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Experimental Investigation on Sediment Transport in Irrigated Channels

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***Abstract*- Sediment transport in the channel is of practical importance in agricultural practice as it provides an opportunity to optimize the nutrient delivery to crops and optimization of water to be supplied to the field. Irrigation channel bed degradation occurs, when the delicate balance among the channel discharge, sediment inflow, and channel slope is disturbed by natural or manmade factors. The primary objective of the present study is to provide an experimental procedure for the prediction of transient bed profiles and the effect of infiltration on degradation. For this purpose, here two types of study are performed. In the first case, the degradation is done without considering the infiltration (under saturated conditions); on the other hand, degradation is done unsaturated condition for considering the effect of infiltration. The results show that more degradation was occurring in the case of saturated condition as compared to unsaturated condition. The infiltration of channel bed was found to be the main factors affecting the depth of degradation of channel bed of sand.**

Keywords: Sediment transport, Infiltration, Irrigation channel, degradation, soil water tension

I. INTRODUCTION

Irrigation channel bed degradation occurs, when the delicate balance among the channel discharge, sediment inflow, and channel slope is disturbed by natural or manmade factors like; sediment coming from main canal, change of sediment supply rate, etc. When the sediment load coming to a reach of the irrigation channel is less than its carrying capacity, the water inflow then picks up the sediments from channel bed and banks to maintain its transport, equilibrium, thereby causing lowering of channel bed which is known as degradation (Garde and Ranga Raju, 2006). Brown et al. (1988) proposed that sediment deposition along the furrow perimeter creates a low-permeability seal that increases the soil water tension at the furrow perimeter.The stress, in act, increases deposition and stabilizes the seal. This self-perpetuating process stabilizes the furrow perimeter and decreases the erodibility of the soil with time. The kinematic-wave model and zero-inertia model was commonly used for flow routing in early studies. Such models are stable and efficient for prismatic channels. These studies showed that the zero-inertia model is applicable with negligible errors for surface irrigation flow of small Reynolds numbers, and the kinematic-wave model is more applicable to channels of steeper slopes. However, these models neglected fluid acceleration, and thus, their accuracy is limited for unsteady flows.

Several sediment transport models have been developed for channel irrigation flows (Lu et al. 1987; Strelkoff and Bjorneberg 2001;Bjorneberg et al. 2006). Trout (1996) showed that Greater than 50% of the detached sediment can be deposited on the lower end of a field. Trout (1996) Studied the soil erosion and deposition distribution within furrow irrigated fields. It found that over half of the soil that eroded from the head end of the furrows deposited on the lower portions of the field as furrow flow rates decreased. Erosion rates on the upper quarter of uniformly-sloped furrows were 6-20 times greater than average rates from the airfield. Nevertheless, the erosion theory predicts that the erosion rate should diminish with distance from the head (inflow) end of the furrow. Zhang et al. (2012) developed a numerical model to simulate unsteady flow, sediment transport, and infiltration in irrigation furrows using the modified St. Venant equations. They considered the density of sediment-laden flow as a special variable. Two types of flume experiments were performed in the laboratory. The first series of experimental runs has a clear-water condition without feeding sediment at the flume entrance and another was with feeding sediments. The transport capacity for fine-grained sediment was determined by the modified Laursen formula. The correlation coefficient between the sediment discharge per unit width and the tractive shear stress found to be 0.883, without sediment feeding and in case of volumetric sediment concentration and the tractive shear stress was less than 0.707. This indicates that the volumetric sediment concentration is less correlated with the tractive shear stress than the sediment discharge per unit width. The present model well simulated the advance time and flow hydrograph as compare to sediment discharge. For the sediment discharge study more refined formula should be practiced. Several studies have been carried out by various authors and nobody has been focused on the effect of infiltration on sediment transport (degradation).

II. EXPERIMENTAL SET-UP

The experiments were conducted in a 46cm wide, 100cm deep and 15 m long recirculatory tilting flume located in the hydraulics laboratory of Indian institute of technology, Roorkee. The flume was provided with glass side wall. The recirculatory system consisted of a rectangular tank sloped bottom to collect the sediment laden flow from the downstream end of the flume. A 25-H.P.pump was connected to the tank and a supply pipe for maintaining the recirculation. The discharge was controlled by a valve. A floating wooden wave suppressor provided at the entrance of the flume for damping the disturbances at the free surface. Rails made from metallic tube provided on the top offside walls. A movable carriage with a pointer gauge having at least count of 0.01 cm was mounted on a carriage which could move on the rails. This was applied for recording water surface and bed profiles. An adjustable gate at the downstream end of the flume was used to control the depth of flow in the flume.

Figure 1. A view of the experimental flume.

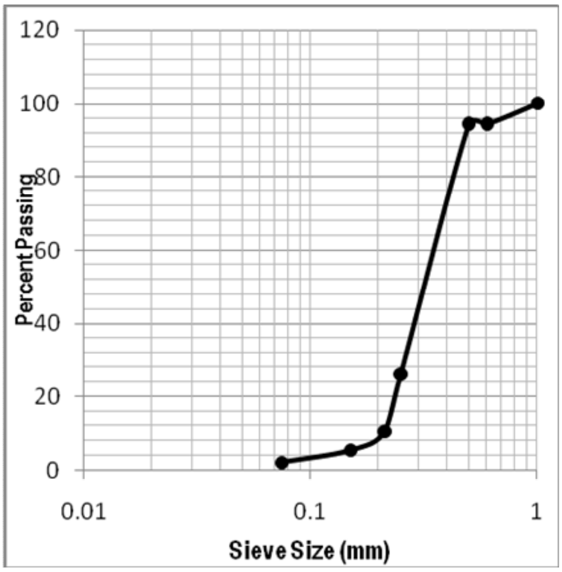


Figure 2. Sieve Analysis

Sediment Gradation: Sieve analysis test is performed to determine the characteristics of the sediment used.
The sediment used in this work is the sand from Ganga River. The size of the sediment used to obtain from the sieve analysis is found to be d_{50}=0. 32 mm. The sand was filled in the flume up to a depth of 35 cm and leveled parallel to the rails. The sand forming the bed and injected material had a median sieve diameter of 0.32 mm and geometric standard deviation of 1.39. The grain size distribution curve of the sand is shown in Fig.1. The specific gravity of the sand was 2.65.

III. EXPERIMENTAL PROGRAM

Experimental Procedure: In this section, a brief explanation of the procedure followed is given. Experiments were conducted in which the sediment was injected at the upstream end and the aggradation downstream studied. Detailed measurement of the bed and water surface profiles at various times was taken; these were useful in the study of sediment transport and resistance to flow under non-uniform flow condition, apart from providing the basic data on aggradation.

Figure 3. Transient bed and water surfaces profiles in sand bed

In these experiments the flume was filled with sediment as mentioned earlier and then was given the desired slope. The recirculatory system was then filled with water and pumps started. The valve was slowly adjusted to give specified discharge and uniform flow was obtained by adjusting the tailgate at the downstream end of the flume and allowing the bed to adjust. Because of the effect of entrance and exit conditions on the flow, about 3 m length of the flume at the upstream and downstream ends was not considered in assessing the uniformity of the flow. After maintaining the flow, the required discharge was increased with the valve. The carrying capacity of irrigated channel was increased. Consequently degradation took place along the length of irrigated channel. Here two types of study were performed. In the first case, degradation was done without considering the infiltration (under saturated conditions), on the other hand, degradation was done unsaturated (drybed) condition for considering the effect of infiltration.

Figure 4. A view of degradation channel

The flow depth was measured with the help of pointer gauge having a least count of 0.1 mm whereas the bed profile was measured by using the gauge having a flat bottom (diameter = 10 mm) which also had the least count of 0.1 mm. The pointer gauge and the flat bottom gauge intruded into the flow only for very short time durations while taking the observations so as not to adversely disturb the flow and bed conditions. The flow depth and bed surface profiles were recorded for various time interval of about 30 min while the bed level changes were rapid, and subsequently at an interval of about 60 min during later part of the runs when the bed transients became more gradual. The point gauge readings for both flow depth and channel bed elevations were made at longitudinal spacing of 0.3 m along the centerline of the working section of the flume. First the bed elevations were recorded at each section along the channel centerline followed by the recording of flow depth at the same sections.

The degradation is measured along the length of flume at regular time interval t = 60, 75, 120 minutes.

IV. RESULTS AND DISCUSSION

Effect of infiltration on Degradation: The effect of infiltration on degradation is investigated with flow conditions (Q = 9.6 l/sec, y = 5.0 cm, d_{50}= 0.32 mm). The degradation is measured along the length of the flume at regular time interval t = 60, 75 and 120 minutes respectively. Maximum depth of erosion was occurred in the upstream of the irrigated channel. Transient bed and flow depth in irrigated channel are shown in figures (5).
Degradation without infiltration resulted in decreased bed elevation as compared to bed elevation measured by with infiltration. Also, infiltration is found to be the primary parameter which affecting both bed elevation and water elevation.

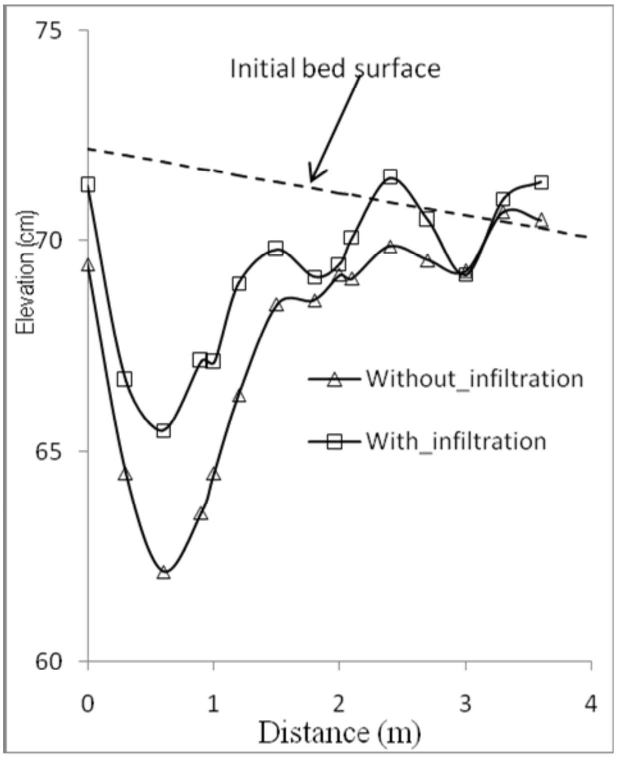


Figure 5. Transient bed profiles in the sand bed for 60 minutes.

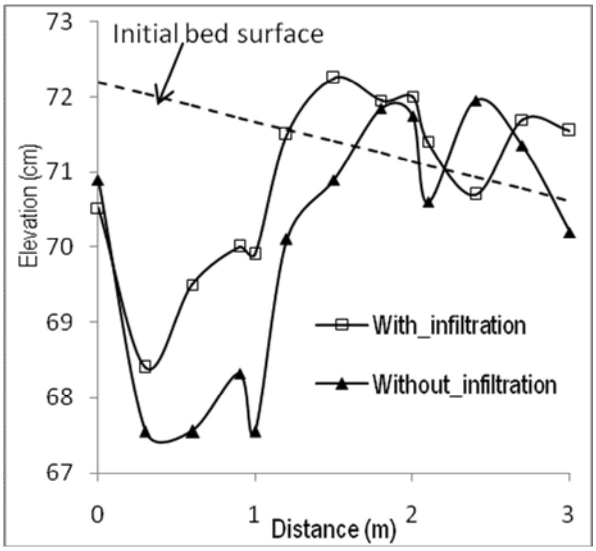
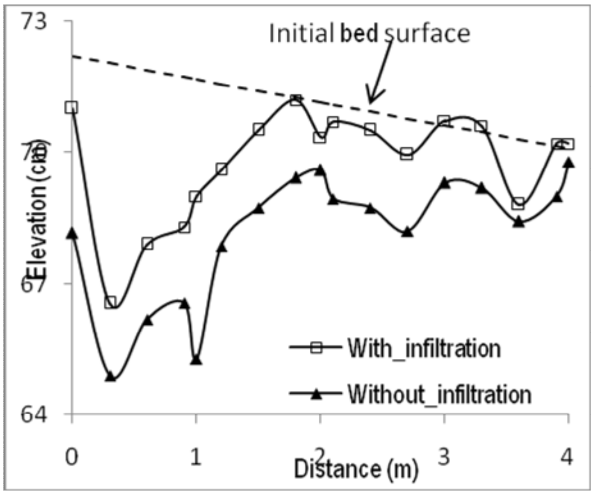
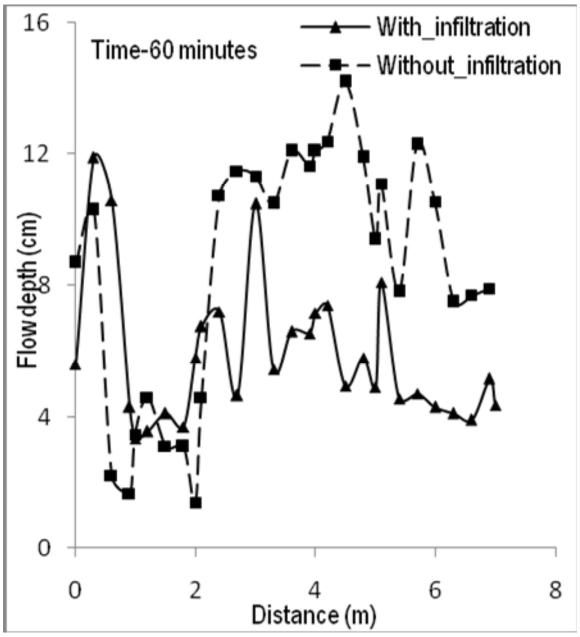
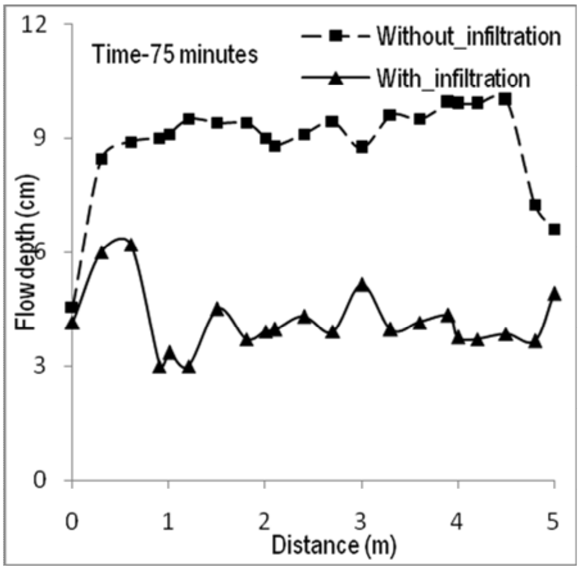


Figure 6. Transient bed profiles in the sand bed for 75 minutes.

When the duration was 60 minutes the corresponding bed and water surface elevation with infiltration was found to be 0.56m and 0.60m. However, in cases without infiltration values of bed and water surface elevation were 0.53m and 0.57m respectively.







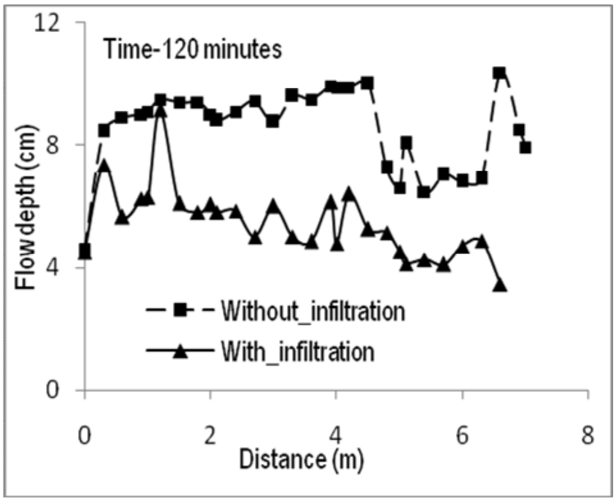


Figure 7. Variation of flow depth with time

V. CONCLUSIONS

1. Infiltration influenced the bed elevation and water elevation during degradation effectively.
2. However, bed and water elevation were increased during the infiltration. Compared to the without infiltration case (saturated condition for 60 minutes), Maximum bed and water surface elevation were found to be 0.53m and 0.57m. However, when the infiltration case (unsaturated condition for 60 minutes), corresponding maximum bed and water surface elevation were found to be 0.56m and 0.60m. Similar pattern were followed by other duration of transient bed and water surfaces, profiles eq. 75, 120 minutes.
3. Degradation without infiltration resulted in decreased bed elevation as compared to bed elevation measured by with infiltration. Also, infiltration is found to be the primary parameter which affecting both bed elevation and water elevation.
4. Due to infiltration (during unsaturated condition) tractive force is reduced, which the primary force is caused increased bed and water elevation. However, in the case of saturated condition tractive force may be greater than unsaturated condition.

VI. REFERENCES

[1] A.G.Segeren and T.J.Trout "Hydraulic resistance of soil surface seals in irrigated furrows" Soil Sci. Soc. Am, J. 55, 1991, pp. 640–646
[2] Alcrudo et al., "Flux difference splitting for 1D open channel flow equations" Int. J. Numerical Methods Fluids, 14, 1992, pp.1009–1018
[3] Bjorneberg et al.,"Sediment and phosphorus transport in irrigation furrows" Journal Environmental Quality,35 (3), 2006, pp.786 –794
[4] Brown et al., "Sediment, erosion and water intake in furrows" Irrigation Science, 9(1), 1988, pp.45-55
[5] Celia et al., "A general mass-conservative numerical solution for the unsaturated flow equation" Water Resources Research, 26(7), 1990, pp.1483-1496
[6] F.Abbasi et al., "Overland water flow and solute transport: model development and field-data analysis. Journal Irrigation Drainage Engineering,129(2),2003,pp. 71 – 81
[7] H.Zhang and R.Kahawita "Nonlinear model for aggradation in alluvial channels" Journal Hydraulic Engineering,113(3), 1987,pp. 353-369

[8] I.Park and S.C. Jain "River-bed profiles with imposed sediment load" Journal Hydraulic Engineering 112(4), 1986, pp. 267-279
[9] K.E. Abderrezzak and A.Paquier "One-dimensional numerical modeling of sediment transport and bed deformation in open channels" *Water Resources Research*, *45*,W05404, 2009, pp.10.1029/2008WR007134
[10] M.A.Gill "Diffusion model for aggrading channels" Journal Hydraulic Research, 21(5), 1983a. pp.355-367
[11] R.F. Carsel and R.S.Parrish "Developing joint probility distributions of soil water retention characteristics" Water Resources Research, 24(5),1988, pp.755-769
[12] S.Bhallamudi and H.chaudhry "Numerical modeling of aggradation and degradation in alluvial channels" Journal of Hydraulic Engineering,117(9), 1991, pp.1145-1162
[13] S.Zhang et al.,"Simulation of Unsteady Flow and Soil Erosion in Irrigation Furrows" Journal Irrigation Drainage Engineering, 138(4), 2012,pp.294-303
[14] Shobha Ram et al., "Estimation of border- strip soil hydraulic parameters" Journal Irrigation Drainage Engineering, 138(6), 2006, pp. 493–502
[15] Soni et al., "Aggradation in streams due to overloading" Journal Hydraulic Divison(ASCE), 106(1), 1980, pp.117-132
[16] T.J.Trout "Furrow irrigation erosion and sedimentation: On-field distribution" Trans. ASAE ,39, 1996, pp.1717–1723
[17] T.J.Trout and W.H . Neibling "Erosion and sedimentation processes on irrigated fields" Journal Irrigation Drainage Engineering,119(6), 1993, pp. 947-963
[18] T.S.Strelkoff and A.J.Clemmens "Transport capacity for eroded silts in irrigation furrows" Journal Hydraulic Engineering, 131(10), 2005, pp.921 – 926
[19] T.S.Strelkoff and F.Souza "Modeling effect of depth on furrow infiltration" Journal Irrigation Drainage Engineering,110(4), 1984, pp.375 – 387
[20] U.C.Kothyari and R.K. Jain "Experimental and numerical investigations on degradation of channel bed of cohesive sediment mixtures" Water Resources Research, 46(W12534), 2010, pp.1-15
[21] V. Singh and S.M. Bhallamudi "Complete hydrodynamic border irrigation model" Journal Irrigation Drainage Engineering, 122(4), 1996, pp.189–197
[22] W.F.Jaramillo and S.C. Jain "Aggradation and degradation of alluvial channel beds" Journal Hydraulic Engineering,110(8), 1984, pp.1072-1085