Conference Paper, Published Version

Yilmaz, Nazli A.; Testik, Firat Y.

Effect of Aquatic Vegetation on Propagation of Fluid Mud Gravity Currents

EFFECT OF AQUATIC VEGETATION ON PROPAGATION OF FLUID MUD GRAVITY CURRENTS

Nazli A. Yilmaz[1] and Firat Y. Testik[2]

Motivated by the shallow-water dredge disposal operations in the coastal zone, this study aims to elucidate the effects of aquatic vegetation on constant-flux fluid mud gravity currents. The propagation dynamics of fluid mud gravity currents, which possess non-Newtonian rheology, over a smooth horizontal bottom and their propagation phase transitions have been previously studied experimentally and theoretically (Chowdhury and Testik, 2012). However, the effects of aquatic plants on fluid mud gravity current propagation characteristics have not been studied to our knowledge.

As gravity currents propagate, they go through slumping (for constant-volume gravity currents) or jet (for constant-flux gravity currents), inertia-buoyancy, and viscous-buoyancy propagation phases. Shallow coastal waters are typically characterized by a canopy of aquatic plants. Presence of vegetation disturbs the form and propagation characteristics of the gravity currents as shown by the theoretical and experimental study of Tanino et al., (2005) on Newtonian gravity currents. Their experiments indicated increasingly distinct effect of vegetation as the density of the vegetation (the ratio of the total cross-sectional area of the vegetation over the total cross-sectional area of the vegetated part of the experimental setup) increase.

In the present study, the effects of emerged stiff aquatic vegetation (such as the Spartina Alterniflora, also known as smooth cordgrass that exist in salt marshes) on the propagation characteristics of fluid mud gravity currents are studied experimentally. A laboratory tank of $4.3\ m$ long, $0.25\ m$ wide, and $0.5\ m$ deep is used to generate constant-flux gravity currents propagating over a $2.0\ m$ long perforated plate with stiff plastic rods that simulate emerged stiff aquatic vegetation. Experiments are being conducted with different concentrations of fluid mud mixtures that are prepared by mixing Kaolinite clay and tap water. In the experiments, different vegetation densities and patterns have been considered. Experimental runs with the vegetation are being complemented with experimental runs without vegetation (i.e. gravity currents propagating over a smooth horizontal bottom) for evaluating the effects of vegetation on fluid mud gravity current propagation characteristics. For each experimental run, the positions of the gravity current with time are obtained using video camera recordings.

The preliminary experiments showed that the effect of vegetation is most obvious during the viscous-buoyancy phase of the fluid mud gravity currents. Figure 1 gives the dimensional comparison of the front propagation of the gravity current with and without the vegetation model for similar experimental conditions. The trend of the gravity current propagation varied due to the vegetation effect after its phase transitioned into viscous-buoyancy phase and the velocity of the gravity current decreased considerably.

[1] Research Assistant, Glenn Department of Civil Engineering, Clemson University, Clemson, SC, 29634, USA
[2] Assistant Professor, Glenn Department of Civil Engineering, Clemson University, Clemson, SC, 29634, USA (ftestik@clemson.edu)

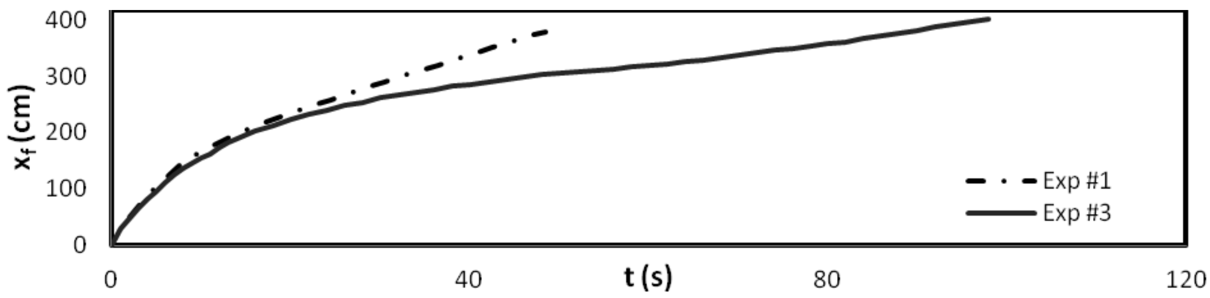

Figure 1 Position of the gravity current head, x_f from the lock gate with respect to time, t. The density of the fluid mud suspension is $\rho_c = 1130\ kg/m^3$, that corresponds to a mass concentration of $250\ g/L$. Experimental conditions are: Exp#1 -$h_i = 5\ cm$, $H = 21\ cm$, $a = 0$; $H = 15\ cm$; Exp#3 - $h_i = 5\ cm$, $H = 21\ cm$, $a = 0.035$; h_i– inlet opening at the lock gate, H – ambient fluid depth and a is dimensionless vegetation density.

Figure 2 shows the dimensionless front positions $(X_f = x_f / h_i)$ of the experimental gravity currents as a function of the dimensionless time [$T = t/\left(h_i \cdot B_0^{-1/3}\right)$; $B_0 -$ buoyancy flux at the inlet, $B_0 = (\rho_c - \rho_w)g/\rho_w\, q$; $q -$ inlet discharge rate per unit width]. The propagation data presented in this figure collapse onto two separate lines corresponding to jet and viscous-buoyancy phase propagation and does not exhibit inertia-buoyancy propagation.

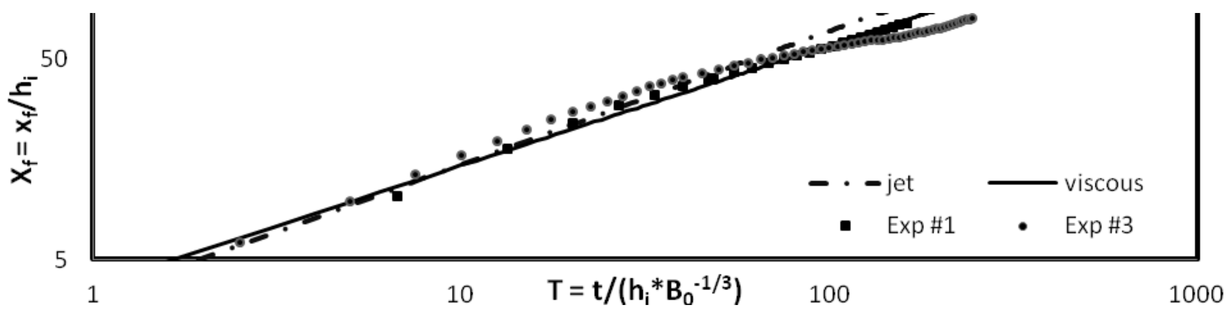

Figure 2 Dimensionless gravity current front position, X_f, versus dimensionless time, T.

REFERENCES

Tanino, Y., H. M. Nepf, and P. S. Kulis (2005), Gravity currents in aquatic canopies, Water Resour. Res., 41, W12402, doi:10.1029/2005WR004216.

Chowdhury, M. R., and Testik, F. Y. (2012) "Viscous Propagation of two-dimensional non-Newtonian Gravity Currents", Fluid Dynamics Research, Vol. 44, pp. 17-34.