MAJOR PROJECT II REPORT ON

FLOW ANALYSIS IN COMPOUND OPEN CHANNEL FLOW USING ANSYS

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE IN MASTER OF TECHNOLOGY

IN

HYDRAULICS AND FLOOD CONTROL ENGINEERING

SUBMITTED BY
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JUNE 2017

CERTIFICATE

This is to ensure that the work titled, “Flow Analysis in Compound open channel using Ansys ” submitted by Dharmendra Bhardwaj (2K15/HFE/07) has been carried out under my supervision at DELHI TECHNOLOGICAL UNIVERSITY, DELHI .This work has not been submitted partially or fully to any other university or institute for the award of any degree.

Signature of Supervisor ....

Name of Supervisor DR.T VIJAY KUMAR

Designation ASSISTANT PROFESSOR

Date ……/……/……………

DECLARATION

I therefore, proclaim that this report is my own work and that, to the best of my insight and conviction, it contains no material already distributed or composed by someone else nor material which to a considerable degree has been acknowledged for the honor of whatever other degree or confirmation of the college or other foundation of higher learning, with the exception of where due affirmation has been made in the content.

Signature…………
Dharmendra Bhardwaj
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ABSTRACT

Flooding in Indian rivers is a very serious problem which affects the livelihood and financial condition of that place. This problem has been identified by many Researchers like Tominaga and Nezu , Ackers and V.T Chow. A lot of research work has been devoted to find out desirable solution of flooding problem. While flooding, river flows with high discharge which overflows on its banks and excess water reaches to its flood plains, this excess water leads to formation of compound channel. The nature of flow during flooding is generally turbulent in nature. It has been found that the velocity of flow in flood plain is less than the velocity of flow in main regular channel. It is a well known fact that this change in velocity leads to formation of a shear layer. These shear layers produce resistance to flow, which leads to uncertainty in forecasting of flow and also increases resistance on channel. Geometric similar model can be utilized to find out necessary information. Generally one dimensional empirical model can be used to forecasting of flow taking assumption that flow is uniform in compound channel. However, Compound open channel has partially uniform flow due to momentum transfer in sub sections and unexpected change in depth of flow. Hence the analysis of turbulent flow is necessary in this situation. In Past, researchers have used various models to analyze turbulent flow in compound open channels, basically for low development length. Hence, in this study an effort is made to analyze the turbulent flow by Large Eddy Simulation method (LES) to forecast the flow and its resistance on channel. The LES is carried out by taking sufficient development length so that uniform turbulent flow can be developed. The development length is incorporated in the computational domain. It is fact that experimentally flow analysis of compound open channels with various hydraulic conditions is very expensive and difficult. Hence, this analysis of flow is done by using software approaches such as used in Ansys Software.

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LIST OF ABBREVIATIONS

CFD	Computational Fluid Dynamics
N-S	Navier-Stokes equation
LES	Large Eddy Simulation
DNS	Direct Numerical Simulation
SGS	Sub grid scale
BPNN	Back-Propagation Artificial Neural Network
COC	Compound Open Channel
SCM	Single Channel Method
VDM	Vertical Division Method
COHM	Coherence Method
EDM	Exchange Discharge Method
FCF	Flood Channel Facility
FIS	Fuzzy Inference System

LIST OF SYMBOLS

A	cross-sectional area
Ar	aspect ratio
B	In-bank channel width/over-bank channel half width
c	log-law constant
Cr	Courant number
Dr	depth ratio
E	location of secondary flow cell centre
f	Darcy-Weisbach friction coefficient
ffp	floodplain friction factor
fmc	main channel friction factor
f	overall friction factor
g	gravitational acceleration
h	floodplain height
H	channel height

CHAPTER 1: INTRODUCTION

1.1 GENERAL

Rivers are always a symbol of beauty in world. Many People have been living close to the banks of waterways from hundreds of years for the need of sustenance, water, and agribusiness. Despite the fact that, flooding issue in waterways has been a significant issue for person as this harms a much loss of property and lives of people groups and creatures. Henceforth, the rate of event of surges has expanded as of late because of environmental change, over the top human mediation, developing populace on the banks of waterways and industrialization. In this manner, it is required to take certain measures to comprehend flooding circumstances by breaking down the idea driving it. Streams having limit of passing on direct stream until the point that the stream is bound to its principle course. Be that as it may, when stream step by step expands, the water transcends bank and floods to the surge fields. For whatever length of time that the stream profundity of the surge plain is little and not practically identical to profundity of fundamental channel, the mean speed of principle channel is bigger than the surge plain and conveys more release than surge fields. It is basic to examine the stream structures that exist in compound open channels to comprehend the circulation of stream and its factors. The cooperation between the essential longitudinal speed and the auxiliary stream speeds are in charge of non-uniform dissemination of stream factors in a compound open channel stream. This non-uniform circulation of stream factors changes resistance of stream over the wetted border of compound open channel stream. In such circumstances the adjustment in resistance of stream is composite and makes distinction in singular fundamental channel and surge plain resistance been made in the content. From mid eighteenth century numerous exact models are demonstrated to experience the disparities in estimating composite grinding variable and release in compound open channel. Floods happen when principle channel has serious release and this extreme release takes after towards the flood plain fields. The channels framed so are known as compound channels. Numerous down to earth issues in flow designing require precise estimating of flow in compound open channels. For instance, the water driven reaction to flood counteractive action measures, for example, digging in the fundamental channel and bringing down or smoothing in the floodplains, relies on upon flow speeds in these regions. It is realized that, neighborhood flow conditions decide the disintegration and testimony rates of residue in the principle channel and floodplains. Henceforth, exact expectation of release limit of compound channels is greatly fundamental to suggest in flood relief plans. Waterways are equipped for passing on direct flow until the point when the flow is kept to its primary course. Be that as it may, when flow slowly expands, the water transcends bank and floods to the flood fields. For whatever length of time that the flow profundity of the flood plain is little and not tantamount to profundity of principle channel, the mean speed of primary channel is bigger than the flood plain and conveys more release than floodplains. The distinction of these flow speeds in both these subsections makes vertical Vortices (as appeared in Figure 1.1) along the vertical interface of primary channel and flood plain. These Vortices are made because of force and mass trade between flood plain and principle channel, which produces shear constrain and additional resistance expending additional vitality. Because of the utilization of this additional vitality the expectation of stage release bend ends up noticeably hard to get.

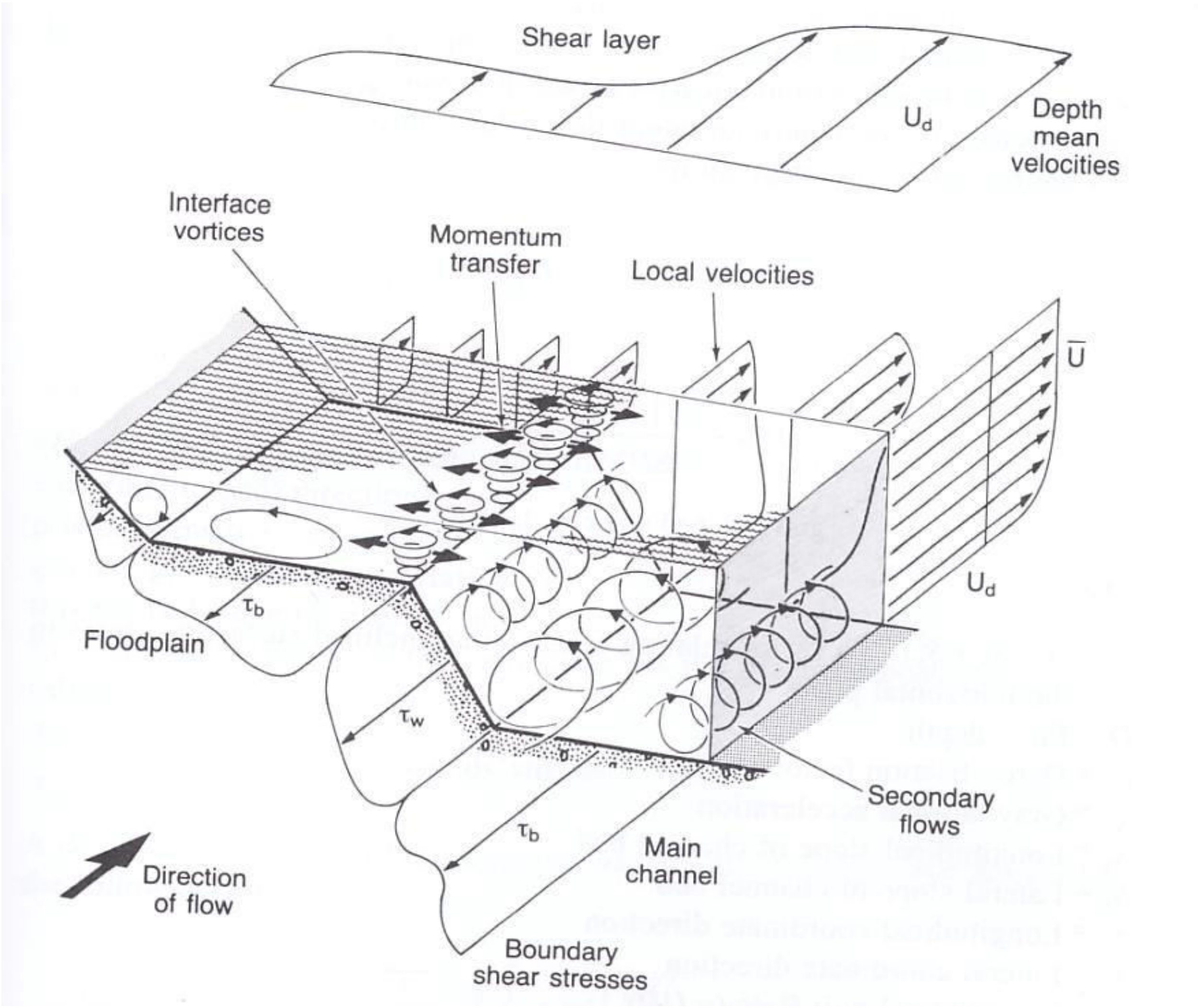

Fig. 1.1 Details of Hydraulic parameters connected with overbank flow (Knight & Shiono 1991)

1.2 AIM AND OBJECTIVE OF PRESENT WORK

Generally nature of flooding is turbulent in compound channel. This turbulent nature of flow in compound open channel is three dimensional because of solid secondary flow. It is notable from past analysis that turbulent flow has coordinate effect in estimating the flow and its resistance on compound channel. To discover flow, the common models known as Single Channel Method, Divided Channel Method and so forth give more error in gauging of flow and furthermore for composite friction factor variable. In this manner, it is important to acquire the information of turbulent flow to examine the impact of flow in open channel flows. Henceforth, in this investigation an exertion is made to break down the turbulent flow by Large Eddy Simulation strategy (LES) to conjecture the flow and its resistance on channel. The LES is done out by taking satisfactory development length so that uniform turbulent flow can be produced. This technique is utilized to get itemized data of state of flow and its resistance on the compound channel. This investigation has an examination of resistance in compound open channel flow and improvement of sufficient versatile techniques for anticipating composite grinding variable and release in compound open channel. The present examination has following perspectives:

(1) Study of turbulent flow in a compound channel using Large Eddy Simulation turbulent method.

(2) Verification and validation of turbulent flow variables such as velocity distribution, discharge, and boundary shear stress. The experimental results are available in the literature.

(3)Validation of the developed models with the models of different researchers applied to different compound channels with different hydraulic conditions

1.3 SEQUENCE OF THESIS

The report has been prepared in total six chapters as discussed below:

Chapter 1: A short introduction of the problem is defined.

Chapter 2: A comprehensive literature review is prepared.

Chapter 3: Numerical CFD analysis of turbulent flow structure of open channel.

Chapter 4: This chapter includes Analysis of discharge prediction models with formation of a BPNN approach to forecast discharge.

Chapter 5: Final outcome and future scope of study are presented

Chapter 6: References

CHAPTER 2 : LITERATURE REVIEW

2.1 GENERAL

As we know that during flooding it is so difficult to do field analysis, investigations & data collection. Hence researchers generally prefer experimental techniques in laboratories to understand the serious phenomenon of flooding problem. But these techniques have some limitations, as data obtain from these techniques can only be collected at a limited number of points. This modeling and detailed turbulence measurement generally cannot be taken. Hence, a computational approach can be used to mitigate some of these issues and gives an alternative tool. Normally, a computational approach is promptly done again and can reenact at full scale and gives a vast scope of field information focuses. In most recent couple of years numerical demonstrating of compound open channel streams has effectively replicated exploratory information comes about. Computational Fluid Dynamics (CFD) has been utilized to break down the model of open channel streams going from principle channels to full-scale displaying of surge plain. One other hand Simulations have been performed by Krishnappan and Lau (1986), Larson (1988), Kawahara and Tamai (1988) and Cokljat (1993). More numerical enumerating of displaying has been performed by Thomas and Williams (1995a; 1995b; 1999) and Shi et al. (2001) to analyze the point by point time subordinate three dimensional nature of the flow in compound open channels. The resistance variables known as drag, resistance coefficient, limit shear stress, shear strength, channel harshness because of optional flow straightforwardly impacts the channel limit and assume an essential part in estimating release in compound open channels .Research concerning imperviousness to flow in compound open channel has been contemplated by such a large number of researchers, known as Lotter (1933),Pavolvoskii (1932), Einstein and Banks (1950) ,Krishnamurthy and Christensen (1972), Myers and Elsawy (1975) created models for the composite grating component. These models gave extension to additionally displaying on composite harshness and release estimation. Rajaratnam and Ahmadi (1979) pondered the stream participation between straight key compound open channel and symmetrical floodplain with extraordinarily smooth cutoff points. The results from them look at gives the vehicle of longitudinal constrain from central channel to surge plain. Posey (1967), Wormleation (1982) have done examinations and watched that the Darcy-Weisbach condition and the Manning's condition are not suitable for compound open channels. Knight and Demetriou (1983) done tests in straight symmetrical compound channels to grasp the farthest point discharge characteristics, discharge qualities confine shear stress and cutoff shear oblige movements in the portion. Knight and Hamed (1984) extended the work of Knight and Demetriou (1983) to unforgiving floodplains. Dracos and Hardegger (1987) proposed a model to predict composite contact compute compound open channel stream by considering vitality move into account and besides said that composite granulating component is depending upon essential channel and surge plain width and the extent between water driven traverse to the significance of the standard channel Pang (1998) drove tests compound direct in straight reaches under isolated and working together conditions. It was found that the scattering of discharge between the key direct and floodplain was according to the stream imperativeness adversity, which can be conveyed as stream resistance coefficient. Christodoulou and Myers (2004) measured the reasonable shear on the vertical interface between central redirect and surge plain in symmetrical compound portions. The undeniable shear extend is imparted the extent that a clear contact computes and the square of the speed differentiate between subsections. Yang et al. (2005) displayed the investigation of Manning's and Darcy's Weisbach condition and through immense number of gathered trial information demonstrated that Darcy's Weisbach resistance consider is an element of Reynolds number however the practical relationship is not quite the same as single channel. This approach is observed to be powerful once the unpleasantness coefficients and pressure driven sweep in various sub-locales have been determined,as well as the Nikuradse harshness stature and thought about the ordinary techniques for assurance of composite grinding element. They grasped that ordinary strategies are not reasonable for the forecast of composite resistance in compound channel stream. Hin et al. (2008) created strategy to anticipate release by methods for composite grating component.

CHAPTER 3: MODELING OF TURBULENT FLOW IN COMPOUND OPEN CHANNEL FLOW

3.1 GENERAL

Computational Fluid Dynamics (CFD) is a computer based scientific instrument. The developing enthusiasm on the utilization of CFD based reenactment by specialists has for quite some time been distinguished in different fields of building. It has begun around 1960 and with the procedure of change in equipment of PCs, CFD recreation is presently indicating surprising precision. The essential rule in the use of CFD is to break down liquid flow in-detail by settling an arrangement of non-straight overseeing conditions over the locale of enthusiasm, subsequent to applying determined limit conditions. The CFD construct reenactment depends with respect to joined numerical exactness, demonstrating accuracy and computational cost. Applications of CFD in open channel flow needs solving Navier-Stokes equation (N-S).These are the non-linear partial differential equations, which provide the fundamental basis for single phase fluid flow.

This processing of the numerical simulation of flow which uses the Navier - Stokes equation (N-S) generally involves these steps.

(a) Pre-Processing
(b) Solver and
(c) Post processing

3.2 SET UP OF GEOMETRY

Governing equations of fluid flow (continuity equation and momentum equation) are illuminated in light of space discretization which utilizes the Cartesian co-ordinate framework. his strategy incorporates disengaging the continuum into predetermined number of center points. The CFD counts require a spatial discretization plan and time strolling arrangement. Basically the zone discretization relies on upon Finite part, Finite Volume and Finite Difference Method. Restricted Element procedure relies on upon parceling the space into segments. The numerical course of action can be gotten in this method by organizing the shape work and weighted consider a legitimate space. This system is proper with respect to both sorted out and unstructured work. The utilization of Finite Volume strategy needs isolating the space into set number of volumes. Here the predefined components are processed by lighting up the discreitized condition in the point of convergence of the cell. This methodology is made by considering insurance law. Restricted Volume procedure is fitting for applying in unstructured territory. Restricted Difference procedure relies on upon Taylor's course of action estimation. This methodology is more sensible for standard space. The discretization of complex computational space is fundamental. These sorts of space don't concur with the co-ordinate lines with that of a composed system, which prompts figure of the geometry. The principle strategy to address complex computational region is to use a stepwise gauge. Regardless, such estimation is moreover troublesome and exceptionally repetitive. Further, the stepwise figure presents truncation botch and that can be overcome by giving fine Cartesian work. Thusly, structure of cross section lines brings on extra wastage of PC stockpiling in view of unnecessary refinement. Accordingly in this examination, the geometry of exploratory channel (S-1 case) grasped by Tominaga and Nezu (1991) is discretized with cross breed unstructured systems as showed up in Figure 3.1.These cross sections are blend of triangular and quadrilateral components used to build the matrix. The most productive element of unstructured work era is that, it permits the computation of flows in or around geometrical elements of discretionary multifaceted nature, for example, change of geometry from fundamental channel to flood plain, without investing more energy in work era and mapping. The channel flume had the setup of 8 m length and 0.4×0.4 m2 cross-segment as appeared in Figure 3.3. Geometry of the compound channel is made utilizing ANSYS 13 outline modeler and appeared in Figure 3.1. For this instance of experimentation, the profundity of flow in primary channel is 0.803 m, flood plain is 0.603 meter and B/H proportion is 4.981. The channel slope is 0.00064 m/m.

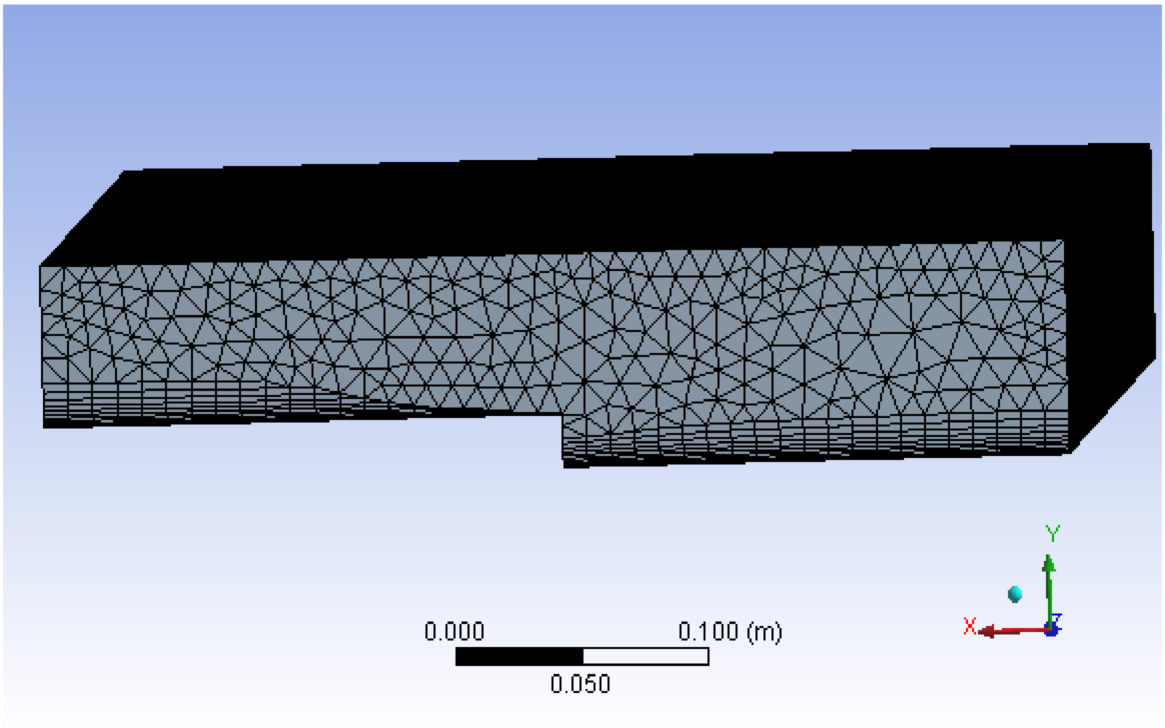

Fig 3.1 Hybrid mesh Schematic diagram

3.3 TURBULENCE MODELING

The nature of flow in compound open channel is turbulent. Gravity, channel geometry is essentially in charge of turbulent flow for this specific condition. Turbulence in nature is an irregular three dimensional time-subordinate eddying movement with numerous length scales. This is additionally effective transporter and blend of force, vitality constituents. The three dimensional nature of turbulent flow can be decayed into mean part and vacillation part, which is called Reynolds deterioration.

The spatial character of turbulence uncovers swirls with extensive variety of length scales. In turbulence, particles of liquid which are broadly isolated are united close by eddying movement. This makes the compelling trade of warmth, mass and energy. Figure 3.2 demonstrates the vitality course handle, where the bigger swirls are changed over to littler vortex and are at last disseminated. In this figure L = bigger turbulent length scale, Re = Reynolds number, lε = length scale at any phase for a specific Reynolds number. The turbulence in open channel is very intricate and the flow structure required in it makes vulnerability in forecast of flow factors. Especially in straight compound channel, turbulent structures are portrayed by substantial shear layers created by distinction of speed between principle channel and flood plain flow. This expansive shear layer district makes vortices both longitudinally and in addition vertically.

Further, turbulent structure, for example, auxiliary current (which is by and large determined by the anisotropy and in-homogeneity of turbulence) makes speed plunge and influences the flow. Despite the fact that, the impact of optional flows for waterway forms has for some time been perceived, however their source, mechanics, impacts and co-relations with essential mean flow and turbulence are as yet a matter of level headed discussion. Thus in this investigation an exertion has made to perceive the effect of the turbulence in compound open channel.

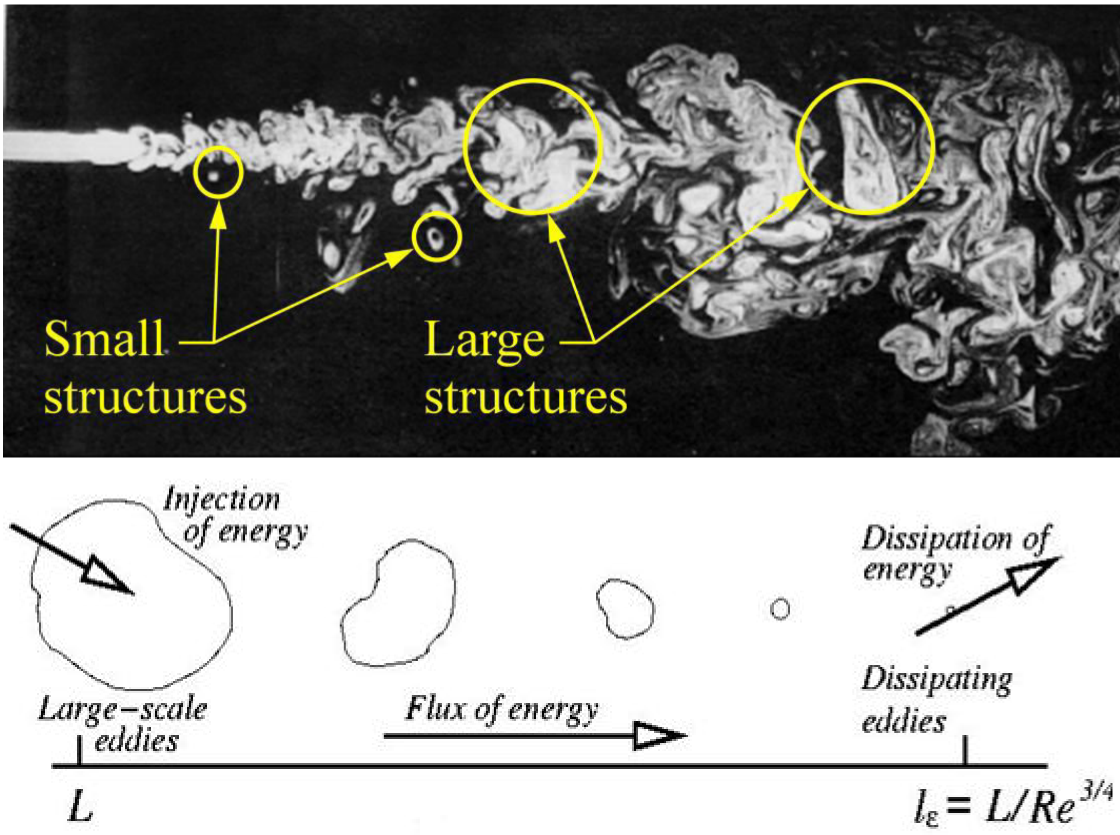

Figure.3.2. Energy cascading process with length scale.

3.4 BOUNDARY CONDITIONS

For a given computational area, boundary conditions are forced which can here and there over determine or under-indicate the issue. For the most part, in the wake of forcing limit conditions in non-physical area may prompt disappointment of the answer for unite. It is in this way critical, to comprehend the significance of very much postured limit conditions. The limit conditions actualized for this investigation are appeared in Figure 3.3. In this way, these conditions are talked about in detail.

3.4.1 INLET AND OUTLET BOUNDARY CONDITION

The channel revealed here permits the qualities on the gulf and outlet limits to met a one point, and a weight angle was again determined over the space to drive the channel stream. All Geometries were made level and the impacts of gravity and compound channel incline actualized by means of a settled gravity vector in ANSYS. It speaks to the point between the channel incline and the flat, the gravity vector is settled in x, y and z segments as (0, -ρg sinθ, ρg Cosθ) Where θ = angle between bed surface to even pivot. Here, the z part means the course in charge of stream of water along the channel and the y segment is in charge of making the hydrostatic weight. From the reproduction, y part of the gravity vector (- ρg sinθ) is observed to be in charge of the meeting issue of the solver.

3.4.3 WALL

A no-slip limit condition is the most well-known limit condition actualized at the divider and recommends that the liquid close to the divider gets the speed at the divider, which is zero. $U = V = W = 0$

Fig 3.1 Table of Simulation subtle elements and Meshing Using ANSYS-CFX

Type	Spacing of mesh (m)	Y_+ Range	H/u* (Sec)	Step Size (sec)	LETOT Initial	Trail
S-1	0.005	9.24-110.7	5	0.001	70	10

3.5 SOLVER

ANSYS-CFX solver supervisor is utilized to do the reproduction procedure. Here the Advection expression is discretized with limited focal contrast plan and transient terms are discretized with Second request plot. Courant number (Cr) is controlled between 0 - 0.5. From that point onward, the condition is iterated again and again till attractive level of precision of 10-6 of lingering esteem is accomplished.

3.6 POST PROCESSING: ANALYSIS OF TURBULENCE MODEL

3.6.1 FLOW PARAMETERS

Tominaga and Nezu (1991) has done experimentation by using fiber-optic Laser-Doppler Anemometer to measure three directional sections of turbulent speed. Their data is possibly available for examination and proliferation. They saw that, the stream is believed to be uniform incompressible turbulent stream at the test zone of 7.5 m. Thusly, to combine this length of channel is taken as 8 m, in light of the way that the uniform stream is created after this length around. The water fueled traverse (R) of the channel is 0.043m. The Reynolds number (Re) of the stream for the case S-1 is 67200.

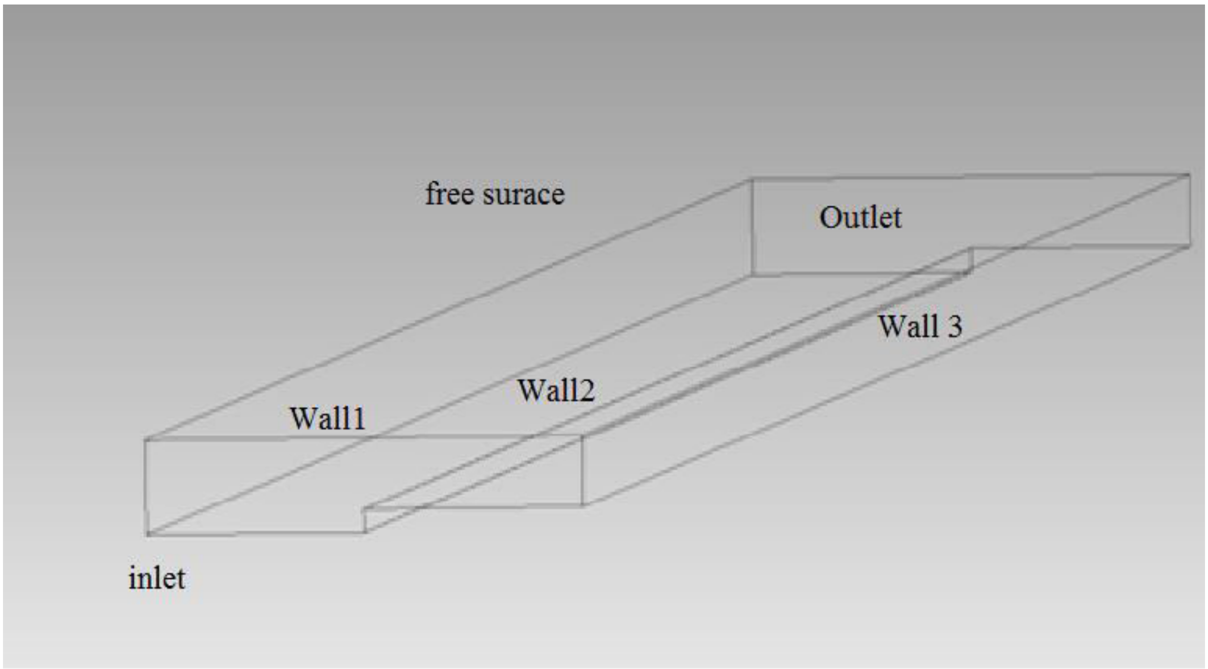

Fig 3.3 Schematic presentation of geometric alignment and boundary conditions of the channel

3.6.2 RESULTS

The numerical reenactments are completed by utilizing ANSYS-CFX solver and these outcomes are contrasted and the exploratory information comes about.

The outcomes are classified in Table 3.2.

$$W_b = \frac{\int w dA}{A} \qquad (3.1)$$

Where, Wb = Bulk Velocity along Flow-line of stream. w = flowline speed anytime, A = Cross segment territory of the channel. The composite Manning's grinding component is figured from Manning's condition.The numerical simulations are carried out by using ANSYS-CFX solver and these results are compared with the experimental data results.

The results are tabulated in Table 3.2.

Table 3.2 Comparison of the experimental and simulation results

Case	Max.Velocity W_{max}(m/s)	Mean of Bulk Velocity W_b (m/s)	Discharge (m3 /s)	Composite manning's 'n'	Shear Velocity u* (m/s)
S-1 (Tominaga and Nezu 1991)	0.409	0.368	0.00738	0.011383	0.0161
Present LES simulation	0.4047	0.366	0.00737	0.011381	0.01604

3.6.2 VELOCITY DISTRIBUTION

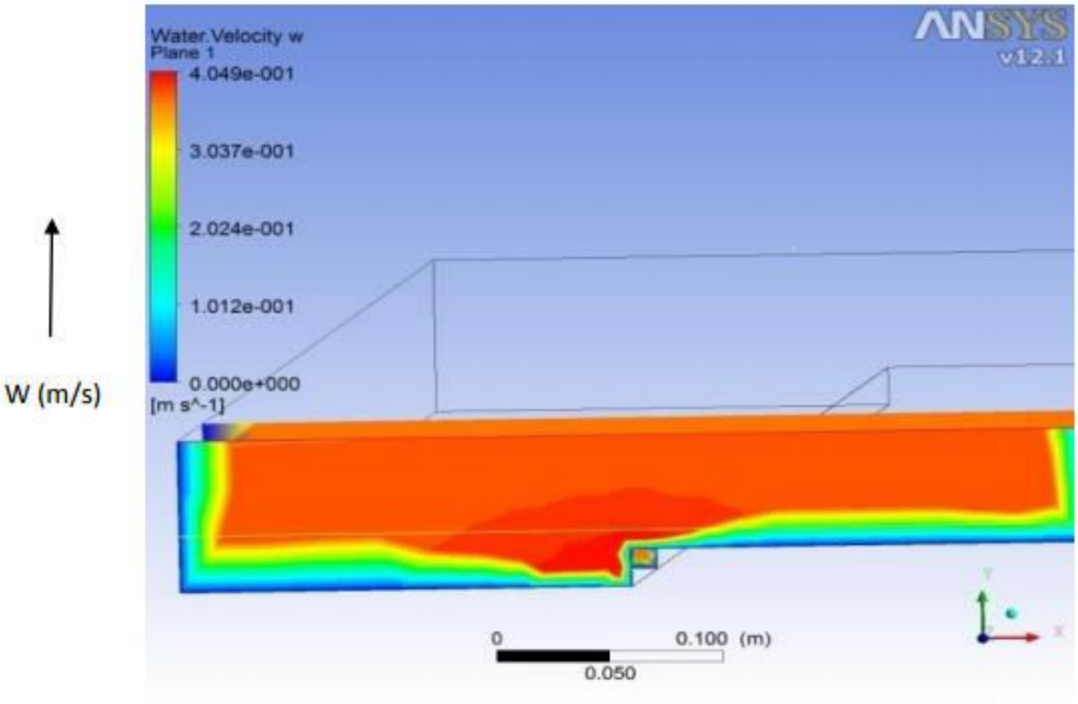

Fig 3.4 Mean Velocity distribution of LES Simulation

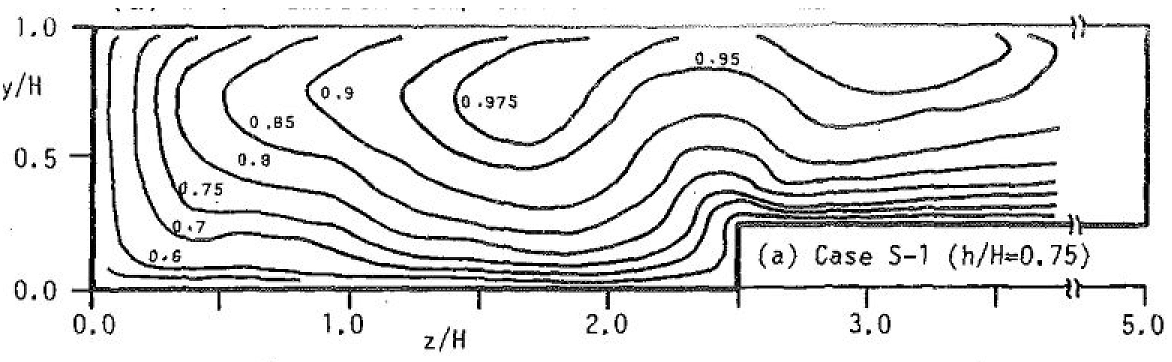

Fig 3.5 Mean Velocity distribution of experiment. (Tominaga and Nezu 1991)

The isovel-lines of the non-dimensional stream savvy speed W (z) are prepared by LES methodology as showed up in Figure 3.4. It shows up from multiplication that most extraordinary speed is 0.4049 m/s and can be seen close centerline of channel at about 0.057m from centerline of the channel.

The mass speed is 0.367 m/s. Isovel lines swell through and through upward in the locale of the crossing point edge along the stream. The cases of the isovel lines are convincingly trailed by LES propagation happens with the trial delayed consequences of Tominaga and Nezu (1991) as showed up in Figure 3.6. The reason of this knot is the decelerated zone on the both side of the convergence locale of essential channel. The decelerated region is made in perspective of low-constrain transport in view of discretionary current a long way from the divider. This causes the bump in the standard channel and surge plain interface as a result of high vitality transport by assistant current. In this manner, fundamental speed is direct affected by drive transport due to assistant current. Figure 3.6 shows the appointment of non-dimensional significance landed at the midpoint of speed head. It exhibits that speed head peaks in the point of convergence of essential redirect and possibly in the floodplain. Significance touched base at the midpoint of speed is determined from Eqn. (3.2):

Equation 3.2 is given below

$$W_d = \frac{1}{H}\int_0^H w dy$$

Where W_d *is* depth averaged velocity along flowline, H = depth of flow.

The peak value of the depth averaged velocity head lies at the main channel just before the junction of main channel and flood plain. Also a subsequent small peak can be observed on the flood plain. It shows the maximum depth averaged velocity lies velocity at main channel with and subsequently at the flood plain which is on line with Cater and Williams (2008).

The mass speed is 0.367 m/s. Isovel lines swell altogether upward in the region of the intersection edge along the flow. The examples of the isovel lines are convincingly trailed by LES reproduction comes about with the trial aftereffects of Tominaga and Nezu (1991) as appeared in Figure 3.6. The reason of this lump is the decelerated area on the both side of the intersection district of primary channel. The decelerated locale is made in view of low-force transport because of optional current far from the divider. This causes the lump in the principle channel and flood plain interface because of high energy transport by auxiliary current. Therefore, essential speed is straightforwardly influenced by force transport because of auxiliary current. Figure 3.6 demonstrates the appropriation of non-dimensional profundity arrived at the midpoint of speed head. It demonstrates that speed head crests in the focal point of primary divert and marginally in the floodplain. Profundity arrived at the midpoint of speed is ascertained from eqn. (3.2):

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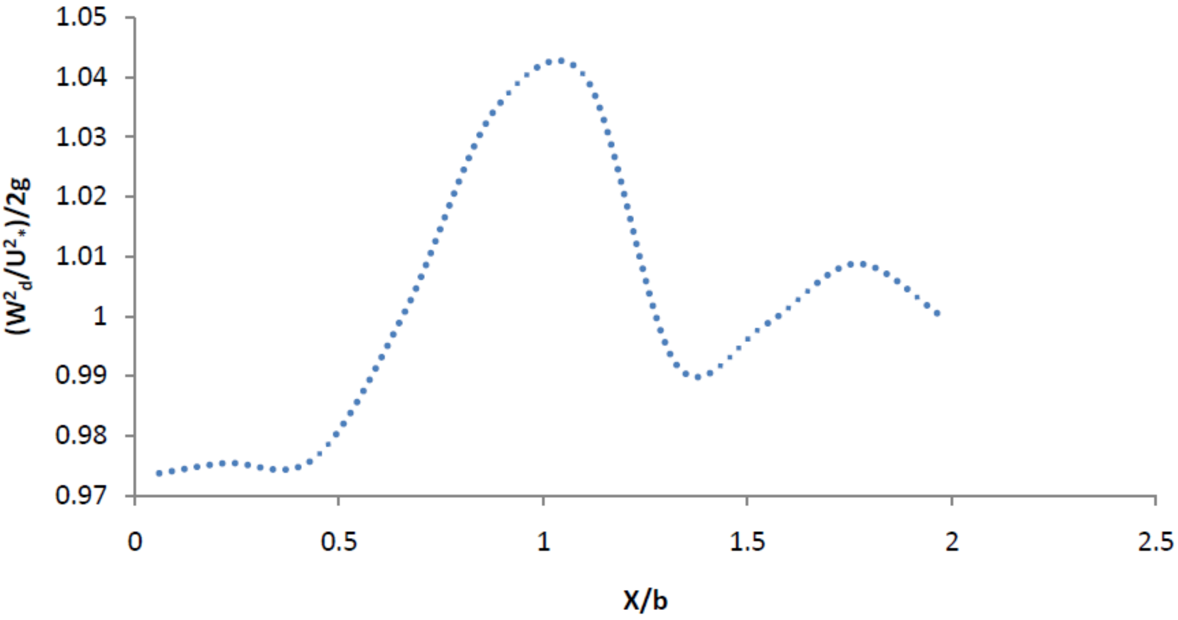


Fig 3.6 The distribution of depth averaged velocity head.

3.6.4 BED SHEAR STRESS

The appropriation of the non-dimensional bed shear push (τ /τ avg.) acquired after reenactment is exhibited in Figure 3.7. The example of dissemination is observed to be conveyed equitably with the test comes about. The real dissemination of bed shear worry in trial comes about achieves two pinnacle one at flood plain and other at the fundamental channel. The reenactment result has likewise achieved a similar example and which indicate high level of exactness of recreation. The dispersion demonstrates that the pinnacles can be watched both side of the intersection of the fundamental channel and flood plain. The normal bed shear conveyance in principle channel is observed to be lesser than the flood plain.

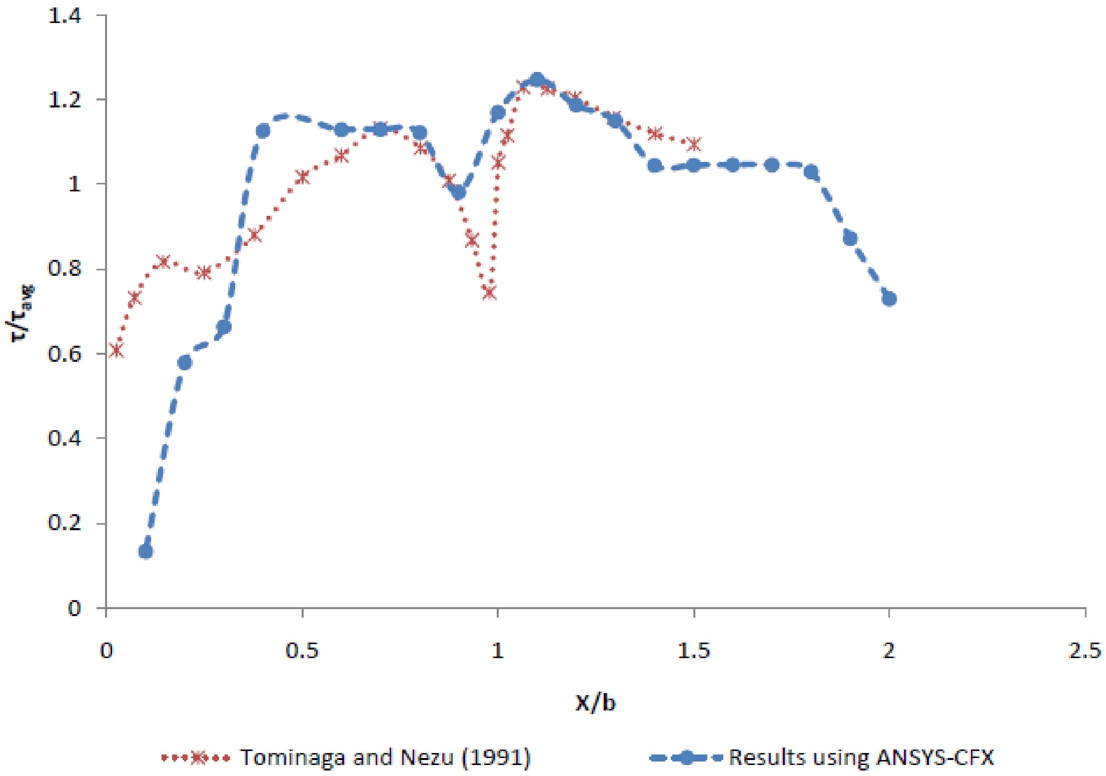


Fig 3.7 The distribution of non-dimensional bed shear stress

3.6.5 SECONDARY CURRENT

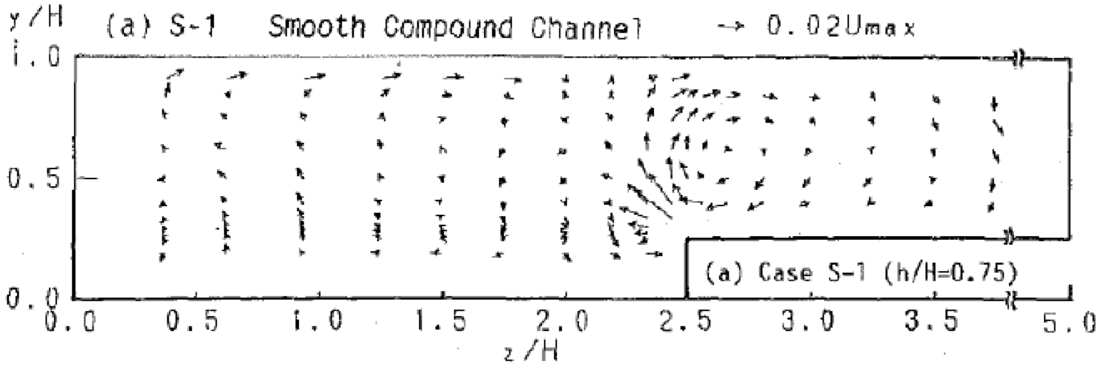


Fig 3.8 Experimental velocity vectors from experimentation ((Tominaga and Nezu1991)

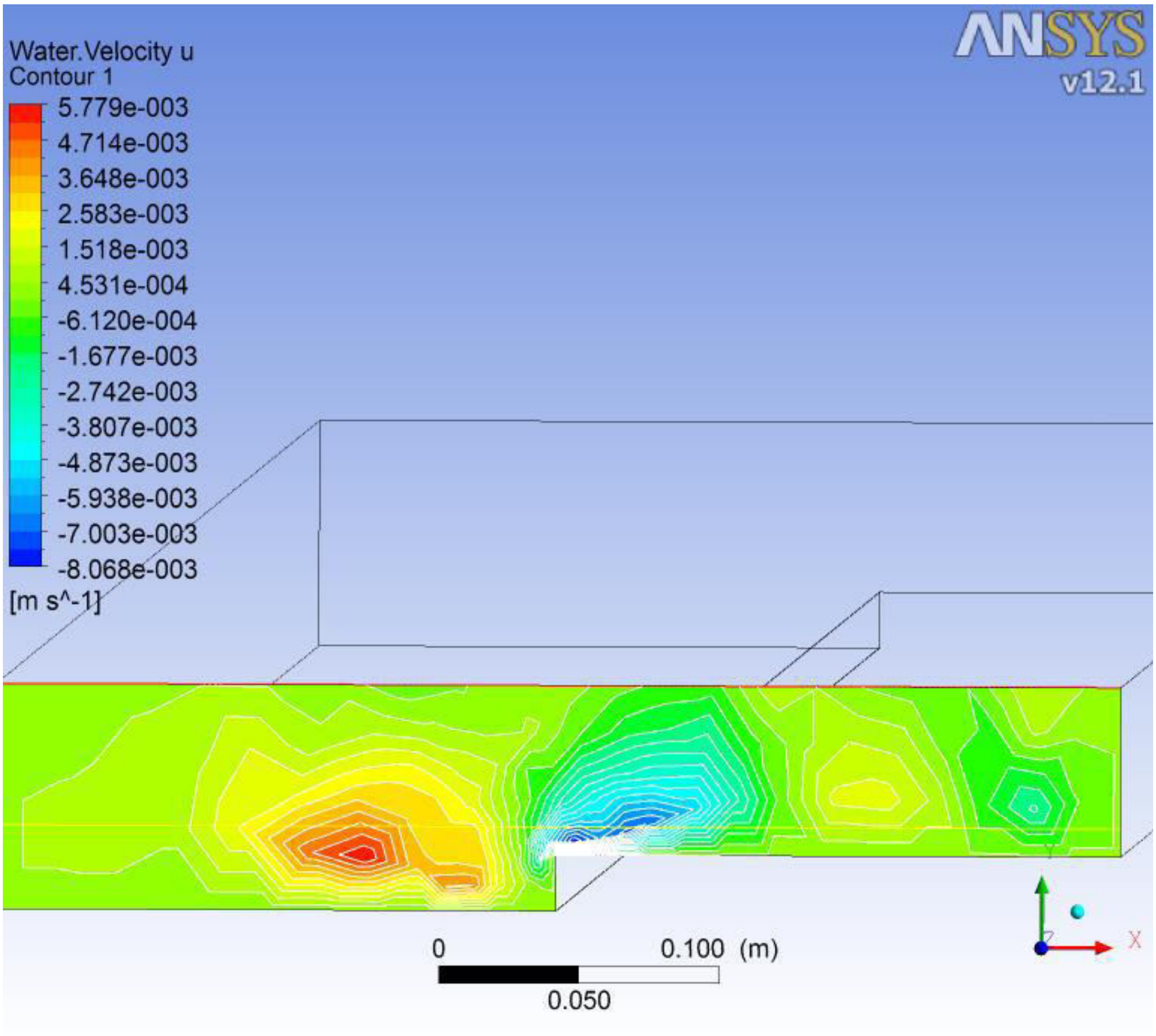


Fig 3.9 Flow-wise non-dimensional averaged secondary velocity contours

From Figure 3.8 and Figure 3.10, it can be observed a pair of secondary currents on the both side of the junction of the main channel and flood plain. These currents can be regarded as longitudinal vortex as mentioned by Tominaga and Nezu (1991).The vortex in flood plain reaches the free surface.

The mean secondary velocity contours show circulation at the main channel corner, main channel flood plain interface, at the corner of flood plain as shown in Figure 3.9. Which are quiet convincing with experimental secondary current vectors as shown in the Figure 3.8. These resemblances of result have significant contribution on the distribution of average velocity. The large counter rotating secondary structure produces usual velocity dip and has maximum impact on flow wise velocity

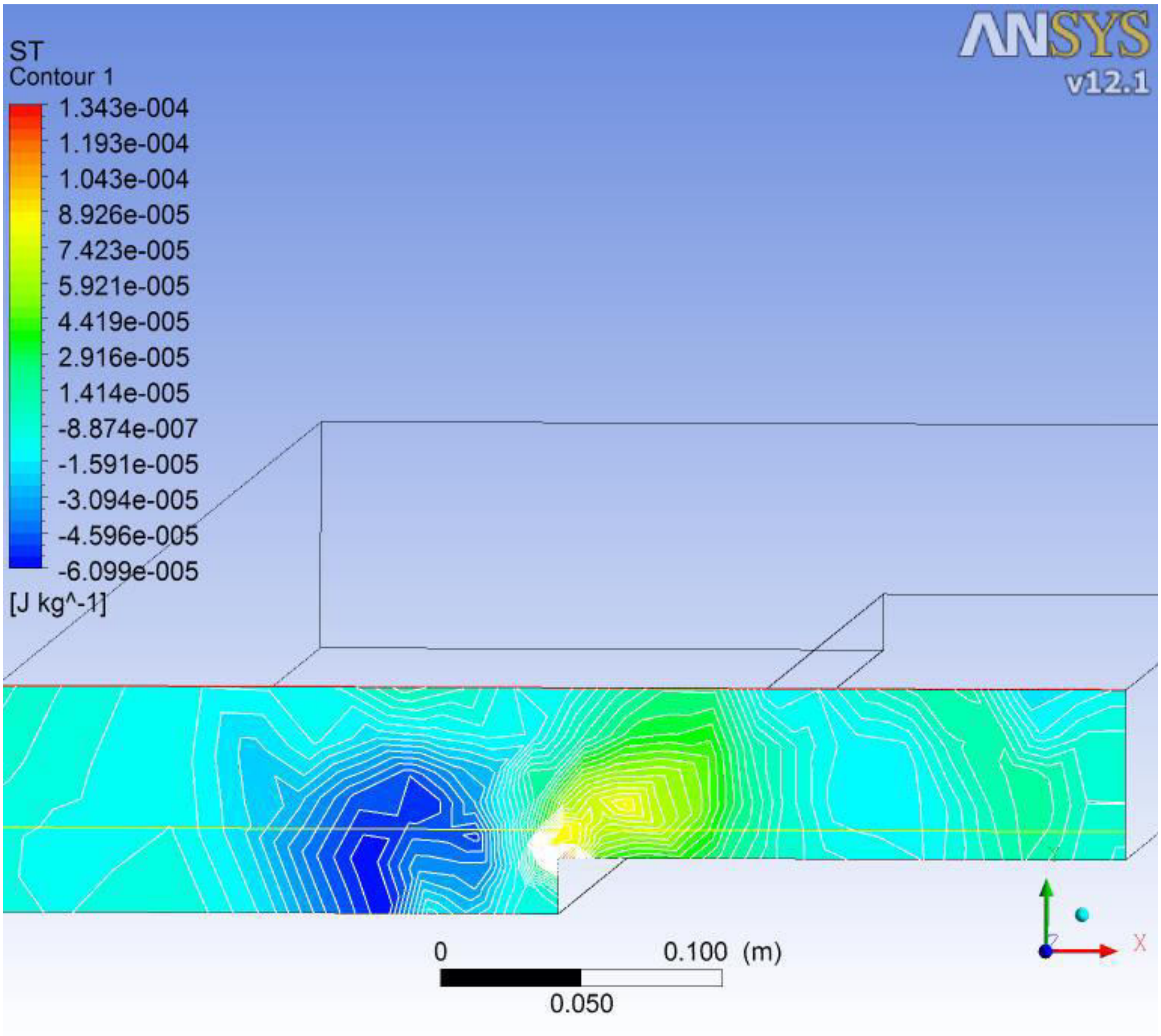


Fig 3.10 Lateral distribution of secondary circulation component (T)

The momentum transfer due to secondary circulation component and turbulent transport is shown in Figure 3.10. Apart from momentum transfer phenomenon, the turbulent flow structure also depends upon the corner of the channel and shape of the compound cross-section. The channel corner circulations can be observed from Figure 3.10. This also retards the flow and exerts resistance.

CHAPTER 4

FLOW ANALYSIS IN COMPOUND OPEN CHANNEL

4.1 GENERAL

In the present study, four well known methods are studied and compared with developed BPNN model to predict the discharge in compound open channel flow. These are (i) Single Channel Method (Chow1959) (ii) Vertical Division Method (Lotter 1993, Khatua et al. 2011) (iii) Coherence Method (Ackers‘1999) and (iv) Exchange Discharge Method (Bousmar and Zech 1998). These methods are applied to the compound channels of different hydraulic conditions. The proposed BPNN approach is also applied to the same data sets.

4.2 ANALYIS OF DISCHARGE IN COMBINED OPEN CHANNEL

Stream in a compound open direct is for the most part turbulent in nature. The turbulent idea of stream in such channels is three dimensional because of solid optional horizontal stream. Besides, it has been seen from before thinks about that turbulence stream structure has coordinate effect in anticipating the release and resistance in compound channel. To figure release, the customary models, for example, Single channel technique, Divided Channel strategy and so forth give higher mistake in forecast of release and comparatively for composite erosion calculate, in light of the fact that the models are disgracefully bookkeeping the turbulent structure, for example, parallel energy exchange. Along these lines, it is basic to obtain the information of turbulent stream structures to dissect the effect of parallel auxiliary

4.3 SINGLE CHANNEL METHOD

Amid late decades, a noteworthy zone of instability in waterway channel examination is that of precisely foreseeing the release ability of compound channel i.e. flow channel with flood fields. Cross segments of these compound channels are for the most part portrayed by profound fundamental channel limited by one or both sides by a generally shallow flood plain. Chow (1959) proposed that, Manning's, or Chezy or Darcy-Weischbach conditions (appeared in Eqn. (4.1), (4.2) and (4.3) individually) are utilized to foresee release limit at low profundities when the flow is just in primary channel.

$$Q = \frac{1}{n} A R^{23} S^{12} \tag{4.1}$$

$$Q = CA\sqrt{RS} \tag{4.2}$$

$$Q = \left(\frac{8g}{f}\right)^{\frac{1}{2}} A\sqrt{RS} \tag{4.3}$$

Where, Q = Overall arrival of the compound channel, A = Area of the compound channel, R = Aspect extent of the compound channel, S = Slope of the central channel, f =Darcy-Weischbach disintegration segment of the compound channel, and n = composite Manning's coefficient of the compound channel.

Exactly when over bank stream happens, these set up formulae either overestimate or criticize the discharge. Composite obnoxiousness methodologies for Chow (1959) are fundamentally deficient when associated with compound channels since compound channel is considered as single substance through the methodology of refined one dimensional procedure for examination. In this manner, the passing on constrain is thought little of in light of the fact that the single channel technique experiences a sudden diminishment in water driven sweep as the principle channel release immerses to surge fields.

4.4 DIVIDED CHANNEL METHOD

The principal sub-division and composite mercilessness systems given in Chow (1959) are not fitting to expect release and stream resistance in a compound channel. In the light of the learning extended about stream structure in compound channels, diverse proposals have been made to account the cooperation strategy in straight compound channels all the more certainly. The typical routine as for discovering release in a compound channel is the use of ‗divided channel procedure'. Recognized vertical, even or corner to corner interface planes running from the rule channel-floodplain unions are utilized to allocate compound area into subsections and the release for every subsection is resolved utilizing Manning's or Chezy's or Darcy-Weisbach condition and suggested give the aggregate release passed on by the compound segment. For the most part, Manning's condition are utilized for release check in compound channels and made as.

$$Q = \sqrt{S}\left(\frac{1}{n_{mc}} {A_{mc}}^{5/3} {P_{mc}}^{-2/3} + \frac{1}{n_{fp}} {A_{fp}}^{5/3} {P_{fp}}^{-2/3} \right) \tag{4.4}$$

Where, S = longitudinal slant of the channel, Pmc = basic channel edges, Pfp = surge torment edges, Amc= rule channel a region, Afp = flood plain ranges, nmc = primary channel Manning's coefficient, and nfp = surge plain Manning's coefficient. In a general sense, the disengaged channel methodology is segregated into three strategies, for example, level, vertical and inclining division frameworks. Level division method, despite the way that a sensible approach, regardless it removes the standard channel and surge plain interface. In the crooked division technique, division lines for all shapes and stream profundities can't be precisely attracted light of the way that shortcoming is aggregated into figure of zero shear line because of three dimensional nature of speed stream field. Consequently, vertical division methodology is considered to presume release in straight compound involve in this examination. There are a few vertical division procedures which depend on after adjusting the wetted edge of the sub-region to address the impact of association. Frequently, the vertical division lines between the basic channel and the surge plain are united into the wetted edge for the release computation in the significant channel stream. This is proposed to have the impact of deterring the stream in main possess and redesigning it in the surge plain.

Regardless, basically changing the wetted edge by the vertical line does not totally mirror the correspondence influence in a fundamental point of confinement Shiono (1999), Khatua et al. (2011). It is discovered that this approach for the most part completed predicts stream rate (Wormleaton et al. (1982)) and skillfully, it is lacking since it applies an awkwardness of shear powers at the interface. A customary case of vertical division system is appeared in Figure 4.1.

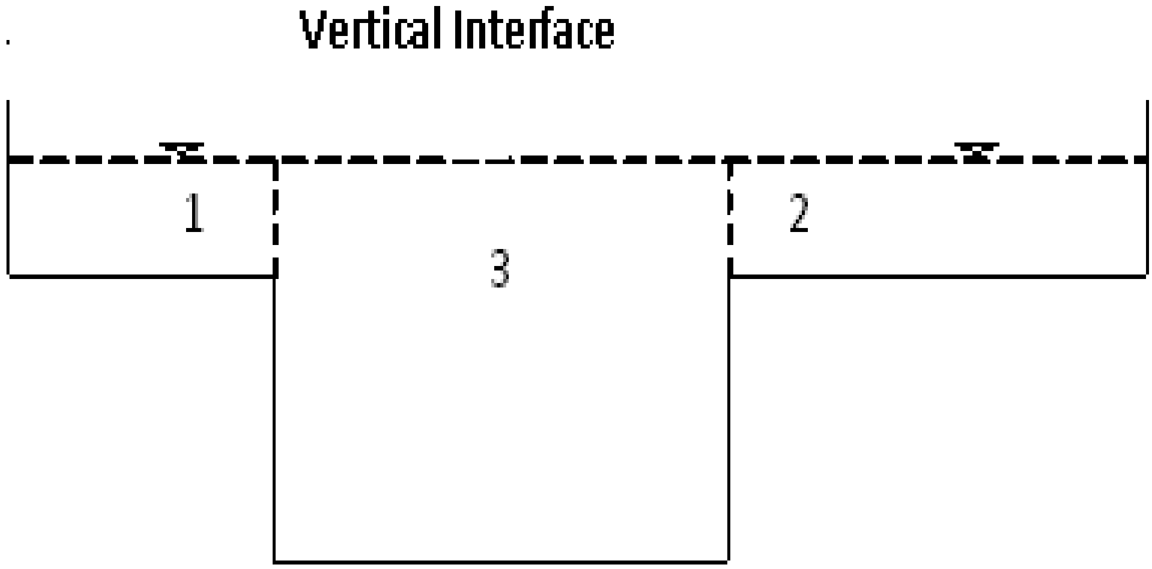


Fig 4.1 compound open channel vertical cross-sectional view.

4.5 COHERENCE METHOD (COHM)

It relies on upon the rule of altering the discharges discovered freely for each sub-an area by a reasonable strategy. The levelheadedness technique (COHM) of Ackers' (1993, 1994) is directly settled 1-D approaches for overseeing overbank stream and the related issues of heterogeneous cruelty and shape impacts. The 'awareness', COH, is described as the extent of the major transport figured by viewing the channel as a singular unit with outskirt weighting of the rubbing variable to that processed by summing the basic developments.

$$COH = \frac{\Sigma A_i \sqrt{\Sigma A_i / \Sigma (f_i P_i)}}{\Sigma \left[A_i \sqrt{A_i / (f_i P_i)} \right]} \tag{4.5}$$

Where, i recognizes each of the n stream zones, an is the sub-run, P is the wetted fringe and f is the Darcy-Weisbach grinding variable. As COH approaches unit, it is legitimate to see the channel as a lone unit using the general geometry and discharge is evaluated by single channel technique. In uncommon cases, COH may be as low as 0.5. Exactly when comprehensibility is an extraordinary arrangement not as much as solidarity by then discharge alteration components are required with a particular true objective to update the individual discharges in each sub-zone and estimations resemble isolated channel procedure. The trial data of surge channel office (FCF) is bankrupt around Ackers (1994). He has recommended four unmistakable levels of stream locales over the primary direct level existing in straight compound channel stream and distinctive release modification elements to be assessed by approaches given by Ackers (1994) for every area to evaluate the Overall release of the compound channel.

4.6 EXCHANGE DISCHARGE METHOD (EDM)

This 1-D model of compound channel streams is made by Bousmar and Zech (1999) and appeared for straight and skew channel with most incredible skew motivation behind 90 by taking the connection between significant channel and surge plain into thought. EDM in like way confines the channel as subsections yet enrolls the aggregate release by summing up the changed release in every subsection release. The EDM requires geometrical trade cure consider and turbulent open display co-productive (ql) for looking over release. Here, compel exchange is in regard to the eventual outcome of speed edge at the interface with the mass release traded through this interface because of turbulence. The standard channel and every subsection of a compound channel can be considered as a solitary channel submitted to an even stream for each unit length ql. By enduring the head catastrophe is the same in all subsections and applying the security of mass and the drive conditions, the subsection release can be assessed as appeared in condition.

$$Q = \frac{A_i R_i^{2/3}}{n_i} S_f^{1/2} = K_i S_f^{1/2} = K\left(\frac{S_e}{1+\chi_i}\right)^{1/2} \tag{4.6}$$

where subscript 2 stays for the essential channel; subscripts 1 and 3 stays for the floodplains; h1 and h3 are standard channel bank level on floodplain 1 and 3 side exclusively; Ki = transport ascertain for each subsection; Sf= contact slant; Se= Energy incline; Ai= region of each subsections; Ri = water driven traverse of each subsections.

4.7 SETUP OF EXPERIMENT AND PROCEDURE

With the genuine goal of present research, one straight test compound channel (Type-I) accessible at Fluid Mechanics and Hydraulics Engineering Laboratory of the Civil Engineering DTU is utilized. The cross-sectional and geometrical parameters are appeared in Figure 4.2. The perspective of Type-I test compound channels with measuring supplies from the upstream side is appeared in Figure 4.3. The game-plan kind of the channel, which is having the straight compound channel (Type-I) with make back the underlying venture with surge plain at both sides of the standard divert as appeared in Figure 4.3. The compound channel is laid inside tilting flume. The flume is outfitted with weight driven jack game-plan. Inside each flume, segregate twisting/straight channels are tossed using 50 mm thick Perspex sheets. To empower creation, the whole channel length has been made in bits of 1.20 m length each. The models thusly made have unobtrusive components as: The straight compound Type-I channel territory has the essential channel estimation of 120 mm×120

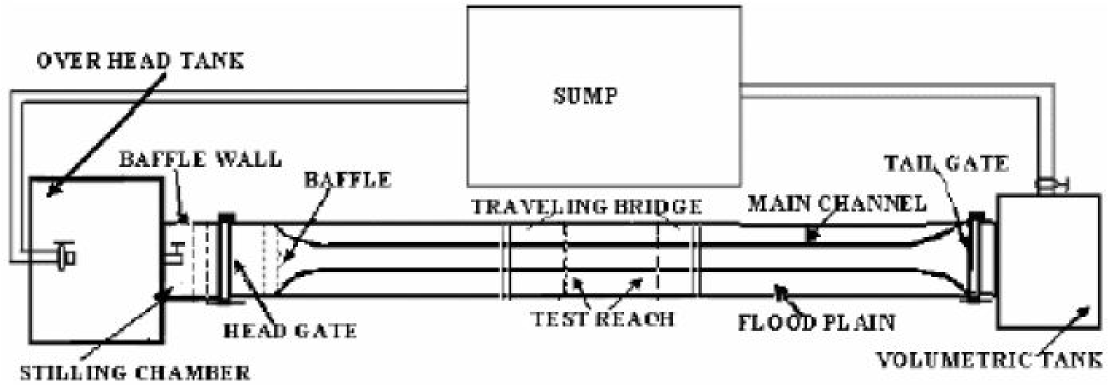


Fig 4.2 Channel plan View

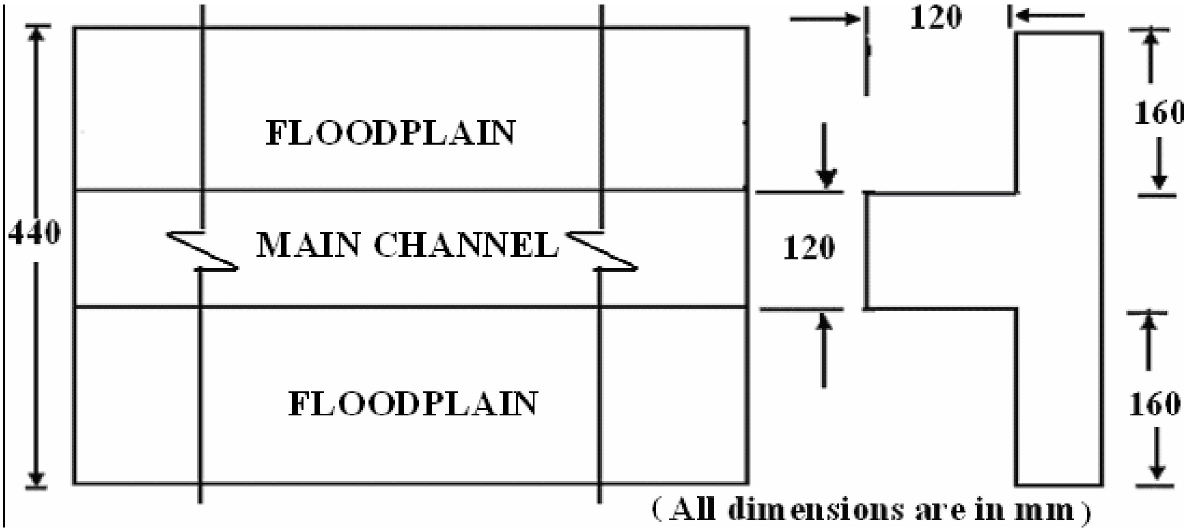
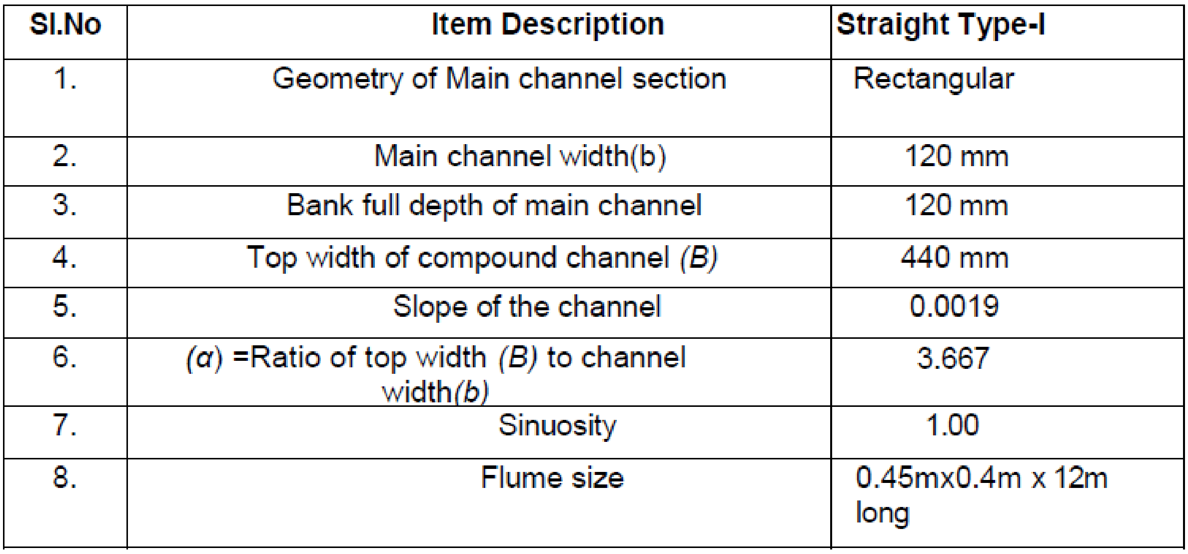


FIG 4.3 Type-I channel Geometric parameters.

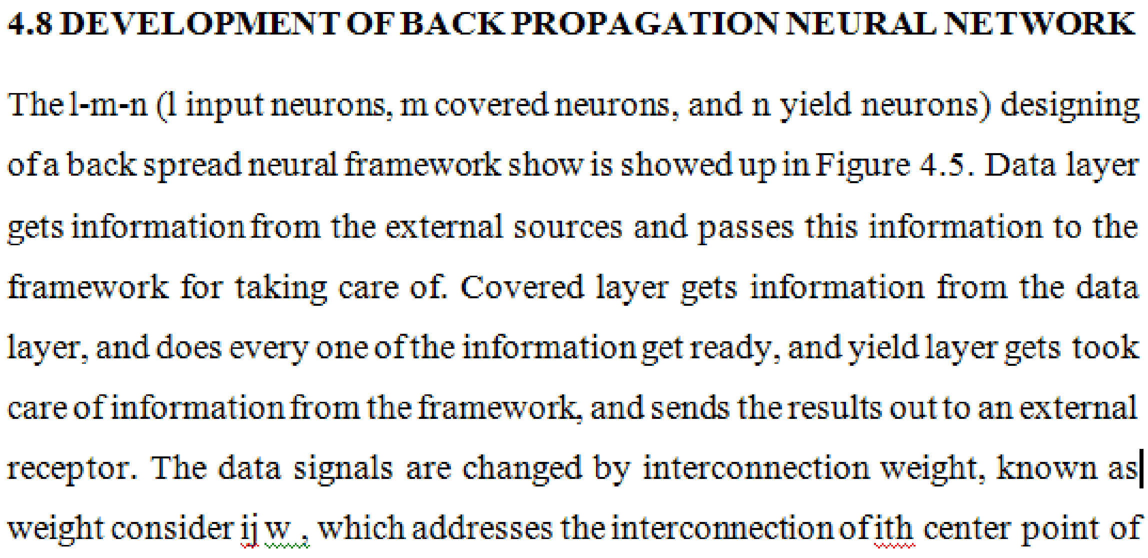
The measuring contraptions includes a point gage mounted on a crossing point instrument to assess stream profundities with littlest tally of 0.1 mm. Point speeds are measured at various domains over the channel segment utilizing a 16-Mhz Micro ADV (Acoustic Doppler Velocity-meter) having exactness of 1% of the consider run. A guide rail was given and no more hoisted motivation behind the trial flume on which a voyaging range is moved in the longitudinal heading of the whole channel. The point gage and the more diminutive scale ADV related with the voyaging growth can move both longitudinal and the transverse heading at the stage position. Readings from the tinier scale ADV are recorded in a PC. As the ADV (down test) was not skilled inspected the information up to 50 mm from free surface, a tinier scale Pitot holder of 4 mm outer width in conjunction with sensible slanted manometer were moreover used to gage speed at some one of a kind inspirations driving the stream cross segment. The Pitot tube was physically turned as for the standard course till it recorded the most absurd redirection of the manometer investigating. A stream heading pioneer having a littlest number of 0.1 was utilized to get the

introduction of most silly speed regarding the longitudinal stream course. The edge of limb of Pitot tube with longitudinal direction of the channel was noted by the circuitous scale and pointer arrange joined to the stream course meter. The purposes of enthusiasm of trial parameters for Type-I Compound Channel are showed up in Table.4.1

Table 4.1details of experimental parameters for Type I compound channel



Sl.No	Item Description	Straight Type-I
1.	Geometry of Main channel section	Rectangular
2.	Main channel width(b)	120 mm
3.	Bank full depth of main channel	120 mm
4.	Top width of compound channel *(B)*	440 mm
5.	Slope of the channel	0.0019
6.	*(α)* =Ratio of top width *(B)* to channel width*(b)*	3.667
7.	Sinuosity	1.00
8.	Flume size	0.45mx0.4m x 12m long



4.8 DEVELOPMENT OF BACK PROPAGATION NEURAL NETWORK

The l-m-n (l input neurons, m covered neurons, and n yield neurons) designing of a back spread neural framework show is showed up in Figure 4.5. Data layer gets information from the external sources and passes this information to the framework for taking care of. Covered layer gets information from the data layer, and does every one of the information get ready, and yield layer gets took care of information from the framework, and sends the results out to an external receptor. The data signals are changed by interconnection weight, known as weight consider ij w , which addresses the interconnection of ith center point of

the principle layer to jth center of the second layer. The total of balanced signs (mean order) is then changed by a sigmoid trade work (f). Therefore, yields banner of hid layer are changed by interconnection weight (ij w) of kth center point of yield layer to jth center point of covered layer.

The total of the balanced banner is then changed by sigmoid trade (f) limit and yield is accumulated at yield layer.

4.9 SOURCE OF DATA

The information are gathered from explore work done in Flood Channel Facility, which is an expansive scale compound channel office, accessible at the research facility of University of Birmingham, Wallingford. FCF information arrangement A for straight harsh and smooth channels, work done by Knight and Demetriou (1983), Atabay (2004) for symmetrical and awry information arrangement, and Tang (2001) for unpleasant quaint little inn channel information arrangement are utilized alongside trial work done in Fluid Mechanics Laboratory, DTU.

4.10 SELECTION OF HYDRAULIC PARAMETERS

Stream water power and energy trade in straight channel are essentially impacted by both geometrical and pressure driven factors. Past investigation attempted by Yang et al. (2005) has proposed that resistance of stream is steady for relative profundity of 0.1 and changed for all different cases. Likewise, the calculation turns out to be more mind boggling when the aggregate channel width to the fundamental channel width esteem diminishes. The stream calculate like (i) relative profundity (Hr) i.e. profundity of surge plain to add up to profundity, (ii) channel longitudinal slant (S0),(iii) impact of surge plain and principle channel unpleasantness (fr) (iv) Ratio of region of surge plain to primary channel (Ar) and (v) proportion of water driven sweep of surge plain and fundamental channel (Rr) likewise shifts with symmetry are in charge of the estimation of general release in mixes channel as proposed by Yang et al. (2005). Consequently, in this investigation, these five stream factors are picked as info parameters and release as yield parameter.

4.11 RESULTS The numerical reenactments are completed by utilizing ANSYS-CFX solver and these outcomes are contrasted and the exploratory information comes about.

The outcomes are classified in Table 4.1.

$$W_b = \frac{\int w dA}{A} \qquad (4.1)$$

Where, Wb = Bulk Velocity along Flow-line of stream. w = flowline speed anytime, A = Cross segment territory of the channel. The composite Manning's grinding component is figured from Manning's condition.The

Table 4.2 Comparison of the experiment and simulation results

Case	Maximum Velocity W_{max}(m/s)	Mean Bulk Velocity W_b (m/s)	Discharge (m3 /s)	Composite manning's 'n'	Shear Velocity u* (m/s)
S-1 (Tominaga and Nezu 1991)	0.409	0.368	0.00738	0.011383	0.0161
Present LES simulation	0.4047	0.365	0.00737	0.011381	0.01604

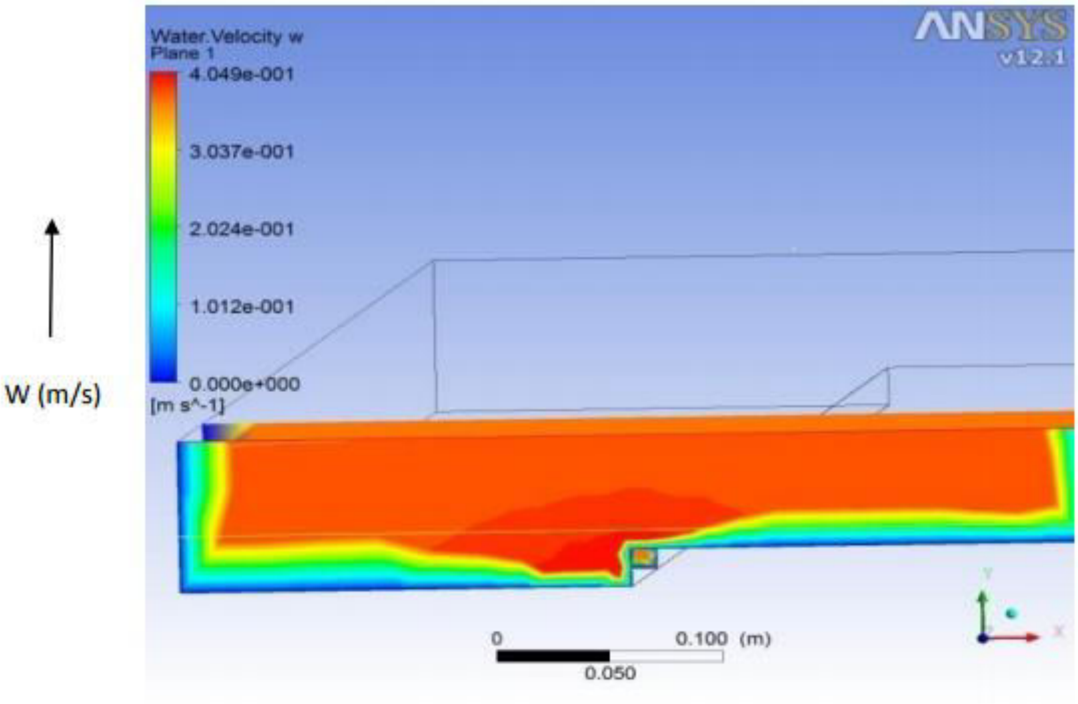


Fig 4.4 Mean Velocity distribution of LES Simulation

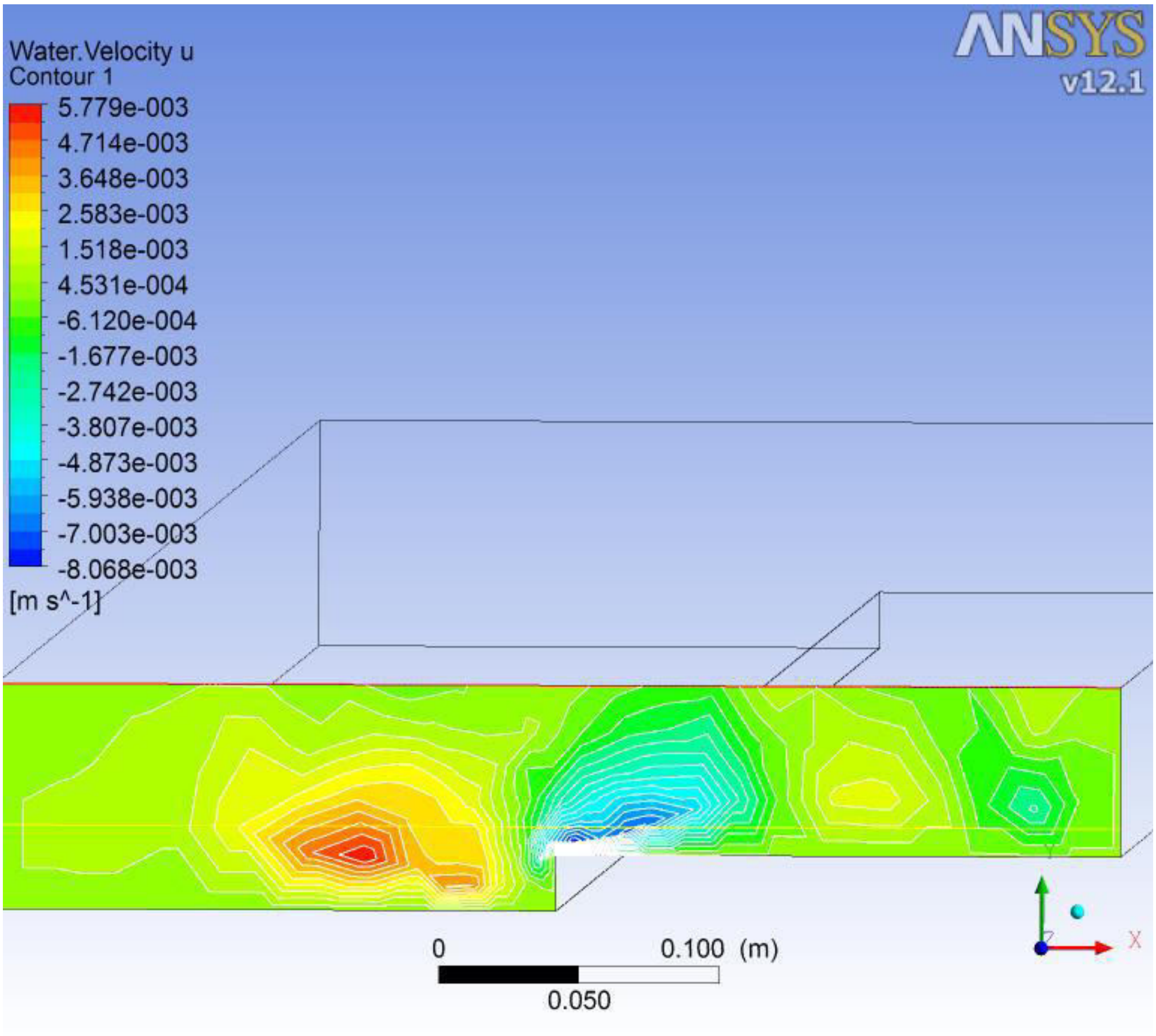


Fig 4.5 Stream-wise non-dimensional averaged secondary velocity contours

From Figure 4.4 and Figure 4.5, it can be observed a pair of secondary currents on the both side of the junction of the main channel and flood plain. These currents can be regarded as longitudinal vortex as mentioned by Tominaga and Nezu (1991).

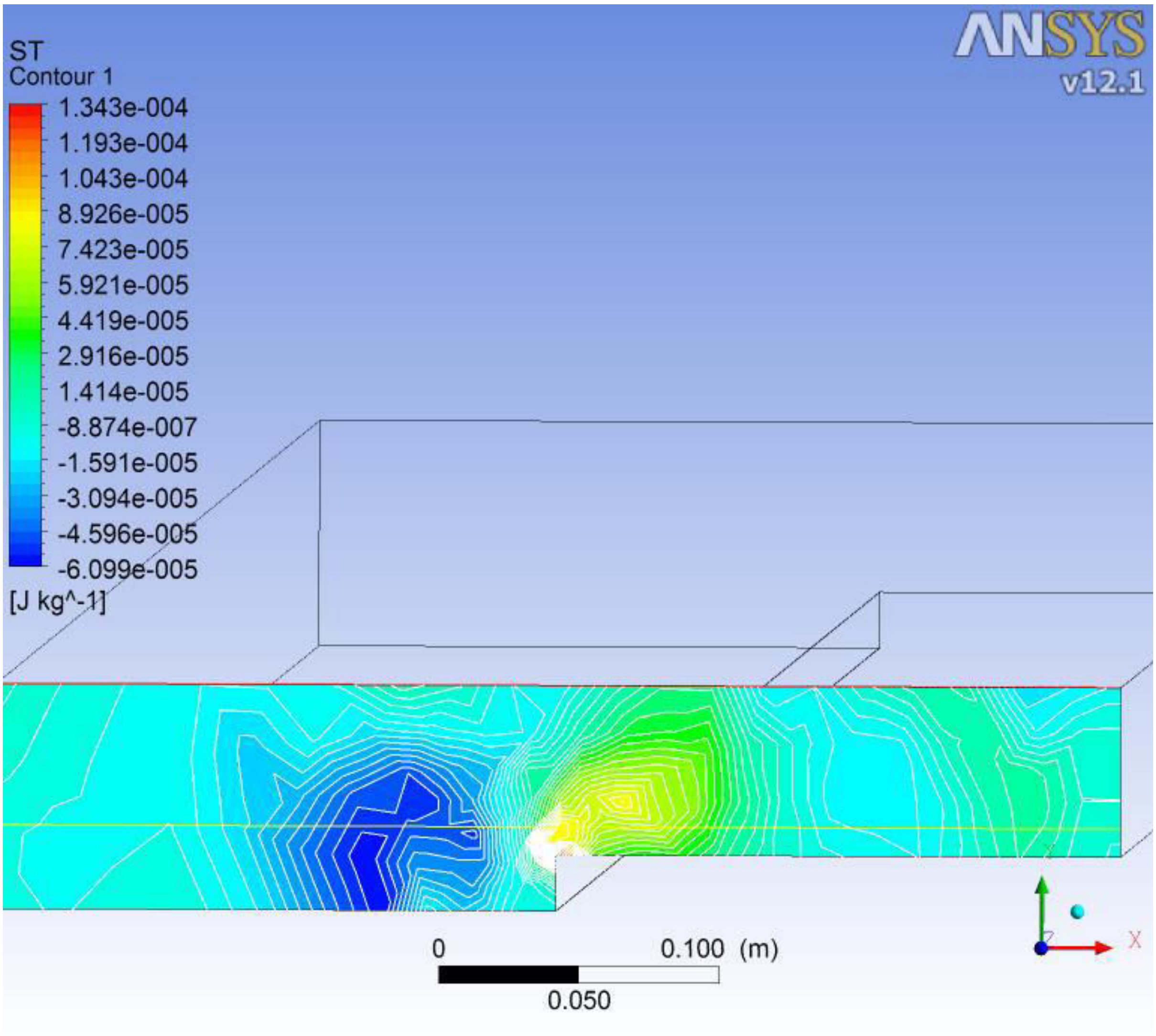


Fig 4.6 Lateral distribution of secondary circulation component (T)

The momentum transfer due to secondary circulation component and turbulent transport is shown in Figure 4.6. Apart from momentum transfer phenomenon, the turbulent flow structure also depends upon the corner of the channel and shape of the compound cross-section.

4.12 DISSCUSION

A BPNN show is proposed for precise estimation of release in compound channel flume.

The discharge data from experimentation covers a broad assortment of arrangement like conditions having both smooth and unforgiving standard channel and surge fields and furthermore flexible and settled channel restrain. In like manner data from compound channel having symmetric and uneven cross-fragment have been considered. The example and case of test data matches with foreseen discharge and predominance of desire of discharge by methods for. ANN has been shown. The central reason of abnormal state of desire precision lies in the truth of limit of non-coordinate mapping of data sources and yields in ANN. The non-straight association of geometrical and water driven data parameters with discharge is difficult to develop with ordinary discharge estimate reasoning. Furthermore, the standard systems can't be viewed as the honest to goodness factors working in the structure.

CHAPTER 5 CONCLUSION

5.1 GENERAL

Based on analysis and discussions of this study certain conclusions can be drawn. The conclusions from the present work are as follows.

LES reenactment comes about are displayed to demonstrate the speed conveyance and auxiliary current, energy exchange from fundamental channel to surge plain and tight clamp - versa in an awry compound channel. The release and composite rubbing variable found from the LES recreations are likewise in great concurrence with trial comes about.

Distinctive release and composite contact consider expectation strategies are examined. These techniques are connected to the distributed information of compound channels with various water driven conditions. The techniques are found to give great outcomes to some compound channels where as neglect to give great outcomes for compound channels of other geometry and pressure driven conditions.

5.1 SCOPE OF FUTURE STUDY

The impact of sinuosity on discharge and composite friction factor prediction in compound open channel flows for different roughness condition and mobile bed condition can be extended.

The study can further be extended for prediction of boundary shear stress, discharge distribution etc. for compound channels of different geometry and hydraulic conditions.