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Analyzing Flow Characteristics in the Neelum River using Advanced Hydrodynamic Simulations

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Abstract

The Neelum River in northern Pakistan has intricate flow characteristics owing to its unique geographic and climatic factors, which are essential for managing water resources and preventing floods. This study employs hydraulic modeling with the HEC-RAS program to assess the flow dynamics and flood risks of the Neelum River. The study focuses on two different river segments: the urbanized Muzaffarabad part and the natural stretch that runs from Panjgiran to Dhani. Based on topographical and infrastructure factors, hydraulic models were used to examine flow velocities, water depths, and flood threats. The topography and channel morphology in the natural segment affect both flow velocity and depth; at River Station 6966, the highest flow velocity of 6.26 m/s and the average water depth of 2.98 m were observed. On the other hand, the urbanized area of Muzaffarabad shows notable changes in its hydraulic behavior; the water surface heights in this area range from 925.65 to 945.20 meters, and the flow rates vary from 915.5 m/s to 940.0 m/s. The natural segment has a more curved channel and less erosion potential than the restricted channels and smaller floodplain regions in Muzaffarabad. These results emphasize the need for region-specific flood management plans that are adapted to the unique hydraulic characteristics and hazards of both rural and urban areas. Effective sustainable river management in both rural and urban environments can be accomplished by creating comprehensive flood profiles.

Keywords: Neelum River Hydrodynamics; HEC-RAS Flood Modeling; Hydraulic Structures Impact; Urban Flood Risk Management

1. Introduction

The Neelum River, located between the coordinates 73° to 76° east and 32° to 36° north, acting as a natural boundary between India and Pakistan along the line of control (LOC) (Ali et al., 2019; Khan, 2022). The river rises in Indian-administrated Kashmir's Himalayan peaks near Kishna Lake and flows into Pakistan at Taobat via Azad Jammu and Kashmir (Khan, 2022; Munir, 2013). It is an essential part of the Indus River Basin in the eastern and northeastern parts of Pakistan, flowing through the Neelum Valley and joining the Jhelum River near the Muzaffarabad Bridge (Ali et al., 2019; Waqar et al., 2020).

The Neelum River, which is the biggest tributary of the Jhelum River, provides around 40% of the water entering the Mangla Reservoir, Pakistan's second-biggest dam. This reservoir is essential for irrigation; it provides water to around 6 million hectares of farmland and produces 1000 MW of electricity, or roughly 6% of Pakistan's installed energy capacity (Ackers et al., 2016; Khan et al., 2020). The Neelum River's strategic significance is emphasized by its contributions to energy production and agricultural productivity, underscoring the river's importance for Pakistan's economy and environmental sustainability (Noor et al., 2011).

The intricate terrain of the Neelum Valley, which is made up of high-altitude flat plains, narrow valleys, and steep mountains, has a substantial impact on the flow dynamics of the Neelum River. These physical features, combined with the region's tropical monsoon climate, render the area highly prone to natural hazards, such as landslides and flash floods (Gul et al., 2020). These problems are made worse by heavy monsoon rains, which cause abrupt changes in sediment transport and water flow, make managing water resources more difficult, and raise the risk of flooding (McVean and Robertson, 1969; Noor et al., 2011).

Water is always been a valuable natural resource for different human activities but its pollution is a major concern (Khattak, 2015; Ahmad et al., 2020). To enhance water resource management in light of these environmental vulnerabilities, it is imperative to establish accurate techniques for assessing the flow dynamics (Ur Rashid, 2017). While some research has looked at the region's wider hydrological ramifications and ecological effects (Waqar et al., 2011; Tehmina et al., 2011). There is a notable gap in the detailed analysis of the river's hydraulic behavior across different areas. Specifically, little attention has been given to comparing the flow dynamics between different sections of the river, which could provide insights into how urbanization and natural features influence flood risks (Kute et al., 2014; Tate and Maidment, 1999).

This study aims to fill this knowledge gap by analyzing the flow patterns of the Neelum River in two distinct sections: Muzaffarabad and Panjgiran-Dhani. The study will do this by developing hydraulic models using Digital Elevation Models (DEMs), river discharge data from nearby hydrological stations, and meteorological inputs. By comparing the two regions, the study will highlight the ways in which topography and human interventions influence the river's flow behavior. In the end, the research will help policymakers and water resource managers adopt more practical and sustainable solutions for flood risk mitigation in the Neelum River Basin.

2. Materials and Methods

This study focuses at two different sections of the Neelum River. The first section is about 50 kilometers upstream and is identified by the geographic coordinates 34.56° N, 73.04° E, and 34.37° N, 73.47° E, respectively (downstream). The second area has coordinates of 34.37° N, 73.47° E (upstream) and 34.34° N, 73.49° E (downstream), and it is located inside the limits of Muzaffarabad. The Neelum River basin is made up of limestone, quartzite, and schist, with plains dotted throughout and steep hills, mountains, and narrow valleys. Rafique et al. (2020) and Malkani (2020) note that the region's topography ranges from 700 to over 4,000 meters, which contributes to the variety of hydrological features. Figure 1 shows the topographic map and geographic position of Pakistan's Azad Kashmir, namely Neelum Valley.

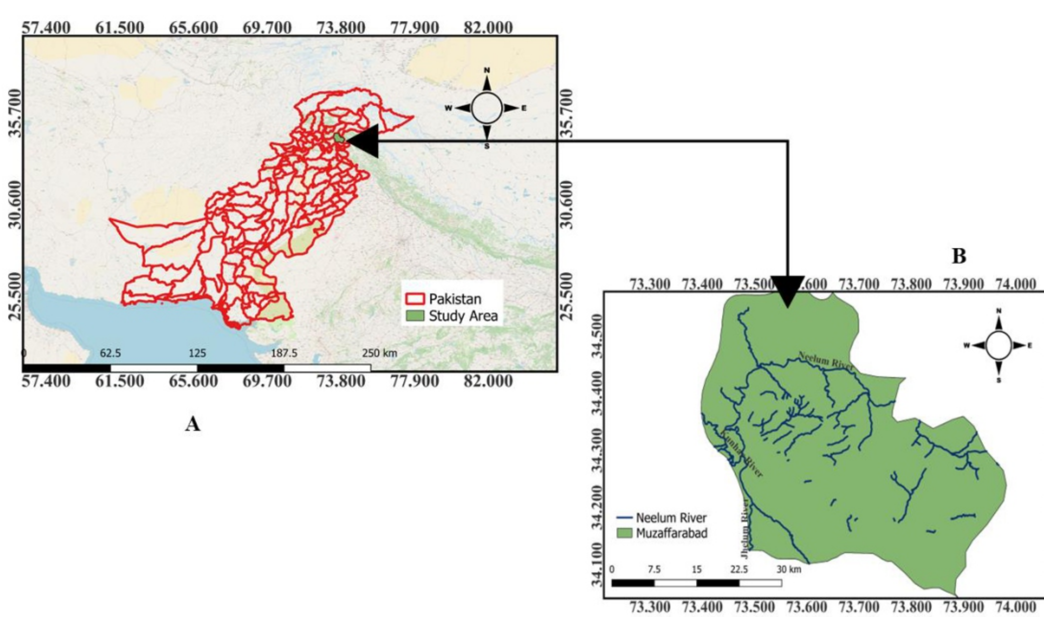

Fig. 1. (A) Map of Pakistan showing the location of Study area
(B) Detailed map of Neelum river in Azad Kashmir

As shown in Table 1, data collecting methods included using Digital Elevation Models (DEMs), projection files, Google Hybrid imagery, and HEC-RAS software. The research area's terrain model was supplied by DEMs, and spatial reference was made easier via projection files. Hydraulic properties were modeled using HEC-RAS software, while land use and cover were evaluated using Google Hybrid images. In order to facilitate a thorough investigation of the river's hydrodynamics in various flow scenarios, stage hydrographs were used for the downstream border and synthetic flow hydrographs were applied to depict fluctuating flow rates at the upstream boundary.

Table 1: Summary of Datasets and Spatial References used in the study

Dataset	Source	Description	Resolution/Scale
Digital Elevation Model (DEM)	SRTM (Shuttle Radar Topography Mission)	Elevation data for creating terrain model and delineating river basin	30 meters*
Land Use and Land Cover Data	Satellite Imagery and Land Use Surveys	Information on land cover types affecting surface runoff and infiltration rates	High Resolution
Projection	EPSG:32643 - WGS 84 / UTM zone 43N	Spatial reference system used for georeferencing all datasets	-

*HEC-RAS software (version 6.5), which facilitates both 1D and 2D flow evaluations (Mehta et al., 2013; Khattak et al., 2016; Leon and Goodell, 2016; Ogras and Onen, 2020), was used to conduct the hydrodynamic analysis. The model setup involves precisely modeling the physical and hydraulic properties of the river reach, including channel distances and flow velocities at various cross-sections. Data on geophysical, hydrological, and hydraulic properties were gathered, preprocessing procedures such DEM processing and cross-section extraction were carried out, and geometry, boundary, and initial condition settings were made. After the model was calibrated using measured data, the roughness coefficients were adjusted, and simulation was run to get 1D and 2D flow results. Comprehensive hydrodynamic analysis was ensured by the findings analysis and reporting included in the end step.

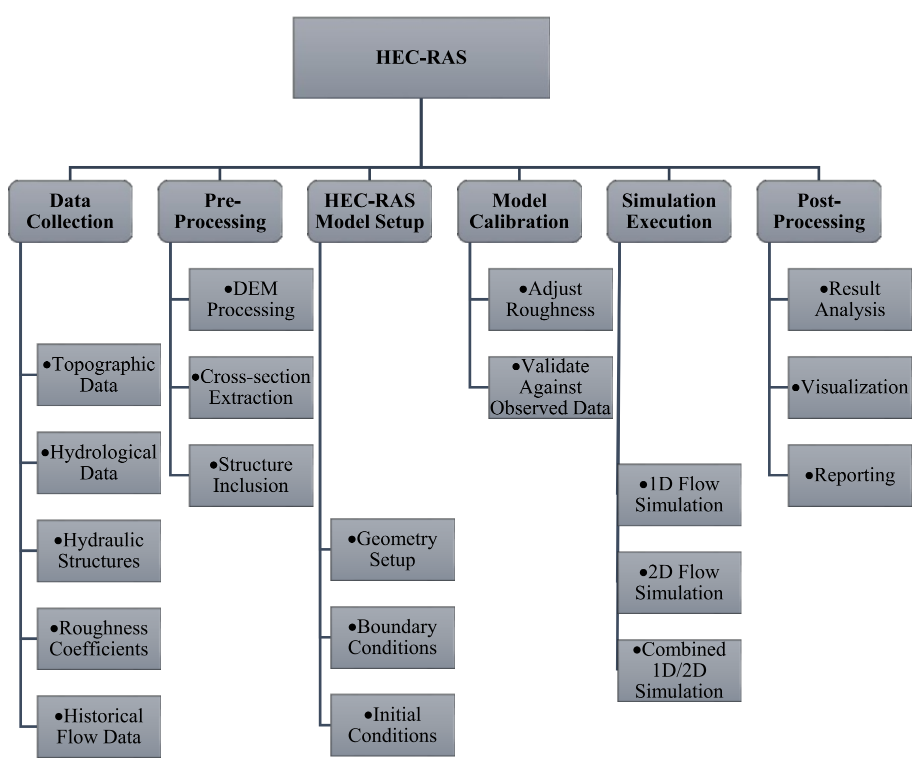

Fig. 2. Overview of HEC-RAS Model Setup and Simulation Process for Hydrodynamic Analysis

The efficiency of the calibrated model was further validated by testing it against an independent dataset that was not used for calibration. This validation evaluated the degree of agreement between the observed data and the modeled results, confirming the model's ability to accurately reconstruct historical flood events and normal flow, backed by field observations. This validation emphasizes the model's suitability for flood risk management, urban planning, and the design of mitigation measures in affected areas.

3. Results

3.1 Hydraulic Analysis of the First Region (Panjgiran to Dhani)

The topography and channel layout of the Neelum River resulted in a variety of hydraulic features. In Figure 3, gematric profiles of the Neelum River from Panjgiran to Dhani are displayed.

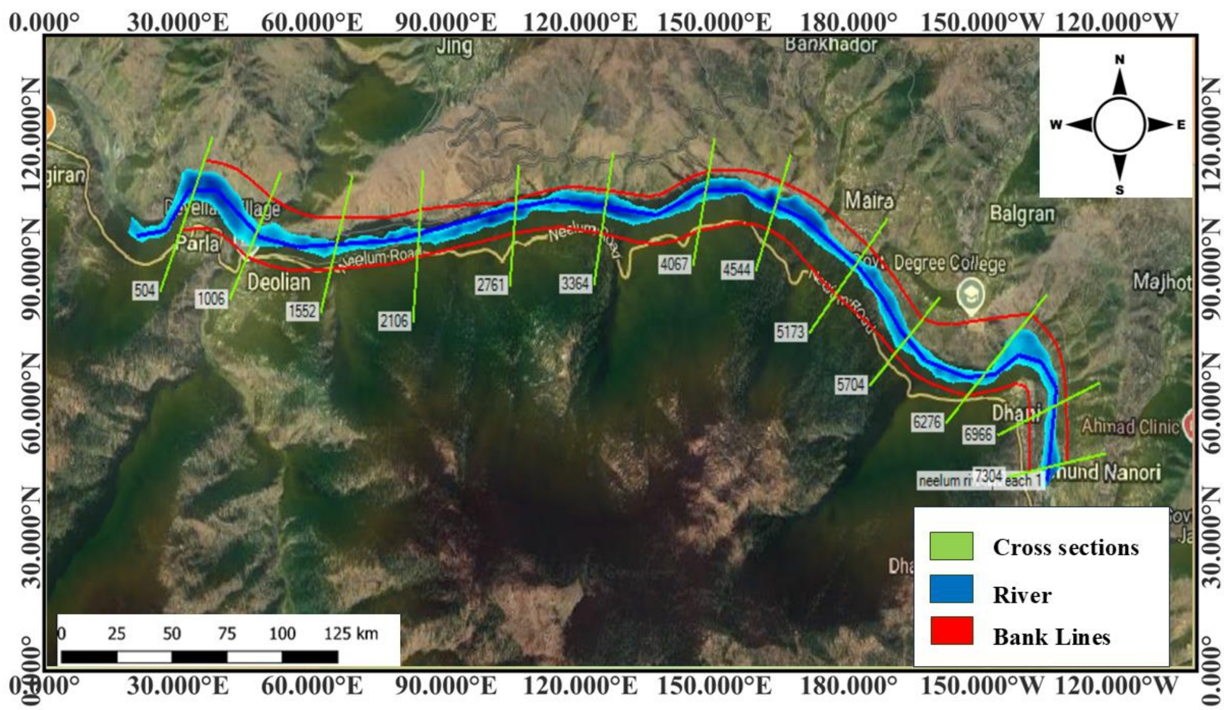

Fig. 3. Geometric Profiling of the Neelum River from Panjgiran to Dhani.

The highest water surface elevation, ground level, and bank station at various river sections are depicted in these profiles. These cross-sectional data are essential for comprehending the channel structure of the river, which greatly affects hydraulic characteristics like water depth and flow velocity. A thorough hydrodynamic evaluation of the Neelum River, with a particular emphasis on the Panjgiran to Dhani segment, is based on these data. Examining this section clarifies the differences in flow characteristics as well as the effects of structural and geographic factors.

Flow Velocity: In hydrodynamic terms, velocity is closely linked to both the slope of the riverbed and the channel geometry. In steep-gradient rivers the gravitational forces act more strongly on the water, causing it to move faster, particularly through narrow sections. This high velocity is a direct reflection of the energy within the river system, which in turn has critical implications for erosion, sediment transport, and flood risks. The velocity distribution in this region, as depicted in Figure 4, shows that while the river generally maintains moderate flow velocities, certain areas experience sharp velocity spikes. These spikes are concentrated in specific cross-sections where the channel is more confined, indicating that localized acceleration occurs in response to narrower sections. This phenomenon is common in rivers with varying topography, where wide sections allow for slower flow and narrower sections force the water to speed up due to reduced channel width.

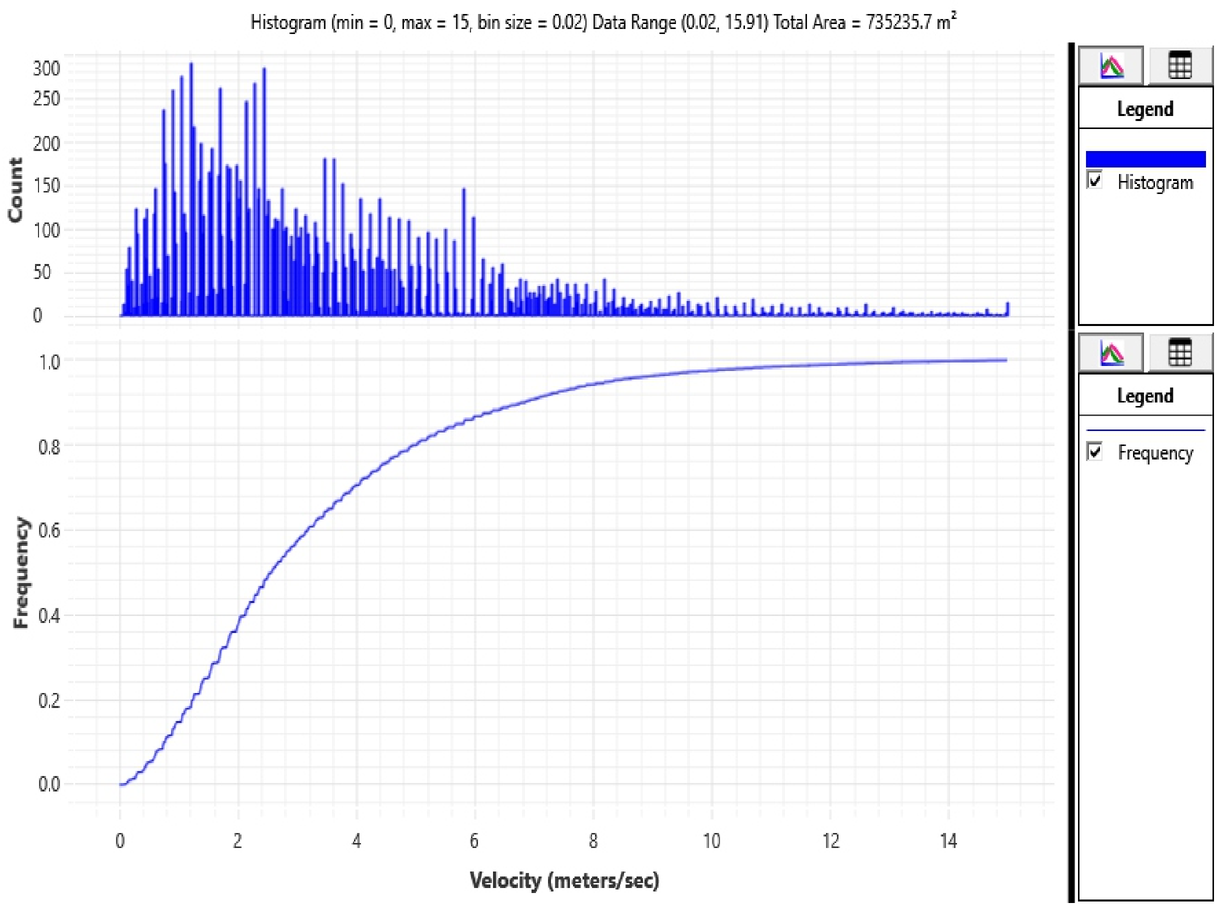

Fig. 4. Velocity Distribution in the Panjgiran to Dhani Region of the Neelum River

Furthermore, the above histogram shows that the speed values lie in a wider range and that the greater frequencies relate to low velocities while the number of cases of increasing velocity is lower. The flow rate in the mid-portion of the river is significantly faster compared to the upper and lower portions, resulting in a moderate flow throughout most parts of the river section. This balanced flow ensures optimal conditions for various activities and adds to the overall appeal of the river. Figure 5 is a velocity map that depicts the distribution of flow velocities in the same river. The color gradient ranges from blue (low velocity of 0.02 m/s) to red (high velocity 16 m/s), clearly indicating flow dynamics within the river reach. High flow velocities, depicted in red and orange, are concentrated near Dhani, where the channel is more confined, leading to increased speeds due to reduced cross-sectional area and steeper gradients. Conversely, the blue and green areas represent regions of lower velocity, typically found in wider sections of the river or those with gentler slopes, indicating potential zones for sediment deposition.

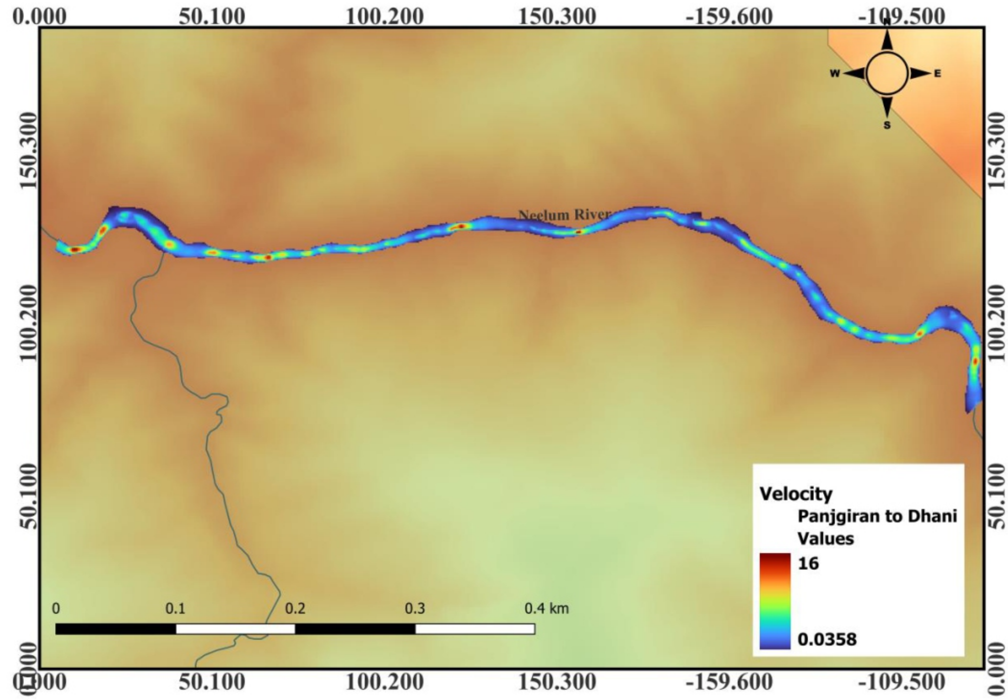

Fig. 5. Maximum Flow Velocity in the First Region (Panjgiran to Dhani)

The integration of the analysis is crucial in identifying areas prone to erosional hazards and transport levels for use in avoiding flood dangers, thereby contributing to the management and control of the relevant rivers.

Average Flow Depth: In this region, mean flow depth was obtained to equal 2.98 m. Therefore, the hydraulic structures and natural channel form affect the depth variation. In the map of Figure 6, darker blue is used to represent shallow parts of the river, while light blue represents deeper parts of the river. In figure 6 significant fluctuations in depth were observed, with most areas near Dhani having a maximum depth of up to approximately 25 m.

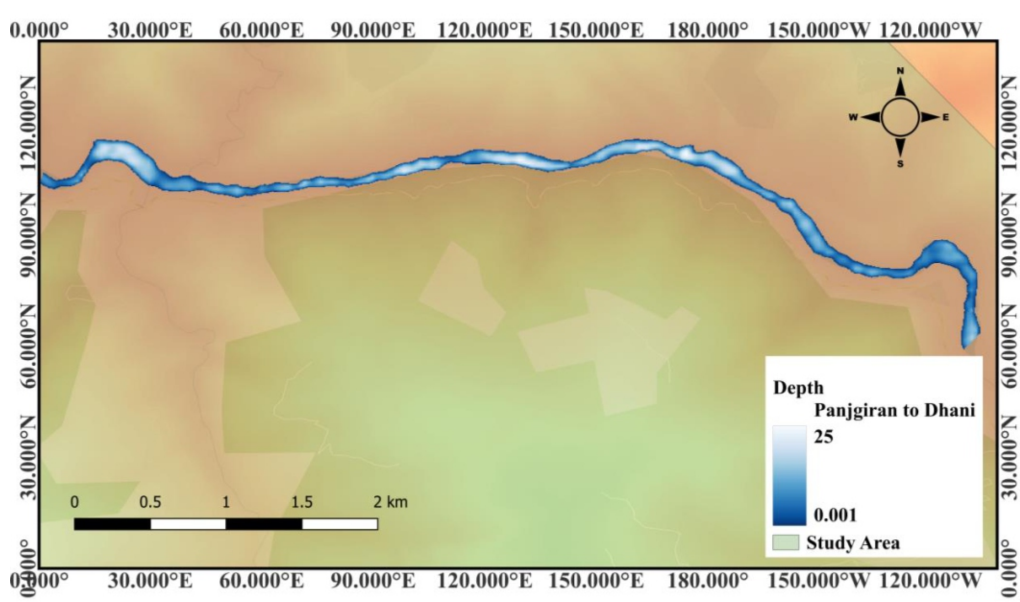

Fig. 6. Maximum depth in the First Region (Panjgiran to Dhani)

The depth map obtained from the hydrodynamic analysis provides essential data for understanding Neelum River behavior and can be used to guide river management and planning efforts effectively.

3.2 Water Surface Elevation (WSE) Distribution

The Water Surface Elevation (WSE) map from Panjgiran to Dhani presents a gradient of elevation changes across the region. The color gradient, ranging from blue to red, visually represents lower to higher WSE values. The areas in blue (886 meters) indicate lower elevations, likely corresponding to broader sections of the river with slower flow, potentially allowing for sediment deposition. As the gradient shifts toward red (948 meters), the higher elevations indicate steeper, narrower sections where water flow is likely faster, suggesting a higher risk of erosion and turbulent flow.

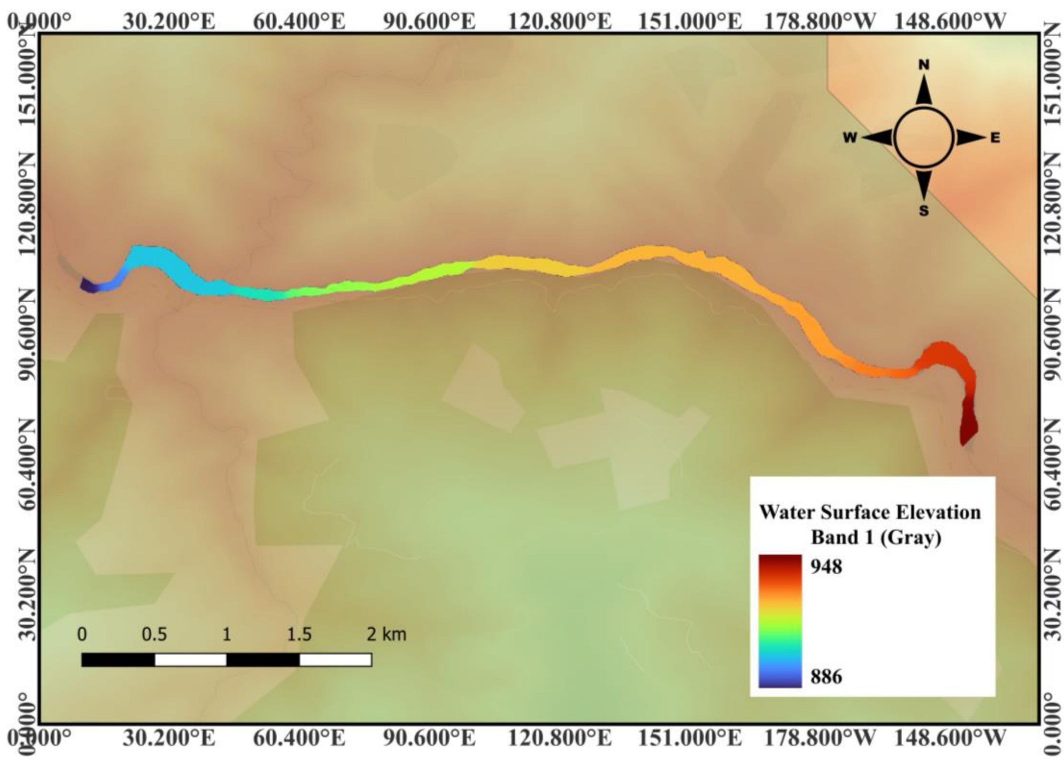

Fig. 7. Variation of Water surface elevation in First Region.

This variation in WSE highlights key zones along the river, where potential flood risks are higher in lower elevation areas, while areas with steep slopes may experience more dynamic flow patterns. Understanding these changes is crucial for assessing hydraulic behavior and managing flood risks in the Panjgiran to Dhani stretch of the Neelum River.

3.3 Hydraulic Analysis of the Second Region (Muzaffarabad City Area)

The second portion of the river, analyzed from coordinates 34.37°N, 73.47°E (upstream) to 34.34°N, 73.49°E (downstream), includes the urban area of Muzaffarabad. Following the detailed assessment of the Panjgiran to Dhani segment, the focus transitions to the Muzaffarabad reach of the Neelum River, where significant hydraulic variations are observed. This section of the river is characterized by complex topographical features and varying channel morphology, both of which exert a considerable influence on flow dynamics. Figure 9 illustrates the geometric profile of the Muzaffarabad region, providing a visual representation of the channel's structure and its impact on flow velocities.

Flow Velocity: Maximum Flow Velocity: In the urban region, the maximum flow velocity was significantly lower at 1.32 m/s at River Station 7304 (Figure 10).

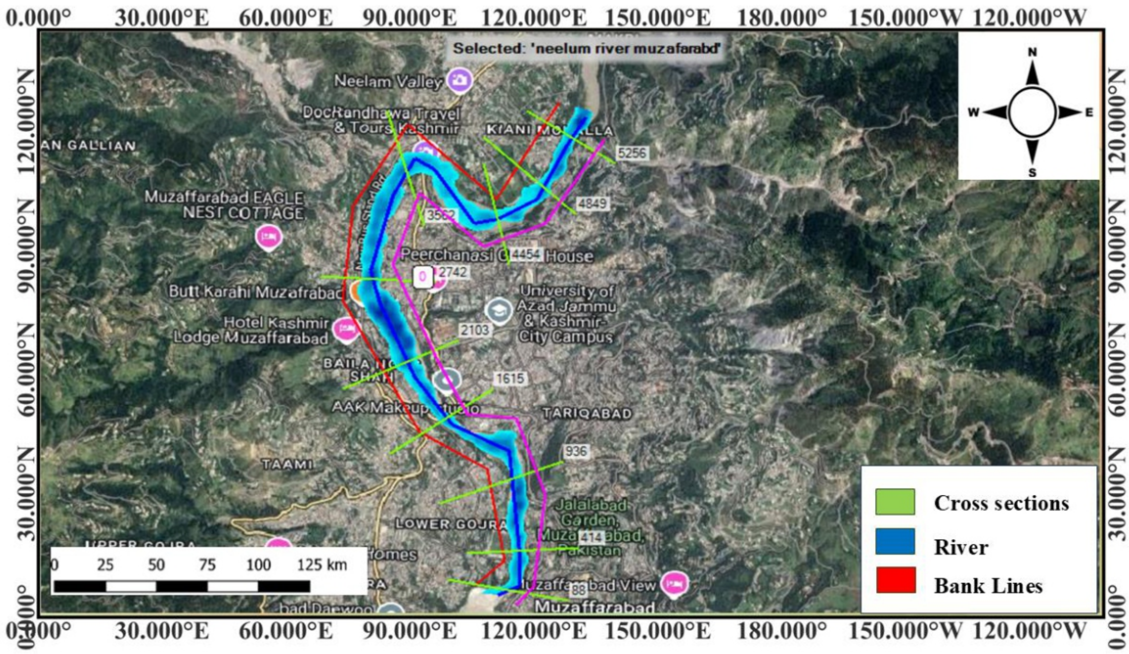

Fig. 9. Geometric Profiling of the Neelum River in Muzaffarabad.

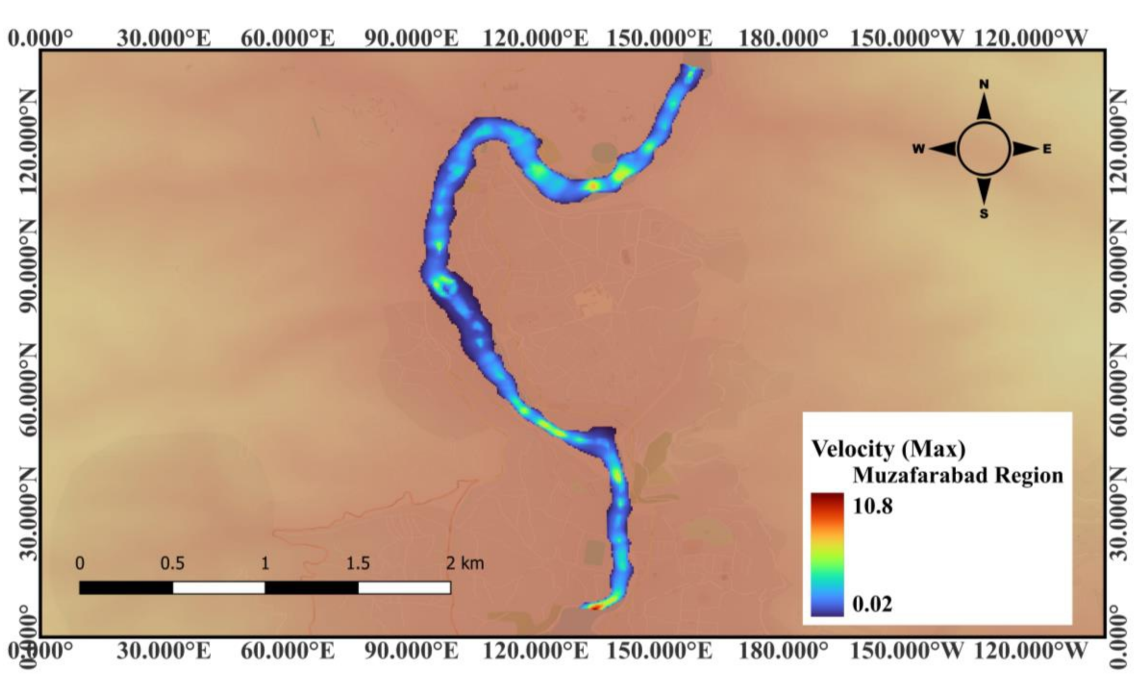

Fig. 10. Maximum Flow Velocity in the second region Muzaffarabad.

The velocity map in Figure 10, superimposed on the geographical background, expresses flow speeds in a gradation of colors, starting with blue, where velocities are low, and ending with red, where velocities are high. This map easily generates spatial awareness of the river's flow pattern.

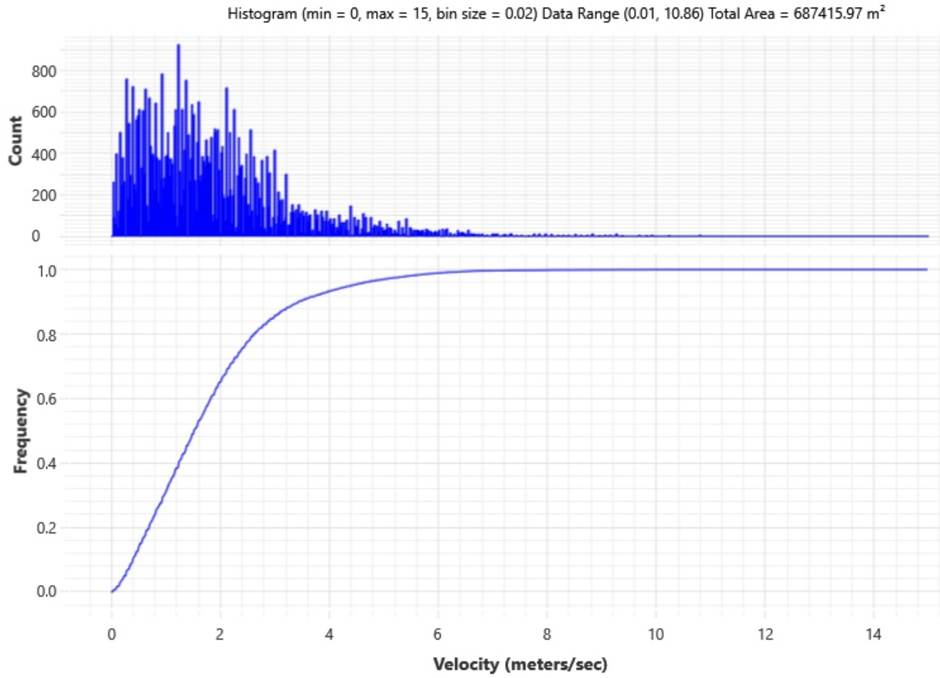

Fig. 11. Maximum Flow Velocity in the Second Region (Muzaffarabad City Area).

This histogram has velocities starting from 0. 01 to 10. 86 m/s. Further, it defines the proportions of flow velocities using the rate of 02 m/s. Greater than 90% of the velocities are likely to occur in the 0 to 2 m/s range, so the flow velocities are likely to be slow. Velocities higher than this 2 m/s are, however, not very common. The cumulative frequency graph thus shows that 90 percent of velocities are less than the value of 6 m/s, indicating moderate to low flow conditions were most dominant.

Average Flow Depth: The average flow depth was higher due to the confined channel within the urban limits, indicating potential areas for flooding during high-flow events.

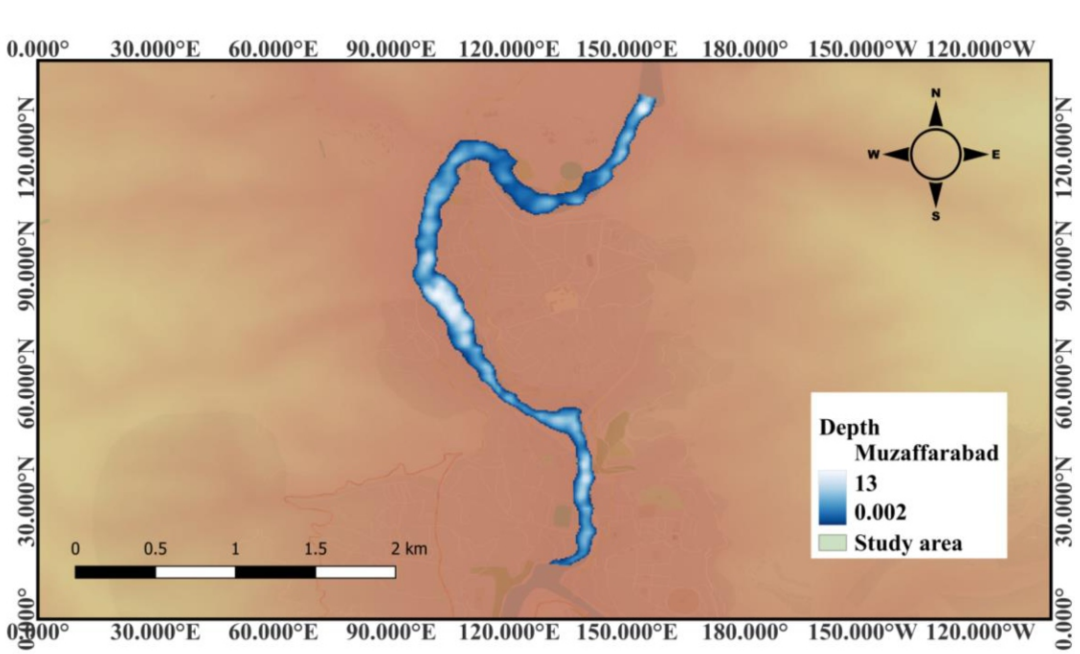

Fig. 12. Depth Distribution Analysis of the Neelum River in the Urbanized Muzaffarabad Region Using HEC-RAS Model

The map displays the depth distribution of the river in the Muzaffarabad region, with depths ranging from 0.002 m to a maximum of 13 m, as indicated by the color gradient from light blue to dark blue. The deeper sections, highlighted in dark blue, are primarily observed in the central and upstream portions of the river. These deeper areas are likely to accommodate a greater volume of flow during flood events, potentially reducing surface flow velocities in these regions. In contrast, shallower areas, represented by light blue, are found predominantly in downstream segments, which may lead to higher velocities and increased risk of flooding in these sections.

Water surface elevation (WSE): WSE is a critical parameter in flood modeling, reflecting the surface height of water relative to a standard datum. It is widely used to understand water flow dynamics, especially in regions prone to extreme hydrological events.

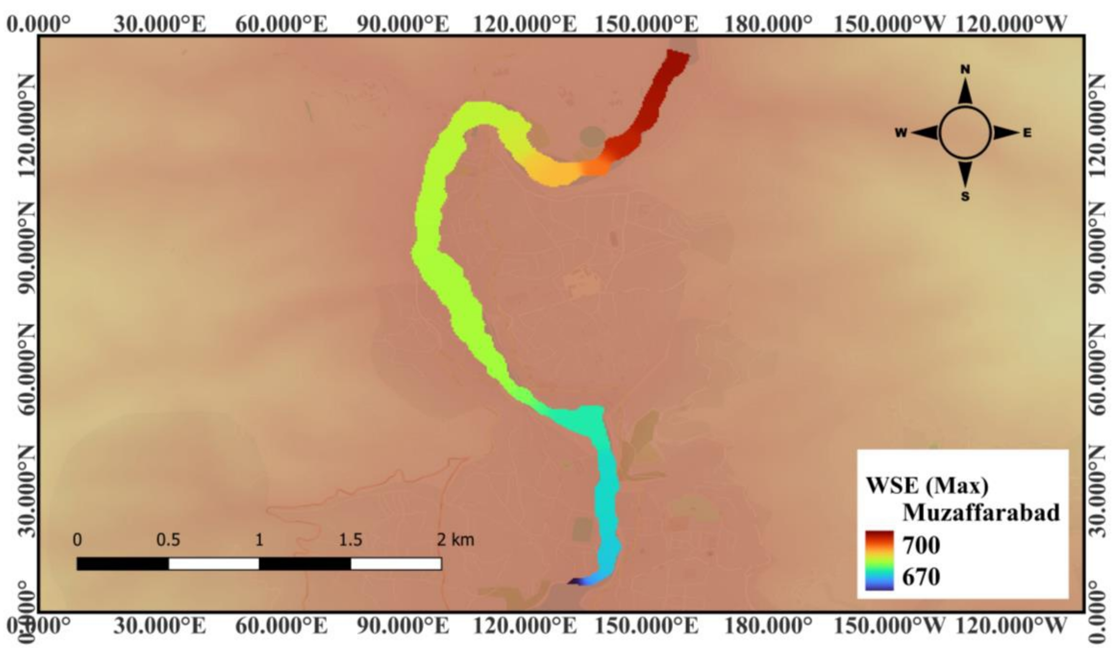

Fig. 13. Variation in maximum Water Surface Elevation (WSE) along the river in the Muzaffarabad region.

The figure illustrates the spatial variation of maximum Water Surface Elevation (WSE) along the river in the Muzaffarabad region. The color gradient represents the WSE in meters, ranging from 670 m (represented in blue) to 700 m (represented in red). The elevation data is spread across approximately 2 km, as indicated by the map scale. The higher elevations (closer to 700 m) appear to be concentrated in the upper northern regions of the river path, transitioning to lower elevations (670 m) in the southern areas. This pattern reflects the topography of the region, with steeper sections near the source gradually flattening as the river moves downstream. The variation in WSE provides important insights into potential areas prone to flooding, particularly in low-lying regions where the elevation decreases.

Additionally, the color gradient aids in understanding water flow behavior under maximum WSE conditions, crucial for hydrological modeling and flood risk assessment.

4. Discussion

The comprehensive analysis revealed significant differences in hydraulic behavior due to variations in topography, urbanization, and the presence of hydraulic structures. The first region from Panjgiran to Dhani depicted more energy and fluctuation in the depth of the channel than the following regions. This is mainly because of the natural slope associated with high gradients and narrow channel sections, which in turn increase the water flow rate. Some benefits associated with lesser numbers of hydraulic structures include that the natural discharge in this area can be maintained. However, considerations can arise as to erosion and sediment transport. The maximum flow velocity measured in this area was 6. 26 m/s at River Station 6966.

The first region features erosion and sediment transport as the top issues regarding flooding. The high gradient contributing to the variable topography of the river means that soil erosion during high flow is likely to occur. It also identifies other hydraulic structures like bridges and weirs that intensify turbulence and erosion locally. As for intervention measures for this region, it should emphasize fluvial zone management, which encompasses planting vegetation and structural enhancement to eradicate erosion and stabilize river banks. Monitoring and maintaining the hydraulic structures that result in localized turbulence and contribute towards structural wear out is also important.

Table 2 presents the hydraulic performances of the first region. It also presents the changes in velocities of peak flow, average stream depth and range of channel dimensions. For instance, the lowest section width is 46. Seventy-one meters and the width at the broadest section was 105. undefined Such differences relate to the river's natural morphology, hence making this area significantly challenging to manage in terms of flow dynamics.

Table 2: Hydraulic Characteristics of the First Region (panjgiran to Dhani)

Cross Section	**Flow Rate** *(m^3/s)*	**Water Surface Elevation (*m*)**	**Velocity (*m/s*)**	**Hydraulic Depth (*m*)**
7304	920.0	942.60	1.32	6.57
6966	913.6	939.75	6.00	2.98
6276	911.6	929.63	6.26	2.08
5704	904.7	925.57	2.28	4.58
5173	901.9	921.69	5.91	3.27
4544	900.2	919.73	1.23	8.68
4067	898.5	915.65	5.94	2.51
3364	892.5	912.17	1.53	7.81
2761	890.7	911.99	1.71	6.67
2106	888.9	910.56	2.03	6.01

In Muzaffarabad, specially organized protection against floods and drainage are required to reduce the threat of floods. This ranges from constructing barriers against floods to enhancing proper drainage systems to control storms and even legal measures that require any development to be carried out not on the flood plains. Thirdly, there must be effective urban planning considerations through the promotion of green and pervious surfaces to improve infiltration and minimize runoff discharge. Thus, there is a detailed difference in the flow rate of Muzaffarabad compared to the first region, which has been observed due to the following factors. The large population of Muzaffarabad and the widespread development cutting across its urban landscape reduces the river's ability to hold and speed up the water flow because the surfaces are now hard. Due to the constriction of the valley and the reduction of the floodplain area in Muzaffarabad, plans to develop flood control measures are more likely to fail, leading to overflow and flooding, as seen in Figure 15. Whereas in the first region, with its wide and diversified geographic formation of the area, the water can be well distributed, and the probability of an overflow is likely to be less.

The following section gives an account of hydraulic characteristics identified and categorized in the study area, as presented in Table 3. As can be deduced from the table above, the presence of urban infrastructure lessens the flow velocity but increases depth because of the expansion of the channel and the limited floodplain. Thus, the above characteristics give a real understanding of the problem of managing floods in the urban area.

Table 3: Hydraulic Characteristics of the Urban Region (Muzaffarabad)

Cross Section	**Flow Rate** ***(m^3/s)***	**Water Surface Elevation** ***(m)***	**Velocity** ***(m/s)***	**Hydraulic Depth** ***(m)***
7304	920.0	942.60	1.32	6.57
6966	913.6	939.75	6.00	2.98
6276	911.6	929.63	6.26	2.08
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4544	900.2	919.73	1.23	8.68
4067	898.5	915.65	5.94	2.51
3364	892.5	912.17	1.53	7.81
2761	890.7	911.99	1.71	6.67
2106	888.9	910.56	2.03	6.01

Contractors such as bridges regulate Floods in the regions, and weirs greatly influence flow patterns. In the first region, these structures result in backwater, which enhances the flood regime upstream, as presented in Figure 7. The existence of such structures requires constant surveillance, as well as repair and management of localized turbulence, to avoid harming the structure.

The authoritative flow seen in Muzaffarabad is because of populace thickness, created urban area, and impermeability that decrease Muzaffarabad's all-natural flow capability and increase retaliate. The former city of Muzaffarabad having smaller floodplain area and the confined channel increases the possibility of the occurrence of flood as shown in figure 15. In contrast, the first region has extensive variation in the features of land. Hence, the possibility of occurrence of the flood is low due to availability of more space for free discharge of flood water.

To manage these risks, what is needed are flood management measures particular to the region. In the first region, specific management techniques are required since erosion is a big problem; this includes applying vegetation planting and structural measures on the riverbanks to control the erosion problem. In the urban area, strong flood control and drainage facilities such as flood prevention walls, better storm water drains, and flood plain control measures should be practiced. Urban planning should also embrace strategies that help increase the greens and surfaces with high percolation rates.

In general, practically any aspect of flood management requires a regional analytical and modeling approach, calling for the development of comprehensive and specific recommendations for each region seeking to address and manage the river's resources sustainably. Therefore, the present research offers useful information pertaining to the Neelum River concerning hydrodynamic stability of the river that is helpful for better river management and planning for having minimum risk in future.

5. Conclusions

The evaluation of the HEC-RAS model shows significant changes in the hydraulic parameters and potential flood hazards in the free flowing Neelum river stretch at panjgiran to Dhani and the urbanized portion of Muzaffarabad city. This natural region is characterized by high velocity in flows resulting from steep gradients and narrow channels and all these causes a lot of erosion and sediment transportation. The flow velocities in the urban area are comparatively small while the water depth is deeper and thus the area is more prone to floods. These findings underscore the necessity of targeted flood management strategies: stabilization of slopes and river banks in the natural region and protection and improvement of flood protection and urban development in Muzaffarabad. This research offers useful information to the policy makers and planners to formulate and execute the desirable interventions in flood danger and rationality developmental work of the Neelum River basin.

Conflicts of Interest:

The authors declare no conflicts of interest.

Authors' Contribution Statements:

Ehtisham Mehmood conducted the theoretical analysis, performed the experiments, and wrote the initial draft of the manuscript. Haishen Lü supervised the project, provided critical revisions, and is the corresponding author. Soban Qamar reviewed the manuscript critically and provided significant insights and feedback. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement:

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interest

References

Ackers, J., Hieatt, M., & Molyneux, J.D. (2016). Mangla reservoir, Pakistan-approaching 50 years of service. *Dams and Reservoirs*, *26*(2), 68–83.

Ahmad, S., Faisal, S., Ali, F., Ullah, S., Ullah, R., Khan, M.A., & Waqar A.M. (2020). Assessment of drinking water quality and human health risks in Karak and adjoining areas, Southeastern Kohat Basin, Pakistan. J*ournal of Himalayan Earth Science*, *53*(1), 126-139.

Ali, U., Ayub, H., & Shafi, N. (2019).

Assessment of water quality parameters and their impact on distribution of fish fauna in River Neelum, Azad Jammu & Kashmir, Pakistan. *Pakistan Journal of Scientific and Industrial Research Series B: Biological Sciences*, *62*(1), 49–57.

Bekhira, A., Habi, M., & Morsli, B. (2019). Management of hazard of flooding in arid region urban agglomeration using HEC-RAS and GIS software: The case of the Bechar's city. J*ournal of Water and Land Development*, *42*(VII–IX), 21–32. doi:10.2478/jwld-2019-0041

Bellos, V., Tsakiris, V. K., Kopsiaftis, G., & Tsakiris, G. (2020). Propagating Dam Breach Parametric Uncertainty in a River Reach Using the HEC-RAS Software. *Hydrology*, *7*(4), 72. https://doi.org/10.3390/hydrology7040072

Brunner, G.W., & Bonner, V.R. (1994). HEC river analysis system (HEC-RAS). US Army Corps of Engineers, Hydrologic Engineering Center. Uncurated online book;https://onlinebooks.library.upenn.edu/webbin/book/lookupid?key=ha102322834

Bibi, T., Gul, S., Rahim, S., Qureshi, J. A., Shadayi, A. A., Jalal, A., & Tariq, H. (2020). Landslide Susceptibility Assessment Using Bivariate Method: A Case Study from River Neelum and Jehlum Catchment Area: Landslide Susceptibility Assessment Using Bivariate Method: A Case Study from River Neelum and Jehlum Catchment Area. *International Journal of Economic and Environmental Geology*, *11*(4), 33-36. https://doi.org/10.46660/ijeeg.v11i4.295

Kamojjala, S. (ed.), 2018. World Environmental and Water Resources Congress 2018 groundwater, sustainability, and hydro-climate/climate change: selected papers from the world Environmental and Water Resources Congress 2018, June 3-7, 2018, Minneapolis, Minnesota / sponsored by Environmental and Water Resources Institute (EWRI) of the American Society of Civil Engineers. Publisher: American Sciety of Civil Engineers. https://doi.org/10.1061/9780784481417

Khan, M.A., Stamm, J., & Haider, S. (2020). Simulating the impact of climate change with different reservoir operating strategies on sedimentation of the Mangla Reservoir, Northern Pakistan. *Water*, *12*(10), 2736.

Khan, M. (2022). Environmental impacts of Neelum Jhelum Hydropower Project. MPhil IDS thesis submitted to Iqra University Islamabad Campus. *Graduate Journal of Pakistan Review (GJPR)*, *2*(2). https://www.pakistanreview.com/index.php/GJPR/article/view/130

Khattak, M.S., & Ali, S. (2015). Assessment of temperature and rainfall trends in Punjab province of Pakistan for the period 1961-2014. *Journal of Himalayan Earth Sciences*, *48*(2), 42-61

Khattak, M.S., Anwar, F., Saeed, T.S., Sharif, M., Sheraz, K., & Ahmed, A. (2016). Floodplain mapping using HEC-RAS and ArcGIS: A case study of Kabul River. *Arabian Journal for Science and Engineering*, *41*(4), 1375–1390. https://doi.org/10.1007/s13369-015-1915-3

Kute, S., Kakad, S., Bhoye, V., & Walun, A. (2014). Flood modeling of river Godavari using HEC-RAS. *International Journal of Research in Engineering and Technology*, *3*(09), 81–87.

Leon, A.S., & Goodell, C. (2016). Controlling HEC-RAS using MATLAB. *Environmental Modelling & Software*, *84*, 339–348.

Malkani, M.S. (2020). Mineral resources of Gilgit Baltistan and Azad Kashmir, Pakistan: An update. *Open Journal of Geology*, *10*(6), 661–702.

McVean, D.N., & Robertson, V.C. (1969). An ecological survey of land use and soil erosion in the West Pakistan and Azad Kashmir catchment of the River Jhelum. *Journal of Applied Ecology*, *6*(1), 77–109.

Mehta, D.J., Ramani, M.M., & Joshi, M.M. (2013). Application of 1-D HEC-RAS model in design of channels. *Methodology*, *1*(7), 4–62.

Mohammadi, M., & Mohtadi, M. (2022). On the hydraulic simulation of River Simineh using HEC-RAS and ArcGIS software. *Hydrogeomorphology*, *9*(30), 103–87.

Munir, M.B. (2013). Climate change impact on flow discharge of Neelum River catchment using snowmelt runoff model. In 2013 *IEEE International Conference on Space*

Science and Communication (IconSpace), 350–355.

Noor, H., Assistant, H., & Khan, M.N. (2011). *Pakistan's water concerns*. IPRI Publications, Lahore, Pakistan.

Ogras, S., & Onen, F. (2020). Flood analysis with HEC-RAS: A case study of Tigris River. *Advances in Civil Engineering*, *2020*(1), 1-13. https://doi.org/10.1155/2020/6131982

Rafique, M., Kearfott, K.J., Jabbar, A., Khan, A.R., Rahman, S., & Mughal, M.S. (2020). Radiometric and petrographic characterization of sediment samples collected from Jhelum, Neelum, and Kunhar Rivers of Muzaffarabad, Azad Kashmir. *Environmental Earth Sciences*, *79*(1), 4. https://doi.org/10.1007/s12665-019-8765-3

Rangari, V.A., Umamahesh, N.V., & Bhatt, C.M. (2019). Assessment of inundation risk in urban floods using HEC RAS 2D. *M odeling Earth System and Environment* , 5(4), 1839–1851.

Siqueira, V.A., Sorribas, M.V., Bravo, J.M., Collischonn, W., Lisboa, A.M., & Trinidad, G.G. (2016). Real-time updating of HEC-RAS model for streamflow forecasting using an optimization algorithm. *Brazilian Journal of Water Resources*, *21*(4), 855–870. https://doi.org/10.1590/2318-0331.011616086

Tate, E., & Maidment, D. (1999). Floodplain mapping using HEC-RAS and ArcView GIS. CRWR Online Report 99-1, Center for Research in Water Resources Bureau of Engineering Research. The University of Texas at Austin J.J. Pickle Research Campus, Austin, TX 78712-4497. http://www.ce.utexas.edu/centers/crwr/reports/online.html

ur Rashid, M., Ahmed, W., Anwar, S., Abbas, S.A., Waseem, M., & Khan, S. (2017). Groundwater resource characterization using geo-electrical survey: A case study of Rawlakot, Azad Jammu and Kashmir. *Journal of Himalayan Earth Sciences*, *50*(2), 125–136.

Waqar, M., Ahmad, S.R., & Khan, A. (2020). flow regime vulnerability over transboun dary rivers in Himalayas region; a case study of the Neelum River Pakistan. *Technical Journal*, *25*(4), 1–7.