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"Revolutionizing Flow Measurement: Smart Conveyance Estimation System (CES) for Precision and Efficiency"

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Abstract: This study focuses on the computation of flow using the Conveyance Estimation System (CES). It presents findings derived from field measurements conducted in frequently flooded natural rivers, including stage-discharge relationships, variations in flow resistance with depth, apparent friction factors, and composite friction factors. The results highlight the complexities of flow resistance in natural rivers, mainly due to interactions between the main channel and floodplain flow. Accurately estimating conveyance plays a crucial role in flood management, water level prediction, and flood defense planning. Most river modeling software incorporates conveyance estimation methods, many of which are based on research conducted over five decades ago, often neglecting recent advancements. In 2001, the Environment Agency initiated a scoping study to reduce uncertainty in conveyance estimation. This paper discusses key conclusions from that study, addressing the diverse needs of users and gaps in existing knowledge. Additionally, it outlines a targeted research program aimed at enhancing river capacity management. Currently, this research initiative is being carried out in collaboration with academic researchers, industry experts, and stakeholders. Critical factors under investigation include the impact of riverine vegetation, the influence of natural or restructured channels, and interactions between river channels and floodplains. The program's ultimate goal is to develop an open-source CES, integrated with modeling tools. This system features a roughness advisor that grants access to extensive knowledge on river resistance estimation. Furthermore, the study examines flow parameters such as depth-averaged velocity, bed shear stress distribution, stage-discharge relationships, Froude number, and average velocity conveyance concerning flow depth. The findings reveal how these parameters vary under different river conditions.

Keywords— Flow Resistance, Hydraulic Friction, Conveyance Estimation, River Hydraulics, Floodplain Interaction, Depth-Averaged Velocity, Bed Shear Stress Distribution.

I. Introduction

Accurately estimating the resistance coefficient and discharge capacity of a river or channel is a critical challenge in hydraulic engineering. Reliable conveyance estimation is essential for designing flood management systems, predicting water levels, and ensuring effective flood defense planning. However, existing methods for determining flow resistance, particularly in channels with dynamic vegetation and varying flow conditions, lack universal applicability. While numerous studies have attempted to refine the estimation of resistance coefficients—especially under overbank flow conditions—most rely on controlled laboratory experiments. These findings may not fully capture the complexities of natural rivers, which exhibit irregular cross-sections and variable surface roughness. This study focuses on estimating flow resistance in natural rivers during flood conditions. One of the major challenges in discharge prediction for compound channels is the interaction at the interface between the main river section and its floodplain. Research has shown that this interaction results in non-uniform velocity distributions and variations in boundary shear stress. Several studies have examined the influence of apparent shear stress at junctions by incorporating geometric and hydraulic parameters. For instance, some models estimate shear stress based on velocity differences between the main channel and floodplain, while others utilize interaction length-based methods for flow prediction. Additionally, existing methodologies such as the slope–area method have been found to overestimate flow rates in compound channels, prompting the development of improved techniques that consider non-homogeneous cross-sections. While advanced two-dimensional (2D) and three-dimensional (3D) modeling approaches offer greater accuracy in discharge prediction, they come with significant drawbacks, including complex computations, extensive data requirements, and higher costs. Comparatively, one-dimensional (1D) modeling is more practical but has inherent limitations in representing complex flow interactions. Several researchers have introduced methodologies to improve the prediction of depth-averaged velocity and energy loss in non-uniform flow conditions. Recent studies have also highlighted the significance of lateral variations in energy slope and roughness coefficients for accurate flow assessment. The objective of this research is to analyze the impact of boundary shear force in non-homogeneous riverbeds compared to homogeneous ones. By utilizing extensive datasets from rough compound channels, a generalized expression for boundary shear force in non-homogeneous conditions is developed. Additionally, a new methodology is proposed to determine flow distribution across unsymmetrical compound channels, incorporating momentum transfer coefficients and differential roughness parameters to improve accuracy in flow predictions.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

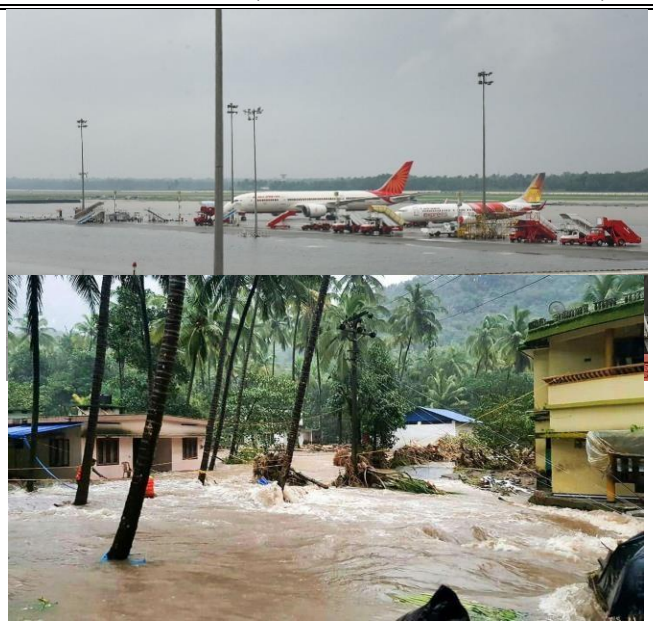


Fig. 1 Flood at Kochi Airport, Kerala

Problem Statement

Effective flood management and timely evacuation of people from flood-prone areas are critical to minimizing damage and ensuring public safety.

- Accurate flood forecasting is essential for proactive decision-making and disaster preparedness. By utilizing CES software, flood predictions can be generated through velocity distribution diagrams and rating curves, enabling better analysis of potential flood impacts.
- Additionally, boundary shear distribution curves provide valuable insights into erosion patterns and sediment deposition within river systems, aiding in the development of effective riverbank protection and sediment management strategies.

Research Objective

- To estimate water flow for effective flood prediction and the implementation of protective measures, aiding in risk mitigation and disaster preparedness.
- To determine flow conveyance, rating curves, and depth-averaged velocity distribution in open channels using the Conveyance Estimation System (CES) software, improving accuracy in hydraulic computations.
- To analyze numerical solutions of the Shiono and Knight Method (SKM) and evaluate flow parameters for predicting depth-averaged velocity in open channel flow through CES, enhancing the reliability of flow modeling techniques.
- To assess bed shear stress distribution curves for understanding erosion patterns and sediment deposition in rivers using CES software, supporting better riverbank stabilization and sediment transport management.
- To examine the three key calibration coefficients—friction factor, eddy viscosity coefficient, and secondary flow coefficient—necessary for accurate SKM and CES modeling, ensuring precise predictions of flow behavior under different hydraulic conditions.
- To improve computational approaches for predicting flow characteristics in complex river systems by integrating real-world datasets and experimental validation with CES.
- To enhance decision-making in water resource management by utilizing CES-based predictions for optimizing channel design, flood forecasting, and sediment control strategies.

Scope of this research

- The adoption of advanced conveyance estimation methods can lead to significant economic advantages by enhancing design efficiency, optimizing operational strategies, and improving maintenance practices while minimizing

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

uncertainties.

- Early-stage strategic decisions in a project's life cycle play a crucial role in its long-term success, as uncertainties in data and information are highest during initial phases and can impact overall project outcomes.
- 1`There is a direct correlation between uncertainty and risk, where higher uncertainty increases the likelihood of deviations from project objectives or inefficiencies in maintenance activities.
- The effectiveness of a system or process in meeting its intended goals is strongly influenced by the level of confidence in its performance and reliability.
- Therefore, optimizing performance and ensuring greater confidence in project outcomes require a comprehensive understanding of uncertainties and the implementation of effective control measures.

II. Literature Review

Amir Motamed Dashliborun, Faïçal Larachi "Hydrodynamics of gas–liquid concurrent downflow in floating packed beds" (2015): An experimental setup combining a six-degree-of-freedom robotic motion and a capacitance wire mesh sensor was developed to study two-phase flow dynamics in porous media within inclined stationary and oscillating packed beds under gas-liquid concurrent descending flows. Non-tilting oscillations had minimal effect on the hydrodynamics, resembling stationary vertical trickle beds. However, tilting oscillations significantly impacted the flow regime due to the time-dependent gravitational and inertial forces, causing secondary fluid displacements. Moment analysis of liquid saturation time series revealed that periodic gravity-driven stratification shifted the transition to pulse flow toward higher fluid velocities as oscillation periods of roll or roll-pitch motions increased [1].

Zhonghua Yang, Da Li, Wenxin Huai, Jianhua Liu "A new method to estimate flow conveyance in a compound channel with vegetated floodplains based on energy balance" (2019): While previous research has explored flow discharge in compound channels, the role of vegetation in flow conveyance has often been overlooked. Vegetation alters the flow structure, increasing resistance and influencing discharge characteristics. Early models typically relied on the equivalent Manning's roughness coefficient to account for vegetation effects. However, recent studies emphasize the importance of considering vegetation drag forces for more accurate predictions of flow conveyance. This study proposes a novel approach by balancing total energy loss due to vegetation drag with the local flow's energy, improving accuracy in estimating flow conveyance [2].

Siprarani Pradhan, Biswajit Pradhan, Kishanjit Kumar Khatua "Experimental investigations and modelling of composite roughness for compound channels" (2025): Accurately predicting composite roughness in compound open channels has been a longstanding challenge. Traditional methods often fail to account for the unique flow dynamics present in these channels. Previous research has shown that simple channel models do not capture the complex interactions between momentum transfer and differential roughness in compound channels. Recent studies emphasize the need for more advanced methods that incorporate these interactions. The proposed NCRM builds on these insights, offering improved accuracy by considering geometric parameters and flow conditions. This method demonstrates significant improvements over traditional approaches and has practical applications in flood management and hydraulic modeling [3].

III. Research Framework and Methodology

Essential Mathematical Models

Shiono-Knight Computational Method (SKM)

CES utilizes the Shiono-Knight Method (SKM), a numerical modeling approach grounded in the Reynolds-Averaged Navier-Stokes (RANS) equation. Developed by Shiono and Knight (1988, 1990, 1991), SKM is a depth-averaged lateral distribution model that incorporates key three-dimensional flow structures commonly found in river systems and both simple and compound channels. This quasi-2D model effectively predicts lateral variations in depth-averaged velocity and boundary shear distributions across natural river channels, irrespective of their cross-sectional shapes. Due to its reliable performance in both controlled laboratory environments and real-world river systems, SKM has been adopted by the UK's Environmental Agency as part of its 'Conveyance and Afflux Estimation System' (CES) software.

Theoretical Underpinnings of the Shiono-Knight Model

The SKM approach solves the depth-averaged momentum equation to analyze steady, uniform, turbulent flow within open channels. This methodology integrates the streamwise momentum equation with the continuity equation to describe fluid behavior in prismatic channels. The governing equation accounts for variables such as velocity components (streamwise, lateral, and normal to the bed), turbulent fluctuations, water density, gravitational acceleration, and bed slope. By depth-averaging these equations, SKM provides a model that accurately represents the velocity and shear stress distribution within a river system. The simplified Navier-Stokes equation in steady uniform flow forms the foundation of this method, incorporating factors such as Reynolds stress, eddy viscosity, and flow resistance. Depth-averaged velocity distributions can be obtained analytically or numerically, depending on boundary conditions and calibration parameters. The accuracy of SKM predictions relies on the correct estimation of parameters

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

including friction coefficients, eddy viscosity, and secondary flow influences. These factors enable the model to be a robust tool for evaluating river flow dynamics, making it a critical component of CES.

Governing Mathematical Equations

$$\rho(\partial UV\partial y + \partial UW\partial z) = \rho gSO + \partial\partial y(-\rho uv) + \partial\partial z(\rho uw)$$

…….. (1)

where (U, V, W) are the mean velocity components in the x (stream wise), y (lateral) and z (normal to bed) directions, respectively; (u, v, w) are turbulent fluctuations of velocity with respect to the mean, ρ is the density of water, g is the gravitational acceleration and so is the bed slope. The depth-averaged momentum equation can be obtained by integrating Eq. (1) over the water depth, H, assumed W(H) = W (0) = 0, as given by Shiono and Knight (1991):

$$\partial\rho gHSO + \partial Hryx\partial y - rb1 + 1s = ((\rho UV)d)\partial y \text{ .....} (2)$$

in which τ_b is the bed shear stress, s is the side slope (1:s = vertical: horizontal), and

$$(\rho UV)d = 1H \int O(\rho UV)dz \text{ and } ryx = 1H \int OH(-\rho uv)dz$$

……...…(3)

Based on the commonly used eddy viscosity assumptions, the depth-averaged Reynolds stress (ryx) can be given as follows:

$$ryx = \rho\epsilon yx\partial Ud\partial y \text{ and } \varepsilon yx = \lambda U \times H \text{ ……..} (4)$$

where εyx is depth-averaged eddy viscosity, λ is the dimensionless eddy viscosity coefficient and (U=τ b/ρ) is the local shear velocity. Using the customary flow resistance relationship that relates local boundary shear stress (τ_b) with the depth-mean velocity (U_d) and the Darcy–Weisbach friction coefficient (f), τ_b can be computed by:

$$rb = \rho f8U2d \text{ or } U = f8 - \sqrt{UD} \text{.....} (5)$$

Then, substituting Eqs. (4) and (5) into (2) yields:

$$\rho gHSO - \rho f8U2d1 + 1s2 + \partial(\rho\lambda H2f8 - \sqrt{Ud\partial Ud\partial y}) = \partial\partial y(H(\rho UV)d) \text{.....} (6)$$

Based on experimental results, the secondary flow term (ρUV)d is assumed to vary approximately linearly with respect to y. Therefore, the lateral gradient of the secondary flow force per unit length may be written as:

$$\partial(H(\rho UV)d) = r \text{.....} (7)$$

where r is a dimensionless secondary flow parameter which is different for each part of the flow.

Equation (6) can be solved to give U_d as a function of y either analytically (Shiono and Knight 1991; Knight and Shiono 1996) or numerically (Knight and Abril 1996; Abril and Knight 2004)

An analytical solution to Eq. (6) for the lateral distribution of depth-mean velocity, can be obtained as follows.

For a sub-area with a constant water depth H, the analytic Ud distribution is written in the form:

$$\text{U } d = (A_1 e\gamma y + A_2 e - \gamma y + k)1/2 \quad \text{……} (8)$$

Where,

$k = 8gSO(1 - \beta)$

$\gamma = 2\lambda - \sqrt{(f8)141H}$

$\beta = r\rho gHSO$

For a sub-area with a main channel side slope of 1: s, the Ud distribution has the form:

$$\text{U } d = (A_3 \in \alpha + A_4 \in -\alpha - 1 + w\epsilon + \eta)1/2 \quad \text{……} (9)$$

Where,

$\alpha = -12 + 121 + (1 + s2)12(8f)12$

$\omega = g(1 + s2)12s(f8) - \lambda s2(f8)12$

$\eta = (1 + s2)12s(f8)$

$\varepsilon = H - y - bs$

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A_1, A_2, A_3 and A_4 are integration constants and can be determined by considering the relevant boundary conditions. The accurate prediction of depth averaged velocity and boundary shear stress depends on proper estimation of the three calibration parameters in SKM model (i.e. f, λ, and Γ) and specifying the appropriate boundary conditions.

The simplified form of Navier-Stokes equation in steady uniform flow is as follows:

$$\rho\left(v\frac{\partial u}{\partial y}+w\frac{\partial w}{\partial z}\right)=\rho g\sin\theta+\frac{\partial \tau_{yx}}{\partial y}+\frac{\partial \tau_{zx}}{\partial z}$$

Shiono Knight integrated the Navier-Stoke's equation that is the momentum equation over the flow depth H, mainly to find out the depth-averaged velocity distribution. The method of solving this equation is known as Shiono-Knight method. They provided a analytical solution for this model from which both depth-averaged distribution and boundary shear stress distribution can be simply found out. Integrating the equation (1) over a flow depth H, Shiono and knight obtained a quasi-2- D equation indicated in equation (2)

$$\rho g H S_0-\rho\frac{f}{8}U_d^2\sqrt{1+\frac{1}{s^2}}+\frac{\partial}{\partial y}\left\{\rho\lambda H^2\left(\frac{f}{8}\right)^{1/2}U_d\frac{\partial u_d}{\partial y}\right\}=\frac{\partial}{\partial y}\left(H\rho UV\right)$$

The right-hand side of equation (2) is taken as secondary flow effect, which is also known as transverse gradient of secondary flow. Γ is the symbol to define the secondary flow parameter

Darcy-Weisbach friction factor (f)

$$f=\frac{8gn^2}{R^{1/3}}$$

Also Calcluated by using Flolowing Equation :

$$f=\frac{8\tau_b}{\rho U_d^2}$$

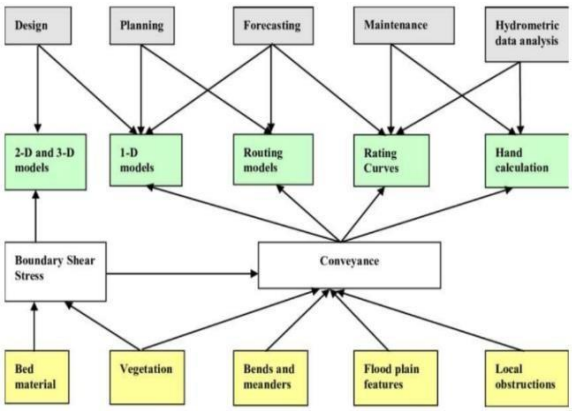


Fig. 2 The conceptual Fame Work of CES

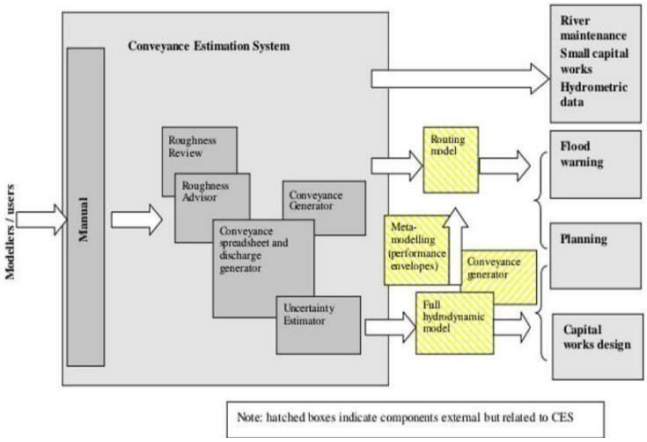


Fig. 3 Components of Conveyance Estimation System

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Main Components of CES

Roughness Advisor: This module serves as a comprehensive database containing roughness-related data, including descriptions, images, and unit roughness values for various natural and artificial surfaces. The database draws from over 700 sources, including the River Habitat Survey. It covers diverse elements such as aquatic vegetation, crops, grasses, hedges, trees, substrates, bank reinforcements, and surface irregularities. Additionally, the Roughness Advisor provides insights into seasonal fluctuations in vegetation roughness, the effects of cutting, and the expected regrowth patterns post-maintenance.

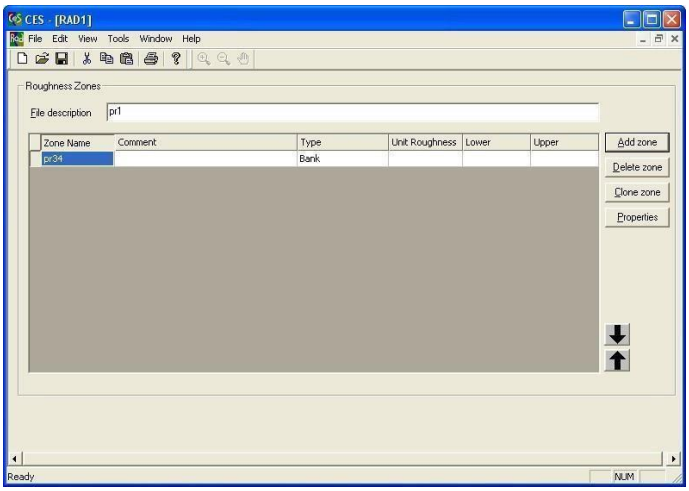


Fig. 4 CES Interface 1: Roughness Generator

The Conveyance Generator evaluates channel conveyance by utilizing roughness data and cross-sectional descriptions. It employs a lateral distribution method, where unit flow rates are computed at 100 points across the channel, and the total flow is determined by integrating these values over the river section. The tool provides output data as a function of depth, including water level, discharge, velocity, wetted area, perimeter, rating curves, Froude number, and Reynolds number. Additionally, it enables the analysis of spatial distributions across the section, offering insights into velocity variations, boundary shear stress, and shear velocity.

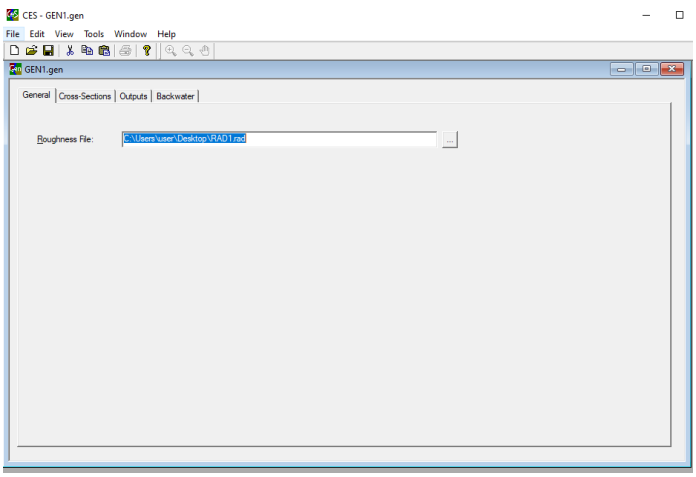


Fig.5 CES Interface 2: Conveyance Generator

Uncertainty Estimator: This tool evaluates the reliability of predicted water levels by generating upper and lower boundary scenarios. It quantifies uncertainty using roughness estimates sourced from the Roughness Advisor, ensuring a range of credible predictions.

Backwater Module: Designed to calculate backwater profiles upstream of a reference control point (where stage and flow are known), this module applies an energy balance approach. The calculation progresses from downstream to upstream and can optionally account for the velocity head term (kinetic energy component).

Afflux Estimator: This computational tool is tailored for gradually varied flows, supporting the modeling of arch and beam bridges (up to 20 openings) as well as pipe, box, and arch culverts (up to 10 identical barrels). Integrated within the CES/AES stand-alone desktop application, it generates a longitudinal water surface profile for bridges and culverts.

Afflux Advisor: A dedicated spreadsheet-based tool for rapid afflux estimation in simple bridge and culvert structures within a uniform channel. While utilizing the same field and laboratory data as the Afflux Estimator, it assumes uniform flow conditions

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

and does not generate a longitudinal water surface profile. The tool requires a single cross-sectional dataset and provides an afflux rating curve as an output.

Data Evaluation and Interpretation

Sampling Design and Methodology

Flooding is commonly attributed to heavy rainfall, but this is only part of the explanation. Floods occur when runoff from land surpasses the capacity of rivers to channel the flow. Several factors contribute to flooding, including rainfall volume, existing ground moisture, and the ability of river channels to contain water. When river channel capacities change, similar rainfall events can result in significantly different flooding outcomes. Rivers are dynamic systems shaped by the water and sediments they carry. Human activities have altered most rivers worldwide, either directly through dam construction and river engineering or indirectly through urbanization, agriculture, and deforestation. These modifications influence water absorption, flow patterns, and flood risk. Climate change also affects river behavior. During dry periods, lower water flow reduces the energy available to transport sediments, leading to rising riverbeds and decreased channel capacity. Additionally, dense vegetation growth can restrict water movement, further impacting river dynamics. Predicting river changes remains complex. In some cases, shifts in channel shape and capacity happen rapidly. For example, after a flash flood in Spain, one riverbed rose by nearly a meter due to sediment deposition. In tropical river systems with high sediment loads, these changes can be even more dramatic. Despite these variations, many flood models assume river channels remain static, leading to potential inaccuracies in flood risk assessments. To address this, we analyzed 10,000 measurements from 67 U.S. rivers over 70 years, examining how climatic factors influenced river capacity. Our findings revealed frequent short-term fluctuations, with capacity increasing during wetter periods due to erosion and decreasing during dry spells. In stable, engineered river systems like those in the UK, minor shifts in capacity pose little risk. However, in sediment-heavy or highly variable rainfall regions, sudden reductions in channel capacity can significantly heighten flood risks. The Ganges-Brahmaputra River system, for instance, is experiencing such changes, impacting millions in densely populated floodplain areas.

Analysis and Key Findings

Field Measurements and Flow Characteristics

Field measurements were conducted in several frequently flooded equatorial rivers to analyze velocity distributions, stage-discharge relationships, roughness behavior, and discharge estimation. These measurements highlighted the significant velocity differences between the main channel and floodplain under flood conditions. The effects of momentum transfer between deep and shallow flows were observed, leading to reduced velocity and discharge capacity in the main channel. Consequently, the overall capacity of the compound section decreases at depths exceeding the bankfull stage. A key finding was that floodplain areas often act as storage reservoirs due to the high resistance caused by dense and tall grasses along the floodplains. Flow resistance relationships were analyzed using Manning's coefficient and the Darcy-Weisbach friction factor, revealing the complex nature of flow resistance in these river systems. These findings emphasize the risks associated with conventional approaches that extrapolate in-bank data for overbank flow analysis. Discharge estimations were compared with actual measurements, highlighting the errors associated with empirical methods when applied to compound channel flows. The magnitude of these errors varied depending on the specific method used. The study focused on natural river systems, including River Senggai, Senggi (B), and River Batu, located in Kuching, the capital of Sarawak State, Malaysia. These rivers were chosen due to their history of severe flooding during the monsoon season. Additionally, extensive flood data from the River Main in Northern Ireland was collected for comparative analysis. The selected rivers have relatively straight and uniform cross-sections, free from backwater and tidal effects. Their geometrical properties and surface conditions at gauging stations are presented in Table 1 for comparison. Figures 1 to 3 illustrate the selected rivers, while Figures 4 to 6 depict their typical cross-sections. Flow gauging was conducted using the velocity-area method from an adjustable bridge built across each river, ensuring precise measurement of discharge and velocity profiles.

Table 1 geometrical properties and surface conditions of the rivers at the gauging stations for comparison.

Geometric Properties	River Severn	River Senggi (B)	River Senggai	River Batu
Maximum Bankfull Depth (m)	5.82	1.315	1.072	1.558
Channel Top Width (m)	34.8	5.62	5.31	5.19
Aspect Ratio (Width/Depth)	5.98	4.275	4.953	3.367
Main Channel Bed Slope (So)	0.031	0.0012	0.0011	0.0017
Left Floodplain Bed	0.038	0.00089	0.0011	0.0014

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Slope (Sl)				
Right Floodplain Bed Slope (Sr)	0.039	0.00087	0.0012	0.0015
Sediment Type - Main Channel	Erodible Soil	Erodible Soil	Erodible Soil	Boulder & Gravel
Vegetation Cover - Right Bank	Dense Vegetation	Tall Grass	Sparse Shrubs	Mixed Bushes
Floodplain Surface Condition	Mixed Vegetation	Long Grass & Shrubs	Thick Grass	Bushy Vegetation

Examination of River Severn



Fig. 6 Morphological cross-section of River Severn

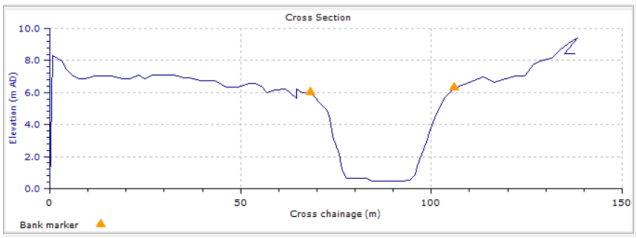


Fig. 7 Elevation vs Cross-Chainage

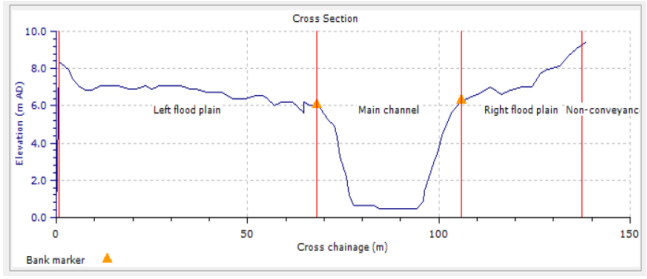


Fig. 8 Bank Marker and Roughness Zones

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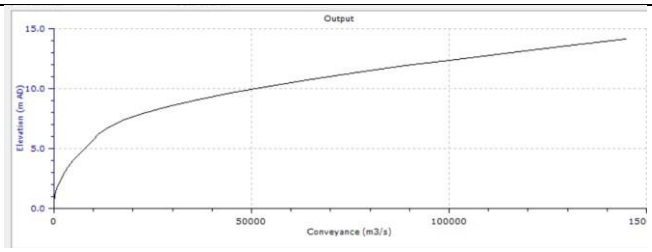


Fig. 9 Elevation vs Conveyance

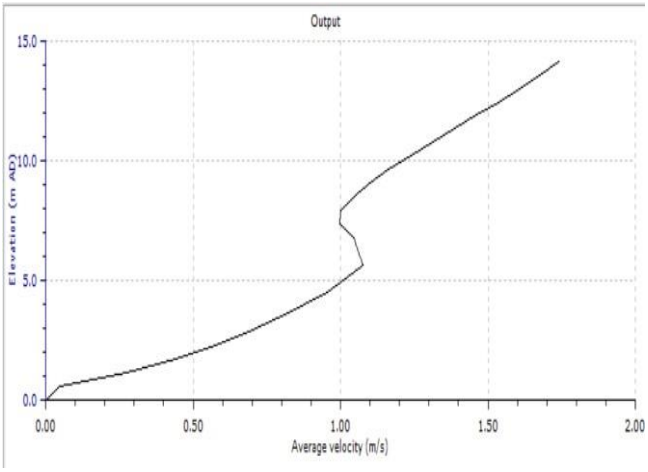


Fig. 10 Elevation vs Average velocity

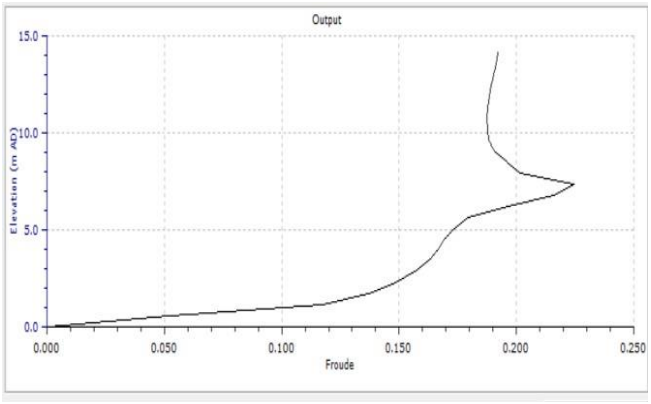


Fig. 11 Elevation vs Froude

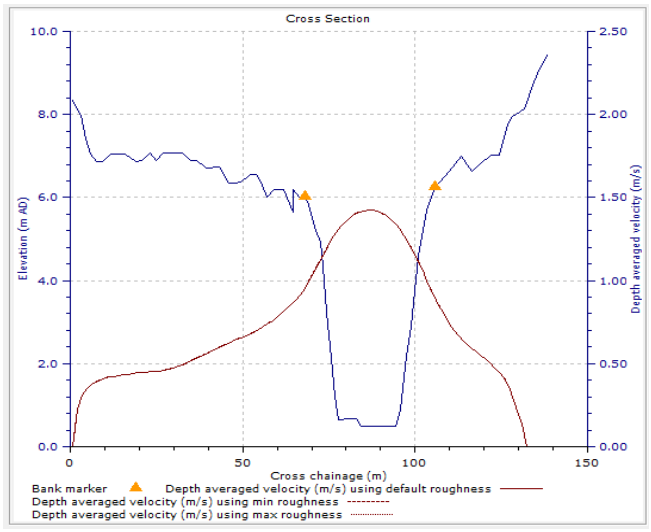


Fig. 12 Elevation vs Spatial velocity

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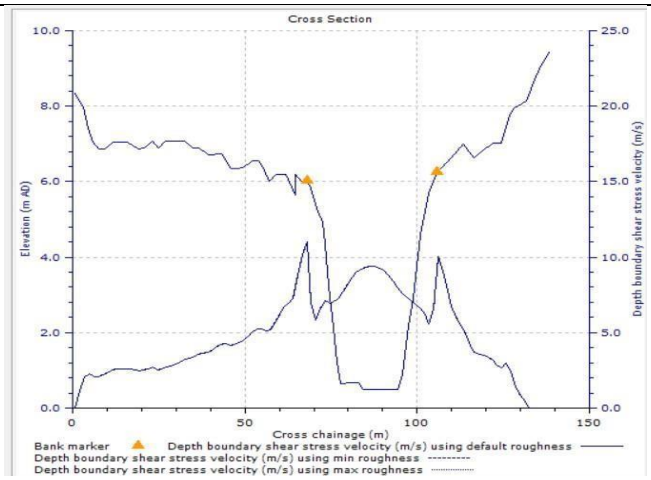


Fig. 13 Elevation vs Boundary shear stress

Examination of River Senggi(B)



Fig. 14 Morphological Cross Section of River Senggi(B)

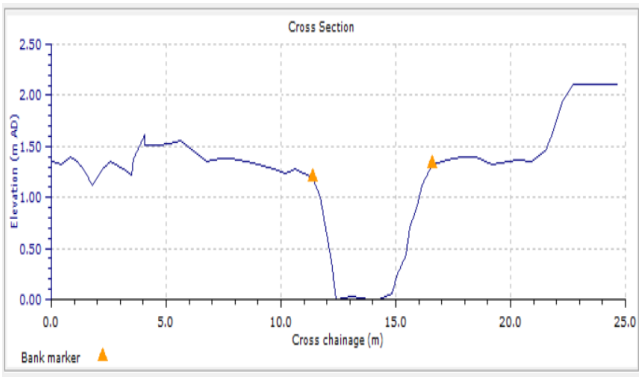


Fig. 15 Elevation vs Cross-Chainage

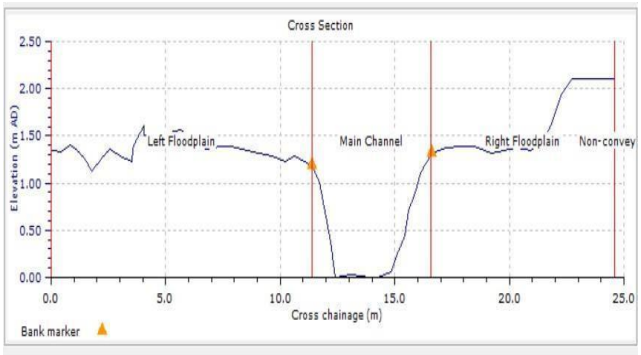


Fig.16 Bank Marker and Roughness Zones

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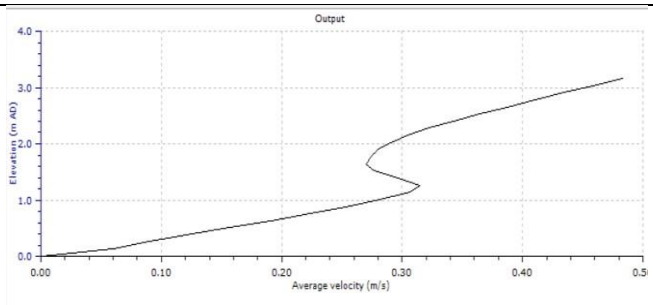


Fig.17 Elevation vs Average velocity

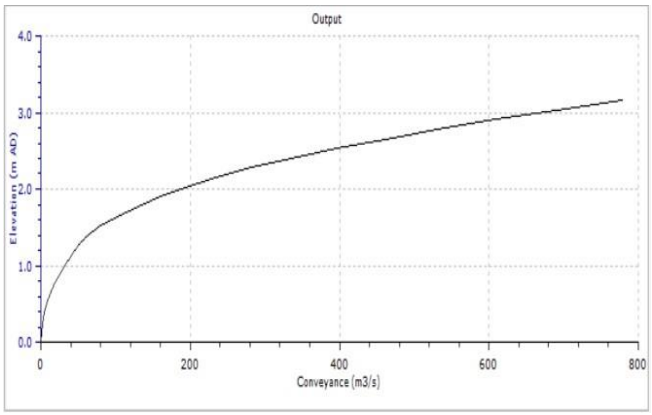


Fig. 18 Elevation vs Conveyance

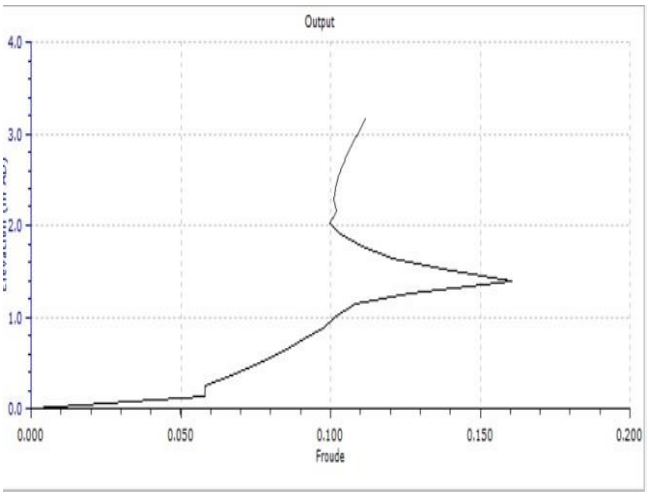


Fig. 19 Elevation vs Froude

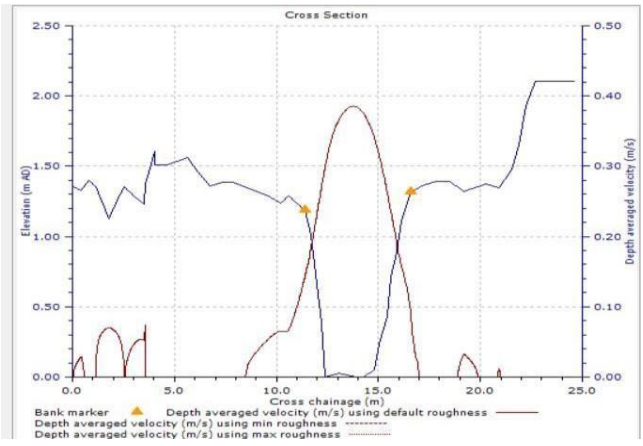


Fig. 20 Elevation vs Spatial velocity

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

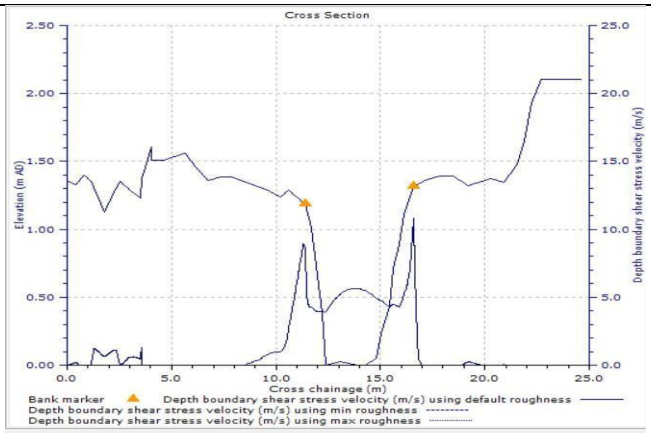


Fig. 21 Elevation vs Boundary shear stress

Examination of River Senggai



Fig. 22 Morphological Cross Section of River Senggai

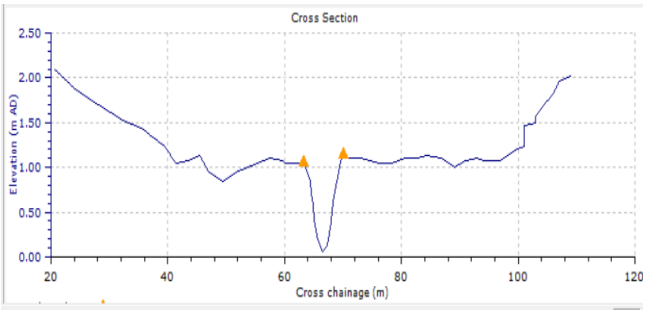


Fig. 23 Elevation vs Cross-Chainage

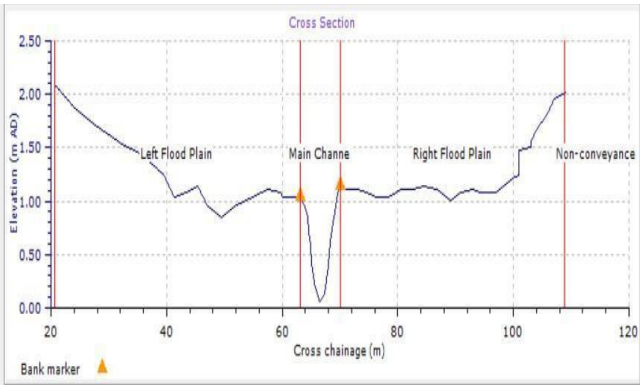


Fig. 24 Bank Marker and Roughness Zones

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

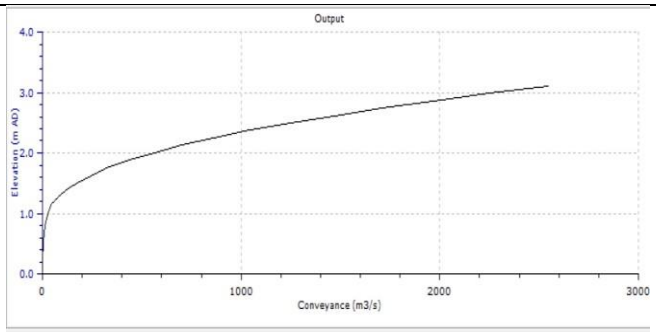


Fig. 25 Elevation vs Conveyance

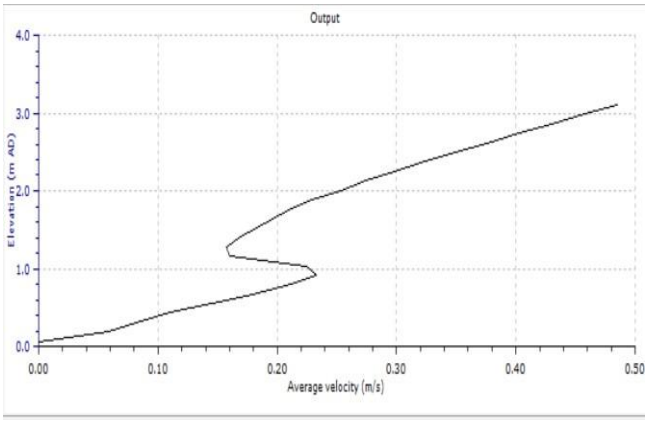


Fig. 26 Elevation vs Average velocity

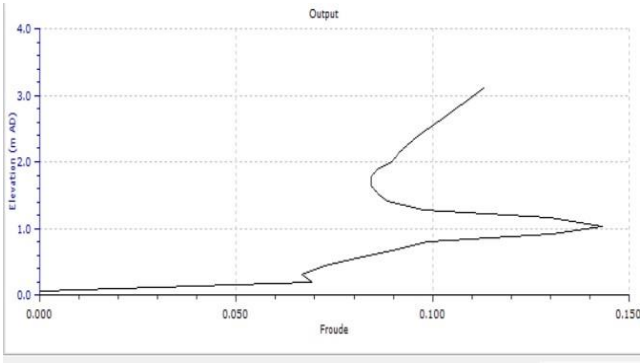


Fig. 27 Elevation vs Froude

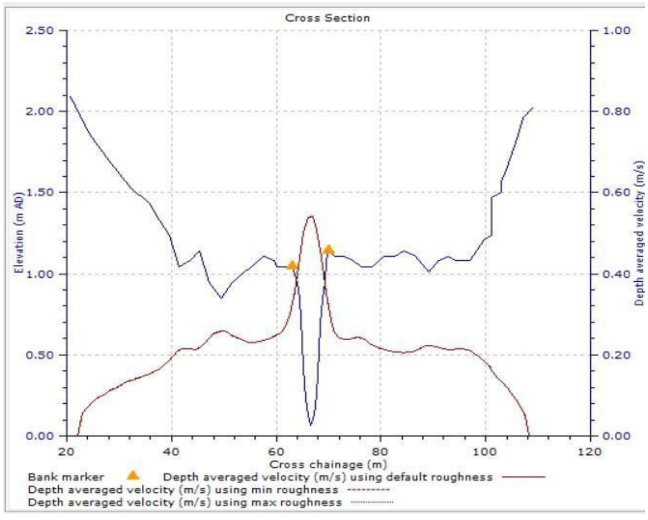


Fig. 28 Elevation vs Spatial velocity

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

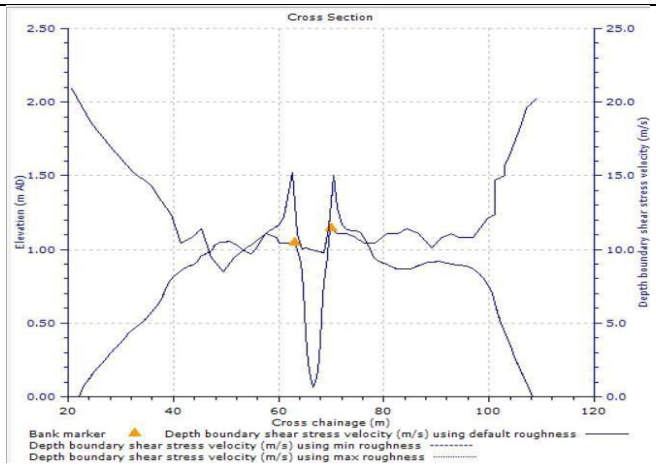


Fig. 29 Elevation vs Boundary shear stress

Examination of River Batu



Fig. 30 Morphological Cross Section of River Batu

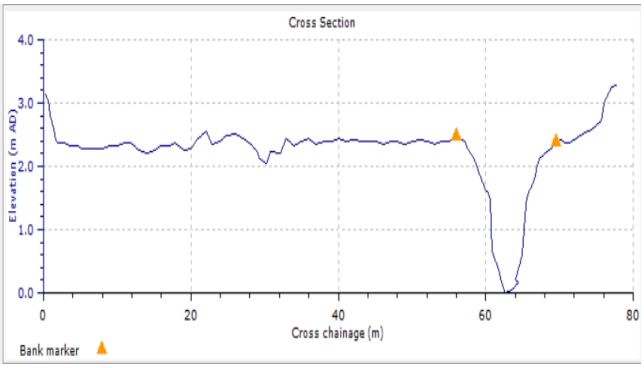


Fig. 31 Elevation vs Cross-Chainage

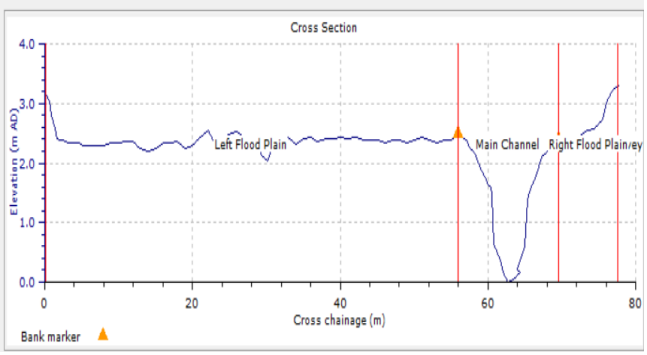


Fig. 32 Bank Marker and Roughness Zones

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

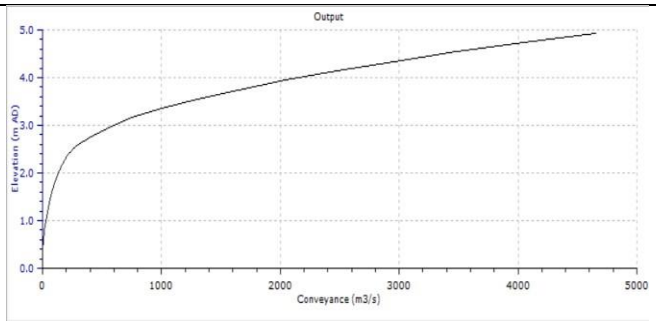


Fig. 33 Elevation vs Conveyance

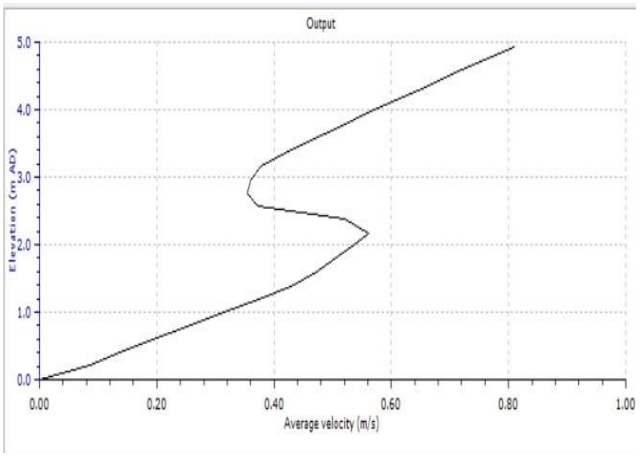


Fig. 34 Elevation vs Average velocity

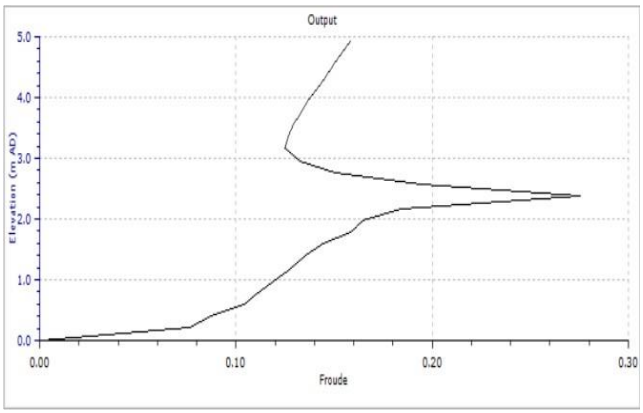


Fig. 35 Elevation vs Froude

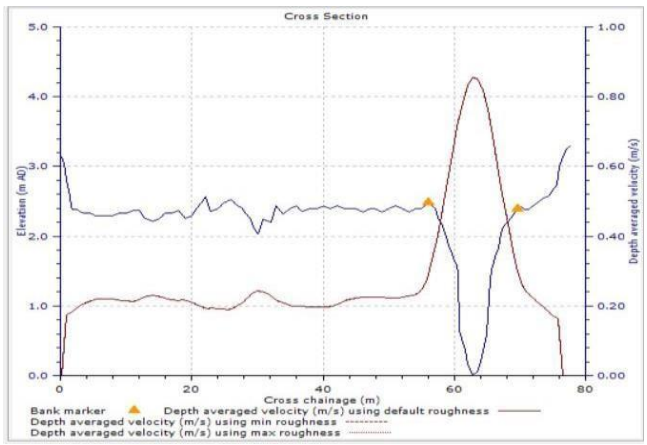


Fig. 36 Elevation vs Spatial velocity

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

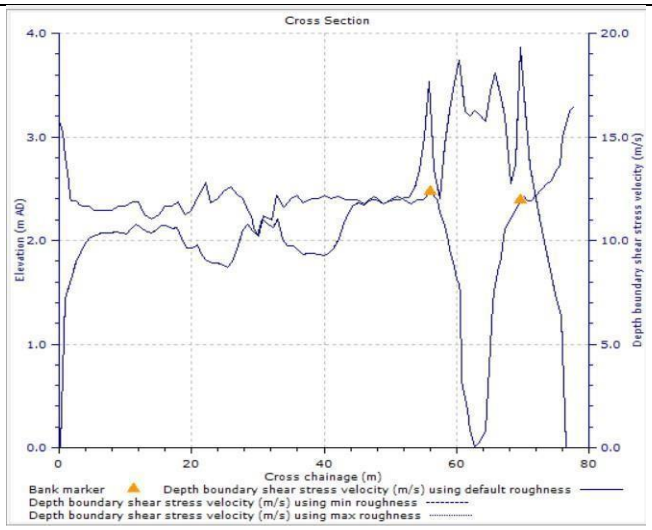


Fig. 37 Elevation vs Boundary shear stress

The observed fluctuations in the graphs are attributed to the natural irregularities of the riverbeds. To quantify flow resistance in the main channels of each river, we calculated the Manning's roughness coefficient (n) and the Darcy-Weisbach friction factor (f).

Each graph delineates two distinct zones:

In-Bank Flow Zone: Here, both Manning's n and the Darcy-Weisbach f decrease linearly with increasing flow depth. This trend is due to the reduction in relative roughness as water depth increases, leading to smoother flow conditions within the main channel.

For the main channels of Rivers Senggai, Senggi (B), and Batu, the calculated Manning's n values range from 0.07 to 0.10, while the Darcy-Weisbach f values vary between 0.54 and 0.89. These figures indicate that the surface roughness in these natural river channels is significantly higher than that typically observed in laboratory-based compound channel studies, which often report lower roughness values.

Understanding these resistance coefficients is crucial, as they directly influence the accuracy of flow modeling and flood prediction in natural waterways.

IV. Conclusions and Future Prospects

Conclusion:

This study's analysis of river flow data has led to several key findings:

- Reduction in Main Channel Capacity Due to Interaction with Floodplains: The interaction between the main channel and adjacent floodplains during inundation results in a decrease in the main channel's conveyance capacity. This interaction reduces the overall efficiency of the compound channel system under flood conditions.
- Minimal Contribution of Floodplains to Discharge Capacity: The presence of dense vegetation on floodplains introduces significant resistance to flow, causing flow velocities in these areas to approach zero. Consequently, floodplains contribute minimally to the overall discharge capacity of rivers during flood events.
- Increased Flow Resistance During Flood Conditions: The study confirms a notable increase in flow resistance when rivers exceed their banks. This finding underscores the risks associated with extrapolating in-bank flow data to predict overbank flow behaviors, as such practices can lead to inaccurate assessments and potential mismanagement of flood risks.
- Application of the Shiono and Knight Method (SKM): Traditionally employed for modeling flow in prismatic compound channels, the SKM's applicability to non-prismatic channels with complex floodplain geometries was evaluated. The research indicates that with appropriate calibration of secondary flow coefficients, the SKM can effectively predict depth-averaged velocity and boundary shear stress in these non-prismatic settings.
- Enhanced Predictions Through Calibrated SKM: Comparisons between SKM predictions and experimental data reveal that calibrating the model's secondary flow coefficients significantly improves its accuracy in forecasting depth-averaged velocities and boundary shear stresses in non-prismatic compound channels.
- Utilization of Computational Engineering Software (CES): Implementing flow computations via CES software provides hydraulic engineers with a robust tool for simulating and predicting flood events. This capability is instrumental in designing effective flood mitigation strategies and managing riverine systems more efficiently.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue III, March 2025

Future Prospects:

To advance the methodologies and findings of this study, the following recommendations are proposed:

- Comprehensive Data Acquisition in Diverse Channel Geometries: While the current study focused on straight river reaches, extending data collection to encompass both straight and meandering two-stage natural channels is essential. This expanded scope should include measurements of discharge, water levels, depth-averaged velocities, and, where feasible, turbulence characteristics. Such comprehensive data will enhance the understanding of flow dynamics across varied channel configurations.
- Investigation of Lateral Shear Effects in Two-Stage Channels: The study underscores the significance of lateral shear forces in two-stage channels. Therefore, a detailed examination of the Shiono and Knight Method (SKM) is recommended, focusing on its applicability in predicting the lateral distribution of the dimensionless eddy viscosity (λ) within these complex channel systems. This investigation will contribute to refining predictive models for flow behavior in two-stage rivers.
- Implementing these enhancements will provide a more robust framework for analyzing and modeling riverine systems, leading to improved flood management and river engineering practices.

References

1. Amir Motamed Dashliborun, Faïçal Larach, (2015). Hydro dynamics of gas–liquid concurrent downflow in floating packed beds. Elsevier, Chemical Engineering Science137(2015)665–676.
2. Zhonghua Yang, Da Li, Wenxin Huai, Jianhua Liu, (2019). A new method to estimate flow conveyance in a compound channel with vegetated floodplains based on energy balance. Elsevier, Journal of Hydrology 575 (2019) 921–929.
3. Siprarani Pradhan, Biswajit Pradhan, Kishanjit Kumar Khatua, (2025). Experimental investigations and modelling of composite roughness for compound channels. Elsevier, Journal of Hydrology 651 (2025) 132554.
4. Amirreza Kavousizadeh, Arash Ahmadi, (2018). High-performance approach for estimating stage-discharge curves in the open channels. Elsevier, Journal of Hydrology 565 (2018) 197–213.
5. Sachin K. Dahikar, Jyeshtharaj B. Joshi, Manish S. Shah, Avtar S. Kalsi, Chaganti S. RamaPrasad, Daya S. Shukla, (2010). Experimental and computational fluid dynamic study of reacting gas jet in liquid: Flow pattern and heat transfer. Elsevier, Chemical Engineering Science 65 (2010) 827–849.
6. Li Liu, Bofeng Bai, (2019). A mechanistic model for the prediction of swirling annular flow pattern transition. Elsevier, Chemical Engineering Science 199 (2019) 405–416.
7. S.B. Kuang, K. Li, R.P. Zou, R.H. Pan, A.B. Yu, (2013). Application of periodic boundary conditions to CFD-DEM simulation of gas–solid flow in pneumatic conveying. Elsevier, Chemical Engineering Science 93 (2013) 214–228.
8. Peter J. O'Rourke, Paul (Pinghua)Zhao, DaleSnider, (2009). A model for collisional exchange in gas/liquid/solid fluidized beds. Elsevier, Chemical Engineering Science 64 (2009) 1784 -- 1797.
9. Adnan Almuttahar, Fariborz Taghipour, (2008). Computational fluid dynamics of a circulating fluidized bed under various fluidization conditions. Elsevier, Chemical Engineering Science 63 (2008) 1696 – 1709.
10. Wei Du, Xiaojun Bao, Jian Xu, WeishengWei, (2008). Computational fluid dynamics (CFD) modeling of spouted bed: Influence of frictional stress, maximum packing limit and coefficient of restitution of particles. Elsevier, Chemical Engineering Science 61 (2006) 4558 – 4570.
11. Raghvendra Gupta, David F. Fletcher, Brian S. Haynes, (2010). CFD modelling of flow and heat transfer in the Taylor flow regime. Elsevier, Chemical Engineering Science 65 (2010) 2094–2107.
12. Subhashini Ghorai, Vishal Suri, K.D.P. Nigam, (2005). Numerical modeling of three-phase stratified flow in pipes. Elsevier, Chemical Engineering Science 60 (2005) 6637 – 6648.
13. A. J. M. Oprins, G. J. Heynderickx, (2003). Calculation of three-dimensional #ow and pressure %elds in cracking furnaces. Elsevier, Chemical Engineering Science 58 (2003) 4883 – 4893.
14. Amol A. Kulkarni, Jyeshtharaj B. Joshi, (2004). Simultaneous measurement of Flow pattern and mass transfer coefficient in bubble columns. Elsevier, Chemical Engineering Science 59 (2004) 271 – 281.
15. C. Deng∗, D.M. Martinez, (2005). Viscous flow in a channel partially filled with a porous medium and with wall suction. Elsevier, Chemical Engineering Science 60 (2005) 329 – 336.