been summarized to avoid unnecessary expenditure. The frequency of cleaning based on the discharge of the watercourses was also developed to facilitate planning and execution of cleaning and maintenance programme.

INTRODUCTION

In case of large variations in canal water level, the outlets are set closer to the bed to minimize their effects on the discharge and to enable them to receive water during periods of low flow. Such an irrigation system tends to attract more sediments into the watercourses. The discharge through the watercourses in non-SCARP areas usually range from 28 to 85 lps (litres per second) depending on the command area. The sediment transport capacity of such unlined watercourses is constained by the low topographic gradient and substandard maintenance. The raised water level in the watercourses resulting from irrigation of higher elevation fields also causes sediment deposition. Thus, the nonuniform flow conditions in the watercourses are frequently contributing to the sediment deposition which in turn raise the water level in the watercourses resulting in excessive water losses through the banks (Akram *et al.*, 1978).

Like canals, the proper functioning of watercourses also requires maintenance of sediment discharge equilibrium through a proportionate outflow of sediments to the fields, periodic cleaning or entrapping the sediments at a suitable point on the conveyance system. The alternatives of cleaning and maintenance as practiced by the farmers and the consequent problems are summarized by Mirza and Merry (1979).

The reported study was, therefore, developed to assess the extent of sediment problem in the watercourses and to develop a design criteria of settling basins with a self-cleaning mechanism to overcome the sediment problems faced by the farmers.

MATERIALS AND METHODS

Settling basin design considerations: The volume rate of sediment loaded water passing through the tank per unit discharge (Q) is given by the equation:

$$Q = B \times D \times V_t$$

where B stands for width, D for depth of water and V_t for the velocity of water through the tank. The flow rate causing a downward movement of sediments would be B x L' x V_s, termed as surface loading rate. For complete settling of all the particles above the selected size, the rate of surface loading should be equal to the flow rate through the tank, i.e.

$$B \times L' \times V_s = B \times D \times V_t \text{ or } L' = V_t \times D/V_s$$

where L' represents the length of settling basin and V_s as the velocity of settling sediments.

If the width of preceding watercourse is assumed to be 0.61 m and the angle of divergence (α) = 10^0, the basin length is given by:

$$L = L' + (B - 0.61)/2 \tan 10 \qquad (3)$$

Discharge and sediment load measurement: Thirteen watercourses on the Nasrana distributory were selected for the study. The discharge was measured with a cut throat flume. Each watercourse was sampled for sediment load determination near mogha.

Table 1. Discharge and sediment load of selected watercourses of Nasrana distributory

Mogha No.	Village No.	Discharge ($l\ sec^{-1}$)	Silt load ($g\ sec^{-1}$)
832996L	68/JB	62.8	51.31
86336R	69/JB	35.4	16.35
87054L	70/JB	43.9	25.43
87478R	69/JB	39.6	20.43
88229L	70/JB	62.5	51.31
88513R	71/JB	43.0	24.07
89480L	74/JB	34.8	15.89
90816R	73/JB	37.6	18.16
94825R	73/JB	36.8	17.71
95026L	74/JB	38.5	19.07
96292R	73/JB	39.3	20.43
97249L	74/JB	30.8	24.98
99455L	76/JB	43.6	24.98

Sudden expansion of watercourse into a rectangular settling basin causes development of dead storage on the corners due to boundary layer effect, which may add to the excessive cost without contributing much to the settling of incoming sediments. Hence a diverging section should be provided. The length of diverging section (L") can be determined from the equation:

$$L'' = (B - \text{Width of watercourse})/(2 \tan \alpha) \qquad (2)$$

Since water in this reach was highly turbulent causing almost uniform distribution of sediments with depth, each determination consisted of two samples one from near the bottom and the other from 7 to 10 cm below water surface. The sediment concentration was estimated by treating the suspension with 0.1% solution of aluminium sulphate and then oven drying the solid materials. The collected sediment samples were analysed by hydrometer method for particle size distribution.

RESULTS AND DISCUSSION

Sediment load and discharge relationship: Table 1 summarizes the values of measured discharge and the corresponding sediment load entering each watercourse. These data are plotted in Figure 1. The statistical analysis using least square resulted in the following relationship between discharge and sediment concentration:

$$S = e^{(0.042\,Q\; +\; 1.318)} \qquad (4)$$

where S represents the sediment load in g sec^{-1} and Q in l sec^{-1}.

Particle size distribution: Particle size analysis of the collected sediment load resulted in 83.8 to 84.8% sand, 12 to 13% silt and 2.2 to 3.2% clay particles. It showed that the main source of sediments in the watercourses was sand which ranged from 2.00 mm to 0.05 mm size. Therefore, detention of particles greater than 0.038 mm in the settling basin would mean removal of 85% of total sediments from watercourses. The remaining 15% sediments consisting of mainly silt and clay could be allowed to enter the fields with irrigation water. Hence, 0.038 mm particle size was selected as the minimum size to be settled in the basin. Mahmood (1973) has also indicated that almost all the methods of sediment exclusion can only limit the amount of sediments entering

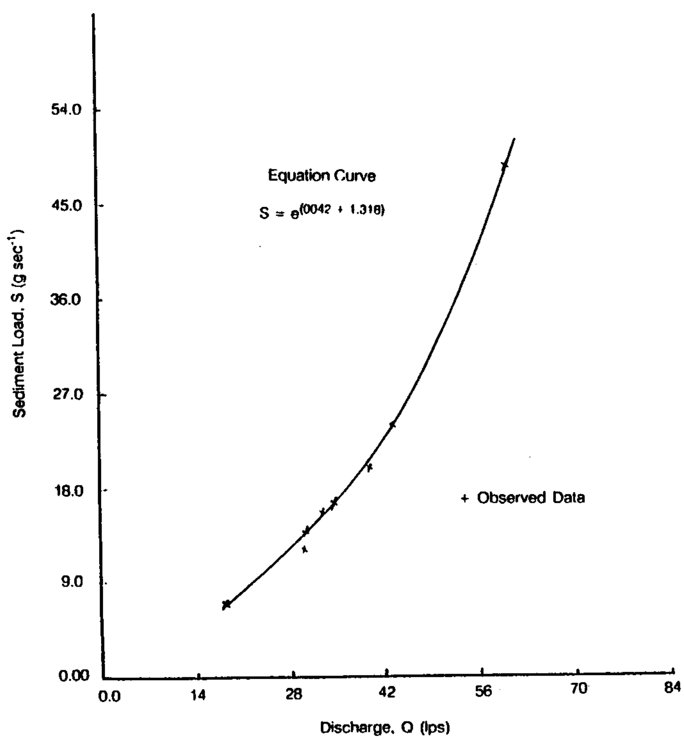

Fig. 1. Plot of silt load vs discharge.

a system and they cannot by completely eliminated.

Settling velocity: The settling velocity of the smallest size to be entrapped is critical in establishing the design length of basin. Accordingly, the settling velocity of selected minimum size, i.e., 0.038 mm as determined by Stock's law, was found to be 1.38×10^{-3} m sec^{-1}.

Design specifications of settling basin: Considering an average flow rate of 28 to 84 l sec^{-1}, 1.22 m depth of basin and using the procedure detailed above, the basin lengths for given widths of 1.85, 2.44 and 3.1 m and discharge range of 14 to 56 l sec^{-1} were calculated (Fig. 2). It can be observed that with increasing flow rate the length tended to approach infinity at smaller widths which confirms the possibility of deposition of sediments in whole the length of the watercourse when no settling basin is provided. Smaller length was required with increasing width. Moreover, for a given width, greater length of basin was required for increasing discharge.

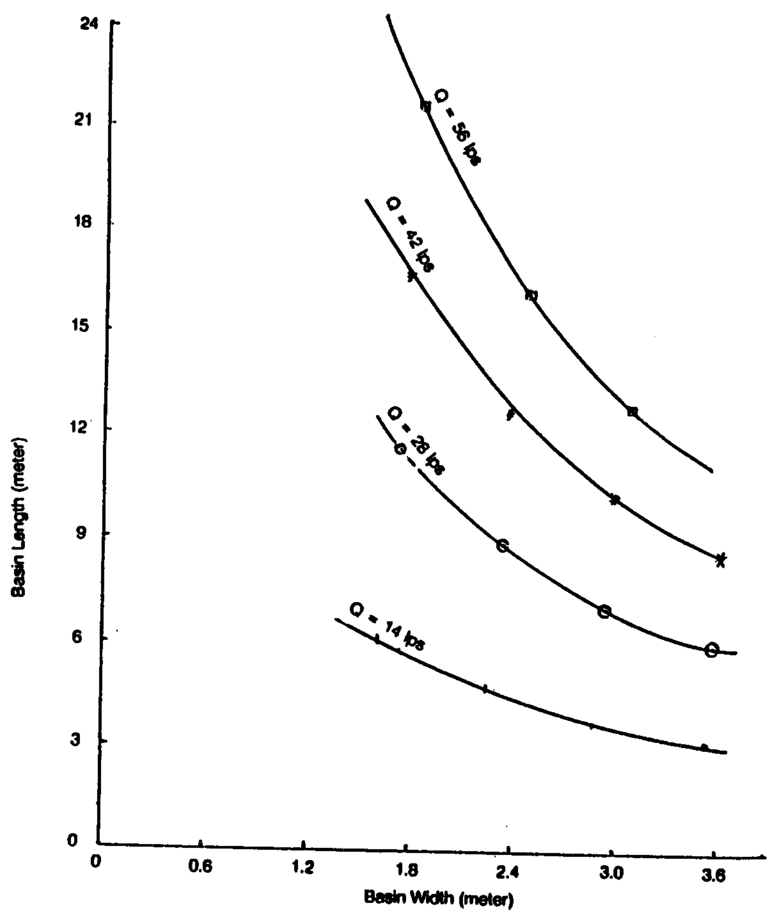

Fig. 2. Basin length as affected by width for various discharge values.

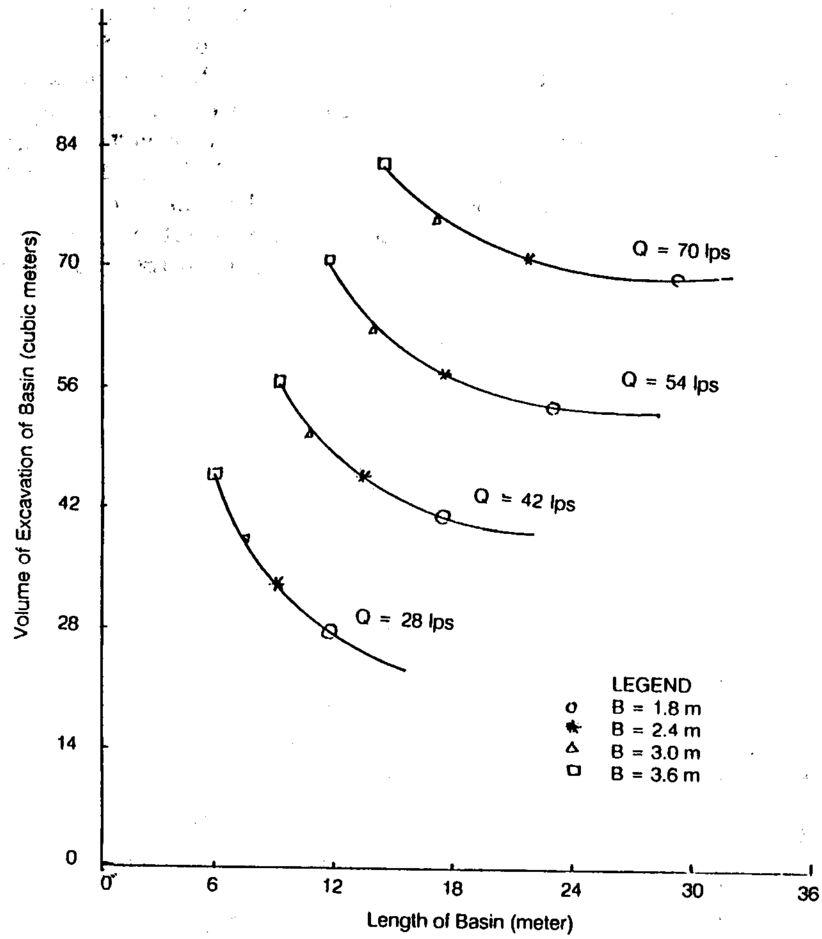

Fig. 3. Volume of excavation as affected by the width of basin.

Optimum width: There is no unique width that may be suggested for all the flow rates. However, an optimum range may be suggested on the basis of rate of change in volume of excavation with respect to the length. Figure 3 shows that the slope of the curve for 3.6 m width is very steep, indicating a high rate of increase in volume of excavation with small change in length. However, at 1.83 m width, there is a greater increase in length with a smaller change in volume of excavation, especially at high flows which may also be undesirable. Therefore, a range of 2.4 m to 3.0 m will hold good for flow rates of 28 to 85 lps. For greater flows the basin width may be increased to range from 3.0 to 3.7 m. The design specifications developed for settling basin using optimum width of 2.75 m and a mogha discharge of 56.6 lps are given in Figure 4.

Cleaning interval: The interval of cleaning was calculated on the basis of time taken to fill an empty basin up to the bed of watercourse for given discharge and sediment load (Table 2).

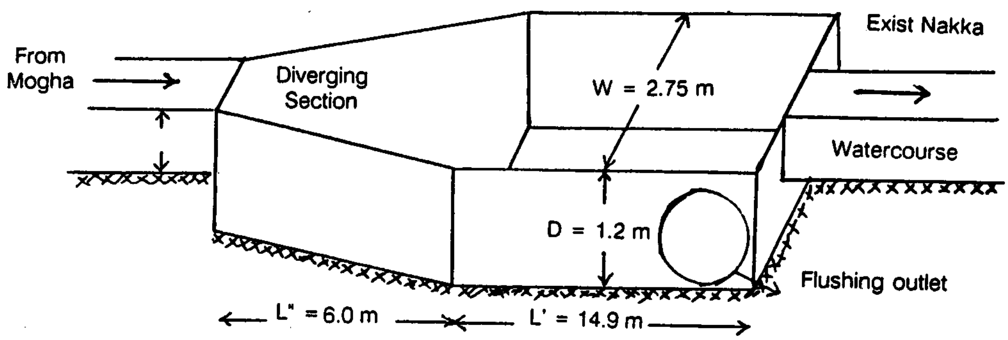

Fig. 4. Designed settling basin with automatic flushing.

Table 2. Recommended intervals of cleaning (days) for given discharge and width of settling basin

Discharge ($l\ sec^{-1}$)	Basin width			
	1.83	2.44	3.05	3.66
35.4	64	72	82	95
42.5	57	64	71	81
56.6	40	44	48	54
60.3	37	40	43	48

A self-flushing arrangement can be provided by installing the basin at a suitable point on the watercourse, where adjoining fields could accommodate the disposed sediments with irrigation water without deteriorating the agricultural productivity of the fields. For a discharge of 56 lps commanding about 222.7 ha in non-SCARP area, the total incoming sediments if uniformly distributed over the entire command area can give an annual rise of 0.04 cm per acre.

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