



MONITORING OF THE RELOCATED ČEHOTINA RIVERBED

**Petar Jelić^{1a}, Ivan Jelić^{1b}, Saša Stepanović^{1c}, Jelena Đorđević^{1d},
Jelena Stefanović^{1e}, Aleksandar Doderović^{1f}, Tanja Stanković^{1g}**

¹ Mining and Metallurgy Institute Bor, Alberta Ajnštajna 1, 19210 Bor, Serbia

^{1a} petar.jelic@irmbor.co.rs, <https://orcid.org/0009-0008-5276-3137>;

^{1b} ivan.jelic@irmbor.co.rs, <https://orcid.org/0000-0003-4534-0706>;

^{1c} sasa.stepanovic@irmbor.co.rs, <https://orcid.org/0000-0003-3485-201X>;

^{1d} jelena.djordjevic@irmbor.co.rs, <https://orcid.org/0000-0001-5406-0074>;

^{1e} jelena.stankovic@irmbor.co.rs, <https://orcid.org/0000-0001-6418-1814>;

^{1f} aleksandar.doderovic@irmbor.co.rs, <https://orcid.org/0000-0002-2353-6751>;

^{1g} tanja.stankovic@irmbor.co.rs, <https://orcid.org/0000-0002-2714-7016>

Abstract

After relocation of the Čehotina riverbed in Pljevlja, the attention is shifted to monitoring the new channel in order to ensure its stability. The regular data collection was ensured through a system of piezometers for groundwater monitoring, the water gauge profiles for the water level control, and geodetic and inclinometers observations for tracking the terrain changes. This comprehensive approach allows promptly identification any changes or potential risks and taking the appropriate measures to maintain the channel stability and minimize the environmental impact.

Keywords: river monitoring, piezometers, geodetic benchmarks, inclinometers

1. INTRODUCTION

1.1 General

The coal deposits are often found near rivers due to the geological processes that have shaped their location over millions of years. Their proximity frequently poses a risk to the mining operations due to flooding, bank erosion, and rising the groundwater levels that affect the slope stability. Perhaps most importantly, the river flow presents a barrier to the mining activities when the mining front overlaps with the riverbed path. Due to these reasons, it is sometimes necessary to relocate the river flow to ensure a continuity in the mining operations.

The macro-location of the area in question refers to the exploration area "Potrlica-Kalušići," situated in the northwest part of Montenegro, within the municipality of Pljevlja. The Pljevlja coal basin almost entirely encompasses the Pljevlja basin, located in the central course of the Čehotina River, at the point where it is joined by its left tributary Vezišnica.

In the past, due to the mining activities, the Čehotina River in the Pljevlja basin had to be relocated southwest. Since November 22, 2008, the river has been flowing along its new, relocated route. The river diversion system includes: a concrete diversion arch dam with a height of 25.85 meters, the Rudine tunnel with a length of 373 meters, an open trapezoidal channel with a length of 2.840 meters, the Velika Pliješ tunnel with a length of 795 meters,

and a channel from the tunnel exit to the confluence with the Čehotina River, with a length of 320 meters.

Now, 16 years after its initial relocation, the river is once again in the mining front area, and due to the continuity of the mining activities, its relocation is necessary once more.

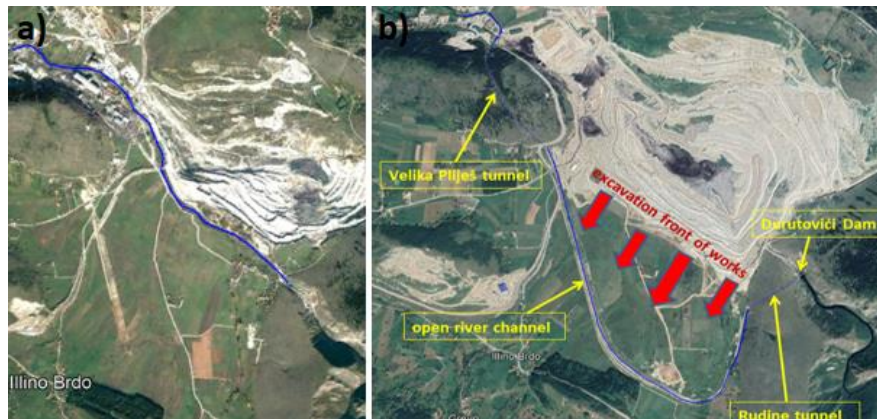


Figure 1. Route of the Čehotina River, a) natural course, b) route after the 2008 relocation

1.2 Description of the Design Solution and its Specifics

At the beginning of the third decade of the 21st century, the issues began to emerge at the Potrlica-Kalušići open-pit mine that were directly related to the Čehotina River. Primarily, there was an onset of groundwater at the working levels of the open-pit mine, leading to the instability in certain sections of the mining front. This limited the mining activities and accelerated the preparation of the design documentation, which was completed in 2024.

The river will be diverted northeast across the internal landfill. The landfill is characterized by a differential settlement, which poses a challenge given one of the main requirements of the design task: the channel impermeability. The channel must be impermeable, as any breach could undermine the stability of the landfill, potentially leading to the significant economic consequences and even loss of life.

The newly designed Čehotina River channel consists of several sections: 1) weir and overflow threshold, 2) channel with a trapezoidal cross-section, base width $B = 13$ m, 3) first transition section, 4) reinforced concrete channel, base width $B = 8$ m, 5) cascade with a waterfall and fish ladder, 6) second transition section, 7) gabion channel with a complex cross-section in the landfill area, 8) third transition section, 9) channel with a rectangular cross-section, base width $B = 12$ m

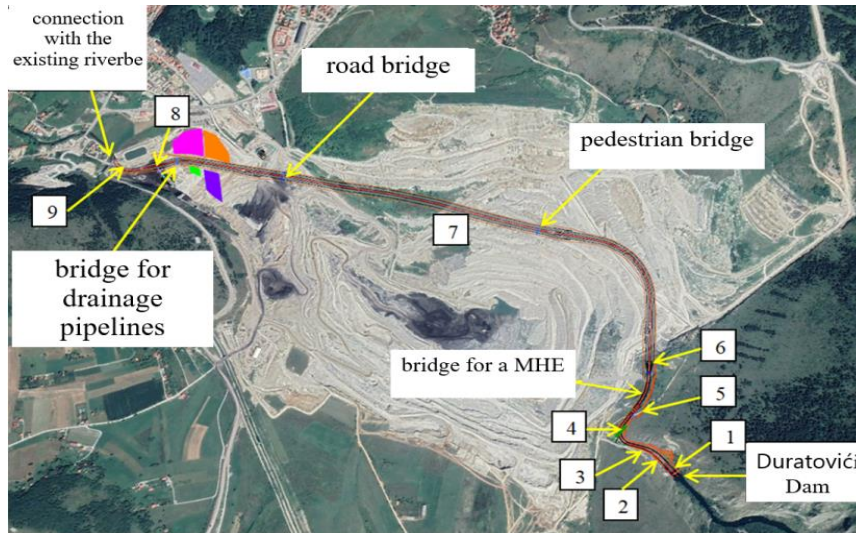


Figure 2. Route of the newly designed bed of the Čehotina River

The channel in the landfill is designed as a flexible structure, made of gabion mattresses and stone fill, with impermeability ensured by the geosynthetics. Since consolidation of the landfill material has not been measured so far, and critical zones with significant uneven settlement are unknown, the design solution includes placing a geocomposite (geogrid + geotextile) on the prepared subgrade for soil reinforcement, followed by a layer of selected excavation material with a thickness of 20 cm. On this prepared base, a nonwoven geotextile (500 g/m²) is installed, on the top of which a GCL (geosynthetic clay liner) film is applied as a secondary protection against leakage. Above this, an EPDM geomembrane with a thickness of 1.5 mm is installed (primary protection against leakage), and protective geotextile (1200 g/m²) is placed on the top. Finally, a layer of material with a granulation of 0-2 mm is added on the top of the protective geotextile to serve as a buffer zone, preventing damage to the insulating layers during the installation of gabions and stone fill.

To prevent the EPDM geomembrane from tearing, due to uneven settlement at the junctions with concrete, the expansion joints with a gap of 3x0.5 meters are provided so that these areas can accommodate a differential settlement of up to 1.0 meters. Settlement calculations for the landfill indicate a settlement value of $h = 0.11$ meters.

2. MONITORING

The construction of the river channel across the internal landfill of the newly formed terrain of varying ages is a highly complex hydrogeological and construction undertaking. Since the corridor for the river diversion was established less than a year ago, and the future settlements that could affect the stability and impermeability of the channel are anticipated, and monitoring is planned. This monitoring includes the following measurements:



groundwater and surface water level measurements, geodetic measurements, inclinometer measurements

2.1 Monitoring and Tracking of the Groundwater and Surface Water Levels

Monitoring the groundwater levels involves establishing a network of piezometers to verify the effectiveness of the waterproofing during operation. The monitoring network will consist of the piezometers, placed along 4 profiles along the Čehotina River, with three piezometers per profile. The first piezometers will be installed 3 meters from the left bank, with the additional piezometers, placed every 50 meters. The groundwater level measurements will be conducted weekly, synchronized with the river water level measurements and precipitation tracking to ensure a timely response in case of issues.

For monitoring the water levels, it is planned to establish the water gauge profiles at the stations 0+520 and 3+125. Data on precipitation will be obtained from the existing automatic rain gauge station “Pljevlja.”

2.2 Geodetic Observations

In addition to monitoring the groundwater levels, the plan includes controlling the vertical and horizontal movements using the 28 geodetic benchmarks along the new channel of the Čehotina River, spaced approximately 100 meters apart. The geodetic measurements will employ both terrestrial and satellite methods to monitor the movement of points relative to the reference network. The network should allow for detection the horizontal movements of 2 cm or more, as well as the vertical movements of 1 cm or more.

During the first six months after commissioning, the measurements will be conducted weekly, followed by monthly, then quarterly, and biannually. If the vertical movements greater than 50 cm are detected, the settlement control should be performed, and the measurement frequency should be increased. The maximum differential settlements that the EPDM linings can tolerate are 1.0 meter at transitions and 2.0 meters along the flexible channel. If the measured values approach these limits, the measures should be taken to protect the impermeable layer.

2.3 Inclinometer Observations

To monitor the changes in slope and stability of the new river channel, three inclinometers will be installed: at the end of the second transition section (transition from paleo-relief to the landfill), at the gabion channel with a complex cross-section at station 2+220 meters, and at the beginning of the third transition section.

To obtain the reliable measurement results, it is essential that the inclinometer construction is embedded in the bedrock to a depth of approximately 2 meters, so that the lower end can be considered immovable in the calculations.



3. TRIAL OPERATION

After connecting the old and new channels of the Čehotina River, the foundational discharge at the Durutovići Dam will be opened, marking the start of the trial operation phase for the new channel. The trial operation is planned to last for 6 months. During this period, the old channel will remain operational as a precaution. Throughout this trial phase, monitoring and measurements will be conducted more frequently to allow for timely remediation of the new channel in case of arising any issues.

4. CONCLUSION

The diversion of the Čehotina River channel is a complex and necessary step to maintain the continuity of the mining activities at the Potrlica-Kalušići open-pit mine in Pljevlja, Montenegro.

Continuous monitoring of the groundwater and surface water levels, along with the geodetic observations, facilitates the timely identification of potential risks and their effective management. The inclinometer measurements further contribute to understanding the ground movements and ensuring the stability of the river corridor.

The trial operation represents a crucial phase in the process of diverting the Čehotina River channel at the Potrlica-Kalušići open-pit mine. By retaining the old channel during the trial phase, a safe and controlled transition is ensured. Should the geodetic, inclinometer, or hydrological measurements reveal deviations or potential problems, the presence of the old channel provides an alternative route for the Čehotina River, allowing time for identifying and addressing any deficiencies.

This approach ensures that the river channel diversion process is conducted with the maximum safety and environmental consideration. The trial operation is a crucial step towards the successful implementation of the new channel, ensuring that any potential issues are resolved before they escalate into serious problems.

ACKNOWLEDGEMENTS

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REFERENCES

- [1] Ivan Jelić, Nikola Lekić, Nikola Stanić, Miomir Mikić, Selection of an Optimal Route for Relocation of the Čehotina River Bed, 54th International October Conference on Mining and Metallurgy, Proceedings, October 18-21, 2023, Bor Lake, Serbia.
- [2] B. Božić, et al., Main Project for Geodetic Observation of Horizontal Movement of the Riverbank 'Nova Kolubara', Tehnika - Our Construction, 64(4) (2010) 11-17.



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<https://ioc.irmbor.co.rs>

- [3] Main Mining Design for Exploitation of Coal, Claystone, and Clay as Associated Mineral Resources at the "Potrlica-Kalušići" Open-Pit Mine until the end of Exploitation, Mining and Metallurgy Institute Bor, 2023.
- [4] Main Design for Emergency Interventions for Relocation the Čehotina River Across the Internal Landfill of the Potrlica Open-Pit Mine AD Pljevlja Coal Mine, Mining and Metallurgy Institute Bor, 2024.