COMPARISION OF 2D AND 3D MODELING OF CONVERGING AND DIVERGING FLOOD PLAINS

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ABSTRACT

The objective of this study to predict the depth-averaged velocity in a compound channel having diverging and converging floodplains with varying transverse velocity from main channel to flooded plain. The problem come across to select the best applicable model for natural flooded river system. This happens when impacts are considered in both the flood estimation of the stream as well as in pressure driven hydraulic modelling. It can be especially imperative with regards to the expanding to consolidate hydrological and water driven models in a way that gives a point by point and spatially reasonable representation of flood risk with depth averaged velocity. For modelling of depth averaged velocity experimental data observed from Diverging channel with relative depth 0.25. The same experimental setup is modelled in ANSYS (Fluent) using LES model and CES (conveyance estimation software) to find depth-averaged velocity and it is compared with the data obtained from other researchers. The depth averaged velocity from both experimental work and numerical experimentation through ANSYS-Fluent package and CES is compared to evaluate the efficiency of the approached model.

Keywords- *depth averaged velocity, Fluent LES model, CES, Angle of divergence and convergence*

1. INTRODUCTION

River engineering is the analysis of hydraulic flow behaviours. Thus flow in simple and compound channel get affected by the channel geometry. During high discharge simple channel become compound channel as water flow out of the main channel boundary and thus develops flood plain. The analysis of flood plain is as important as main channel flow. When main channel flow interacted with flood plain then momentum transfer start. Due to transfer of momentum lateral distribution of flow start, this flow develops a complex secondary cell structures with main channel and floodplain. The rivers which have two stage channels gives advantage by increasing the channel conveyance. It is important to understand the complexity of river flow in both inbank and overbank flow. The difference in velocity flow from main channel and flood plain flow produces large turbulent and depth averaged velocity change form section to section. River structure generally classified as converging and diverging channel according to the flow condition. The depth averaged velocity changes according to the converging and diverging section and different shape of channel. The depth average velocity depends on roughness of channel, angel of divergence or convergence, and geometry of floodplain and main channel.

Field and laboratory studies are therefore essential in order to improve our knowledge of the flow mechanisms in prismatic and non-prismatic floodplains. However, it is incredibly hard to give adequately exact and thorough field estimations in natural rivers system where unsteady flood flow conditions are generally develop. Laboratory studies are therefore needed in order to improve our knowledge about the effect of overbank flows on flow behaviour in compound channel with both prismatic and non-prismatic floodplains, and to develop more accurate predictive models. The fluvial used in this study is a non-prismatic compound channel which means throughout the length the cross section of river is not uniform. The river system generally develop both converging and diverging type banks when it flow in the city or between hills then converging type of passage developed and when it flow in the open then wide bank shows diverging type passage. The purpose of constructing such model is to know hydrological behavior of the natural river system which passes through a packed area and its floodplain is reduced to null by human township and building construction. The devastation produced by the flood is generally due to change of energy due to divergence or convergence in the floodplain. The total energy loss can be calculated by using the conservation of energy theorem. Recently, a number of two-dimensional and three-dimensional approaches to modelling the depth-averaged velocity and the boundary shear stress distributions have been developed.

Knight and Mohammed (1984) reported that due to the presence of this shear layer, the conveyance capacity of the main channel decreases, while on the floodplain it increases. However, this interaction between the main channel and the floodplains decreases the conveyance capacity of the whole cross section. **Myers (1987)** has explained that the theoretical considerations of ratios of main channel velocity and discharge to the floodplain values in compound channel which follow a straight line relationship with flow depth and are independent of bed slope but dependent on channel geometry only. Among them, the Shiono and **Knight method (SKM) (Shiono and Knight1991)** was developed, based on the depth-averaged Navier–Stokes (N–S) equations, for predicting the lateral distributions of depth averaged velocity and boundary shear stress in prismatic compound channels. Lambert and Sellin (1996) used the mixing length concept, and Ervine et al. (2000) used the depth-integrated N–S equations to obtain the lateral distribution of velocity. **Shiono and Knight (1999)** proposed a model which resolve were based on the depth-averaged flow velocity U(y), as a function of the cross-channel coordinate, to improve the prediction capability. Knight *et al*. (2007) calculate the lateral distributions of depth-averaged velocity and boundary shear stress by using new SKM model by Shiono and Knight (1988) for flows in straight prismatic channels which also accounted secondary flow effect. **Rezaei and Knight (2009)** developed the SKM for compound channels with non-prismatic floodplains by introducing an interface shear stress between adjacent compartments parameterized in terms of the velocity difference between main channel and floodplains and the channel dimensions. Substituting the energy line slope (Se) with the channel bed slope (S0x), the convergence effects were accounted. This method was named the modified SKM. **Rezaei and Knight (2011)** investigated the discharge distributions along three non-prismatic compound channel configurations for different converging angles. They also found that the discharge evolution seems linear for lower water depths; whereas non- linear for higher water depths and in the second half of the converging length the mass transfer is higher than that in the first half of the converging reach i.e. velocity increases significantly in the second half of the converging length. **HOJJAT ALLAH YONESI (2013)** investigated that increasing the depth ratio or decreasing roughness ratio the velocity gradient between main channel and floodplain at middle and end of divergence reach decrease. Increasing angle of divergence led to an increase in the gradient of velocity. Percentage divided discharge directly was impressed by roughness ratio and depth ratio. With an increase in the roughness on floodplain surface, the shear stress gradient increases.

2. MATERIAL AND METHODS

In this paper, two channel geometry used to observed the experimental data 1) Non –prismatic diverging channel 2) Non prismatic converging channel. For diverging channel, analytical model was validated by comparing the computed results with experiment were performed in non-prismatic compound channel flume with 15 m length and 1.2 m wide by **HOJJAT ALLAH YONESI (2013)**. In this non prismatic compound shape, 5m of the upstream taken as main channel and then diverging start. The roughness value (n) for main channel and flood plain considered same. The experimental data were taken from 6 m and 7 m length from the starting inlet flow and the main channel width (d) 0.4 m.

Table 1. Diverging non-prismatic compound channel

Flow depth H(m)	Roughness value (η)	Q_{actual} (lit/s)	Depth ratio dr=(H-h)/H	Diverging angle(ϴ)	Flume size(m^3)	Main channel depth (h) (m)	Slope of channel Se
.24	.0139	50	.25	11.31	15*1.2*.4	.18	.00088

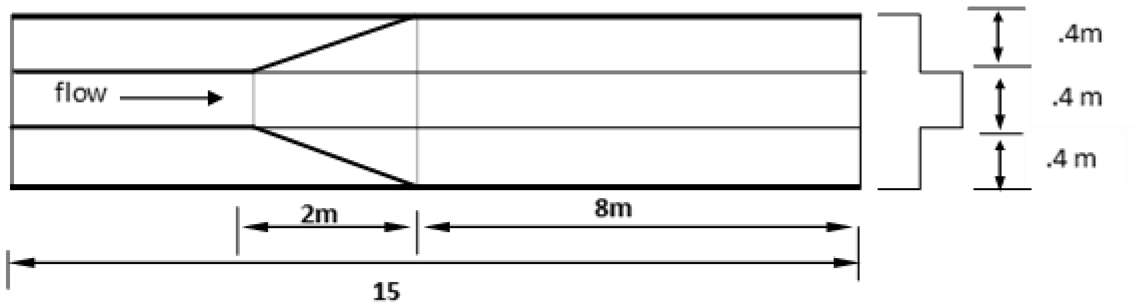

Figure 1. Schematic view of diverging channel (ϴ=11.31°)

The second part of this analysis involved numerical modeling of hydrodynamics via 3D CFD model in the selected portion of analytical model through the use of field dimensions managed at the study site. They include modelled-stress depletion and grid-induced separation, depth average velocity, boundary layer and slow development of LES content in separated shear layers. In many cases, adhoc efforts to improve performance relative to one of these issues (for example modification of the grid scale definition to promote rapid growth of LES in separated flow regions) leads to an exacerbation of one or more of the others (further depletion of the modeled stress in the attached boundary layer).

Hodskinson (1996, 1998) was one of the first to present results using a commercial CFD. In this case FLUENT was used to predict the 3D flow structure in a 90-degree bend on the River Dean in Cheshire **Thomas and Williams (1995a)** and **Cater and Williams (2008)** simulated an asymmetric rectangular compound channel using LES for a relative depth of d*r* = 0.5. They have predicted mean stream wise velocity distribution, secondary currents, bed shear stress distribution, turbulence intensities, TKE, and calculated lateral distribution of apparent shear stress. **Kara *et al.* (2012)** compared the depth averaged velocities obtained by LES with calculated by analytical solution of Shiono and Knight Method (SKM), and concluded that the analytical approach to their problem requires calibration of the lateral eddy viscosity coefficient, λ, and the secondary current parameter, Γ.A number of CFD packages (Fluent, CFX, Star-CD, amongst others) are now available and have been used for research in water flows. In recent past, a good number of researchers have used these software packages for prediction of different aspects of 3D flow field's**.** In this work, an attempt has been made to improve the understanding of 3D flows in converging compound channels and diverging compound channels. For this purpose, a 3D numerical code FLUENT has been tested for its suitability for simulation of flood flows. Average N-S equations gives fundamental development of Large Eddy Simulation (LES). Large Eddy Simulation (LES) comprehends the spatially arrived at the average of N-S conditions. Large eddies are directly resolved, but eddies smaller than the mesh are modeled Less expensive than DNS, but the amount of computational resources and efforts are still too large for most practical applications.

3. RESULTS AND DISCUSSION

A variety of flow characteristics can be considered in the post-processing software of CFD packages and in the CES software. This work has been concerned with the velocity distribution and the results are compared with experimental measurements. In general the user should make an attempt to validate the simulation results with known data so that there can be some confidence in the solution. In the case of open channel flow, the validation is most likely to take the form of a comparison against physical measurements and a qualitative understanding of what features should be present in the flow.

3.1 Diverging compound channel

In the following analysis one can find that the CES produce an overestimated result over the entire channel including main channel as well as floodplain. Even though it's a 2D modeling technique, it gives comparable results in accordance to experimental dataset. Meanwhile, looking into 3D modeling (i.e. ANSYS-Fluent) it is clearly observable that the results are underestimated over the main channel but it show a good agreement over the floodplain. Results in ANSYS are in good agreement in middle section fig.3 (a) in comparison over end section fig.3 (b). In end section, it is visible that the main channel results are deviated in the 3D modeling due to the meshing discrepancies. Even though, unstructured meshing was considered throughout the channel but due to intricacies over non-prismatic channel is high, it is always better to redefine mesh over channel bed, wall and bottom simultaneously. Considering the contour mapping it is seen that the velocity profile is increasing over the top surface in both fig.4 (a) and fig. 4(b). Corresponding to the conclusion before it is observed that the velocity in the middle section is higher over top surface in comparison to the end section because of the fact that the channel cross sectional area is increasing over the length.

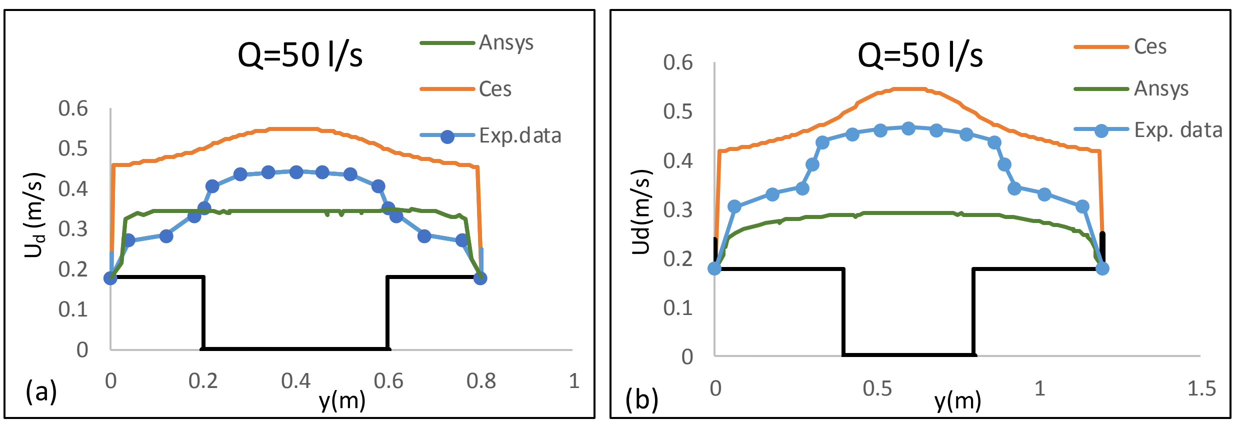

Figure 3. Comparison between computed (CES, ANSYS-FLUIENT) and experimental depth average velocity U_d in the rectangular non-prismatic diverging compound channel (a) middle and (b) end section for dr=.25.

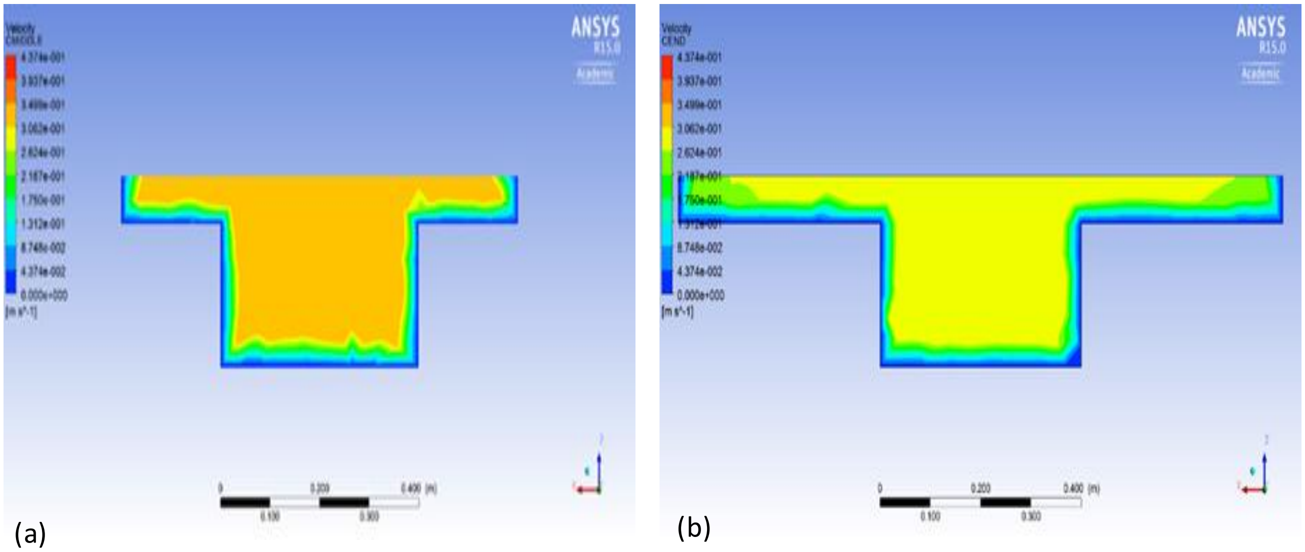

Figure 4. Contour of Computed (ANSYS-FLUIENT) depth average velocity U_d in the rectangular non-prismatic diverging compound channel (a) middle and (b) end section for dr=.25.

4. SUMMARY AND CONCLUSIONS

Data from two previous studies were used to develop and evaluate two models for predicting depth-averaged velocity distributions in non-prismatic straight rectangular compound channels.

A 3D model (ANSYS) and a 2D CES model have been applied to the past researcher experiments. Depth-averaged velocity measurements have been taken and plotted at two selected sections for diverging and three selected sections for converging compound channel. The Figures clearly show the following effects of the expansion and contractions on the velocity distributions:(a) the maximum velocity increases along the channel as the floodplains converge and vice versa for diverging channel; (b) the velocity in the second half of the converging reach increases significantly due to water leaving the floodplains and coming into the main channel at the end of the convergence which is not in the case of divergence; (c) 2D modeling by CES is constantly overestimates the depth average velocity in both channels. While 3D ANSYS modeling underestimate but gives closer value to the experimental datasets; (d) over main channel ANSYS gives reliable result.

NOTATION

Symbol	*Description*	*Unit*
d	Main channel width	[m]
D	Flood plain width	[m]
x	Stream wise direction	[m]
y	Lateral distance across section	[m]
V_d	Depth-averaged velocity	[m/s]
τ_{yx}	Reynolds stress	[N/m^2]
dr	Relative depth	[-]
(Se)	Energy line slope	[-]
(S0x	Channel bed slope	[-]
(n)	Roughness coefficient	[-]
τ_b	Bed shear stress	[N/ m^2]
β’	Coefficient for the influence of lateral bed slope on the bed shear stress.	[-]
λ	Lateral eddy viscosity coefficient	[-]
Γ	Secondary current parameter,	[N/m^2]
ρ	Density of the fluid	[Kg/m^3]
H	Water depth	[m]
$\overline{U}$	Time-averaged streamwise flow	[m/s]
$\overline{V}$	Time-averaged spanwise flow	[m/s]

REFERENCES:

Cater JE, Williams JJR. (2008) Large eddy simulation of a long asymmetric compound open channel, Journal of Hydraulic Research 46: pp. 445-453

Donald W. Knight, John D, Demetriou, and Mohammed E. Hamed (April, 1984) Discussion of *Boundary Shear in Smooth* Rectangular *Channels*. Journal of Hydraulic Engineering, 113(1):119-120 Hodkinson A (1996) Computational Fluid Dynamics as a Tool for Investigating Separated Flow in River Bends, Earth Surface Processes and Landforms, Vol. 21.

Hojjat Allah Yonesi, Mohammad Hossein Omid and Seyed Ali Ayyoubzadeh (2013) The Hydraulics of Flow in Non-Prismatic Compound Channels. Journal of Civil Engineering and Urbanism 3(6): 342-356.

Kara, M. C, Stoesser, T. and Will, K (2012) A Numerical Method to predict fluid structure interaction of flow past an elastically mounted circular cylinder. International Offshore and Polar Engineering Conference, Rhodes, Greece, June 17–22

Lambert, M. F., and Sellin, R. H. J. (1996). Discharge prediction in straight compound channels using the mixing length concept. Journal of Hydraulic Research 34 (3): 381–394.

Myers WRC (1987) Velocity and discharge in compound channels. Journal of Hydraulic Engineering 113(6):753-766.

Rezaei, B. (2006), Overbank flow in compound channels with prismatic and non-prismatic floodplains, PhD Thesis, Univ. of Birmingham, U.K.

Rezaei B and Knight DW (2009) Application of the Shiono and Knight Method in compound channelswith non-prismatic floodplains. Journal of Hydraulic Research, 47(6): 716–726

Rezaei B and Knight DW (2011) Overbank Flow in Compound Channels with Non-prismatic Floodplains. Journal of Hydraulic Engineering, 137(8): 815-824.

Shiono, K. and Knight, D. W. (1991). Turbulent open channel flows with variable depth across the channel. J. Fluid Mech., 222,617–46.

Shiono, K. and Knight, D.W. (1988) Two-dimensional analytical solution for a compound channel. Proceedings of the 3 rd International Symposium on Refined Flow Modelling and Turbulence Measurements, Tokyo, Japan, 503-510.

Shiono K, Muto Y, Knight DW, Hyde AFL (1999) Energy losses due to secondary flow and turbulence in meandering channels with overbank flows, Journal of Hydraulic Research 37: pp.641-664

Thomas TG and Williams J (1995b) Large eddy simulation of turbulent flow in an asymmetric compound open channel. Journal of Hydraulic Research 33(1): pp. 27-41.

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