

ASSESSMENT OF FACTORS AND CONDITIONS INFLUENCING BANK STABILITY OF FUTURE LAKES

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ABSTRACT

While including gradual long-term flooding of individual residual mining pits, the re-vitalization program of the Podkrušnohorská brown-coal basin area has to assure - beside general water quality standards - satisfactory stability level of future lake banks and their wider environment as required for safe usage of future water lakes.

General assessment of factors and conditions influencing bank and/or slope stability of future lakes was realized within the frames of the Czech Republic Academy of Sciences grant project. The grant project solutions include a study of exogenous processes on localities where the mining has been terminated. Also, prognoses were developed on behaviour of future banks during flooding and subsequent operation of future lakes. The presented paper is focused on assessment of mayor factors that participate on initiation and intensity of the bank abrasion and sliding deformations.

KEYWORDS: flooding of residual mining pits, dangerous geodynamic phenomena, stability of banks and slopes

1. INTRODUCTION

If situated in unfavourable engineering-geological conditions, the bank deformation problems of the future reservoirs (lakes) create an important aspect connected with the revitalization of the Podkrušnohorské basins through filling of residual pits with water. Overburden and dump slopes were originally designed and realized according to primary requirements of mining technology, i.e. with short-time or medium-time stability. The filling of residual mining pits with water will lead to creation of large water surfaces with maximum water depths up to 170 meters, where majority of factors and conditions initiating exogenous processes will be present. Complex knowledge as well as assessment of mayor factors form a basis for the development of a geotechnical model describing the relevant section of the future bank. Activation and/or development of exogenous geological processes on the flooded lake banks will be initiated in dependence on joint action of all actually present risk factors. Their underestimation can be documented in a number of cases in the North-Bohemian brown coal basin (e.g. residual pits of Libík, ČSA, Otakar and Barbora) as

well as on water reservoirs of the Podkrušnohorské basins (e.g. Nechanice, Jesenice) (Anonym, 1991).

2. METHODOLOGY OF THE GRANT PROJECT STUDY

Collection of background data and documents was focused namely on extensive geo-mechanics documentation archived by Palivový kombinát company, Ústí nad Labem and by BPT Mining projects company, Teplice. A newer documentation was acquired from various libraries of the Czech Academy of Sciences. Thus we assume that the most important background data have been included into the study. The overview of all references is given at the end of the paper.

As concerns the selection of suitable pit-locations for the Grant Project Study, the selection criterions included types of rocks found on the residual pits slopes, stage of the re-vitalization preparation works, termination date of mining activities and, last- not-least, date and method of the pit flooding. Thus, the selected locations include:

- Chabařovice residual pit, represents the Teplice-Ustí part of the North-Bohemian brown -coal basin,
- Most-Ležáky residual pit is found in the central part of the North-Bohemian brown -coal basin
- Libík-Medard residual pit represents the Sokolov brown-coal basin

Preliminary engineering-geological mapping of the retention actual state had been performed with a special reference on the occurrence, type and extent of slope deformations. Finally, a hypothesis on likely changes of the residual pits bank shapes in dependence on the time scales had been designed.

For formulating of real ideas on processes, factors, and conditions that eventually may occur in residual pits bases, experience and/or knowledge acquired during the long-term survey of exogenous phenomena occurring on the existing water reservoirs and residual mine pits banks, had been used as model situations.

Comments on the methodology of digital data analyses using a GIS system.

The digital data analyses were systematically performed in a GIS-environment, namely using Arc View and ArcGis software. These programmes allow not only to calculate statistical and mathematical properties, but also directly create cartographic and other visual outputs. At present, the GIS systems are more and more often used (Halounová and Pravda, 1999; Hroch et al., 2002) for the research of the natural hazards of slope and erosion processes. The mayor goal of the executed analyses was seen in creation of slope deformation risk maps and bank abrasion danger of flooded residual mine pits, based on the multicriterial analyses (Pauditš and Bednárik, 2002). Most of the GIS outputs within the project in question are based on calculations and analyses of the digital elevation model (DEM). The model is constructed from the data originating from detailed geodetic mapping. In the case of three involved residual pits the DEM was calculated from an irregular point field where each point is defined by relevant co-ordinates x , y , and z . The developed DEM was constructed after modification of the resource data from 27 978 points (Chabařovice Mine), 14841 points (Most-Ležáky Mine) and 7308 points (Libík-Medard Mine). The data were supplied by Palivový kombinát company, the data developer. Beside the DEM, maps of 1:10 000 scale had been used as input data for the Chabařovice Mine, and, in addition, field maps prepared during the mapping campaign in 2003-2005 (showing the position of water springs, landslides, bedrock type, erosion furrows and protection zones) as well as the GPS-documentation points.

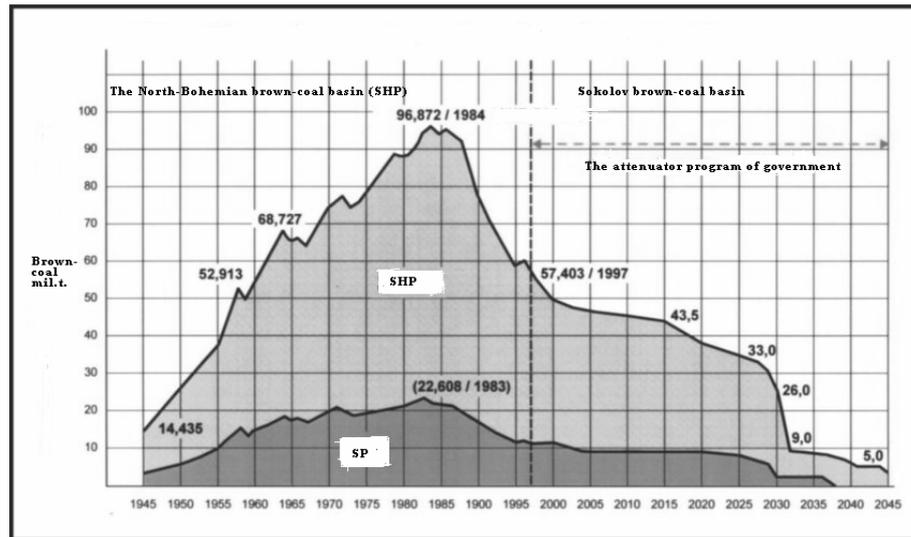
Comments on the mathematic modelling of the residual pits slope stability

Mathematic models of slope stability had been developed together with proposals and assessments of suitable corrective measures. The stability calculations had been performed using the least elements method (MKP). All up to date developed models are the two-dimensional ones. The MKP-calculations might be divided into two basic groups: Searching for the suitable way of the problem modelling, and calculations with an assessment of suitable corrective measures. The first phase of the concerned problem modelling, i.e. finding of the suitable modelling method, is very important for the solution of the problems under the following conditions:

- For modelling of the main residual pits it is very important to know the procedure of the pit construction. It concerns the volume cut away in time scales and thickness of removed earth layers. Destructions of primary tensions occur during the earth cut-outs and *s.c.* "breathing-out" is encountered. The process influences also the slope stability calculations. It means that modelling of the residual pit in its final shape is not useful, while it is necessary to perform the modelling after (basic) phases according to its cutting steps (at least in two phases, i.e. before and after its construction). The resulting stress states and slope stabilities are then different with relevant consequences in the slope stability indices.
- During modelling, it is useful to know - at least approximately - the sedimentation base location and it is necessary to keep several basic rules. The first, it's important to select suitable model size together with correct boundary conditions. The numerical model boundaries have to be selected so that their location might not influence the calculation proceeding and/or results (quantitatively). Generally it can be stated that the distance of the boundary from the modelled problem should be at least fivefold the model size. Materials creating residual pits are very "plastic" (compared to the numeric solution calculations) and the fivefold distance rule is not sufficient. Final sizes of the mathematic model can reach up to several hundred meters and the lower boundary condition of the model location (according to the above rule) is lower than the crystalline complex basis. When the basis is not introduced, the calculation is rather distorted. The tenseness changes are propagated into locations where this action really does not take place. The resulting slope stabilities are lower than in the case when the location of boundary condition is introduced at the base location or the base modelling in the case when the boundary condition is even lower.

Table 1 Present situation of re-cultivation activity.

Type of reclamation	SHP total area (km ²)	SP total area (km ²)
Agricultural	48.82	10.42
Forestry	78.63	21.49
Hydrous	3.31	0.43
Other	11.94	0.73

**Fig. 1** Long-term development of brown-coal mining in Podkrušnohorské basins - attenuation variant.

- **Modelling of the residual pit flooding.** Correct description of the water influence on the slope stability in a residual pit is not easy. Water can be introduced into the numeric model by several ways. It is possible to introduce free water surface and groundwater surface or to introduce water within the slopes using pore tensions. According to calculations made so far it seems to be more suitable to introduce water by pore tensions, however, this method of the water influence modelling is still in the phase of calculation testing.

3. LAND RECLAMATION WITHIN THE PODKRUŠNOHORSKÁ BASINS

Due to already almost fifty-years tradition, the actual temporary reclamation activity ranks the Czech Republic into the group of states with the top technology in the field of the world mining industry (Frölich and Valášek, 2000; Fig. 1). During the last almost 50 years, the total removal of agricultural land in the North-Bohemian brown coal basin increased from 70 to 293 km², i.e. more than four times. The operation area of mines, open mine pits and dumps has, however, increased only 2.5 times comparing with the state 1950, because nearly one-half of

originally removed agricultural land acreage had been already retrieved (142.7 km²) after its reclamation to initial or actually modified purposes according to the actual needs of regional inhabitants (Jiskra, 2000).

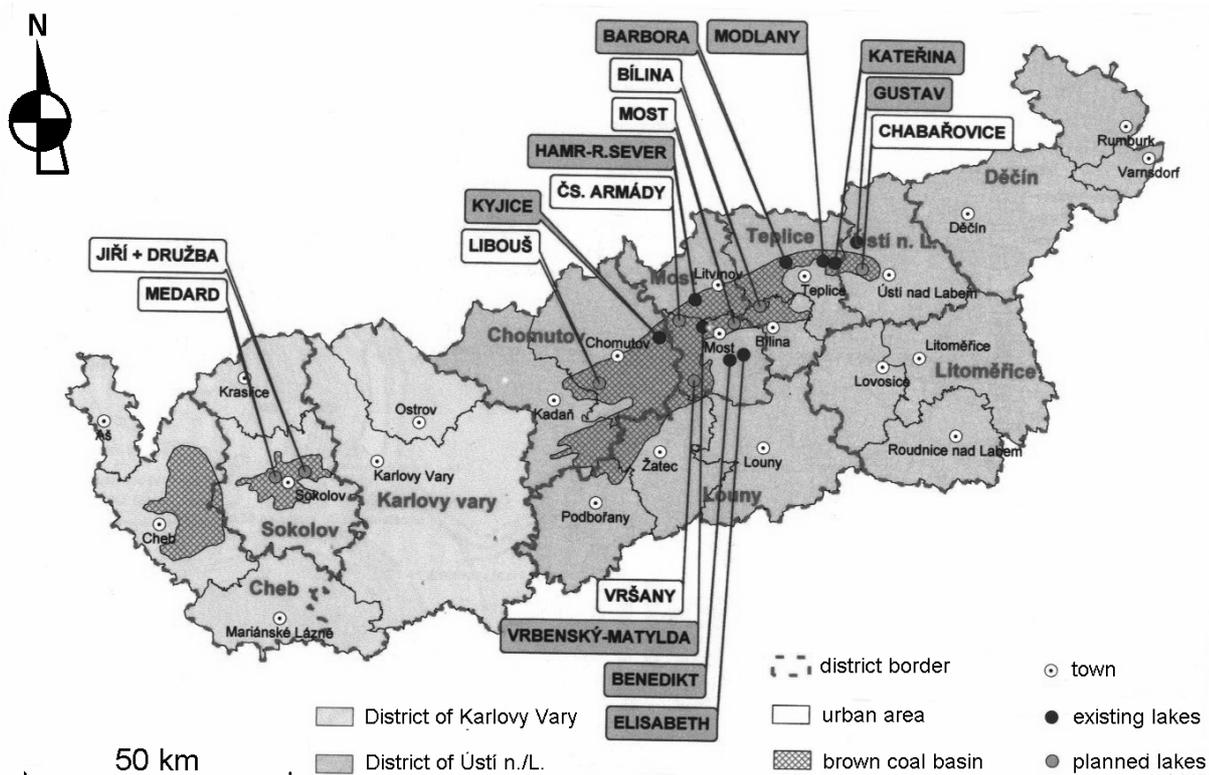
Out of all finished and/or already started re-cultivation works covering in the North-Bohemian brown-coal basin (SHP) in total 142.7 km² and in the Sokolov brown-coal basin (SP) in total 33.07 km², the following acreages belong to different types of reclamation (Table 1).

Total area damaged by coal mining activities within the North-Bohemian brown-coal mining fields (SHP) represents nearly 150 km², while in Sokolov brown-coal basin (SP) it is about 60 km² (Svoboda, 1999). When an attenuation variant of future coal mining is to be realized within the frames of ecological limits, another about 178 km² and 65.5 km² of land removed for mining activities will require reclamation and re-cultivation in SHP and SP respectively.

During several past decades of re-cultivation work focussed on lands badly affected with old opencast coal mining, nine smaller water reservoirs have been constructed in brown-coal basins of north-western Bohemia. Some of the reservoirs served for protection of mining activities in large-scale opencast

Table 2 Parameters of future mine lakes in SHP and SP brown-coal fields (Chour, 2001).

Opencast mine name	Variant	Anticipated start of flooding	Water surface area (km ²)	Water surface level (m a. s.)	Stored water volume (Mm ³)	Water depth (m)	
						mean	max.
Chabařovice		2001	2.52	145.3	35.0	15.6	23.3
Most – Ležáky		2006	3.225	199	72.354	22.4	59.0
Libík -Medard	flowthrough type	2010	5.014	401	138.0	27.5	51.0
ČSA	deep	2020	12.59	230	760.0	60.4	150.0
Šverma – Hrabák	No. 1	2030	3.42	195	35.6	10.4	37.0
	No. 2	2050	3.90	215	73.6	18.8	40.0
Bílina	any flow-through	2037	11.45	200	645.0	56.0	170.0
DN–Březno–Libouš	flowthrough	2038	6.40	277	110.4	17.3	52.0

**Fig. 2** Water reservoirs to be created in connection with coal-mining activities (Valášek, et al.2003).

mines against flood flushes of surface water (e.g. Kyjice, Modlany, Kateřina Water Reservoirs), while other reservoirs were designed as "wet" recultivations of former smaller mine residual pits (e.g. Gustav in Varvařov, Barbora northwest from Teplice, Hamr near

Litvínov, Elisabeth, Benedikt and Vrbenský-Matylda near Most, see Table 2 and Figs. 2 and 3).

During the closing phase of mining on individual mining localities from about 2020 to 2040 years, eight large lakes are to be constructed with water surface

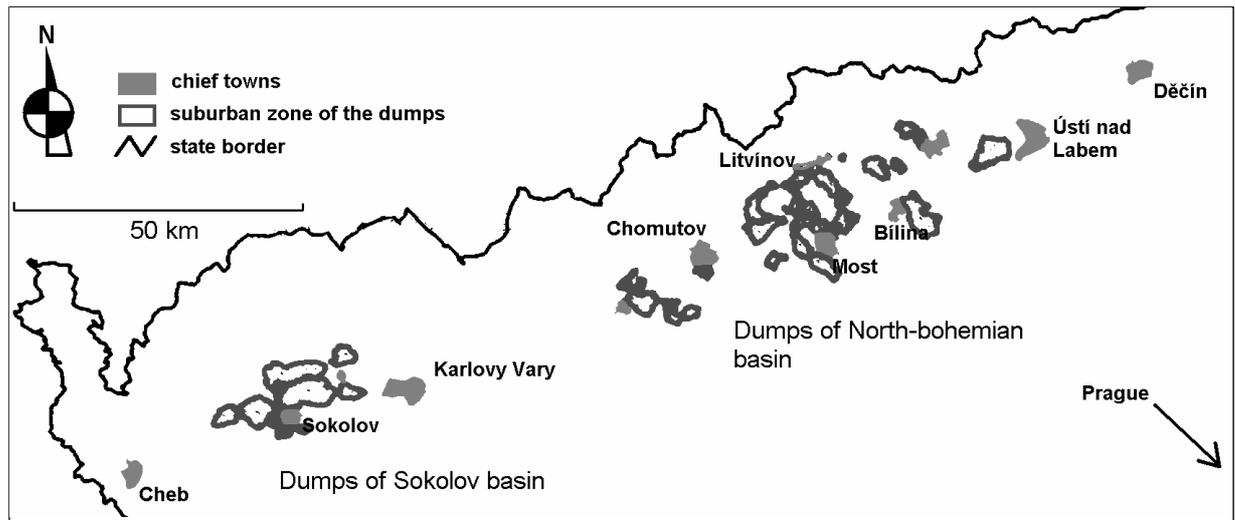


Fig. 3 A Setting of dumps created in connection with coal-mining activities.

areas of several hundred km² - from the smallest one - Chabařovice Lake (about 2.52km²) to the largest Jiří – Družba Lake (SP – about 14.70km²). Maximum stored water volume of about 760 Mm³ is planned in the residual pit of former ČSA Mine in 2020–2050 years. The relevant reclaimed area is planned to be between 46 and 53 km² of total water surface areas.

Opencast-mine lakes within the Most part of the coal-deposit basin only (e.g. Most – Ležáky, ČSA and Šverma – Vršany Lakes) will cover water-surface area of 19.72 km² in total, thus equalling the area of historical Komořany lake as existed in 1831.

The basic rehabilitation conditions for the future usage of water areas can be briefly summarized as follows:

- assurance of proper sealing-of the coal stratum and ,eventually, of other permeable layers
- assurance of the stability of the future banks and their wider environment as required for planned usage of the landscape
- assurance of proper water quality
- assurance of minimal water flow in the relevant river and brook network during filling of residual pits so that minimum sanitary discharges below the water output profile are always kept
- realization of emergency-control facilities equipped with hydro-chemical, biological, toxicological, and - if required - even geo-technical monitoring

At present, long-term slope stability concepts are studied for each of the residual pits assumed for future flooding. Within the phase of preparation rehabilitation work, there is an overall effort to realize as possible milder slopes. After the mining activities are terminated, the correctly reshaped slope should represent equilibrium state and respond to basic conditions for effective landscape usages. Slopes of

the coal basin infillings are usually modified into a linear profile with slopes from 1 : 6 to 1 : 12. In case of high soil dump bodies, the slopes of both convex, and concave outlines are justified by a limit-equilibrium theory. The slopes are usually reshaped into final general slopes of 1 : 12 to 1 : 18 (Kryl, 2000).

4. THEORETICAL ASSUMPTIONS OF THE GEODYNAMIC PHENOMENA OCCURRENCE

Long-term stability of future banks and their vicinity, i.e. changes in behaviour of rock massive in contact with water and the following rheologic changes of the massive create the basic problem of residual pits planned for flooding (hydrous) form of re-cultivation (see Fig. 4).

Due to both intensive mining activities, and subsequent work on mitigation of resulting damages, totally new hydrological and geo-morphological development conditions have occurred within the area planned for rehabilitation. Gradual changes of physical-mechanical properties of rocks both in cut-off slope, and in quite new geological environment - dumps soils- are registered under the influence of water and its current pressures (Záruba et al., 1986).

There are usually two basic causes of the slope deformation (Záruba, 1987):

Flooding of slopes leads to water saturation of rocks and subsequently to decrease of their actual mass weight under influence of buoyancy. While the rock load above water surface is not changed, the cohesion of fine-granulated soils is substantially diminished. During sudden and deep depression and/or increase of water surface level in a reservoir, the inclined components of soils weight are suddenly increased and the load originated from water current is introduced into the soil and rocks due to water flows. When the initial flooding reaches up to the relatively

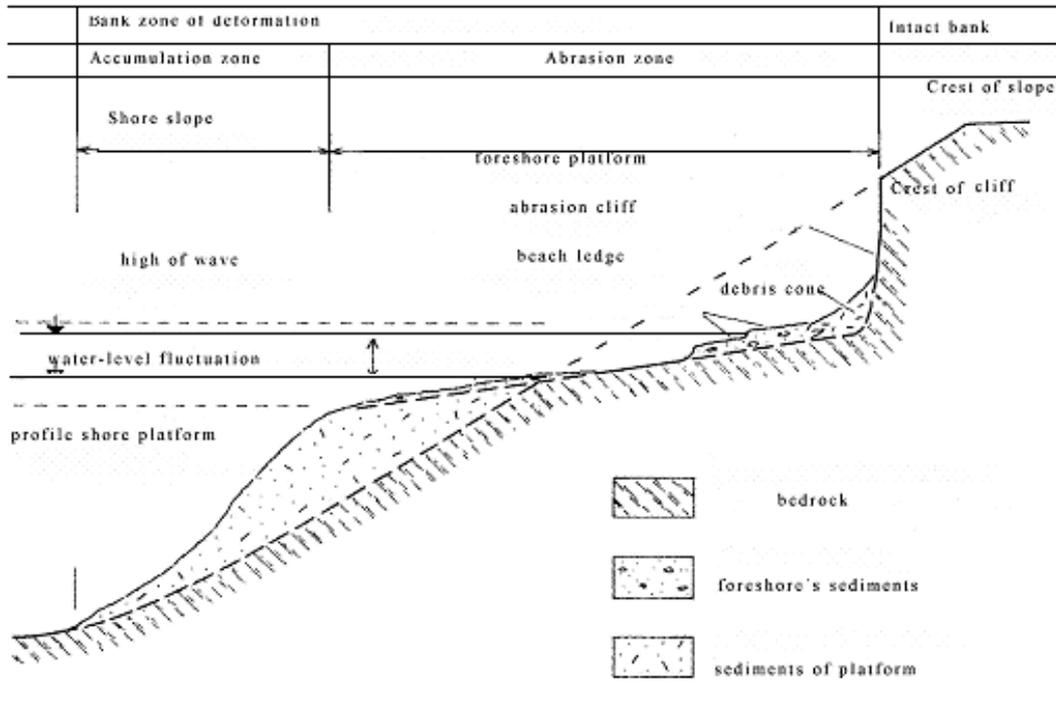


Fig. 4 Scheme of the bank abrasion profile.

firm original slope, any larger deformation of banks usually occurs. In the first phase, an increased stability occurs, due to increased loading of the bank toe and under the spout-pressure influence during bank infiltration of water directed towards the slope. The situation worsens when the slope is left for a longer time under water surface. The rocks are saturated with water and their actual mass weight is decreased due to buoyancy effects. The layers found near the surface start to be heaved and their shearing resistance starts to be diminished. When the overburden formations are developed in thicker layers inclined in direction to a lake and, namely, when they had been already earlier deformed, water level fluctuations may cause bank land-sliding. This brief description of bank deformation occurrence on water reservoirs will be also probably applicable for residual pit banks.

Simultaneous effect of basic factors will lead to gradual development of the following processes (Rybář and Spanilá, 1980; Spanilá and Rybář, 1983):

- abrasion,
- slope deformations,
- collapse, debris cones,
- suffosion,
- erosion
- weathering
- submerged density of rock changes: Loosening, swelling, shrinkage, collapsibility, freezing, slaking.

Out of a number of geodynamic processes, namely abrasion and sliding take part on the geo-

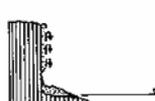
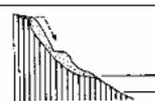
morphological shaping of bank slopes. When mutual influence of the processes occurs, abrasion-sliding deformation is considered. Nature, mechanism, and extent of the above mentioned processes are being studied on many water reservoirs, however, the level of the task recognition as well as the mechanism and extent of the above processes and their initiating factors is quite different (Spanilá, 1994). At the same time, there exist only a limited number of studies focussed on the behaviour of future banks of flooded residual pits. We are going to describe very briefly the nature and mechanism of emergence of the most serious individual processes.

Abrasion is a process of mechanical distortion due to wave motion action. It occurs almost on all water reservoirs and flooded lakes. Wind-initiated wave motion damages banks in a form of undermining (scouring) that leads to creation of typical shore (abrasion) platform and a beach usually ended by a steep abrasion cliff undercutting the slope that is then prone to sliding according to the character of local rocks.

Within the reaches of water-surface influence, an abrasion type of the bank is created, that can be described either as abrasion accumulative or abrasion-sliding type.

Bank material loosened by the wave action - namely in the case of clay sediments - is floated-up and removed in a form of suspension into deeper locations of a reservoir. The abrasion platform is composed from both above- and below-water level parts and is considered as a basic characteristic of bank stability conditions because its slope and length

Table 3 Types of bank deformations on some water reservoirs in the Czech Republic.

Type of bank deformation	Geodynamic processes	Lithological composition	Abrasion cliff (h) meters	Type of cliff	Water reservoirs
	Tertiary -	Quaternary			
Abrasion	Weathering, abrasion, slope erosion, stone fall and rockfall	Alluvial and deluvial soils, clayey sediments, slate, sand loam, sandy shale, silt rock	0.3-10.0		Nechranice, Jesenice, Zemanice, Orava
					Nechranice, Jesenice, Olešna, Orava
					Nechranice, Hracholusky, Orava, Lipt. Mara
Sliding	Slides, landslides, weathering, abrasion, suffosion	Clays, claystones, sandy loam, sandy shale, silt rock, marl slate, loam and clay slate	5.0-20.0 and more		Šance, Lipt. Mara, Orava, Karolinka
					Orava, Jesenice
	Weathering, slides, abrasion, suffosion, slope erosion	Silty loam, terraces, gravel, clay, clayey sediments	5-10		Jesenice, Nechranice

advise actual stadium of the bank profile development.

High and steepness of the abrasion crib crate conditions for development of sliding deformations, collapsing, creation of debris cones, erosion etc.

On the basis of accumulated data on the origin of all exogenic processes involved in the formation of the bank zone, genetical classification types of the monitored water reservoirs were suggested with regard to their lithological structures, as presented in Table 3.

In the case of banks consisting of clayey sediments, the abrasive and accumulation slope types are very involved.

The abrasion bank types are found practically everywhere, particularly in the higher bank slopes, where the formed abrasion block pile rises up to ten metres. From the geodynamic processes involved in

the deformations of banks in water reservoirs, we can mention, in this case, the abrasion tumbling, bestrewing, landslides, erosion and weathering. Special attention should be paid also to the abrasion-type banks with the occurrence of landsliding deformations along the ancient or activated shear planes, where the intensive abrasion is caused by deteriorated physical and mechanical properties of landslide-impaired rocks.

The sections, where sliding deformations dominate and initiate the abrasion process, are sometimes characterized as abrasion-sliding.

The accumulation bank type is typical of morphologically gentle section with low abrasion block piles (below 1 m) consisting mainly of terrace gravels, sorting of the beach materials is quite common here.

5. ANALYSIS OF FACTORS AND CONDITIONS INFLUENCING THE BANK STABILITY ON OVERBURDENED SLOPES

Bank and slope deformation is very complex process dependent on a number of mutually acting factors. Some of them undergo great spatial changes, others are changed in time. The factors determining the character of bank reshaping can generally be divided into two groups: geological and hydrological ones.

a) Geological factors

Determination of the extent of wash-out, shape of a new slope, and a type of exogenous processes that were described earlier (Spanilá, 1996). The factors include:

- **geological-lithological** composition of the slope,
- **geomorphology** of the bank abrasion profile: it concerns the slope steepness and length of (the future abrasion platform) under water, width of slope (abrasion platform, foreshore beach above water surface during the first years of flooding). Those parameters influence action of wave energy namely in the first years of the water basin operation, and, also, the exposition of the bank profile against predominating winds (the greater angle under which the wave is approaching the bank line, the greater is the wave energy). In exposed sections, scouring and detachment occur, while in less exposed ones accumulation of detached material is found.
- **morphology of the surrounding terrain**, depth of the assessed site below the surrounding terrain,
- **hydrogeologic conditions** and present geological processes,
- **physical-mechanical properties of rocks** influence the extent of bank deformations, that is dependent on the rocks resistance against wave impacts, in other words, their wash-out ability. The wash-out ability is influenced mostly by the following properties: Strength, granularity, consistency, plasticity, mineral and chemical composition, compactness, level of weathering, intensity of cleavage, stratification, schistosity, grain bonding, kind of cementing agent etc.

b) Hydrological factors

Majority of authors rank hydrological factors between those decisive as concerns the nature of bank deformation itself, which is based on mutual influence of banks (firm component) and water (Spanilá and Simeonova, 1993). They are divided on horizontal water-surface movement (wind waving) and vertical movement (fluctuation of water-surface level in a reservoir). We distinguish two main movements of water surface that basically influence the extent of bank and slope deformations:

1. **horizontal movement (waving)** of water surface is determined mainly by the following parameters:

- characteristics of wind flow in velocity classes and individual directions in the assessed locality, time of their duration, decisive is, first of all, occurrence of winds with high velocities with duration in minute ranges.
- parameters of water surface, namely its size influencing the wind-running route length,
- bank morphology (angle of the offshore zone leads to the water depth and influences parameters of the waving energy. Annual summary waving energy is reduced by the period of water surface freezing.

2. **vertical movement** (fluctuation of water surface according to the reservoir manipulation schedule) water surface in the reservoir gives limits of vertical zone of the wave abrasion impact. In the case of residual mining pits it will not be necessary to consider any significant impact of the vertical fluctuation of water surface in a reservoir on the abrasion deformations intensity because of only a short-time evaporation losses of water. However, the time of duration of water surface level on a certain altitude is important while it enables modelling of the wave impact on the abrasion profile including the abrasion platform below water. This is why general time horizon of the reservoir filling is important for the flooding of residual pits.

c) Geographic factors

geographic location, conditions of climatic and vegetative cover.

6. ANALYSIS OF FACTORS AND CONDITIONS INFLUENCING THE BANK STABILITY OF DUMPS

Complex knowledge and assessment of mayor factors create a basis for the development of a geotechnic model of the assessed section of the future bank. Basic engineering-geology factors deciding on the dump-structure stability are as follows:

- **morphology of the base:** The terrain relief before the waste dumping, the base inclination in ranges from 0° up to 12° and more being assessed from sub-horizontal up to very inclined dump foundation, improvement of rock environment quality by the additional compaction of the base with a drainage using for example plane drain, indenting of the base in slopes etc.,
- **geological and hydrogeological conditions** include structural-geology composition of the base and its sealing properties (bearing capacity, compactibility, permeability),

- **hydrogeological factors:** presence of water saturated zones and their basic hydraulic parameters, possible impact of the dump on the surrounding groundwater and surface waters. Possibility of the dump base improvements: a) by the relief treatment, e.g. indenting of the base in slopes, b) drainage (planar drain), c) improvement of mechanical properties using additional compaction of the base or replacement of unsuitable earths with more suitable materials or by a combination of methods a) to c),
- **geomechanic properties of the dump structure** are ones from decisive criteria for determination of the general behaviour of the base, e.g. for determination of possible position of the critical slide plane. Good knowledge on geomechanic properties of both the base, and the dump body earths enables - between others - to clarify anticipated position of the dislocation plane,
- **geomechanic properties of dumped soils** are given namely by lithologic character, mineralogical composition and level of the earth and overburden rocks. These factors influence physical and geomechanic properties of the removed overburden,
- **hydrogeological conditions of the dump body itself.** Loosely dumped material exhibits granular character with typical content of small debris that - in contact with water - change their consistency. There was a detailed analysis of the development of hydrologic conditions caused an extensive sliding of the Vintřov dump (Rybář, 1991),
- **atmospheric precipitations, temperature changes, vegetative cover, natural and induced seismicity** belong to factors that might directly or indirectly influence dump stability conditions,
- **age of the dump.** There is a general rule that an age of dump significantly influences the stability of its structure. Plasticizing of the dump base part under the influence of increasing geostatic pressures leads to gradual saturation of the dump body with water and, roughly after thirty years to its consecutive collapse (e.g. Merkur, Loket, Vintřov dumps). Quality, but also availability of background information required for assessment of all risk factors of stability is dependent on the dump age.

Actual state of the brown-coal mining in the Czech Republic and prognoses of its future development, however, does not expect any preparation of new dump areas.

7. CONCLUSIONS

It is without any doubts that mitigation of mining activities based on flooded pits will be connected with gradual decrease of bank-slope stability, which might lead to unacceptable slope deformations. This is very

important namely in areas of occurrence of old sliding, where it is needed to consider residual values of shear strength on sliding planes which might lead to reactivation of slope deformations.

Slopes of residual mining pits in Podkrušohorské brown-coal basins are mostly composed of fine granular soils (grey Miocene clays and claystones) generally exhibiting rather low permeability. Due to this fact, the planned flooding of the pits will lead to rather slow and gradually changing impact on the slope stability. Additional loading of the slopes toe by the hydrostatic pressure - as concerns the slope stability - will be after a certain time reduced by an adverse buoyancy effect of water seeping through more pervious sandy-silt layers in overburden strata including locations of thin upper brown-coal beds occurring in covering soils layers of the main coal strata. It seems clear that it does not concern full buoyancy impact that would be functional in deeply mined-out coal strata in the case of neglecting its sealing.

In the case of abrasive deformations it is important to know how they will develop during the flooding and in final stage of bank development, how they will influence the changes in lake banks shape, etc. Eventually, it will need to consider necessity and selection of measures protecting against unacceptable changes reaching deep into the surrounding terrain in accordance with planned future usage of bank zones (i.e. back replacement of the bank profile). Undoubtedly, the banks of the future lakes will suffer not only from gradual deformations induced by water flow. Wave abrasion process might initiate more extensive bank deformations by sliding as they have been experienced by surveys of bank deformations on several water reservoirs (e.g. Nechanice, Jesenice, Barbora). This is why the studies of slope stability around residual pits both in natural state, and in water-saturated state are considered as a task of top importance.

Bank deformations or reshaping on flooded water reservoir is very complex geodynamic process dependent on a number of mutually functioning factors.

During the solution of the project the attention was paid to the slope stability and, first-of-all, to abrasion and sliding deformations on future banks and their wider surrounding zones. Considerations were also given to the specific geologic-lithologic conditions (sections constructed from dump materials).

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