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Trends in the development of deformations of the Turiya riverbed (Volyn Polissia)

T. Pavlovska *(Lesya Ukrainka Volyn National University),* **Iv. Kovalchuk** *(National University of Life and Environmental Sciences of Ukraine),* ***M. Fedoniuk** *(Lutsk National Technical University),* **Ir. Kovalchuk** *(National University of Life and Environmental Sciences of Ukraine),* **V. Fedoniuk** *(Lutsk National Technical University)*

SUMMARY

The paper presents a retrospective analysis of the dynamics of channel processes of the Turiya River plain over many years. The data from hydrometric and hydrological observations at the Kovel hydrological observation point since 1983 have been analyzed. The flow rates and water levels of the river, as well as changes in the transverse profile of the channel over different years, were evaluated; corresponding diagrams were constructed. A separate comparison of topographic maps and space images of this territory at various times was carried out to track horizontal deformations of the riverbed. Areas of minimal changes, as well as significant (up to 140 m) channel displacements, were identified. Trends in the development of channel deformations were assessed, and periods of dominance of erosive or accumulative channel processes were highlighted.

Keywords: Turiya (river), river bed, vertical deformations of the bed, horizontal deformations of the bed, erosive and accumulative processes, transverse profile of the bed, the Polissia lowland.

Introduction

The riverbeds in various regions of Ukraine experience complex deformations caused by both natural factors (such as seasonal and long-term changes in water flow and sediments, climate variations, etc.) and human activities (such as channel straightening, land reclamation, water withdrawal, and wastewater discharge). Understanding and studying these deformations are crucial for water management, environmental protection, engineering assessments, and geological predictions.

Numerous studies by domestic and international scientists have focused on investigating horizontal and vertical deformations of riverbeds in mountainous and highland areas. Notable works include those by O. Obodovskyi (2018), Andrzejewski L., Krzemień K. & Zwolinski Z. (2018), Kovalchuk et al. (2020, 2022), Bayrak & Kovalchuk, U. (2017), Łajczak, A. et al. (2021). Burshtynska, Shevchuk, Tretyak S. & Vekliuk (2016), Burshtynska, Tretiak, S. & Halochkin (2017), Horishniy (2014), Pavlovska et al. (2019) and others.

However, the dynamics of riverbeds in lowland regions have not received sufficient attention. Hence, it is essential to address this gap and assess the directionality of channel deformations in the Turiya River, one of the small rivers in the Volyn Polissia region.

The object of our research is the Turiya River (the right tributary of the Pripyat, the Dnipro basin), the subject is horizontal and vertical deformations of the channel and the factors influencing its formation.

Method and Theory

The main methods used in the study of deformations of the Turiya River bed included: the method of repeated leveling of the transverse profile of the river to determine the scale, intensity, and direction of the erosion-accumulative process; the method of constructing and analyzing curves that show the relationship between measured flows and water levels in the channel, allowing for the identification of the dominant erosive, accumulative processes, or the transit of sediments in the stream without altering its hypsometric position; a method of comparative analysis using different temporal large-scale maps and remote sensing data of the Earth to detect horizontal deformations of the river and assess their scale and intensity; the method of searching and analyzing literary sources dedicated to the study of horizontal and vertical deformations of riverbeds.

Results

During the initial stage of studying the deformations of the Turiya River bed, we constructed and analyzed cross-sections of the river for the years 1983, 1988, 2008, 2018, and 2023 (Fig. 1). It's worth noting that no cross-section leveling was conducted between 1988 and 2008 and from 2009 to 2017.

The transverse profile of the Turiya River channel at the Kovel hydropost in 1983 revealed a more active erosion near the left bank of the river. By 1988, siltation in certain areas of the riverbed with the greatest depths in the previous period became evident. The average rate of sediment accumulation between 1983 and 1988 was approximately 4 cm per year. From 1988 to 2008, some deepening of the river was observed, particularly in its central part, where erosion processes led to an additional 20 cm increase in depth over two decades. Comparing the cross-sections of the riverbed in 2018 and 2008, it became apparent that accumulative processes had intensified, especially near the right bank, approaching the present day. The transverse profile as of January 4, 2023, follows the same trend. However, it is worth noting that a minor erosion of the stream also occurred near the left bank.

For a more detailed investigation of the directionality of erosion-accumulation processes in the Turiya River channel, we expanded our analysis beyond cross-sections and also constructed and analyzed the relationship curves between measured flows and water levels in the channel. It is well-known that shifts in these curves on the graphs, either upwards or downwards, indicate the accumulation of river alluvium (accumulation) or the erosion of the river bed (erosion) (Obodovskyi Yu., Khilchevskyi & Obodovskyi O., 2018).

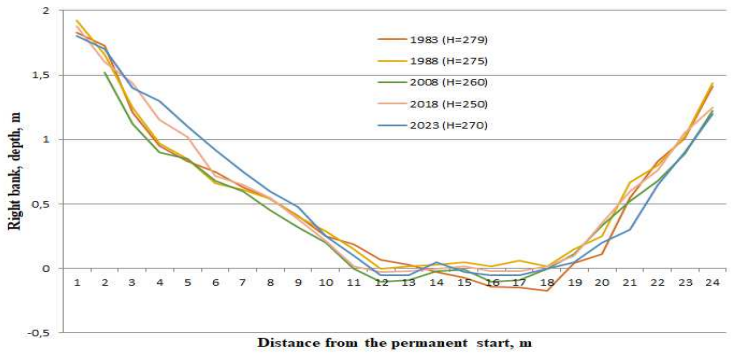

Figure 1. *Combined cross-sectional profiles of the channel of the Turiya River at different times (hydro station Kovel, built according to the data of the Volyn Center of Hydrometeorology)*

Figure 2 displays the cost curves for the years 1983, 1988, 1996, 2000, 2005, 2008, 2009, 2012, 2013, 2014, and 2017–2023. It's essential to note that the cost curves for 2017 and all subsequent years up to 2023 are considered identical and are represented by a single line. During these years, measurements of costs and their corresponding water levels were not feasible due to the presence of obstructions in the channel, such as vegetation and ice formations.

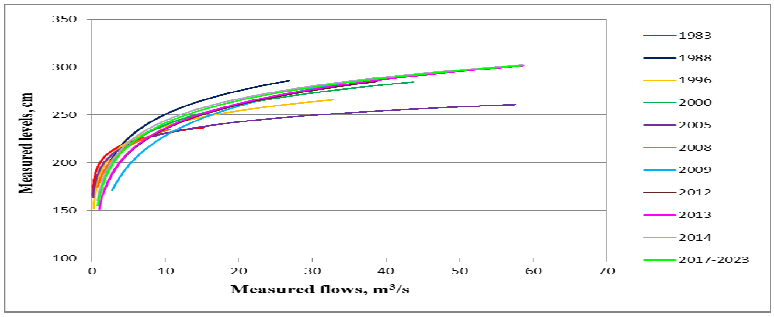

Figure 2. *Combined time-varying curves of the flow and water levels of the Turiya River (hydrostation Kovel, built by the authors according to the data of VCGM)*

As can be seen from figs. 1–2, the consumption curve of 1988 deviates from the curve of 1983 upwards, which indicates the accumulation of alluvium in the river bed. The thickness of the material accumulated over these five years was almost 17 cm. The curve of 1996 shifts downward from the curve of the previous time section (the so-called "subsidence of levels"), which reflects the more active development of erosion processes in the time interval between 1988 and 1996. The total deepening of the river was 12 cm. The reason for this is the increase in maximum flows in 1996 to the normal level, whereas in the previous fifteen years the maximum flows were very low (Fig. 3).

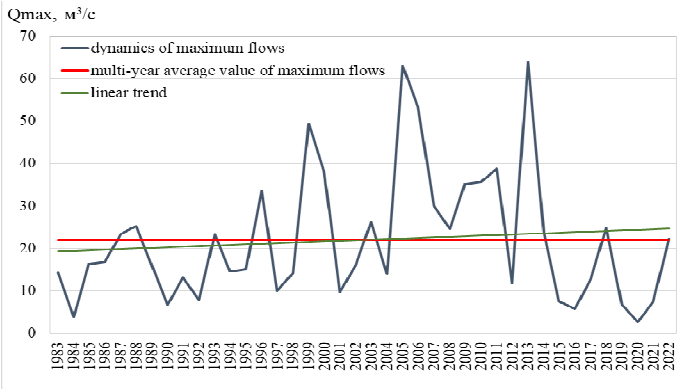

Figure 3. *Long-term fluctuations of the maximum flow of water in the Turiya River (hydrostation Kovel) and the trend of their changes*

The curve of 2000 is located above the curve of 1996. Probably, during this period, the accumulative processes intensified again, which led to the deposition of almost 8 cm of sediment in the river. The discharge

curves of 2005 and 2008 occupy some of the lowest positions on the graph, which indicates the dominance of erosion processes at this time due to the increase of maximum discharges in 2005 and 2006 compared to 2001–2004, when the maximum flow rates were significantly below the norm (see Fig. 3). The curves of the flow and water levels of Turiya in 2009, 2012, and 2013 are almost in the same field, which indicates the relative stability of the cross-sectional area of the river bed in the studied reservoir during the last decade (erosion in one place was compensated by the accumulation of alluvium in another and the transit of sediments). The expenditure curves of 2014 and 2017–2023 occupy a slightly higher position compared to previous years, which indicates the dominance of accumulative processes over erosive ones.

To investigate long-term horizontal deformations, we conducted a comparison between historical WIG topographic maps from 1925 to 1929 (scale 1:100,000) and more recent satellite images (Google Earth images for May 2021 and June 2008). The spatial mapping of raster data was performed using the QGIS 3.22.11 program, with an error of less than 3 pixels for each point. Through this analysis, we identified several sections along the river that have remained unchanged in channel configuration over time. However, we also discovered significant channel deformations in certain areas (see Fig. 4). The most substantial displacements were observed near the village of Horodylets, where, after a 3 km stretch of almost unchanged channel, two large meanders emerged with a distance of 139 and 115 meters from the old channel.

Figure 4. *Fragments of comparisons of the channel of the Turiya River on maps of the 1920s and modern maps and satellite images (blue lines, modern configuration)*

Over the course of almost 100 years, the Turiya River has experienced varying degrees of displacement along different sections. In the Turychany - Kulchyn segment, the displacements are relatively insignificant. However, as the river turns to the northeast below Kulchyn, the tortuosity increases significantly. Notably, areas of significant channel straightening have been observed in front of Turiysk and within the settlement itself, leading to the disappearance of at least 3 fairly large meanders. Moving downstream to the village of Selets, the channel has undergone minimal changes, although it remains relatively winding in certain areas. As previously mentioned, two large meanders were identified in front of the village of Horodylets. Further downstream, two additional meanders have disappeared, while another meander still exists but is gradually eroding away. Continuing towards the town of Kovel, the channel becomes significantly distorted due to the construction of several reservoirs. Overall, the horizontal deformations on the left bank are more noticeable along the studied section of the river, with the largest displacements recorded up to 140 meters. Additionally, the meandering of the river has increased along most of its length.

Conclusions

1. The conducted studies on the vertical deformations of the Turiya River's transverse profile, using the method of repeated transverse leveling and constructing combined curves of flow rates and water levels at different times, demonstrate a close connection between the direction and intensity of the erosion-accumulative processes within the channel. These relationships are primarily influenced by fluctuations in river flow and the morphological conditions of the channel.
2. Data obtained from the repeated leveling of the Turiya River's transverse profile at the Kovel hydropost during 1983–2023 reveal alternating periods of river erosion and silting. Specifically, the period from 1983 to 1988 was characterized by dominant accumulative processes, while from 1988 to 2008, the erosive processes prevailed. Over the last decade, there has been an active manifestation of accumulative processes, especially near the right bank of the river. These findings are further supported by the curves depicting the relationship between costs and water levels of the Turiya River.
3. The dynamics of erosive and accumulative processes correlate with the long-term fluctuations in

the Turiya River's maximum flow. During the 1980s, there was a significant drop in maximum flow values, attributed to factors such as reduced annual precipitation and the influence of the Kovel Reservoir, which led to a weakening of erosion processes. Conversely, from the 1990s through the 2000s, there was a slight increase in maximum flow values, reinforcing the stream's erosive capacity during floods and resulting in a slight enlargement of the channel's cross-sectional area. In the last decade, maximum flow values were mostly below their average multi-year values, resulting in weakened erosion processes.

4. The reduction in the Turiya River's maximum flow, cases of absence of flow during the low-water periods from 2015 to 2023, and the dominance of accumulative processes within the channel contribute to eutrophication of the watercourse. This reduction in transport capacity leads to the further accumulation of solid material in the river. If this trend continues in the future, the risk of floodplain flooding along the Turiya River will increase during powerful floods or freshets.

5. Over the past 100 years, horizontal deformations of the channel have varied across different areas, ranging from nearly imperceptible with slight increases in tortuosity to significant channel straightening or the formation of new meanders with distances between 90–140 meters. In future research, we plan to conduct a detailed analysis of the detected deformations in connection with the geological structure, neotectonic features, and lithological composition of the rock-forming deposits.

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