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OBSERVING LANDSCAPE CHANGES USING DISTANT METHODS

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ABSTRACT

Landscape changes are a very common phenomenon in the area of North-West Bohemia (the Czech Republic) as this area is heavy industrialized. This paper presents two methods for observing the landscape – the bathymetric mapping and the aerial mapping. The bathymetric mapping is used to reconstruct the original surface in area where the Nechranice dam was built in 1960' and to evaluate the sedimentation caused by the Ohře River. The original surface of the Ohře river canyon was reconstructed using old maps and the bathymetric mapping was performed with Lowrance HDS-5 Sonar. The aerial mapping introduced in this paper is a new method of using Small Format Aerial Photography in connection with an ordinary aircraft. The gimbal (camera stabilization) normally used by Unmanned Aerial Vehicles is mounted into a small aircraft and allowing the scanning of very large areas – in our case the open-pit mine Tušimice was the target of our study. The derived orthophoto and Digital Surface Models were used to complete the georelief development analysis based on old maps and aerial photographs.

KEYWORDS

North-West Bohemia, Nechranice dam, Bathymetric mapping, open-pit mine, aerial survey.

INTRODUCTION

Every minute the surrounding landscape changes. Heavy industrialization in connection with other human activities is changing land-use, georelief, settlement patterns and even river networks very quickly. Every year hundreds of hectares of land covered with new structures are transformed by open-pit mines or flooded by water dams. Such changes have happened in the past as well but on a much smaller scale. A very significant area influenced by these changes is the Ústí nad Labem region (the Czech Republic). This region has undergone dramatic changes in the past when brown coal mining started in the 1930s using open-pit technology. This had a destructive impact on the surrounding landscape – land-use structure has been completely changed, hydrological networks displaced and many towns and villages vanished. In this paper we would like to introduce two methods of observing landscape changes using distinct methods in the form of case studies. In the past years many studies using the Unmanned Aerial Vehicles (UAV) used as a spatial data collecting tool in order to record and analyse the landscape changes have been presented. Nowadays UAVs are becoming the standard tool for digital terrain model and orthophoto creation. The disadvantage of this tool is the relatively short range based on battery life (coverage of several hectares during one mission) and legislative restrictions. In this paper, we would like to present "UAV style" data collection with ordinary aircraft used as a carrier. The other distinct method presented in this paper is Sound Navigation and Ranging (Sonar) used to detect changes in dam-bottom within almost the same area of interest.

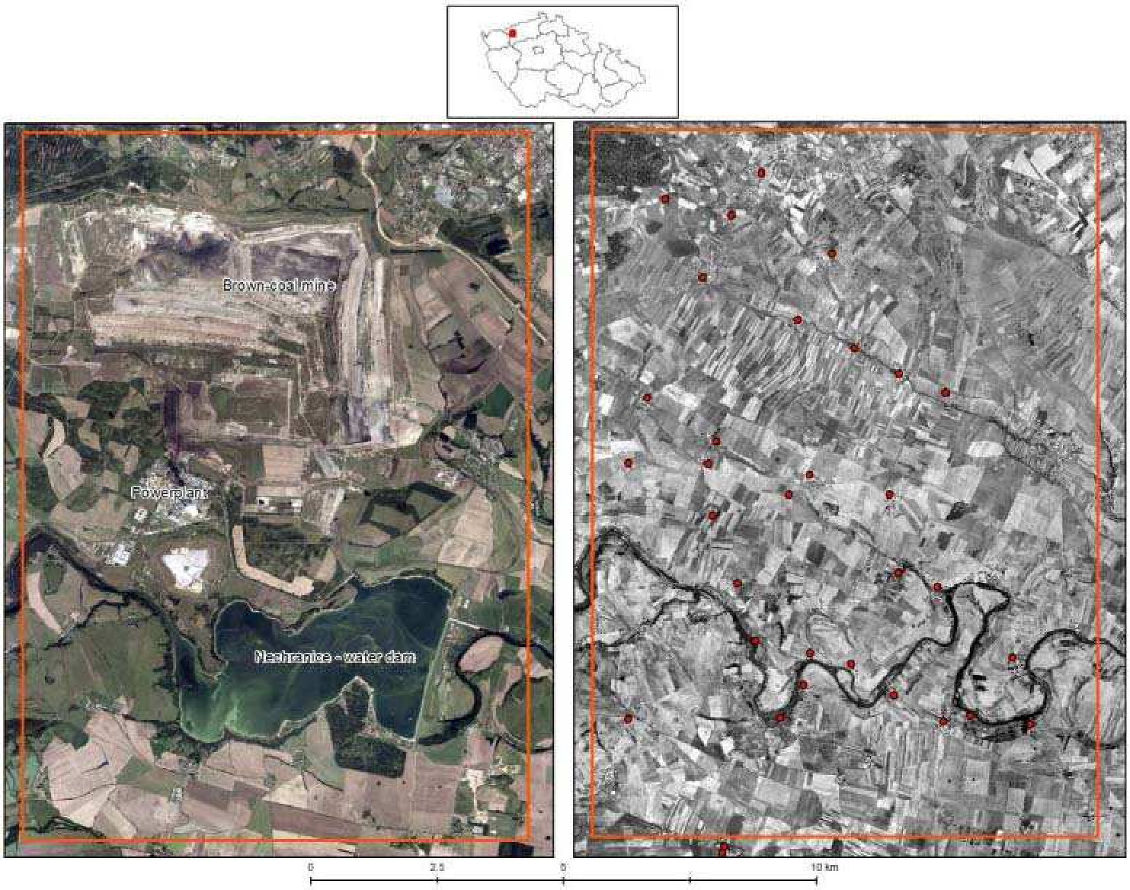

Fig. 1 - Area of interest overview. The current state (left). The original state visualized in a 1953 orthophoto (right). The red dots indicate extinct settlements in the area.

METHODS AND RESULTS

Area of interest

The area of interest is situated in the Ústí nad Labem region (North-West Bohemia, in the Czech Republic). Several areas were subject to perform the case studies in order to test and present the distinct methods for observing landscape changes [0]. All of the areas of interest have specific characteristics and different method requirements. A very significant area influenced by the human activity has been selected as so to present the not very common spatial collection methods. The area of interest is presented in *Fig. 1.*

The area of interest (140 km^2) is located in the south-west part of the Most brown coal basin in-between the towns Kadaň and Chomutov. The active brown-coal mine Nástup Tušimice covers approx. 14 km^2 and the water dam Nechranice 13.4 km^2. Brown coal mining in this region began at the end of the 18th century using the primitive ways of mining. Intensive open-pit mining started after World War II. In the 1960s – 1970s four large power plants were built in the close surroundings to the brown-coal source– Tušimice 1 (output 660 MW, shut down in 1998), Tušimice 2 (800 MW), Prunéřov 1 (440 MW) and Prunéřov 2 (1050 MW) [0], [0]. The water dam Nechranice (built in 1960)

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is situated ca. in the middle of Ohře river flow (103.4 km) and contains the total volume of 9.5 million m^3 (one of Europe's biggest rock fill dams) and as well as having the longest damming in the Central Europe (3280 m). The main purpose of this water dam is the water supply for the surrounding industry, power plants and large area irrigations. [0], [0]

Within this area of interest, the two methods of spatial data collection were tested – the Sonar method (bathymetric mapping) used to detect dam-bottom changes caused by the sedimentation process (Nechranice dam) and an aircraft "UAV-style" photogrammetry campaign focused on volumetric computations. The Sonar scanning was performed in cooperation with the Povodí Ohře Company (the owner of the dam). The photogrammetric imaging was tested upon the Severočeské doly's (the mining company) request.

A very detailed landscape development analysis, including hydrological network reconstruction and georelief development analysis was performed in this area as an initial point to the Nechranice dam bottom Sonar analysis (see [3] and [0]). Several old maps were processed in [0]. The oldest processed map is Müller's map of Bohemia (ca. 1720) followed by the 1st, 2nd and 3rd Military survey of Habsburg empire (1792, 1894, 1938). The Military survey presents the natural development of the area until heavy industrialization. This time-line is well supported by the Stabile cadastre maps (1842, 1:2880) containing detailed information about land-use. The time period of heavy industrialization is covered by State maps and State maps derived in the scale of 1:5000 (SMO-5) from the years 1953, 1972 and 1981.

The bathymetric mapping

The history of the bathymetric mapping in the Czech Republic is dated back into the end of the 19th century when the glacial lakes in the Bohemian Forest were mapped [0]. Bathymetry is the measurement of the depths of water bodies from the water surface. It's the marine equivalent to topography. Bathymetric surveys are generally conducted with a transducer which both transmits a sound pulse from the water surface (usually attached to a boat) and records that same signal when it bounces from the bottom of the water body. An echo sounder attached to the transducer filters and records the travel time of the pulse. At the same time that the pulse occurs, a GPS unit can record the location of the reading. After many of these readings are taken, corrections are made based on fluctuations in the water surface elevation that may have occurred during the survey. The individual points are then mapped - easily done in a GIS. [0]

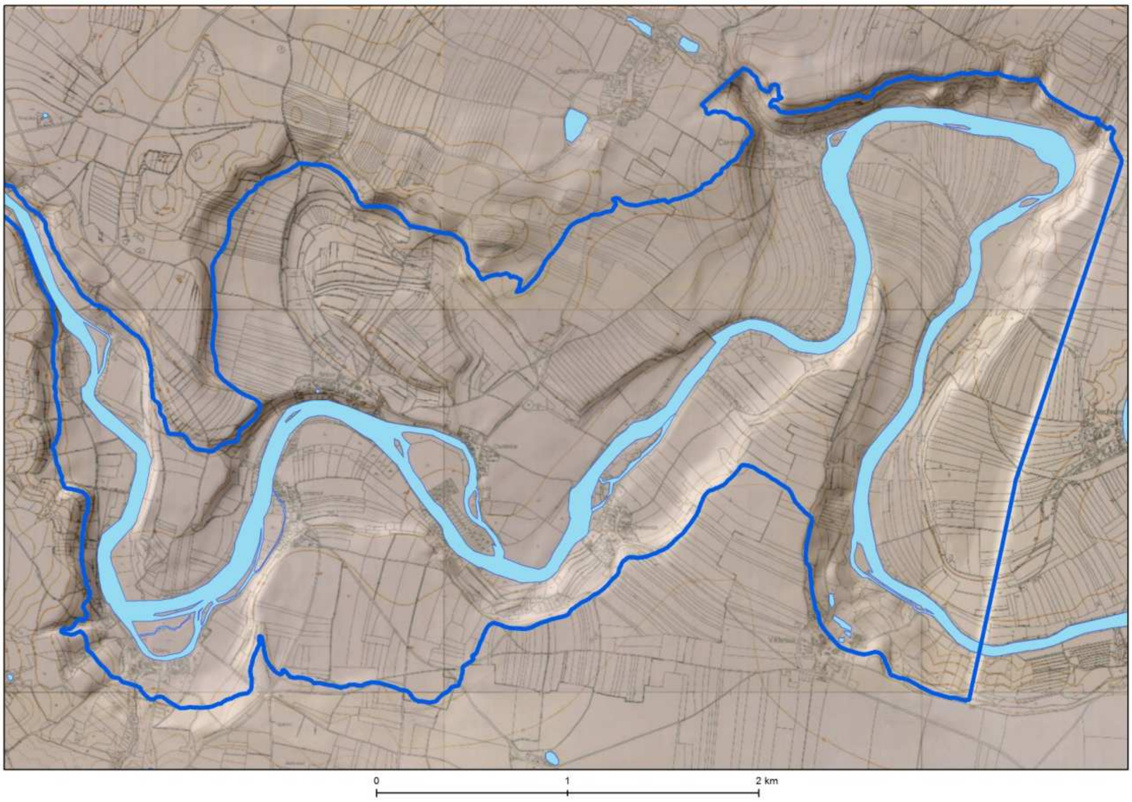

Fig. 2 The original Ohře river canyon derived from the SMO-5 (year 1953) maps

The purpose of our bathymetric mapping is to compare the original surface of the former river Ohře canyon and the current dam-bottom flooded more than 30 years ago. The analysis between these two DTMs could show the amount of sediment transported into the dam during the given years and other georelief changes caused by the dam's construction not contained in contemporary maps. It would be very interesting to identify the former Ohře riverbank.

In order to perform the dam-bottom development analysis, the original shape of the landscape is required. The oldest maps within the Ústí nad Labem region, with terrain represented by contour lines (with interval 5 to 20m), are the maps of the 3rd Military survey of the Habsburg Empire - renewed in 1930s. The renewed 3rd Military survey maps in scale of 1:25 000 do unfortunately cover the whole area of the Nechranice dam. Thus another map source used as the reference layer had to be chosen. The other important source of data for landscape reconstruction in the Nechranice water dam area is the derived state map in the scale of 1:5000 (SMO-5). The whole Czech Republic has been covered by SMO-5 maps since the year 1950. This map is not based on direct field measurements, but is derived from existing map sources. In these maps, elevation data are presented in the form of contour lines, elevation points and technical hachure. The base contour interval is 1 meter, 2 m or 5 m in addiction to base map elevation data [0]. Unfortunately the SMO-5 maps in this area contain contour lines with 10 m interval. This is (so far) the only data discovered in the map archives containing the elevation information prior to the dam's construction. The reconstructed Ohře river canyon is presented in *Fig. 2.*

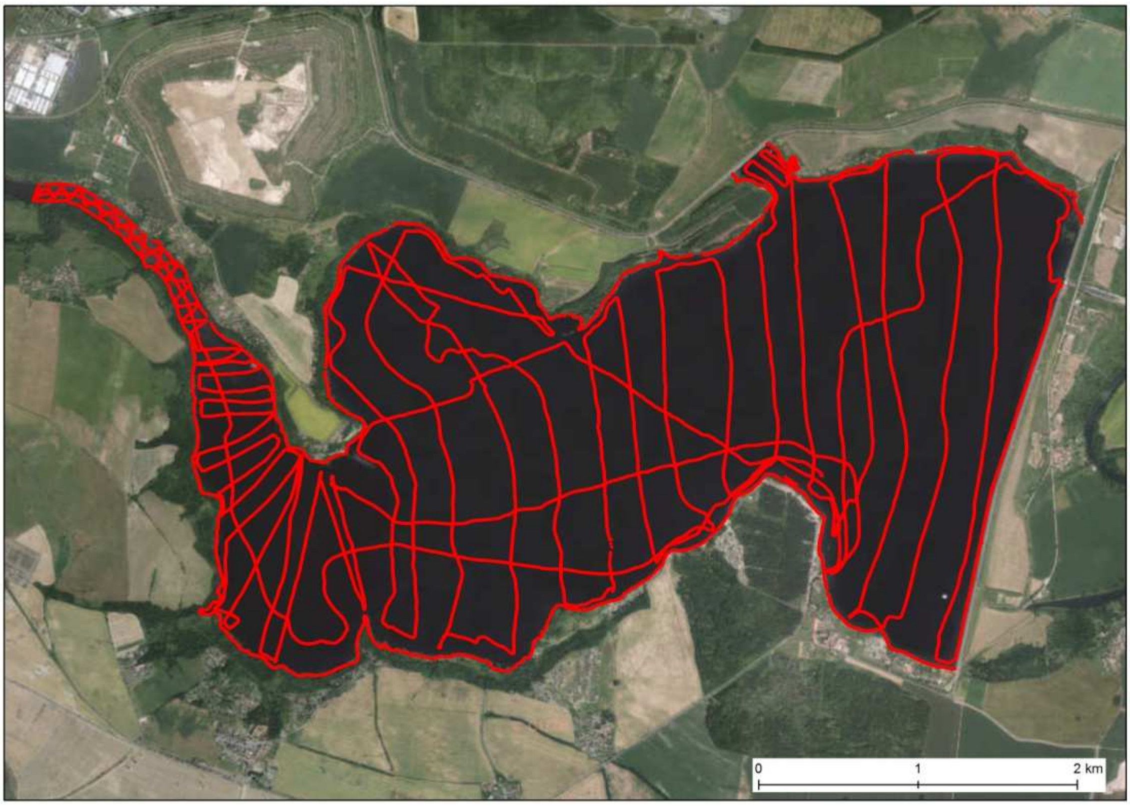

Fig. 3 Nechranice dam - transects scanned with Sonar

The bathymetric mapping of the Nechranice dam-bottom was performed in the summer of 2014 using the Lowrance HDS-5 Sonar and the boat owned by the water rescue service. The ideal speed for the bottom scanning is between 5 – 10 km/h and more than 40 transects across the water dam were scanned (the total length over 80km). The average distance in-between transects is about 250[1]m. The Sonar records the data as single points which can be further interpolated into a DTM. The scanner area is presented in *Fig. 3.*

[1] The shorter distance in-between the transects would produce results of higher quality, but with respect to the dam area and limited boat hire time we may consider these data satisfactory for desired analysis.

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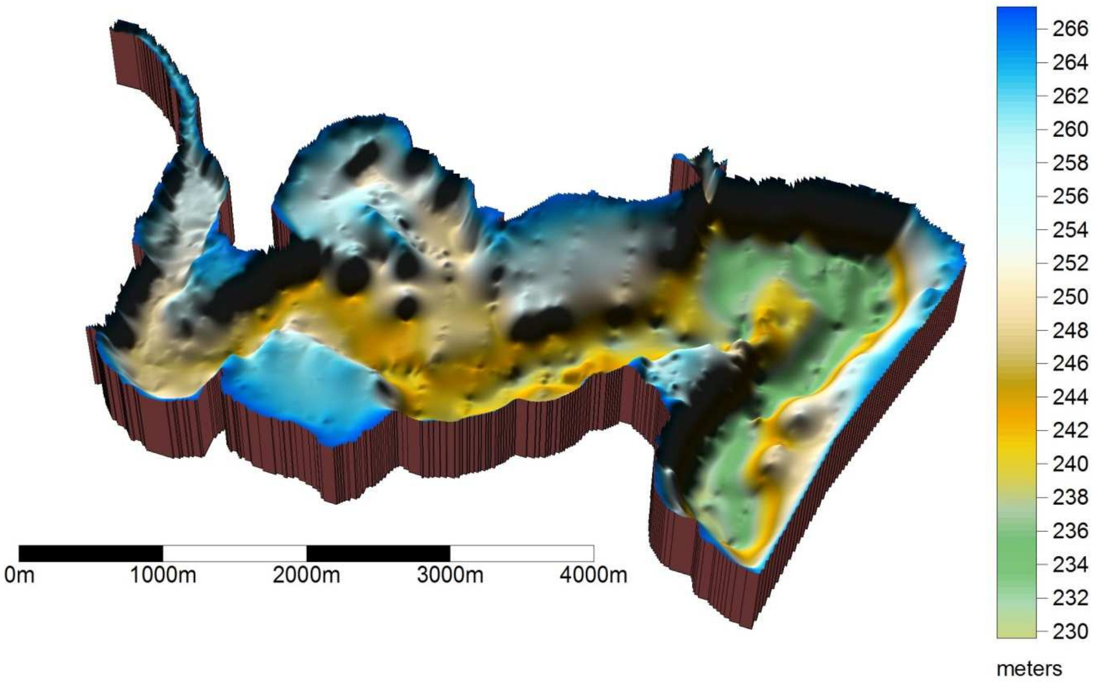

Fig. 4 Nechranice dam bottom reconstruction based on Sonar data

Data received from the bathymetric mapping represent the exact water depth in the place of acquisition. The actual water level was measured using the RTK GNSS receiver and was set to 266.75 m. The scanned points were interpolated into a DTM using *Topo to Raster* interpolation methods (implemented in ArcGIS) – see *Fig. 4.*

The differential analysis (see Fig. 5) shows the differences within the dam area. Many of the positive differences are the interpolation artefacts caused by the sparse data. There are three major differences visible in areas sufficiently covered with scanned data. Area 1 located in the Ohře river inflow is possibly caused by sediment deposition. Area 2 and 3 are the results of possible human activity prior to dam construction. All of these differences have to be analysed in the future.

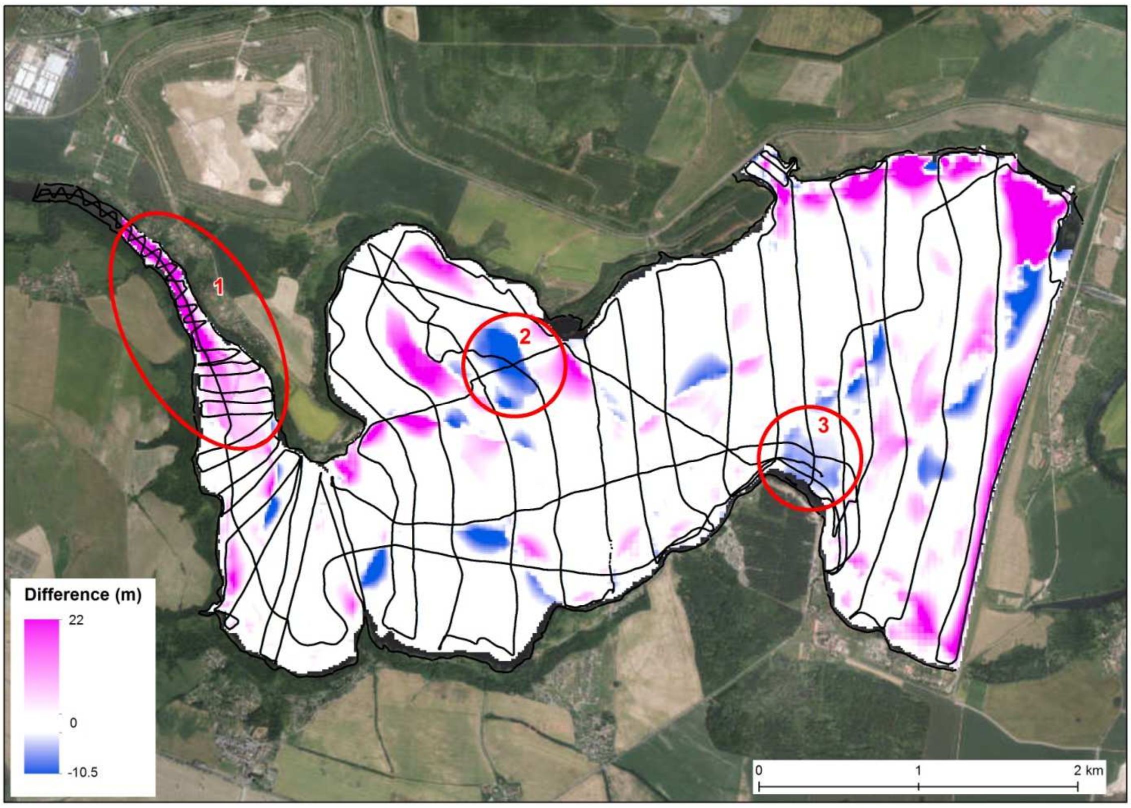

Fig. 5 Dam bottom differential analysis results

The aerial mapping

Georelief development analysis is the other task of our project. The reconstruction of the original landscape in the area of interest (Nechranice dam – Tušimice mine) is described in detail in [0].

Four different time-periods were reconstructed based on the input data. The original *untouched* georelief is derived using hand digitized contour lines from the SMO-5 maps – year 1953 and is presented already in the bathymetric mapping chapter. The second derived DTM is from the 1970s where the Nechranice water dam was already built and the Ohře river canyon flooded. The SMO-5 maps from the 1980s show the beginning of the brown-coal mining. A section of the Nechranice dam is missing as the original maps sheets were missing in the map archive. Nevertheless, there is no major change of the georelief in the missing section. The current state of the georelief is reconstructed using the DMR 4G data. These data represent a picture of nature or terrain modified by human activity in a digital form as heights of discrete points with X, Y, H coordinates in regular 5 x 5 m grid. These data were obtained using LIDAR technology [0]. The resulting DTMs for the year 1953 and 2012 are presented in

Fig. 6.

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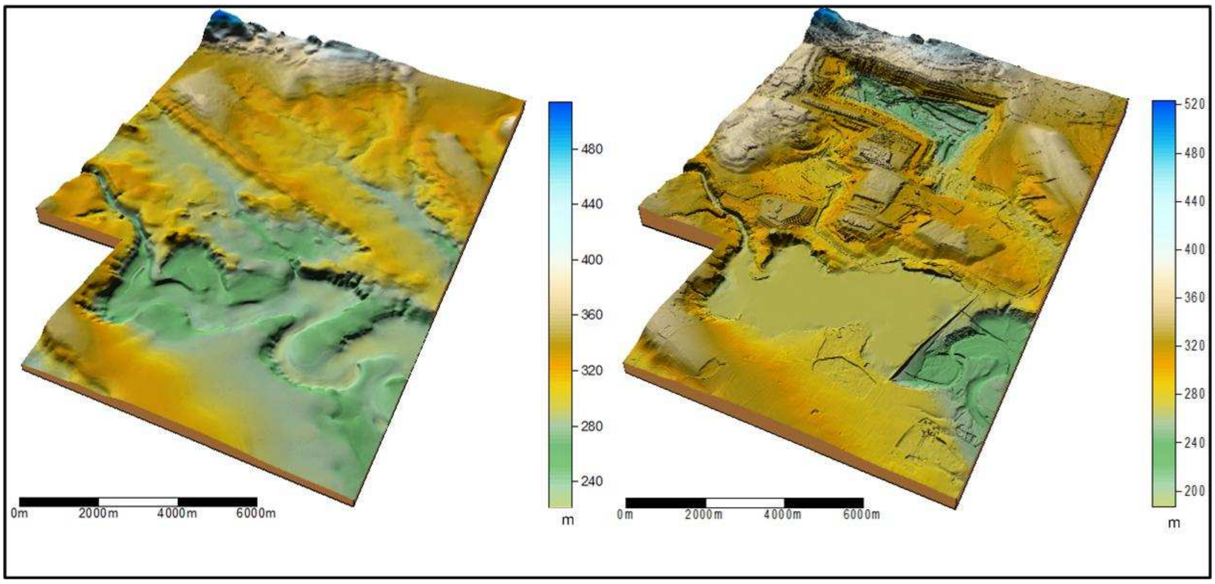

Fig. 6 Georelief reconstructions of the area of interest

The Tušimice open-pit mine is expanding every minute towards Chomutov (the neighbouring town) and precise data describing the volumes of the transported material are required. The open-pit mine is regularly surveyed by a photogrammetric company using an aircraft flying at about 1 km altitude. This method is expensive and weather dependent. In the autumn – winter – early spring period, the whole area is commonly covered with fog for several weeks and the standard way of photogrammetric survey can't be applied.

In the autumn of 2014, cooperation with the Severočeské doly, a.s. and Vršanská uhelná, a.s. began to test the possibilities of UAV mapping of the desired mining areas. The advantage of UAV mapping over standard photogrammetric surveying is the flexibility and much lower flying altitude. This method can be thus used during foggy days. The disadvantage of UAV mapping is the range and the required presence at the surveyed site. According to Czech civil aviation regulations, one can operate the UAV (drone or the fixed-wing solution) under manual or automatic flight only:

- The *manual* flight means that the pilot operates the UAV during the whole flight. This method is suitable for taking oblique photography of for shooting videos.
- The *automatic* flight is suitable for surveying larger areas within the direct sight of the pilot. The UAV follows the planned mission, assuring the coverage (and overlap) of the images. During the automatic flight the pilot MUST HAVE visual contact with the UAV and must be capable of taking control over the UAV at any minute. This means that large areas, like the open-pit mines, would be cumbersome to survey with UAVs. The desired surveyed area is about 900 hectares.
- An *autonomous* flight using a fixed-wing UAV is the best solution for such large areas. The UAV flies along with the planned mission outside of the pilot's sight and returns when the mission is accomplished. The fly time ca. 40 minutes per battery is suitable for surveying such large areas. This method is NOT allowed to be used in the Czech Republic.

Based on these facts a new method using a small aircraft for Small Format Aerial Photography was developed [0]. Many studies ([0], [0] and [0]) have proved that the classic compact cameras preciseness for close-range (aerial and earthbound) photogrammetry is, in comparison with professional aerial cameras, sufficient for the given tasks (DSM creation, orthophoto).

This method uses the same gimbal (camera stabilization) as the drone. A special mount was developed allowing the placement of the gimbal into the aircraft and shooting time-lapse images. The Nikon D3X camera in combination with a Sigma 35mm f/1.4 DG HSM Nikon lens was used in the test survey. The average flight altitude was 200 m, flight speed 90 km/h and images were shot every second assures about 90% image overlap (see *Fig. 7*). The imagery side-lap was estimated to be 70 – 80% assuring the resulting model complexity. The spatial resolution of the produced DSM (Digital Surface Model) and orthophoto may be up to 5 cm/pixel. The test area is fully covered with ground control points (GCP) normally used for photogrammetric survey and densified by additional GCPs.

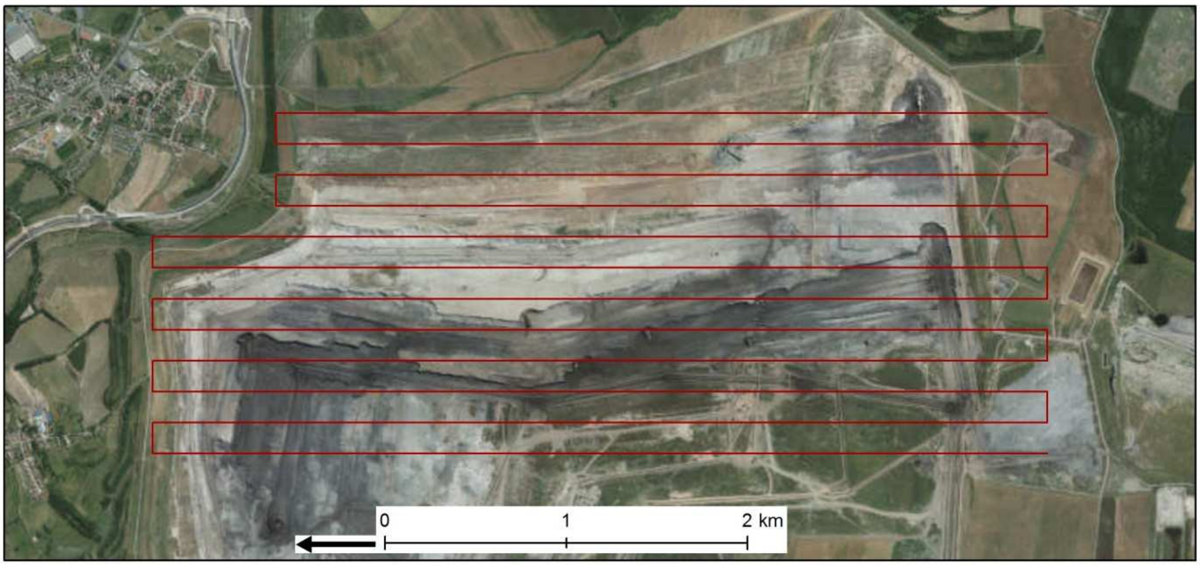

Fig. 7 The flight plan over the Tušimice open-pit mine

The images are processed in PhotoScan (Agiosoft LLC) software. The detailed processing workflow is introduced in [0]. The total amount of processed images was in this case 2400. The results are currently subjected to statistical tests that should prove the accuracy of the resulting 3D models. An overview of the results are presented in *Fig. 8.*

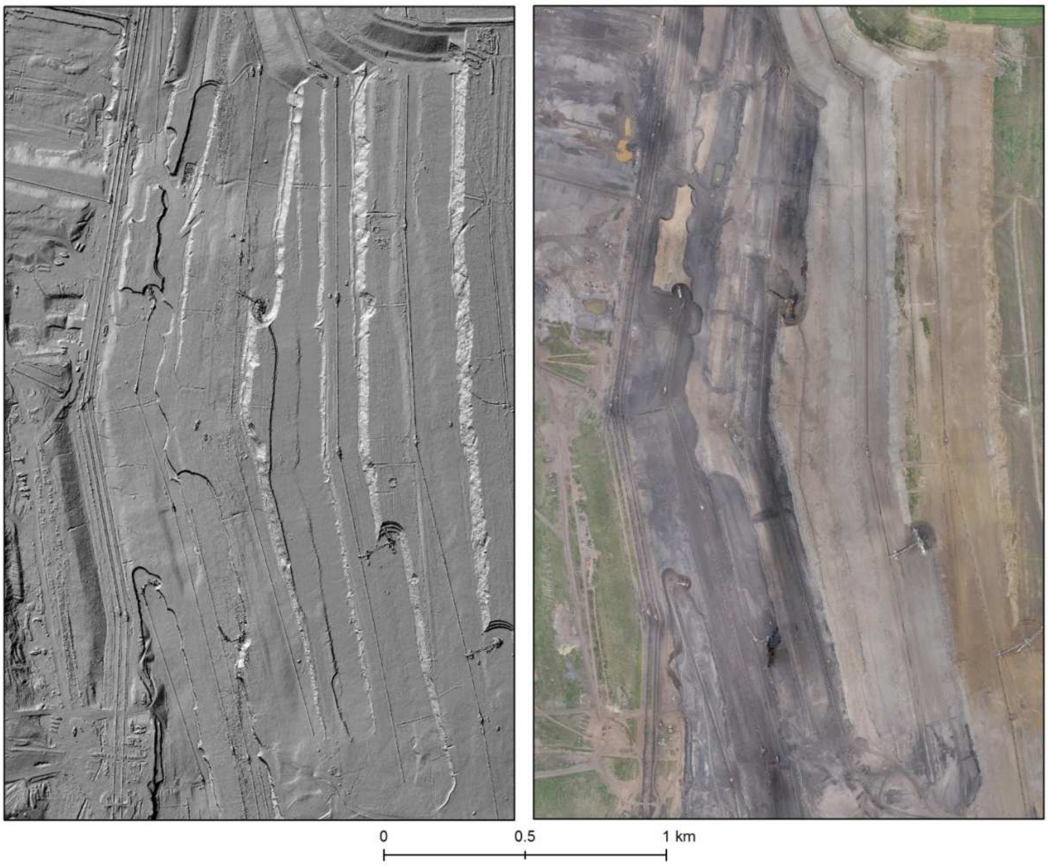

Fig. 8 The resulting DSM and orthophoto of the Tušimice open-pit mine

CONCLUSIONS

In this paper, methods offering a new point of view on the landscape changed by human activity are presented. The bathymetric mapping performed on the Nechranice dam discovered very thick (10 – 15m) sediment layer in the underwater fan at the Ohře river inflow area. The sediment research is the future scope of this project. Materials contained in the sediments (small particles, pollen) may show the human activity impact on the surrounding landscape. The data processed within this area of interest are accessible at http://mapserver.ujep.cz/Projekty/NAKI_mapy/Nechranice/.

The method of the "UAV-style" aircraft data collection seems to be a very reasonable way of close-range photogrammetry application on large areas. The image and the resulting 3D models quality seems to be sufficient for the mining company requests. The statistical data quality evaluation will be performed on these datasets. The DSM and the orthophoto compared with other data sources are accessible at http://mapserver.ujep.cz/Projekty/Ukazky/Tusimice/ and the 3D model visualization is published at https://skfb.ly/BTpv.

ABBREVIATIONS

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