

# THE STABILITY OF BANKS IN POST-MINING LAKES AS A LIMIT TO THEIR RECREATIONAL POTENTIAL

**Jan Deutscher, Miloslav Šlezinger, Ondřej Hemr, Petr Pelikán, Kateřina Sedláčková**  
*Faculty of Forestry and Wood Technology, Mendel university in Brno, Zemědělská 3, 613 00 Brno, Czech Republic*

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## Abstract

In the lowland areas of the Czech Republic, the mining sites of sand and gravel-pits are often naturally filled with groundwater. This creates typical post-mining lakes of great importance in the landscape. Not only do these lakes create valuable semi-natural habitats sought after i. a. endangered water bird species and become hotspots of local ecological stability, they also quickly become popular destinations for various recreational activities. Wanted or unwanted, spontaneous recreation cannot be stopped as fisherman; swimmers; divers; various sportsmen etc. always seem to find a way to enter the lakeside. This phenomenon has to be reckoned with at all stages of the restoration, planning and management of these areas. In post-mining lakes, where recreation is one of the desired functions, bank stability plays critical role in ensuring the safety of visitors and thus becomes one of the main limiting factors of its recreational potential. In this article, we present a unique low-cost approach how the stability can be improved. This can hopefully contribute to a reasonable management of these precious areas by supporting both its ecological and recreational values.

**Key words:** bank stabilization, grain size distribution, lowland floodplains, post-mining sites, recreation

## Introduction

In the Czech Republic we can find more than 200 registered sand and gravel pits. Their occurrence is associated with the lower stream of larger rivers and most sand and gravel pits are located in river floodplains. Annual production of sand and gravel pits in the Czech Republic (CR) in 2020 was 11.3 million m<sup>3</sup>. This mineral resource is relatively limited, but both sand and gravel are important commodities desired especially in construction industry (buildings, road surfaces, or terrain work). According to the study by Czech geological survey (CGS), a large part of the sand and gravel reserves will be extracted within ten years (CGS, 2022).

Due to their location in river floodplains, the excavated pits are often filled with water. A water-filled sand and gravel pit is referred to as a post-mining lake and is an important feature of the landscape with distinct functions. Large water surface creates a new ecosystem, which often includes endangered species of animals or plants. Of course, these areas are also attractive in terms of recreation, i. a. swimmers, fishermen or other water sports. Also the post-mining lakes can act as a natural water reservoir.

On large reservoirs, bank abrasion and bank stability are important factors. The banks of post-mining lakes are not very stable mainly due to the material they are made of – sand and gravel. Waves interacting with such unstable banks only increase bank abrasion. Fine soil particles are washed out of the banks and carried away. There is a risk of landslides, which are a danger especially if the lake is used for recreation. To prevent this, the banks of post-mining lakes need to be stabilized. Bank stabilization has three basic principles - technical, biological (vegetation) and biotechnical (a combination of the previous two). When stabilizing, it is important not only to prevent erosion, but also to utilize the most natural processing possible, that's why biotechnical solutions are often implemented (Šlezinger, 2005).

As already indicated, the post-mining lakes have a huge recreational potential. From a locality to which the public previously did not have access to, it changes into a place with recreational opportunities for citizens from the surrounding area. The challenge with the management of such areas lies in finding the right balance between allowing people to recreate while still sustaining the ecosystem functions of the post-mining lake. This process is linked to the above-mentioned biotechnical bank stabilizations. Their purpose is to revitalise the lake to its natural appearance and at the same time make it a safe place for recreation.

## Material and methods

In this article we present a unique low-cost approach how the stability can be improved. The data come from a post-mining lake where the following experiment was carried out during 2019-2021 as

part of a project supported by the Internal Grant Agency of the Faculty of forestry and wood Technology of Mendelu in Brno (IGA). The former mining site is situated near Hulín city, in the Zlín region. The reservoir is located in the Morava river floodplain. The water area is more than 60 ha with steep banks. The so-called “wet sand and gravel mining” took place in the mining-lake.

The basis of the bank stabilization experiment was sloping, followed by direct bank stabilization at the abrasion platform. There we expect the damage of water erosion to happen. Three experimental segments were created to simulate for bank erosion observation. All segments were sloped to 1:10, 1:5 and 1:2. In segment A, the bank was provided with a wooden palisade and weed plantings. Segment B was stabilised with willow cuttings and as a supplement with reed stabilisation. Segment C was partly stabilised with a gravel layer and with willow cuttings.

To prove the functionality of bank stabilization, the grain size distribution curve analysis was performed. The analyses were performed on pre- and post-stabilization soil samples. A sieve analysis was performed on each sample. This analysis consists of removing the sample of the finest particles and then sieving it through a system of different mesh size sieves. A grain size distribution curve is then formed from the sample treated this way. A hydrometer test was also performed on samples from the post-stabilization period. This test consists of measuring the sedimentation of fine particles (under 0.063 mm).

The bank stability was treated as one of the most important limits to the recreational potential of the lake. The recreational potential was assessed using a SWOT analysis, which included a number of factors related to this issue.

## Results

### The monitoring of the site

The visual monitoring of the experimental site on segments A-C proved that the sloping of the bank in the ratio 1:10, 1:5 and 1:2 towards the bank ensured the lowest run-up of the wave with gradually reducing its momentum and erosion potential. It turned out to be a very efficient way to achieve slope stabilisation. We found that the waves did not reach the steepest slope section by the former abrasion cliff (resulting in no more destruction caused by waves). This specific structure of sloping was named the “half-bowl shape” and we expect this to be a very effective way to handle unstable banks on this kind of habitat.

### The granulometry analysis

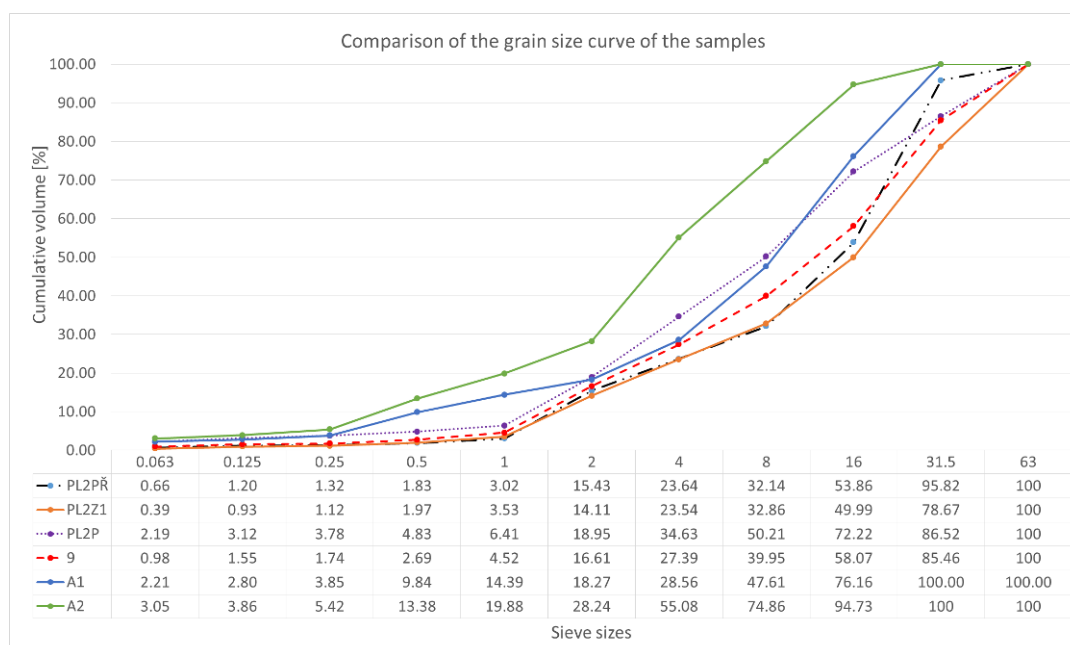


Fig. 1: Comparison of the grain size distribution curve of the samples from the shores (PL2PŘ-9 were taken in 2019, A1 and A2 were taken in 2021).

The comparison of the grain size distribution curves of the individual samples (Fig. 1), we can see a markedly finer-grained composition in the soil samples taken after bank stabilization. We can conclude that this method of stabilization was useful to mitigate the wash out processes of the fine soil material.

### The evaluation of the recreational potential

One of the main goals of this article was to evaluate the use of the recreational potential of the post-mining lake and connect it to the importance of the bank stability.

Tab. 1: SWOT analysis of the recreational potential

STRENGTHS	WEAKNESSES
Good transport accessibility	Erosion
Multifunctional area	Steep shores
Species diversity	
OPPORTUNITIES	THREATS
Bank stabilisation	Parking spaces capacity
Stabilization measures	High attendance
	Endangerment of animals and plants

The main strength is the multi-functionality of the area. Swimmers, fishermen, bird watchers, ordinary tourists and cyclists, as well as water sports, will all find their place here. The location is also easily accessible from the surrounding urban areas; in addition, it is connected to the natural park Záhnilické ponds. This however poses one significant risk - overloading the site with attendance. Due to its location, the post-mining lake can be expected to be a tourist destination all year round. Too many visitors could endanger and disturb the rare species of plants and animals that might dwell in the locality. Due to the unstable sand and gravel, they could also cause further erosion, which is important to prevent. At present, the main risk for visitors is the steep sloping of banks of the reservoir as well its shoreline. Not far from the shore, the bottom falls sharply and thus creates an obvious danger for the inexperienced visitor. This problem, as well as the potential risk of landslides, is being addressed by bank stabilization and other measures and was indicated as the most important weakness in the SWOT analyses (Tab. 1).

### Discussion

The transformation of post-mining sites into areas satisfying both public recreation and ecological needs is a common and expectable challenge that follows nature resources exploitation and reshaping of the landscape (Stonina et al., 2019). Wave run-up behaviour and research on reservoirs is being studied (Hager and Evers, 2020) as well as the role of coastal vegetation on the shoreline protection (Gedan et al., 2011; Zhao et al., 2021). Considering the stabilisation methods we recognised that most appropriate technique was a 1-2 m narrow reed belt combined with a 5-7 rows wide stand of willow shrubs. Planting of willows on the site was also one of the key means to ensure the long-term slope. Another benefit of the added biological stabilisation was the initiation of natural succession processes which resulted in effective, yet semi-natural bank stabilisation. Interestingly, the gravel layer in segment C did not perform significantly better; rather it limited the speed of the natural regeneration of the willows as compared to segments A and B. However, it has to be noted that in specific cases, bare banks can be considered as important for appearance of endangered species (Brus et al., 2020) such as bee-eaters (*Merops apiaster*).

In this paper we outline the possibilities of increased safety for wide range of recreational users. Considering recreation on post-mining sites, we feel insufficient knowledge about the conditions of wheelchair users (Jakúbisová, 2014) is available. Since the usual sloping of banks after technical restoration is 1:1 to 1:2 it is too steep for wheelchair users as reported from forest environment and geocaching (Fialová et al., 2018; Fialová, Matušková, 2020). The half-bowl sloping might server as one of the best-practice solutions combining i) the bank/shore protection against water erosion, ii) speeding-up the succession as a natural habitat iii) enhancing the recreational potential for all sorts of users and groups.

### Conclusion

The post-mining lakes have a great recreational potential as well as the potential for ecological ecosystem functions. As a result, rare and endangered species of animals and plants can dwell there. Visitors have a wide range of recreational possibilities, but at the same time recreation in mining areas carries certain risks. One of them is the threat to the ecosystem by excessive attendance; the other is the threat to visitors due to low bank stability. Bank stabilization measures can be used to mitigate this second problem and if located properly along the shoreline might be used to direct recreants to

specific parts of the lake thus helping with the problem of excessive recreation as well. The lakes are a valuable artificially created ecosystem and deserve further research.

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## Souhrn

Potěžební jezera mají velký rekreační potenciál i potenciál pro plnění ekologických funkcí. Díky tomu zde mohou žít vzácné a ohrožené druhy zvířat a rostlin. Návštěvníci zde mají široké možnosti rekreace. Rekreace v důlních oblastech však s sebou nese určitá rizika. Jedním z nich je ohrožení ekosystému nadměrnou návštěvností; druhým je ohrožení zdraví návštěvníků zejména kvůli snížené stabilitě břehů. Ke zmírnění druhého problému lze použít stabilizační opatření, která mohou být při správném umístění podél pobřeží, použita k nasměrování rekreantů do konkrétních částí jezera. Tím lze také pomoci s problémem nadměrné rekreace. Potěžební jezera jsou cennými uměle vytvořeným ekosystémy a zaslouží si další výzkum.

## Contact

Jan Deutscher

E-mail: jan.deutscher@mendelu.cz

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