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Landscape and hydromorphological assessment of river valleys as a method for delineating natural and cultural landscape protection zones as applied to a reach of the Vistula near the Benedictine Abbey in Tyniec, Poland

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Summary

Rivers and their surroundings significantly affect the character and quality of the landscape. These landscapes have been created or defined to a considerable degree by the river. This specific quickly changing type of landscape is in a need of decision making as to which parts of it should be protected.

This article is an attempt to assess the landscape of a reach of the Vistula river in Poland, considering the hydromorphological components of the riverbed. Moreover, the aim of this research was to determine which vistas should be protected.

We have used landscape and hydromorphological assessment. The method integrates the ECOVAST landscape assessment for evaluating quality and identification with the hydromorphological assessment method for assessing river quality. Hydromorphological, landscape, and integrated elements were assessed at cross-sections. The cross-sections were marked at 500 m interval. Additional cross-section was chosen based on the local characteristics. The values assigned to the parameters during the landscape and hydromorphological assessment varied significantly.

Following the landscape and hydromorphological assessment, we delineated zones of the Vistula river landscape in need of protection along the Piekary–Ściejowice–Kraków (Tyniec) reach. Integrating landscape and hydromorphological characteristics is efficient in the assessment of riverbeds. Such assessment should be used while shaping landscape of the river valleys by local development plans and landscape protection programmes.

Keywords

LandScape and HydroMorphological Assessment of River Valleys method (LSHM method) • cultural heritage • river landscape • Tyniec

1. Introduction

The landscape has become a primary topic of debates on sustainable development focusing on environmental [Cassatella and Peano 2011, Gavrilidis et al. 2016], cultural, social [Brown and Raymond 2007], and aesthetic [Gobster et al. 2007] issues.

Indicators of the ecological quality of the landscape can be used to assess the landscape [Lindan Du et al. 2023]. The river landscape is a landscape that is completely dependent on the river. Its ecosystems have been created or defined to a considerable degree by the river [Štěrba 2008]. It is a specific type of landscape characterised by an evident contrast with the surrounding area [Jakubínský and Báčová 2013]. Water flow makes the patch structure of riverine landscapes quite dynamic. Patches move and change shape and composition as the streamflow varies. The directional flow of water enhances the connectivity of the riverine landscape. In rivers and streams, connectivity is provided by the medium of the landscape more than by the structural configuration of the mosaic itself [Wiens 2000].

The new landscapes assessment methods proposed by the authors demonstrates an integrated approach to the landscape and environment [Nawieśniak et al. 2016, Sargolini 2012]. Landscape assessment is a broad concept connected with all ways of looking at, describing, and classifying its components. Such assessments serve various purposes. The main one is to identify the landscape type, diagnose the existing state, and form proposals for its conservation, management, and improvement [NRA 1993]. The literature offers diverse approaches to landscape assessment employing various indicators. Considering that the landscape represents the perceived environment [ELC 2000], landscape quality assessments are often based on visual [Gavrilidis et al. 2016, van Zenten et al. 2016] and auditory [Brown and Brabyn 2012, Sherrouse et al. 2011] perceptions, especially in the case of river landscapes.

In practice, all landscape assessment approaches require combining the objective with the subjective. Conscious professional judgement is vital in the assessment. The professional judgement must be anchored in a systematic and organised framework [NRA 1993]. The visible landscape is believed to affect people in many ways, such as aesthetics, health, and well-being [Velarde et al. 2007]. Therefore, most of the methods available today hinge on subjective landscape assessment influenced mostly by the aesthetic preferences of the beholder [Jingwei et al. 2013]. Moreover, analysis of landscape changes in protected areas is an intuitive way of monitoring and assessing them [Huang 2020].

The introduction of protected areas effectively inhibits the degradation of natural ecosystems and furthers the protection of biodiversity [Li et al. 2020, Tang et al. 2011]. Protected vista zones may play an important role in the river landscape protection system. They can be used to designate protected sites that are valuable in terms of their aesthetics, landscape, or vistas. These areas are then protected by additional restrictions. The proposed restrictions in the protected vista zone may include the prohibition on the development or modification of green spaces.

Landscape evolution is based on the dynamic interaction between structure and functioning and also on history, which makes each landscape unique [Antrop 2000]. Considering that the expert approach has dominated the environmental management practice [Daniel 2001], a method for assessing river landscapes that could be employed by local authorities, which often decide on landscape protection matters, is necessary. The target method for preliminary assessment should be simple, transparent, and clear.

This article is an attempt to assess the landscape of a reach of the Vistula, considering the hydromorphological components of the riverbed. We focused on the protection of cultural heritage by preparing the area for tourism activities. Following the landscape and hydromorphological assessment [Nawieśniak and Wilkosz-Mamcarczyk 2019], we delineated zones of the Vistula river landscape in need of protection along the Piekary–Ściejowice–Kraków (Tyniec) reach.

2. Research area

The research area is a river landscape along the Vistula from Ściejowice, Piekary, Tyniec, to Kąty in Małopolskie Voivodeship (Fig. 1). The research area had been free of human intervention for ages. Recent decades saw meaningful changes due to intensified development of the river banks, especially near the abbey. The Vistula is the longest river in Poland with 1,047.5 km. Geographically, the river has two sources. These are two streams in Silesian Beskids at 1,107 m AMSL (the Czarna Wisełka) and 1,080 m AMSL (the Biała Wisełka). Hydrologically, the Vistula starts at the confluence of the Malinka Stream and the Wisełka Stream. The upper course of the Vistula down to the Przemsza confluence is called the Mała Wisła. About 50 km from its mouth in the Baltic, the Vistula branches off into two channels the Leniwka and the Nogat that form a broad delta referred to as Żuławy.

Tyniec sits right on the bank of the Vistula. The built-up area of Piekary is not very far from the river. The buildings are clearly visible from the right bank near the abbey in Tyniec. Tyniec is home to a Benedictine Abbey. They were brought there by Casimir I the Restorer in 1044. The abbey stands in the place of a – probably oval – fortified settlement. Artefacts found around the place suggest it could date back as far as the Lusatian culture (about 500 years BC). It was rebuilt after its destruction by the Tatars in 1260. A church was built there in the fifteenth century, and the developments were expanded further in the sixteenth century. The abbey's defences were improved with towers in the seventeenth century. In the time of the Bar Confederation (late eighteenth century), it was fortified with bastions and outlying forts. The complex is situated on a high rock right above the Vistula, which makes it a dominant landmark in the land-

scape of the Vistula Gorge and Kraków Gate [Bogdanowski 1993]. At a slight distance from the abbey, there are former Austrian forts Szpitalka and Winna Góra.

Source: Authors' own study

Fig. 1. The study area against the contour of the country and the region

3. Method

The protected vista zones of the river landscape of the Vistula between Ściejowice, Piekary, and Kraków (Tyniec) were delineated following a landscape and hydromorphological assessment. The assessment followed an integrated LandScape and HydroMorphological Assessment of River Valleys method (LSHM method) [Nawieśniak et al. 2016]. This method combines landscape and hydromorphological components to offer a holistic insight into the investigated area.

The LSHM method distinguishes three main groups of factors: landscape (L), hydromorphological (H), and integrated (I). All the factors are assessed using a ten-point scale and assigned to one of five classes (0; 1–2; 3–5; 6–8; 9–10). The first group of elements are the landscape components (L). This group includes the following parameters: land cover and topography (L-1), open landscape (L-2), settlement areas (L-3), and historical features/structures (L-4). Extreme values for this group of components as per the LSHM method are shown in Table 1.

Parameters assessed in the second group – hydromorphological elements (H) – are the geometry of the watercourse (H-1), river bed material (H-2), vegetation assessment in the channel (H-3), and erosion/deposition (H-4). This group of elements pertains solely to the river channel. Table 2 shows extreme values of the assessed parameters according to the LSHM method.

Components in the third group are integrated components (I) that could not be definitely assigned to either of the previous groups. These parameters integrate hydromorphological and landscape elements: flow characteristics (I-1), anthropogenic elements/modifications (I-2), use and vegetation in areas adjacent to the watercourse channel (I-3), and mobility and connection of the channel to a floodplain and/or adjacent open area (I-4). Table 3 contains extreme values for the parameters according to the LSHM method.

Table 1. Extreme values of landscape components as per the LSHM method

Landscape components (L)	Scale	
	10–9	0
Land cover and topography (L-1): assessed on the basis of visible diversity (or homogeneity) of topography and land cover	Clearly varied topography and land cover, presence of hills and valleys, forests, meadows, cultivated fields; perfectly harmonised landscape: coexisting landmarks perfectly match each other, without causing eye strain	Homogeneous topography, absence of diversity in land cover
Open landscape (L-2): values assigned depending on the occurrence (or not) of spatial order and characteristic features and patterns related to agriculture and forestry	Spatial order, clear boundary between cultivated fields and forests, high feelings and associations, distinguishing agricultural and forestry features and patterns, preservation of traditional arrangement of farmland	Total absence of spatial order, absence of boundary between cultivated fields and forests, as well as distinguishing agricultural and forestry features and patterns, absence of traditional arrangement of farmland
Settlement areas (L-3): assessed depending on the occurrence (or not) of region-specific developments and building condition	Spatial order, preserved regional features of development, high feelings and associations, visible distinguishing features of houses and settlements, buildings in good condition	Total absence of spatial order, absence of regional features of development, buildings preserved in poor condition with no distinguishing features
Historical features/structures (L-4): assessed on the basis of occurrence of historical structures, characteristic features, and patterns of cultural landscape	Presence of historical structures (castles, ruins of castles, walls, etc.), which clearly attract observer's attention	Absence of historical structures and distinguishing features and patterns of the cultural landscape

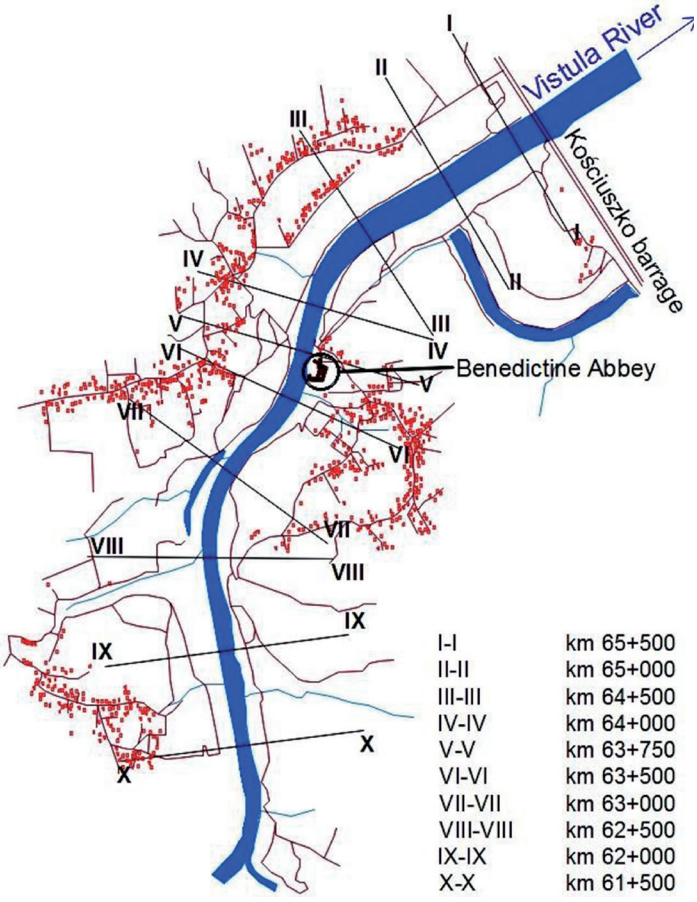
Table 2. Extreme values of hydromorphological components as per the LSHM method

Hydromorphological components (H)	Scale	
	10–9	0
Watercourse geometry (H-1): assessed value of change in the channel section, change (or lack thereof) in the longitudinal profile and cross-sections of the watercourse	Up to 5% of the section of the watercourse channel changed, no human impact (or minimal interference) in the course of the river channel, no change in the longitudinal profile and cross-sections of the river, any changes are slight, almost imperceptible	90 to 100% of the section of the watercourse channel changed, change in the entire geometry and course of the river channel (straightened), complete change in the longitudinal profile and cross-sections of the watercourse
Watercourse bed material (H-2): the value of the parameter is higher if the material is natural, diversified, and unaffected by human activity. Lower values are assigned to artificial beds or beds improved using engineering materials (such as concrete channels or groynes)	Natural course bed, very large diversity of watercourse bed material, natural occurrence of rough elements	Course bed completely artificial, concrete
Plant life in the channel (H-3): assessed depending on the degree of channel improvement and plant potential, in particular on bars	Channel unregulated, presence of various species of plant life on bars and banks of the watercourse, natural woody debris	Channel is completely regulated (concrete), absence of vegetation
Erosion/deposition (H-4): assessed depending on the present forms of erosion and deposition, which is also related to watercourse bed improvements (or lack thereof).	Presence of erosion and deposition in the watercourse channel, presence of many point bars and mid-channel bars, existence of natural riffle-pool sequences, occurring forms of erosion do not cause undue damage associated with lateral erosion	Watercourse channel completely regulated (concrete); absence of erosion or deposition forms

Table 3. Extreme values of integrated elements as per the LSHM method

Integrated elements (I)	Scale	
	10–9	0
Flow characteristics (I-1): assessed based on the occurrence (or not) of diversified hydromorphological units in watercourse channel and feelings related to the sound of flowing water (or lack thereof due to human activity)	Many different hydromorphological units in the watercourse channel, sound of flowing water is unobstructed by any anthropogenic activities, a clear, unique sound landscape	Absence of hydromorphological units in the watercourse channel, inaudible sound of flowing water (completely disturbed by human activities), no unique sound landscape
Anthropogenic elements/modifications (I-2): assessed in the watercourse channel and in river valley based on the occurrence (or not) of bank and bed modifications and anthropogenic elements in river valley that disrupt the landscape structure	Watercourse channel: completely natural river channel, no anthropogenic elements, river valley: few anthropogenic elements perfectly integrated into the landscape, harmonious landscape	Watercourse channel: presence of hydraulic and concrete structures across the channel, as well as bank and bed revetment made of artificial materials, river valley: presence of many unnatural, anthropogenic elements that disturb the spatial order and harmony of the landscape (e.g. motorways, dumps)
Utilization of and vegetation in areas adjacent to the watercourse channel (I-3): assessed depending on the surface area of the land adjacent to the channel and its use	The area directly adjacent to the watercourse channel is a wide belt covered with natural vegetation and alluvial forests	The area directly adjacent to the watercourse is very narrow and used for technical infrastructure or development
Mobility and connection of the bed to the floodplain and/or adjacent open area (I-4): assessed based on the possibility (or lack thereof) of channel shifting in the adjacent area	The channel has an unlimited ability to shift (meandering, braiding), very good channel connection to floodplain and/or adjacent open area	The channel is completely regulated and unable to shift, absence of channel connection to floodplain and/or adjacent open area

The research area includes ten cross-sections subjected to the landscape and hydromorphological assessment (Fig. 2). The first cross-section I-I is situated at km 65+500 of the Vistula, while the last one X-X is at km 61+500. The cross-sections are positioned every 500 m along the river axis. The only exception is cross-section V-V at km 63+750, which was selected as an additional cross-section. The position of this cross-section is due to a significant tourist load near the Benedictine Abbey.



Source: Authors' own study

Fig. 2 Research cross-sections

Each research cross-section was assigned numerical values of the assessed parameters in line with the integrated landscape and hydromorphological method for assessing river valleys. High values reflect the outstanding aesthetic quality of the landscape, visual perception (downstream), and attractiveness of the cross-section [Buława and Ahn 2024].

Today, researchers investigate river basin conditions using eco-hydrological modelling with remote sensing, landscape ecological analyses, and GIS [Sewada et al. 2014, Xin Li et al. 2021, Bedla et al. 2021]. No analyses focus strictly on perceived vistas and landscapes. The present analyses are carried out from the tourist perspective: as seen from a boat, pedalo, kayak, or along the river banks.

The innovative potential of the method lies in that it is non-invasive and can be used to modify the landscape by obscuring or exposing important tourist sites. It should be acceptable to municipal authorities and the public as a low-cost approach.

The research method is also founded on the place of landscape perception. In this case, it is either the channel or the banks of the river.

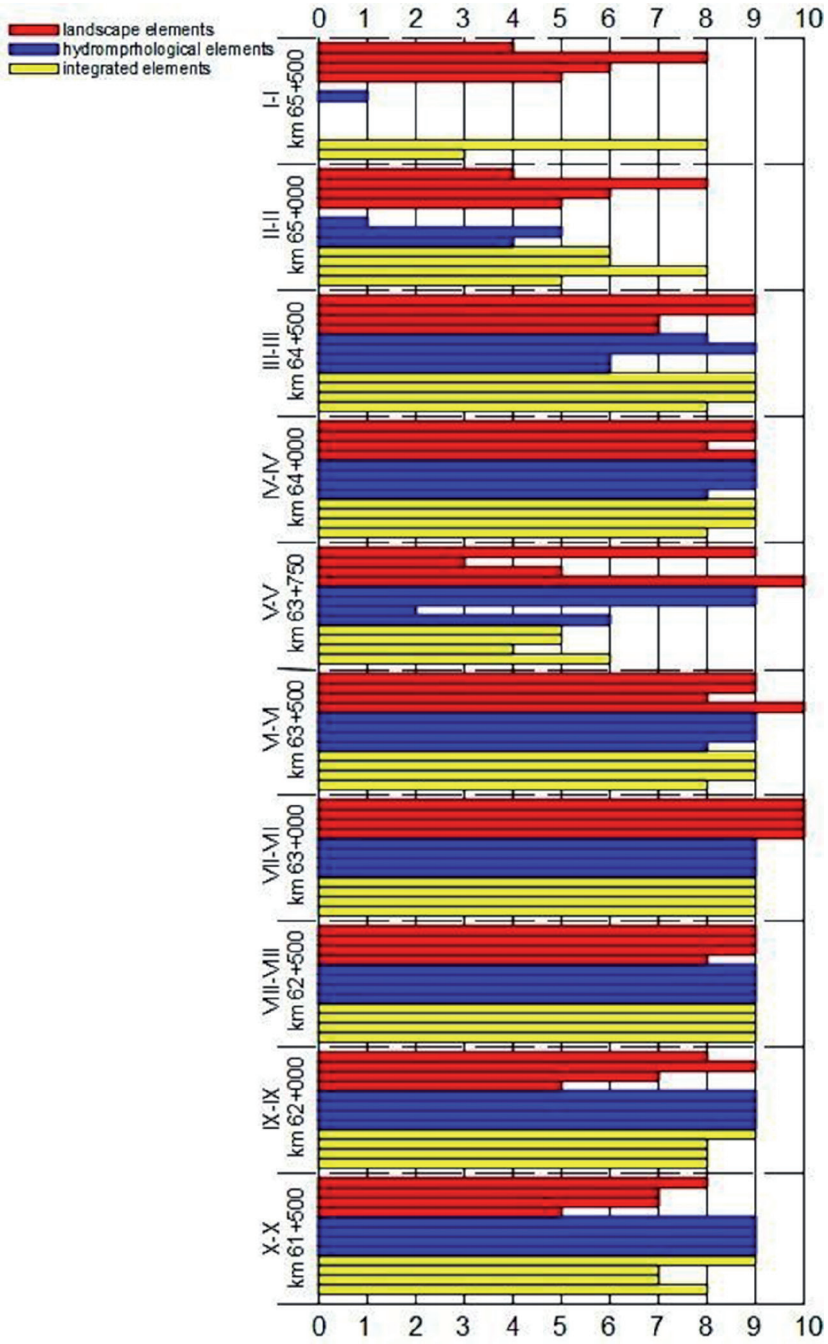
4. Results

The landscape and hydromorphological assessment of the ten cross-sections (Fig. 3) yielded information on the 'state of the landscape' of this reach of the Vistula. The area as a whole is a unique complex of entwined vistas where the 'across-river' image is central. The landscape is dominated by green components dotted with landmarks of rock outliers, the Tyniec abbey, a fortified settlement from the time of Konrad I of Masovia, and a park in Piekary.

Cross-section VII-VIII (km 63+000) was assessed as the best one of all under the landscape and hydromorphological assessment. All four landscape components were assigned the top value of 10 in this cross-section, and all hydromorphological and integrated components were assessed at 9.

Cross-section I-I (km 65+500) received the worst notes. The landscape parameters for this cross-section were rated at 4–8. We rated 'open landscape (L-2)' at 8, while 'land cover and topography (L-1)' at 4. Only one hydromorphological parameter, 'watercourse bed material (H-2)' was valued at 1. The other parameters were given values of 0. Two parameters in the integrated component group: 'flow characteristics (I-1)' and 'anthropogenic components/modifications (I-2)' were rated at 0. The other two parameters were given: 8 to 'use and vegetation in areas adjacent to the watercourse channel (I-3)' and 3 to 'mobility and connection of the channel to a floodplain and/or adjacent open area (I-4)'. The cross-section is situated adjacent to the Kościuszko barrage, which significantly affects hydromorphological components in the Vistula channel and the surrounding landscape. Note further cross-section V-V (km 63+750), which requires the most attention to determine the boundaries of the protected vista zone due to tourism. The values assigned to the parameters during the landscape and hydromorphological assessment varied significantly. Landscape parameter values ranged from 3 to 10. Hydromorphological parameter values ranged from 2 to 9. Integrated parameter values ranged from 4 to 6.

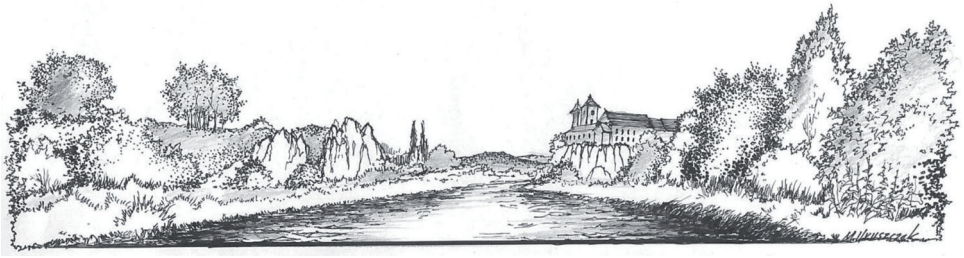
Having analysed the results, determined that the protected vista zone should be established on two cross-sections. The first zone will be located at cross-section VII-VII (km 63+000) (Fig. 4). This cross-section was assigned the highest values during the river valley landscape and hydromorphological assessment process. Both banks and



Source: Authors' own study

Fig. 3. Results of the landscape and hydromorphological assessment for the selected stretch of the Vistula

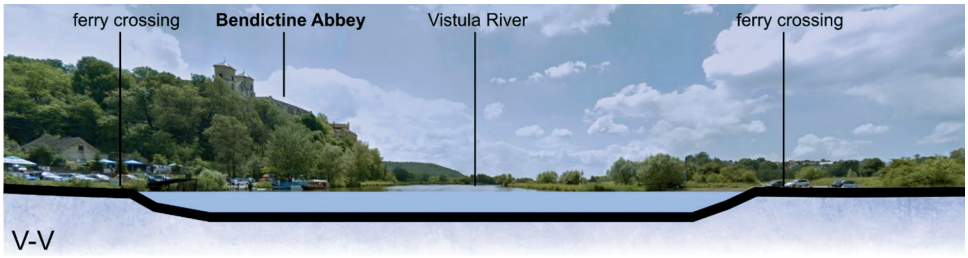
the distant panorama with the abbey offer a unique vista, a combination of natural and cultural components at this cross-section. It includes the abbey on a high rock. The cross-section includes riparian areas, forests, and limestone rocks typical of the Kraków-Częstochowa Upland.



Drawing by Michał Uruszczak

Fig. 4. Vista at cross-section VII-VII (km 63+000). The left bank of the Vistula is on the left-hand side

The parameter values of cross-section V-V (km 63+750) (Fig. 5) are not the highest, however, the site has exceptional potential due to its outstanding cultural landscape values (Benedictine Abbey in Tyniec). The parameters of the cross-section are lowered due to temporary buildings related to tourist services, i.e. small catering and portable toilets. The evaluation of the cross-section does not fully comply with the accepted methodology, but the immediate vicinity of such an exceptional object cannot be ignored. It combines historical religious buildings among several components of high natural and landscape value, such as the Vistula, large limestone rocks, riparian areas, and hills overgrown with trees. If the intangible – and yet important – layer is considered, which includes the history of each place (fortified settlements, bunkers, and a historical park), the result is a unique cultural and landscape combination even more valuable due to its location near Kraków, offering good access and transport possibilities.



Source: https://www.google.pl/maps/

Fig. 5. Vista at cross-section V-V (km 63+750)

5. Discussion

River valleys are an important element of the natural and cultural environment and play an important role in shaping settlement units and the lives of their inhabitants. Scientific research on the protection of river valleys has been carried out for years [NRA 1993]. Attention is now being paid to making river research interdisciplinary.

Eros and Lowe [2019] noted that research on rivers requires new insights based on how the structure of water networks affects the formation of river channels and natural and ecological processes.

This year, research results were published emphasizing the need for a holistic approach to river management, which is credited with improving coordination among local government units [Isla et al. 2024].

New research methods involving interdisciplinary analysis of river valleys, such as the presented LSHM Method and RHS [Bedla et al. 2021], can contribute to the protection of the river bed along with its immediate vicinity from a landscape and nature perspective. The obtained results put into practice will help maintain or restore the high visual quality of the river's surroundings.

6. Conclusions

Landscape assessment is a pragmatic tool for describing the landscape to identify the right methods for protecting, managing, and improving it. Various landscape assessments are intended to describe, classify, and value it methodically to offer design guidelines. Surroundings of river banks are a component of the complex landscape structure. They are a sequence, a snapshot that builds the image and opinion about the place.

The establishment of protected vista zones in the river landscape of the assessed reach of the Vistula may facilitate additional protection of the area and landscape correction in the important space near the Tyniec abbey.

Thanks to the landscape and hydromorphological method for assessing river valleys, we could identify spaces with particular landscape cross-section qualities on the reach of the Vistula, even though their general score was not the highest. The general trend today is to promote the tourism function of river valleys, where landscape qualities are important. The presented method can be used to investigate and design the space near rivers from within using the user's (habitants and tourists) point of view. This method can identify components of the river landscape in need of improvements. It can also provide valuable insights into the landscape for conservation efforts in spaces that contribute to river landscapes.

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