VODOHOSPODÁŘSKÉ TECHNICKO-EKONOMICKÉ INFORMACE
(WATER MANAGEMENT TECHNICAL AND ECONOMIC INFORMATION)

VTEI/2024/2

60 years ago in VTEI

In 1962, Ing. M. Kredba from the Water Research Institute in Prague described the development of the cleanliness of the Labe River using Czechoslovak criteria in the journal *Technicko-ekonomické informace (Technical-Economic Information).*

Like any river, the Labe is subject to ever-increasing pollution from wastewater sources of all kinds along the entire length of its route (i.e. 370.4 km) from its sources on Labská louka in Krkonoše to the state border in Hřensko, where it leaves Czechoslovakia.

Depending on the amount of pollution, individual stretches of the river have a characteristic quality of their water, which we express in the purity classes of the Czechoslovak criteria. In order to be able to assess the water according to purity classes, we consider long-term comprehensive monitoring obtained by field research. In addition to chemical and biological-bacteriological analyses, we also pay attention to the corresponding flow, which makes it possible to evaluate the ratios for the required water bearing.

In the light of the individual periods when the actual Labe's flow was monitored in terms of water purity (i.e. up to 1940, 1950, and 1960), the longitudinal representation of individual purity classes tended to shift to classes that are indicators of poorer water quality due to the gradual increase in sources of polluted water.

When we sum up the individual purity classes represented on the Labe River at medium water bearing, we discover that the classes incorporating suitable water (i.e. water classes 1 to 3) in the period up to 1940 had a clear superiority over classes 4 to 5, which are indicators of poor water quality. The following decade is characterized by an increase in the representation of classes 4 to 5 at the expense of others. Subsequently, the last observed period already shows a predominance of unfavourable class representation in the total length of the river.

If we compare the three monitored periods with respect to the ratio of the length of representation of suitable river water to unsuitable, i.e. classes 1–3 to classes 4–5, the results is the deterioration of river water quality with time.

If we take 1940 as equal to 100 %, suitable water of classes 1–3 by 1952 is 72 % and by 1959 53 % of the original state. In contrast, unsuitable water of classes 4–5 exceeds the original state of 100 % in 1940 by 278 % in 1952 and by 398 % in 1959.

The unfavourable amount of water of unsuitable quality stands out in particular if we evaluate the conditions of the Labe water at critical water bearing, i.e. for 355-day water.

If we compare the range of representation of individual classes for medium annual waters and for 355-day waters, the shift from class 3 to class 4 stands out in particular.

Under this condition, river sections in classes 4–5 contain 83 % versus 54 % of the total length of the watercourse at medium flow. The opposite ratio results in the representation of classes 1–3, where for 355-day water it corresponds to 17 %, while for normal average flow to 46 % of the total length of the Labe.

From TGM WRI archives

VTEI Editorial office

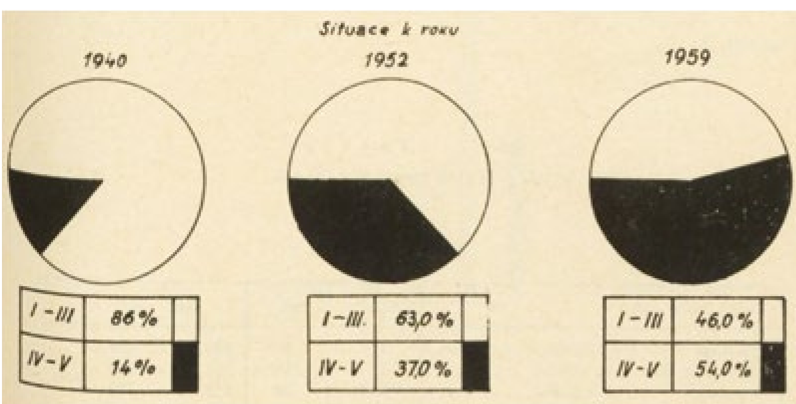


Fig. 1. The ratio of suitable and unsuitable water

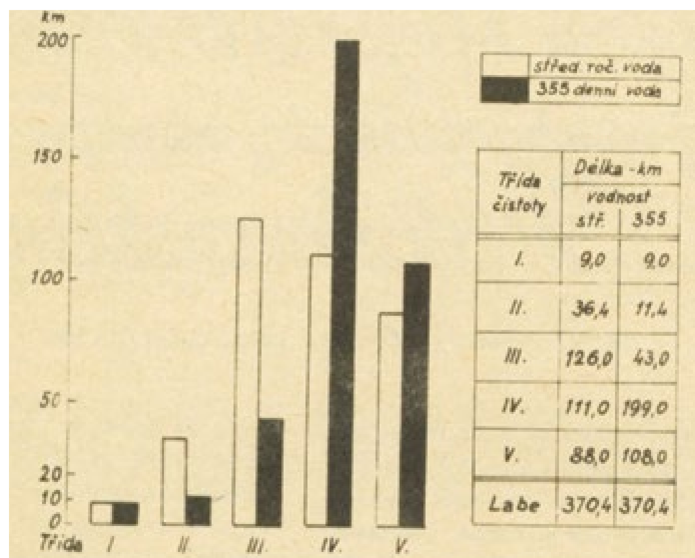
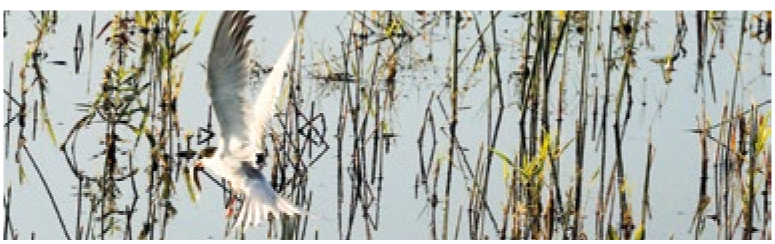


Fig. 2. Comparison of purity at medium and critical water bearing

Content



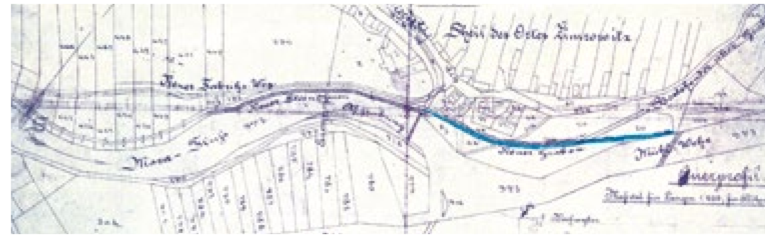



Photo: 123rf.com

Dear Readers,

The April issue of VTEI journal is published between two important holidays related to the environment – World Water Day (22 March) and Earth Day (22 April). At first glance, this year's themes of these international holidays are different; however, they both have the same goal – to preserve sustainable life on Earth.

The theme of World Water Day is "Leveraging Water for Peace". The United Nations website says: "Water can be a tool for peace when communities and countries cooperate over this precious shared resource. But, water can also spark and intensify conflict when access is denied and usage unfairly shared. World Water Day 2024 is about working together to balance everyone's needs, with a dedication to ensure no one is left behind, to make water a catalyst for a more peaceful world."

The theme of the second significant day is "Planet vs. Plastics". Earth Day points to the demand to reduce plastic production by 60 % by 2040. It also aims to spread awareness about the health risks of microplastics in particular. The effort is to end the production of single-use plastics and to limit "fast fashion", which is produced in huge quantities without regard for the environment and the working conditions.

But back to the current April issue. We would like to point out the professional article of Luděk Bureš (CZU) dealing with the choice of a suitable interpolation method for determining the gradient of watercourses at selected sites in Šumava. Following that is an article by Pavel Richter (TGM WRI) on the subject of disappeared pond systems on the lower reaches of the Doubrava river. This paper complements his previous professional articles focused on disappeared pond systems in the Pardubice and Hradec Králové regions. The professional part concludes with an article by Václava Maťašovská (TGM WRI) about QField – a new mobile application for data collection.

The informative part deals with the activities of Nadace Partnerství (Partnership Environmental Foundation), including an interview with the current director of the foundation, Petr Kazda. The article by Jan Unucka (CHMI Ostrava) is also interesting – it is about the history and hydrological analysis of the Weisshuhn flume in Žimrovice, an important and still functional technical monument. Our excursion into VTEI's past "60 years ago in VTEI" will present you with a period article about the development of the cleanliness of the Czech section of Elbe River in 1942–1959, followed by a report on a significant event, which is the handing over of the presidency of the International Commission for the Protection of the Elbe River to the TGM WRI Director, Tomáš Fojtík. And there is also a note on Mill Open Day.

We wish you not only a pleasant time while reading our journal, but also a relaxing start to the spring.

VTEI Editorial Office

Comparison of the quality of thalweg lines extracted from data of DMR 4G, DMR 5G and its derivatives

LUDĚK BUREŠ, RADEK ROUB, LUCIE POLÁKOVÁ, TOMÁŠ HEJDUK, ŠTĚPÁN MARVAL, MARTIN ŠTICH

Keywords: DTM — watercourse — slope — gradient

ABSTRACT

Determining the gradient of watercourses in the case of local applications is a common problem, which is most often dealt with by geodetic surveying. However, determining the gradient of all watercourses in the Czech Republic is a challenge. The use of geodetic methods on such a scale is usually unrealistic. Therefore, it is necessary to choose a different approach, such as the extraction of the gradient lines from other already existing elevation data. The DMR 4G and DMR 5G are elevation models currently available for the Czech Republic. For the extraction of gradient lines, it is necessary to create a digital terrain model (DTM) from the available datasets. Various interpolation methods are used for this. But which of the available interpolation methods is the most suitable? What role does the size of spatial resolution play in the quality of altimetry representation and subsequent sizes of the stored DTMs? To find answers to these questions, we chose four study sites (fourth order catchments) in the Otava river basin. Eight different DTMs were then created at each site, which were then compared. The results show that choice of raster size has a significantly greater influence on the resulting quality of the gradient lines than the choice of interpolation method in the case of DTM creation from DMR 5G data. DTM from DMR 4G data gives worse results than from DMR 5G at the same raster resolution.

INTRODUCTION

Determining the longitudinal slope of a watercourse bed is important from the point of view of a wide range of engineering and scientific applications, such as analysis of bed stability, detection of transverse obstacles, design of bed modification, and assessment of watercourse hydropower potential. In most cases, local studies requiring the slope of a watercourse bed use geodetic methods to survey them (tachymetry, positioning of GPS points). Geodetic approaches are very accurate; however, their use in the case of regional, district, or nationwide projects is not realistic. To survey an area the size of the Czech Republic, spatial data collection methods can be used. Satellite measurements or airborne laser scanning (ALS) methods are mainly used for this. Even today, satellites produce altimetry data with an error of several metres [1]. In contrast, ALS methods are able to achieve an error of only a few dozen cm [2, 3]. More recent studies report accuracy of a few cm [4]. Scanners with a beam with a wavelength close to the infrared spectrum are most often used for scanning the Earth's surface. A specific feature of using infrared beams is the inability to measure under the water surface because water surface absorbs them. In such a location, the beam does not return to the measuring device, and thus does not determine the height mode. The advantage is a clear distinction between the water surface and the solid Earth surface [5]. However, there are variants of ALS that combine laser beams with different wavelengths (infrared and blue-green), which can also be used for scanning the terrain under the water surface [6].

The ALS method was used to survey the entire Czech Republic in 2009–2013. The measurement was carried out using LiteMapper 6800 device from IGI mbH using RIEGL LMS – Q680 aerial laser scanner. The measuring equipment was placed in a special L 410 FG aircraft. Scanning was done from an average height of 1,200 m or 1,400 m [7]. To scan the surface, RIEGL LMS – Q680 laser scanner uses a beam with a wavelength close to infrared spectrum [8]. The products of this focus are DMR 5G, DMR 4G and DMP 1G data sets. The first product available to users was DMR 4G data. The data can be found in the form of XYZ points at a regular spacing of 5 × 5 m. The height accuracy of this data is 0.3 m in open terrain and 1 m in densely built-up areas or forest cover. A certain limitation of this data layer may also be the reduced ability to describe fracture edges, which is based on the minimum spacing of points [9]. DMR 5G data is accessible in the form of irregularly spaced XYZ points. The height accuracy of this data is 0.18 m in open terrain and 0.3 m in densely built-up areas or forest cover. DMR 5G data is able to better describe terrain breaks and edges. Their disadvantage can be their volume, which is related to their point density [10]. DMP 1G data displays a digital model of the surface. This means that they also contain forest stands and buildings (listed in the real estate cadastre). However, in open terrain the data is identical to DMR 5G data [11].

It is usually not possible to compare directly the quality of the representation of the Earth's surface with DMR 4G and DMR 5G data. The reason is a different position of source points in individual data sets. The solution to this problem is usually the use of interpolation methods, on the basis of which DMTs with identical resolution are created, which are then compared. Another possibility is the use of 3D control lines. Commonly used interpolation methods are Delaunay triangulation (TIN), inverse distances (IDW), minimum curvature (Spline), Natural Neighbor, or Kriging [12]. Evaluating the comparison of the interpolation method effect on the resulting quality of DMT based on DMR 5G data shows that different interpolation methods achieve comparable results both in open and in forested terrain. This is due to the high density of DMR 5G data [13].

MATERIAL AND METHODS

Study sites

Novosedelský stream – site No. 1

The site is located southwest of the town of Strakonice and is part of the Šumava foothills. From a morphological point of view, the area is located at altitudes ranging from 446.75 m to 864.131 m above sea level (a.s.l.), with a total height difference of 417.38 m a.s.l. The highest point of the area is in the south-eastern part and, conversely, the lowest point occurs in the north-eastern part of the site. The average altitude of the site is 636.386 m a.s.l.

Živný stream – site No. 2

The site is located southeast of the built-up area of the town of Prachatice and is also part of the Šumava foothills. The altitude ranges from 546.89 to 1,094.06 m a.s.l., with a total height difference of 547.17 m a.s.l. The highest point in the area is Libín hill in the eastern part of the site, and the lowest altitudes occur in the valley where the Živný potok flows. The average altitude of the site is 766.67 m a.s.l.

Širovská stoka – site No. 3

The site is located south of the town of Vodňany and is part of the České Budějovice Basin. From a morphological point of view, the site is located at altitudes ranging from 388.49 to 619.36 m a.s.l., with a total height difference of 230.86 m a.s.l. The highest point is Holička hill in the south-eastern part of the site. In contrast, the lowest point occurs in its northeastern part. The average altitude of the site is 451.23 m a.s.l.

Vydra – site No. 4

The site is located south of the village of Modrava, which is part of Šumava National Park. From a morphological point of view, it is located at altitudes ranging from 1,035.32 to 1,372.32 m a.s.l., with a total difference in height of 336.895 m a.s.l. The highest points of the area border the southern part of the study site and are formed by Blatný hill, Studená hora, Špičník, Hraniční hora, and Velká and Malá Mokrůvka. Towards the north of the area there is a significant decrease in altitude parallel to the Vydra riverbed. The average altitude of the site is 1,195.12 m a.s.l.

The overview of watercourses in the study sites is given in *Tab. 1*. The location of the study sites within the Czech Republic is shown in *Fig. 1*.

Tab. 1. Specifications of watercourses at study sites

	Catchment area [km²]	TOK ID	Watercourse	Length of watercourse section [m]
LOC_1	41.1	120900000100	Novosedelský stream	13,946
LOC_2	17.75	122180000100	Živný stream	7,587
LOC_3	12.46	122650000100	Širovská strouha	8,582
LOC_4	19.36	119650000100	Vydra	8,562

Data description

When defining a suitable digital relief model (DMR) for determining the gradient on individual watercourses, two basic products of the Land Survey Office were used – the Digital Terrain Model of the Czech Republic of the 4th generation (DMR 4G) and the Digital Terrain Model of the Czech Republic of the 5th generation (DMR 5G) [7].

The fourth-generation digital terrain model of the Czech Republic represents the natural or human-modified Earth's surface in digital form in via the heights of discrete points in a regular raster (5 × 5 m) of points with a complete mean height error of 0.3 m in open terrain and 1 m in forested terrain [9].

The fifth-generation digital terrain model of the Czech Republic represents natural or human-modified Earth surface in digital form via the heights of discrete points with a total mean height error of 0.18 m in open terrain and 0.3 m in forested terrain [10].

The watercourse axes for the study sites were taken from DIBAVOD (DIgitální BÁze VOdohospodářských Dat; Digital Database of Water Management Data). This is a water management extension of ZABAGED (Základní báze geografických dat; The Fundamental Base of Geographic Data of the Czech Republic). Specifically, layer A03 – watercourse (rough sections) was used, last updated on 5th June 2006. It is a section river model of main watercourses of fourth order catchments. The data is vector oriented in the direction of flow and provided in ESRI format [14].

All data used in this article were in the S-JTSK / Krovak East North coordinate system (EPSG 5514) and the Baltic height system after levelling (EPSG 5705).

METHODOLOGY

Creation of digital terrain models

Terrain models were created in the ArcGIS Desktop environment. DMR 4G and DMR 5G datasets were used as input data for DMT creation. 8 DMTs were created for each site, i.e. 32 DMTs in total. The models can be divided into four groups based on the use of their data source and the interpolation method used for their creation. The first group of models was created from the DMR 4G dataset. Its representative is the ras4G_5 model. It is a raster model with a 5 × 5 m raster resolution produced by the Inverse Distance Weighting (IDW) method. The second group of models was also created using the IDW method, but from DMR 5G data. DMTs in this group differ from each other only in raster resolution. Three raster sizes of 1 m, 5 m and 10 m are used. The models are then labelled IDW_1, IDW_5 and IDW_10. The third group of models consists of tin5G. This is a TIN terrain model created from DMR 5G data. The fourth group of models is based on the TIN model from the third group, which was subsequently converted to rasters using the *TinToRaster* function. The models are labelled TTR_1, TTR_5 and TTR_10. They differ from each other only in the resulting raster size to which the models were transformed when they were converted from TIN format to raster format. A simple overview of DMT for each site and their specifications are given in *Tab. 2*.

Tab. 2. List of terrain models created for each study site

DMT	Type	Resolution [m]	Data source
ras4G_5	raster	5	DMR 4G
IDW_1	raster	1	DMR 5G
IDW_5	raster	5	DMR 5G
IDW_10	raster	10	DMR 5G
tin5G	TIN	–	DMR 5G
TTR_1	raster	1	DMR 5G
TTR_5	raster	5	DMR 5G
TTR_10	raster	10	DMR 5G

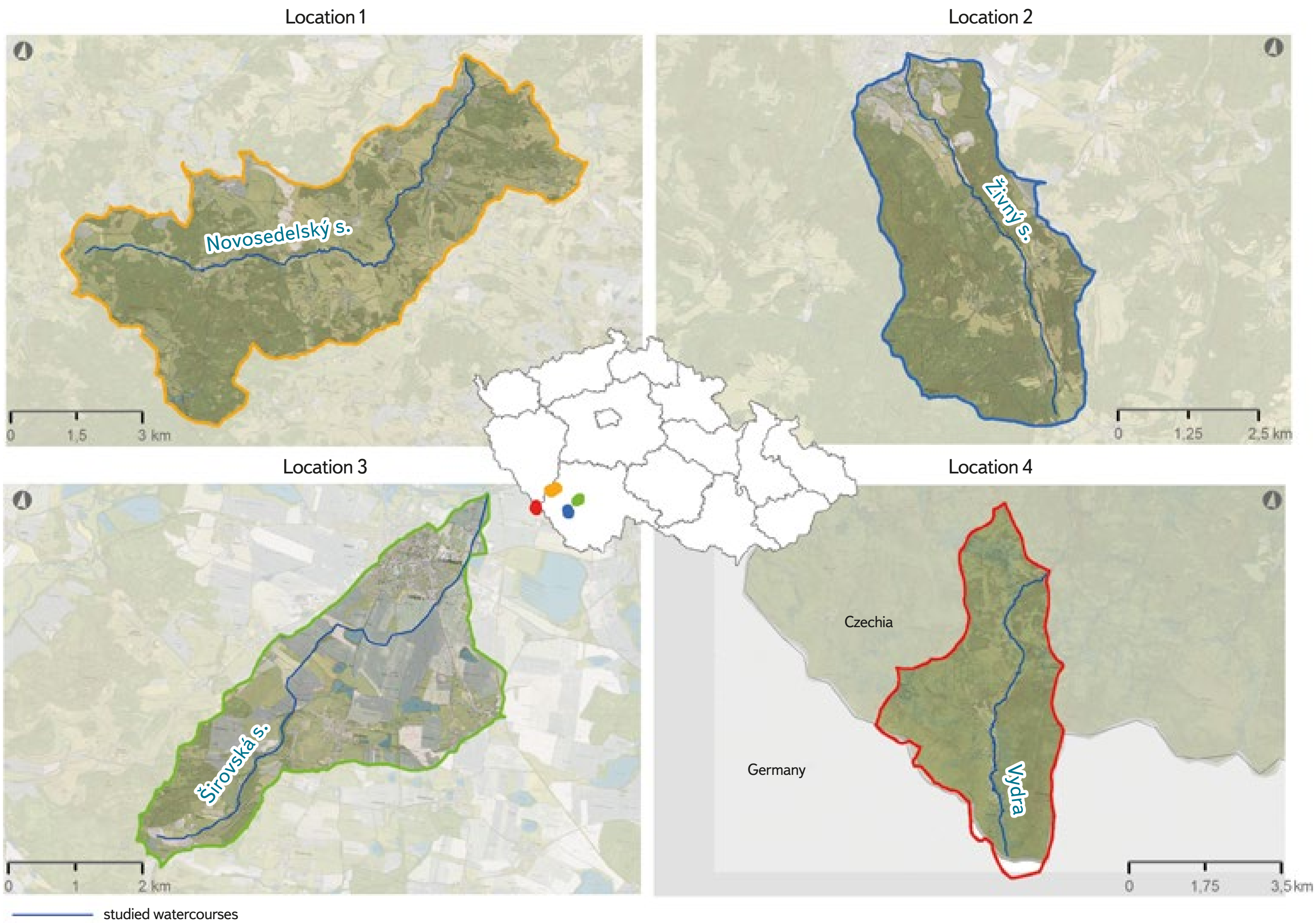


Fig. 1. Selected fourth order basins and their location in the Czech Republic. The extents (watershed boundaries) of individual watersheds to the relevant watercourses are marked in color (orange, blue, green, red). The location of the watershed within the Czech Republic is marked with the same color as its watershed boundary. The thin dark blue line shows the position of the given watercourse in its catchment

Extracting the 3D axis of watercourses

The 3D axes of the most important watercourses in the study sites (*Fig. 1*) were extracted from the prepared DMTs using the *Interpolate Shape* function. The identical *Sampling Distance* parameter was set for all extracted 3D line, which guaranteed that the height value on the watercourse line was always determined by the program for identical stationing. This is a basic condition for the possibility of comparing different height lines of one watercourse with each other. The 3D lines were exported to a text file using the *Profile Graph* function, where they were prepared for further comparison.

Evaluation of 3D lines

The actual processing was carried out in the R program. The 3D lines of the watercourse were loaded for individual sites and processed. DMT tin5G was always chosen as a reference for other raster DMTs of the given site. Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) metrics were used to determine the degree of agreement.

$$MAE = \frac{1}{N}\sum_{i=1}^{N} \left| Elev_{DEM} - Elev_{Ref} \right| \tag{1}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (Elev_{DEM} - Elev_{Ref})^2} \tag{2}$$

where:

$Elev_{DEM}$ is the elevation value (m) extracted from each DMT (ras4G_5, IDW_1, IDW_5, IDW_10, TTR_1, TTR_5, TTR_10)
$Elev_{Ref}$ its corresponding elevation from the reference DMT (tin5G)
N number of height records on a given watercourse line

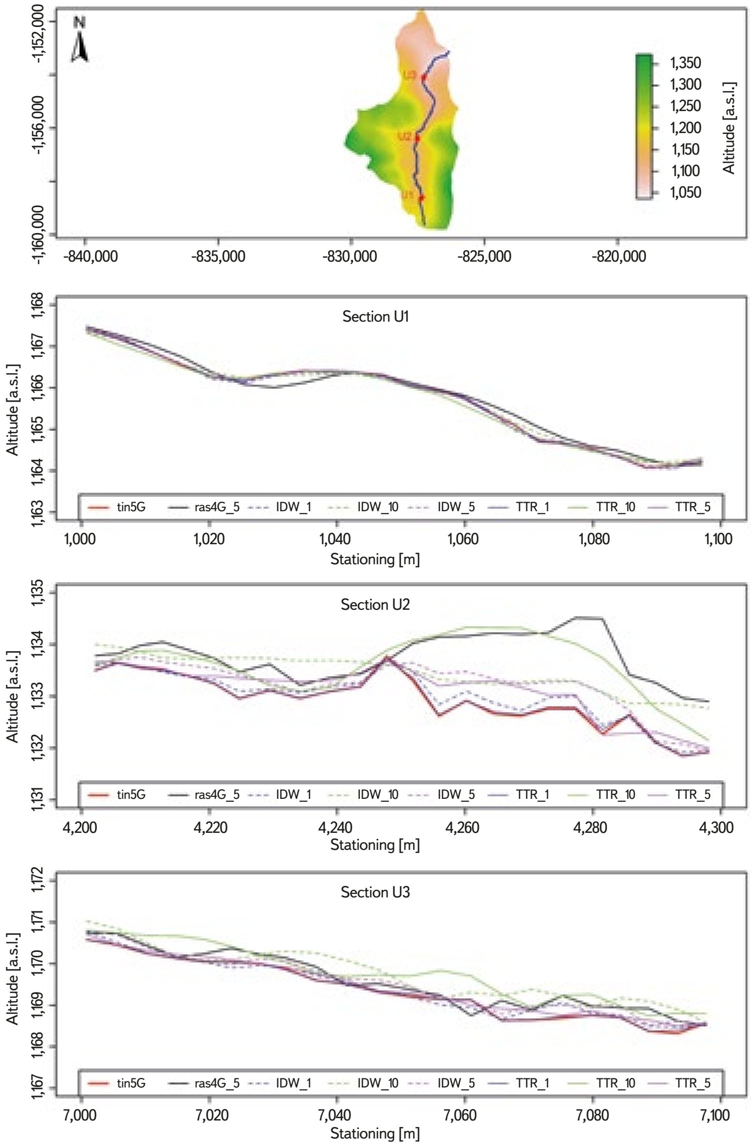


Fig. 2. Visual comparison of the quality of the slope lines extracted from the compared DTMs at the Loc_4 site

Comparison of DMT size when stored on Hard Disk Drive

In this comparison, the size of individual DMTs was determined when stored on a Hard Disk Drive (HDD). Subsequently, the relative sizes of the raster models compared to the comparative TIN models were calculated.

RESULTS

When comparing the quality of the height representation, it was found that the DMTs with a raster size of 1 m (DMT TTR_1 and IDW_1) showed the lowest mean errors. The worst results were achieved by DMTs with a raster size of 10 m (TTR_10, IDW_10), and the ras4G_5 model also achieved similarly poor results.

A visual comparison of the quality of the topographical description for selected watercourse sections in the Loc_4 site is shown in *Fig. 2*. In section U1, all DMTs show a similar quality of schematization. The only significantly different DMT is ras4G. In sections U2 and U3, a more significant deviation of the 10 m resolution models and the ras4G model can be seen.

Models TTR_1 and IDW_1 showed the lowest mean absolute error (MAE). The mean error for TTR_1 was 0.02 m. The range of values ranged from 0.01 m (Loc_1 and Loc_4) to 0.03 m (Loc_3). IDW_1 achieved a mean error of 0.09 m with a range of 0.06 m (Loc_4) to 0.11 m (Loc_2). In contrast, the highest MAEs were found for the IDW_10 and TTR_10 models (both identically 0.36 m); with minimum values of 0.24 m. IDW_10 and TTR_10, they had almost identical error values even for the corresponding sites. The TTR_5 and IDW_5 models achieved an MAE of around 0.2 m. In contrast, the ras4G_5 model (same resolution) gave an error of 0.31 m. The overall overview of the MAE values is shown in *Tab. 3*.

Tab. 3. Summary of achieved MAE values

	TTR_5	TTR_10	TTR_1	IDW_5	IDW_10	IDW_1	ras4G_5
Loc_1	0.12	0.24	0.01	0.15	0.26	0.1	0.25
Loc_2	0.19	0.39	0.02	0.22	0.41	0.11	0.42
Loc_3	0.29	0.52	0.03	0.3	0.5	0.08	0.32
Loc_4	0.11	0.27	0.01	0.13	0.28	0.06	0.23
Mean value	0.18	0.36	0.02	0.2	0.36	0.09	0.31

Also, the RMSE results show that the best values were achieved for the TTR_1 model, where the average RMSE error was 0.03 m. The worst results were again detected for the TTR_10 and IDW_10 models. Other values follow similar trends to the MAE values. The overall overview of RMSE values is shown in *Tab. 4*.

Tab. 4. Summary of achieved RMSE values

	TTR_5	TTR_10	TTR_1	IDW_5	IDW_10	IDW_1	ras4G_5
Loc_1	0.18	0.36	0.03	0.21	0.38	0.15	0.34
Loc_2	0.26	0.55	0.03	0.31	0.56	0.18	0.59
Loc_3	0.38	0.68	0.04	0.39	0.64	0.12	0.41
Loc_4	0.14	0.35	0.02	0.18	0.36	0.09	0.33
Mean value	0.24	0.49	0.03	0.27	0.49	0.14	0.42

The physical size of individual DMTs when stored on a HDD was also evaluated. TIN models have the biggeststorage requirements. The only exception is at the site LOC_3, where the raster models with a resolution of 1 m are larger. The other DMTs with a 1 m raster have a size in the range of 50–75 %. The 5 m raster models have a consistent size ranging from 1.9–5.2 %. The 10 m raster models range within 0.5–1.3 %. The complete list of absolute and relative values of DMT sizes when saved to disk is shown in *Tab. 5*.

Tab. 5. Comparison of the amount of memory needed to store a given DTM on HDD

	TTR_5	TTR_10	TTR_1	IDW_5	IDW_10	IDW_1	ras4G_5	tin5G
Absolute size [MB]								
Loc_1	15.37	3.84	384.33	15.39	3.85	384.41	15.39	524
Loc_2	4.35	1.09	108.73	4.36	1.09	108.77	4.36	226
Loc_3	4.69	1.16	116.25	4.66	1.17	116.29	4.66	90
Loc_4	5.14	1.28	128.4	5.15	1.29	128.44	5.69	251
Relative size [%]								
Loc_1	2.9	0.7	73.3	2.9	0.7	73.4	2.9	100
Loc_2	1.9	0.5	48.1	1.9	0.5	48.1	1.9	100
Loc_3	5.2	1.3	129.2	5.2	1.3	129.2	5.2	100
Loc_4	2	0.5	51.2	2.1	0.5	51.2	2.3	100

DISCUSSION

The tin5G model was chosen as the reference DMT. This model uses the maximum potential of the DMR 5G data set, i.e. all points and their absolute values for the creation of a complete digital terrain model. In contrast, raster models average the available point values within their raster. The fact that a large number of fourth order watercourses flow through the forested area also contributed to this choice. In such conditions, the TIN terrain model provides the best results [13].

There are multiple interpolation methods for creating DMT. In this paper, IDW methods and a combined DMT creation approach were used, when a TIN model was first created which was then transformed into a raster of the given size. The reason for choosing IDW and the combined approach was the speed of creating these terrain models in the R programming environment, which is planned to be used to process data for the entire Czech Republic. The fact that interpolation methods with high point density give the same results was also taken into account [13].

In the Czech Republic, in addition to DMR 4G and DMR 5G data, it is also possible to use 3D contours from the ZABAGED data layer to create DMT. These data were not included in the study; the decision was based on a literature search. The basis for ZABAGED 3D is the ZM 10 map from 1971–1988. These data are burdened by a greater degree of obsolescence (although some map sheets have been updated). Another disadvantage is systematic overestimation, which on average amounts to 0.23 m compared to DMR 5G data. The description using contours also touches on the issue of schematizing small terrain formations (small ridges and valleys) [15].

The results of this paper show the ability of individual DMTs to schematize the height of watercourses (thalwegs). The primary uncertainty of height schematization comes from the specifications of the source data [7, 9]. The authors are aware of these specifications. They are also aware of the limitations resulting from the ALS technology itself that was used for their acquisition (inability to scan watercourse beds). Another uncertainty is the quality of watercourse axis schematization in the DIBAVOD database, especially in forested terrain. In these places, the axis of the watercourse may be guided outside the actual watercourse bed. For the purpose of this study, it would be possible to create the watercourse axes manually; however, it is unrealistic for the application in the entire area of the Czech Republic.

When comparing MAEs, it can be tentatively concluded that raster models with a raster size of 1 m show better results than models with a larger raster size. The surprise was that the ras4G_5 model, which has a raster size of 5, gives similar results to models with a raster size of 10 (IDW_10, TTR_10). While maintaining this level of schematization quality, it would be worth considering whether to choose other models with a 10 m raster instead of the ras4G_5 model, which are also smaller (in terms of disk storage). This results in lower requirements for their computer processing. The best results were achieved by the TTR_1 model, which also outperformed the IDW_1 model. In this case, the method used to create the given terrain probably plays a role, especially the very principle of the IDW technique.

The RMSE values copy the MAE values to some extent. This is due to the fact that RMSE is based on MAE and is modified to reflect more the occurrence of extreme deviations [16]. In our case, it can therefore be stated that none of the tested DMTs carries extreme error values when compared.

A comparison of the physical size of individual rasters (i.e. the size they occupy on disk) shows how changing their spatial resolution (e.g. from 1 m to 5 m) dramatically reduces their size on disk. The exception is the IDW_1 and TTR_1 models at Loc_3. In this case, the size of the raster model exceeds the size of the TIN model, which may be caused by the flat nature of Loc_3. In the case of flat sites, DMR 5G provides a lower density of points than in sloping sites [10]. Lower point density reduces the size of the TIN model.

This article was created within the TA CR project TK04030223 and as such follows its goals. One of them is to create 3D lines of fourth order watercourses for the Czech Republic. For this purpose, it is necessary to use the available datasets covering the entire Czech Republic, process and evaluate them appropriately. Due to the scope of processing and evaluation, machine data processing is then necessary. It is also necessary to take into account the physical size of the produced DMTs due to their subsequent storage. Thus, this article is primarily intended to help answer the questions of which available data sets are the most suitable for the needs of the project and what spatial resolution of the rasters produced by DMT will be appropriate, especially with regard to their accuracy and storability.

CONCLUSION

The results of comparing the height schematization quality of the watercourse line, produced by different DMTs, show that models based on DMR 4G data achieve worse results than models with the same resolution based on DMR 5G data. When comparing models with the identical spatial resolution, based on DMR 5G data and created with a different interpolation method, it is evident that the choice of method for creating DMT plays a role, especially for rasters with a higher resolution. As resolution decreases, the importance of the interpolation method influence declines. The best MAE values were achieved by the TTR_1 model, with MAE of 0.02 m. The worst results were equally achieved by the TTR_10 and IDW_10 models, with MAE of 0.36 m. The RMSE values are only slightly different from the MAE values. It can therefore be assumed that none of the DMTs contain extreme values of residual errors.

Comparing the physical size of DMTs on disk shows how the size of raster DMTs increases with their resolution. The rasters with 1 m resolution reach 50–70 %, with 5 m 1.9–5.2 %, and with 10 m 0.5–1.3 % of the size of the corresponding TIN DMT. However, for rasters with a resolution of 1 m, this reduction does not always apply – it especially applies to flat basins, where the point density of DMR 5G data is low.

Acknowledgements

This article was created with the support of the Technology Agency of the Czech Republic as part of the project No. TK04030223 "Determination of hydropower potential of Pico-Hydropower in current and predicted climatic conditions of the Czech Republic".

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This article was translated on basis of Czech peer-reviewed original by Environmental Translation Ltd.

DOI: 10.46555/VTEI.2024.01.001

ISSN 0322-8916 (print), ISSN 1805-6555 (on-line)

Disappeared pond system in the lower Doubrava river

PAVEL RICHTER

Keywords: archival maps — watercourses — water retention in the landscape — floodplains of watercourses — ponds

ABSTRACT

This article presents the results of research of the pond landscape development in the lower Doubrava river. The results are based on the interpretation of archival map documents and the current state of the site. On the map of the 1st military mapping (1764–1768), a system of thirteen ponds was recorded on the right bank of the Doubrava river. There were three ponds on the left bank of the Doubrava river. On the map of the 2nd military mapping (1836–1852), only four ponds were recorded on the right bank of the Doubrava river and only two ponds on the left bank of the Doubrava river. Of the historic pond system, only Koukalecký pond and a pond near Žehušice chateau have survived to the present day. On the 1st military mapping map, the total approximate area of the ponds was 449 ha, on the 2nd military mapping map it was 107 ha, and today only 0.91 ha.

INTRODUCTION

Today, Polabí suffers from a lack of groundwater and there is large seasonal desorption of small watercourses, mostly straightened and deepened ones. This problem will most probably worsen in the future due to the expected continued occurrence of extreme climate events. It is therefore necessary to focus on the restoration of landscape elements with a positive effect on the water regime and also on the actual management of water in the landscape.

The main goal of the research, the results of which are presented in this article, was to map the development of the landscape around disappeared ponds in the basins of Labe tributaries in Polabí, based on the interpretation of archival maps, especially with regard to the possible restoration of water-retaining elements in the landscape.

The development of the pond landscape in the Doubrava basin is specifically presented here. This location has already been partially mentioned in an article dealing with landscape changes in selected locations in Polabí with a focus on wetlands, including ponds [1]. The development of the pond system on the lower Doubrava river was also recorded in the assessment of the water management development in the Čáslav region [2] and also the development of the landscape of Nové Dvory and Žehušice municipalities [3, 4]. However, in this article, the development of the pond system on the lower Doubrava river is described in more detail and separately, not as part of the assessment of a larger territorial unit.

LOCATION DESCRIPTION

The disappeared pond system is located in the 1-03-05 Doubrava third order basin in the cadastral areas of Sulovice, Žehušice, Horka u Žehušic, Rohozec u Žehušic, Lišice u Sulovic, Brambory, Bílé Podolí, Zaříčany, Bojmany, and Habrkovice in the Kutná Hora district [5]. The geological bedrock consists of calcareous claystones, marlstones, and clayey limestones [6]; the predominant soil types are chernozem arenic and cambisol arenic; in the Doubrava floodplain it is modal and gley fluvisol [7]. Based on the geomorphological division, the majority of the monitored area is located in the Žehušice basin geomorphological district, which is part of the Central Elbe Table geomorphological unit [8].

METHODOLOGY

The first step was the selection and subsequent comparison of the current and historical state of disappeared pond systems in Polabí, based on map interpretation. The next step was a field survey of these locations to verify their current condition. For the primary detection of the occurrence of ponds, a map from the 1st military mapping was used, which is available as part of the oldmaps application of the Geoinformatics Laboratory of the Faculty of Environment at J. E. Purkyně University in Ústí nad Labem [9].

The current basic map of the Czech Republic 1 : 10,000 (BM 10) and the current Orthophoto map of the Czech Republic were used to show the current state. Both maps are provided as a WMS service from the ČÚZK Geoportal [10]. For a more accurate understanding of the development of the landscape between the state recorded on the map of the 1st military mapping and the current state, a map from the 2nd military mapping was used; this is accessible as a WMS service from the INSPIRE National geoportal [11].

In order to approximate the state of the landscape before the 1st military mapping, especially with regard to the very occurrence of ponds rather than their exact location, the positionally inaccurate map from Müller's mapping was used, which is most easily accessible on the map browser of the archives of the Land Survey Office [12].

Current maps used

Current BM 10 and Orthophoto map of the Czech Republic

These maps are available as a WMS service from the ČÚZK Geoportal, where they are continuously updated as required. The state shown on BM 10 may differ depending on individual segments that are registered separately (e.g. road network), and therefore may not show the real overall state of the landscape in a given period. The entire Orthophoto map of the Czech Republic is updated in a two-year cycle. Approximately half of Czech Republic is updated annually; from 2020, the region boundaries are taken into account. Currently, both maps should correspond to the state of the landscape in 2021 and 2022 [10].

Archival maps used

Müller's mapping

The oldest map used here is Müller's map of Bohemia from 1720 at a scale of approximately 1 : 132,000 [13]. The disadvantage for a detailed comparison of the landscape development with the other maps is its unsatisfactory spatial accuracy. Therefore, Müller's mapping can only be used to show water bodies (ponds) as a supplement to newer documents. It does not show all watercourses and their outline is not accurate [14].

1st military mapping

The basis of the 1st military mapping was Müller's map enlarged to a scale of 1 : 28,800. The mapping itself took place in 1764–1768 and then 1780–1783 (revision). It captures Bohemia, Moravia, and Silesia as a whole in the period before the onset of the industrial revolution, at the time of the greatest flourishing of the cultural baroque landscape and its highest diversity [9]. The disadvantage is low spatial accuracy; however, for the initial detection of ponds (water bodies) it is more suitable than the 2nd military mapping map because on the latter most of the pond systems have already disappeared and been replaced by another type of land cover.

2nd military mapping

This is the first relatively positionally accurate map. It was drawn on a scale of 1 : 28,800 in 1836–1852. Its creation was preceded by military triangulation, which was the geodetic basis of this work. The material used were Stable Cadastre maps of Bohemia, Moravia, and Silesia. Compared to the 1st military mapping, accuracy of the map increased. The content of both military mappings is basically the same, but the situation depicted is diametrically different. The 2nd military mapping took place at the onset of the industrial revolution and the development of intensive forms of agriculture; the area of arable land increased by half in 100 years and the forest area reached a historical minimum. The first railway lines are also recorded here [15].

RESULTS

The pond system on the lower Doubrava river lay on the Čertovka watercourse and was fed by a system of canals from the Doubrava river. This system was recorded during the 1st military mapping, including the pond names. There were Bojmanský, Podolský, Bramborský, Horecký, Dvorský, Borecký, Taušek, Světlov, Babický, and Kmotrov ponds. There were also smaller ponds drawn without specifying their names: Koukalecký, and a pond in the village of Horka. On the left bank of the Doubrava river, there were Kravinec and Šibeniční ponds as well as a small pond near Žehušice chateau (*Figs. 1* and *4*).

Fig. 1. Pond system in the lower Doubrava river, 1st military mapping

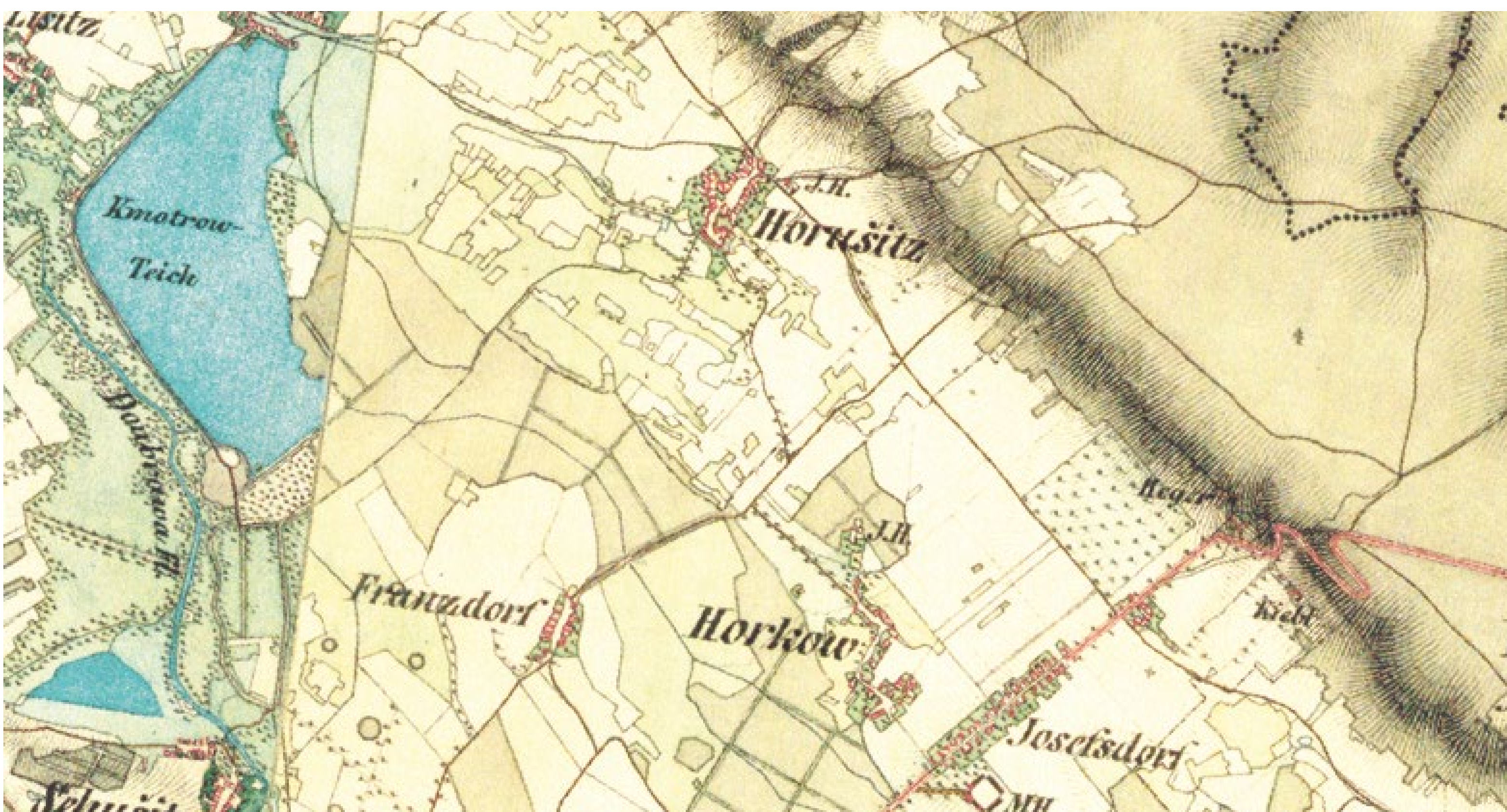

Fig. 2. Kmotrov and Šibeniční ponds in the area of the disappeared pond system on the lower Doubrava river, 2nd military mapping

Fig. 3. Current state of the landscape around the disappeared pond system in the lower Doubrava river, current BM 10

On the map of the 2nd military mapping, only Kmotrov pond, Koukalecký pond and the pond in the village of Horka were shown in the pond system. On the left bank of the Doubrava river, Šibeniční pond remained on a significantly larger area, and the pond near Žehušice chateau (*Figs. 2* and *4*).

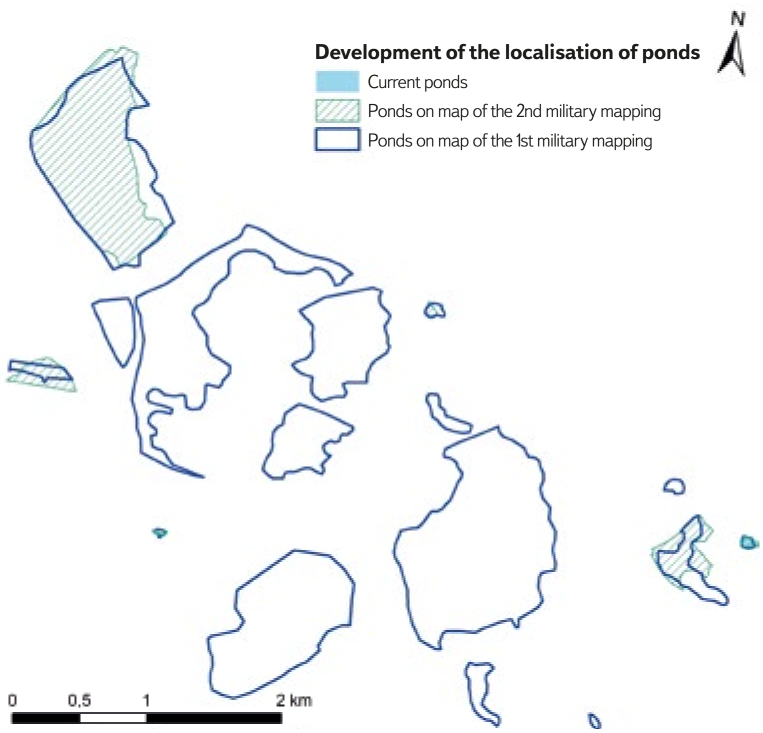

Fig. 4. Changes in the ponds on the lower Doubrava river, from 1st military mapping to the present

Currently, only Koukalecký pond and the pond near Žehušice chateau have been preserved in the studied area, but the latter has a different shape and area size from the state captured on the maps of the 1st and 2nd military mapping. Koukalecký pond is currently a rainwater pond and has no inflow or outflow, although the 1st military mapping shows an inflow and outflow into Podolský pond. The situation recorded in the 2nd military mapping shows Koukalecký pond as it is today, i.e. a rainwater pond (*Figs. 1–4*). Other water bodies in the studied area are not ponds; they have been created by sand mining or has concreted bottom.

Müller's map of Bohemia shows a system of five ponds on the Čertovka. These are the Horecký, Borecký, Taušek, Světlov, and Kmotrov ponds. However, the situation on this map is different from the the one from the 1st military mapping; the shape of Světlov and Horecký ponds is very different, and the location is not completely accurate. Also, the Čertovka watercourse is not recorded in full, but only the part located beyond the confluence with the channel that feeds the pond system. This part – including the canal – is drawn as the main watercourse and the Doubrava river is drawn with a faint line. On the left bank of the Doubrava river is shown Kravinec pond (*Fig. 5*).

In this site, a total of 16 ponds with a total (approximate) area of 449 ha were recorded on the map of the 1st military mapping. The maximum area of one

Fig. 5. Pond system on the lower Doubrava river, Müller's map of Bohemia

Fig. 6. The Hastrman site on a Imperial Imprint of the Stable Cadastre

pond was 116 ha, the minimum 0.25 ha, and the average 28.6 ha. Six ponds with a total area of 107 ha were recorded on the map of the 2nd military mapping. The maximum area of one pond was 87 ha, the minimum 0.15 ha, and the average 17.9 ha. Currently, there are only two water bodies classified as ponds with a total area of 0.91 ha. The area of Koukalecký pond is 0.68 ha, and the pond in Žehušice chateau park is 0.23 ha. The average area of the current pond in this site is therefore 0.46 ha.

At the site of this disappeared pond system today, there is mainly arable land, periodically waterlogged in some places, and to a lesser extent buildings, permanent grassland, small concreted water reservoirs, straightened and deepened watercourses with surrounding greenery (including reeds). The site of the disappeared Kravinec pond is located in the chateau game park, and the pond has been replaced by forest and permanent grassland.

Figs. 6 and *7* compare the current and historical conditions in the Hastrman site behind Bojmanský weir, where the canal began which was used to supply the disappeared pond system, and now returns to the Doubrava river behind the weir. The Imperial Imprint of the Stable Cadastre still show a functional system of canals, although only Kmotrov and Horecký ponds were the only ponds preserved from the pond system shown on the 1st military mapping. *Figs. 8* and *9* show the current state in this site, both the overflow for the canal in front of Bojmany weir and the preserved section of the canal for feeding the disappeared pond system, which flows into Starkočský stream.

Fig. 10 shows the condition of Podolský and Koukalecký ponds, where it is already evident that Koukalecký pond has no inflow and outflow. The current state of Koukalecký pond is shown in *Fig. 11*. Furthermore, the current landscape in the site of the disappeared Horecký (*Fig. 12*) and Bramborský ponds (*Fig. 13*) is shown with successional vegetation including mature trees and reeds. A general view of the current landscape around Koukalecký pond and the disappeared Bramborský and Horecký ponds on the Orthophoto map of the Czech Republic reveals a waterlogged site at the area of the disappeared Horecký pond, and also wetland habitats near both disappeared ponds (*Fig. 14*).

Fig. 15. Current state of the landscape including the Čertovka watercourse at the site of the disappeared Borecký pond (November 2023)

DISCUSSION AND CONCLUSION

For landscape planning, it is advisable to look for inspiration in archival maps and documents. These are applicable in the case of waterlogged sites as the basis for the restoration of ponds, wetlands and springs or for determining (verifying) suitable places to allow succession [16].

The map from the 1st military mapping was taken as a starting point, where the disadvantage is low spatial accuracy. However, for the initial detection of ponds, it is more suitable than the 2nd military mapping because on the latter map, most of the pond systems have already completely or partially disappeared and been replaced by another type of land cover. However, the ponds on the map of the 1st military mapping were very large, with an average area of 28.6 ha, with 5 small ones out of the 16 ponds recorded (less than 1 ha). When determining the location of these ponds, it was possible to start from the location of the preserved ponds from the 2nd military mapping (Kmotrov, Šibeniční, Koukalecký) and also from the current BM 10, where, in addition to the preserved Koukalecký pond, the names of sites reminding of disappeared ponds were used as a guide (Kmotrov, Světlov, Šibeniční, Toušek, Babický, Podolský pond) or the state of the sites regarding their waterlogging, the presence of hygrophilous vegetation, animals, etc. (Na mokřinách, Ve vrbičkách, Žabník, Pod rybníkem, Špatná luka v rybníčku, Na blatinách, Hastrman, U Hastrmana, U luhů, Na ostrovech).

Müller's map of Bohemia shows a system of five ponds on the Čertovka, while on the map of the 1st military mapping there are seven of them on the Čertovka,

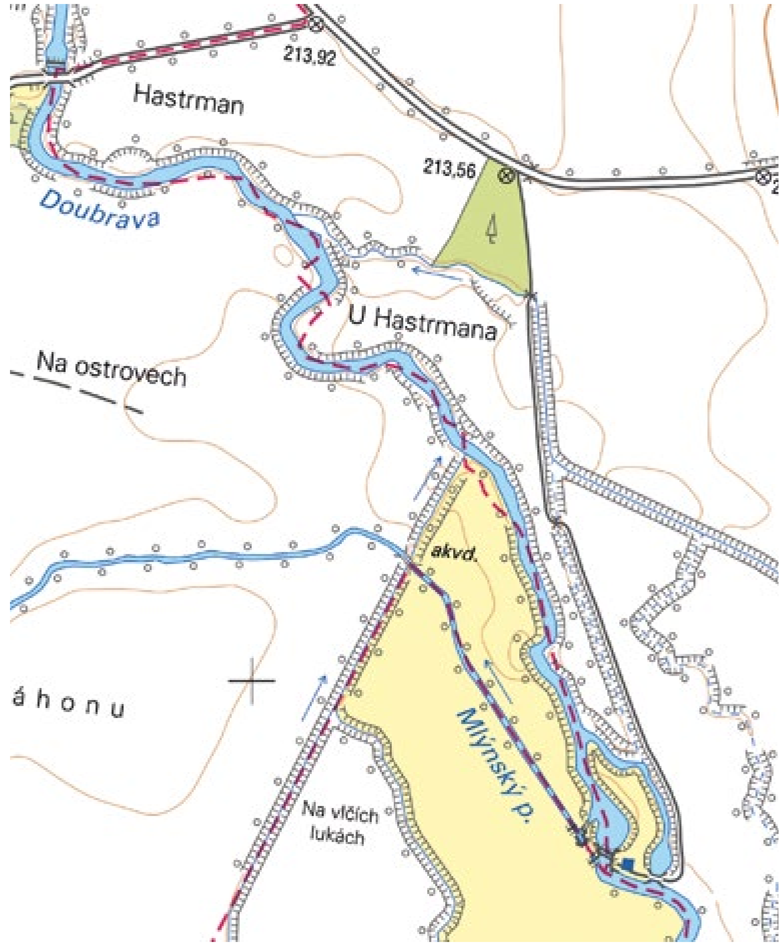

Fig. 7. The Hastrman site on current BM 10

Fig. 8. Current situation below Bojmany weir at the spillway for the riverbed, which was used to supply the disappeared pond system and now returns behind the weir to the Doubrava river (November 2023)

with two of them being smaller areas. However, the drawing of the shape of the ponds on the Müller's map differs from the drawing from the 1st military mapping, and the spatial location is not completely accurate. Considering these differences in the method of mapping, it is not possible to infer from these sources whether Koukalecký pond (which is shown on the 1st military mapping and has survived to the present day) had not yet been built at the time of Müller's mapping. The pond system on the Čertovka has a feeding channel from the the Doubrava river, which returns back to the river, recorded on both maps. However, on Müller's mapping, the Čertovka is shown as the main watercourse, while on the map of the 1st military mapping it is the Doubrava river. On the map of the 2nd military mapping, as well as the maps of the Stable Cadastre, the Doubrava river is also clearly the main watercourse. At the time of Müller's mapping, either the Čertovka could have appeared more watery due

Fig. 9. A preserved riverbed section for the water supply of the disappeared pond system (November 2023), marked as an occasional flow on BM 10

to the supply of the pond system, or it is a faulty drawing, which is not unusual regarding watercourses on this mapping.

The development of the pond system on the lower Doubrava river was also recorded in the assessment of the water management development in the Čáslav region [2]. However, this site was not dealt with separately and in detail, but as part of the classification of the water management development (ponds, mills, dams, floodplains, etc.) in the territory of the Čáslav municipality (a municipality with extended administration; ORP). The pond system described in this paper is located on the northeastern edge of this ORP.

Furthermore, the development of water bodies was also investigated as part of the assessment of the landscape development of Nové Dvory and Žehušice municipalities [3, 4]. This was primarily about the implementation of the European Landscape Convention at the local level in the form of a pilot study in the area of Nové Dvory – Kačina – Žehušice, which represents a segment of intensively agriculturally used landscape with a persistent significant trace of baroque and classicist landscaping. The subject of the study was primarily the development of a strategy and effective procedures to ensure sustainable development of the landscape, respecting both its economic potential and the protection and development of its natural and cultural-historical values. The main output of the project was the individual scenarios of landscape development based on the combination of degrees of anthropogenic use of the landscape and degrees of its protection. One of the inputs was the depiction of the historical form of the studied area based on the interpretation of archival maps. The area covered consisted of 21 cadastral areas, of which Sulovice, Žehušice, Horka u Žehušic, Rohozec u Žehušic, Lišice u Sulovic, Zaříčany, Bojmany, and Habrkovice are part of the territory assessed in this article [17].

Disappeared ponds based on the interpretation of archival maps were studied by David [18]. These were the areas of Blatná, Třeboň, Blaník, and Kouřim. Havlíček et al. dealt with the restoration potential of water bodies recorded on the map of the 1st military mapping [19]. Based on the analysis of three basins (Bystřice, Jevišovka, Opava), it was found that the greatest potential for restoration of water bodies from this period is in the Jevišovka basin, where a preserved dam or a larger part of it was recorded in 51 % of disappeared water bodies. The other two basins show less potential for the restoration of disappeared

Fig. 10. Podolský and Koukalecký ponds on a Imperial Imprint of the Stable Cadastre

Fig. 11. Current state of Koukalecký pond (November 2023)

water bodies: 26 % for the Opava and 24 % for the Bystřice. In the studied area of the disappeared pond system on the lower Doubrava and Čertovka rivers, preserved dams can also be seen by the main ponds in the landscape. However, the restoration of the ponds to their original size is not possible because part of their area is already built-up, or development has spread to the immediate vicinity of the historical location of the ponds. In addition, the site of the disappeared Kravinec pond is located on the territory of the Žehušická obora natural monument. However, according to extant reports, these vast disappeared ponds were mostly shallow and very muddy, forming swamps [2, 20].

If we only take into account the current state of the landscape, the site of the disappeared pond system on the lower Doubrava river and the Čertovka would be suitable for building small wetlands (ponds, pools, wet meadows), in particular on small, waterlogged sites in the place of today's arable land, whether they are waterlogged, or with reeds. On the site of the former ponds are fertile soil types; however, if the crop sown on a waterlogged site does not grow and is eventually replaced by reeds, it would be appropriate to use this fact for the restoration of wetland habitats as stable water-retaining elements in the landscape. In areas with already restored wetland vegetation, it would be useful to establish some territorial protection.

Fig. 12. Current state of the landscape at the site of the disappeared Horecký pond (November 2023)

Fig. 13. Current state of the landscape at the site of the disappeared Bramborský pond (November 2023)

The results presented here could be a practical guide for building small water reservoirs (ponds) and other wetland habitats (wet meadows) in place of the disappeared ones, as the historical location of such elements is a very strong argument for their restoration. These landscape elements are also part of the solution for adaptation to the issues caused by climate change. In the case of landscape restoration in the places of disappeared ponds and other wetland sites, both water retention and landscape biodiversity increase. This fact is in line with the EU Biodiversity Strategy 2030 [21], which is a valid long-term plan to protect wildlife, stop ecosystem degradation, and restore biodiversity in Europe.

Fig. 14. Current state of the landscape at the site of Koukalecký pond and the disappeared Bramborský and Horecký ponds (waterlogged location in the lower part of the image), current Orthophoto map of the Czech Republic

Fig. 15 shows the current state at the site of the disappeared Borecký pond, including the canalized watercourse Čertovka.

Acknowledgements

The article was created within the framework of TGM WRI internal grant No. 3600.54.03/2022 "Water in the landscape as an indicator of territory changes in Polabí" and within the research of the Centre for Landscape and Biodiversity (project SS02030018, supported by the Technology Agency of the Czech Republic).

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This article was translated on basis of Czech peer-reviewed original by Environmental Translation Ltd.

DOI: 10.46555/VTEI.2024.01.003

ISSN 0322-8916 (print), ISSN 1805-6555 (on-line)


Photo: J. Unucka

QFIELD – mobile application for data collection established on the principles of open source software

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Keywords: QField – mobile GIS – Open Source Software – QGIS – field data collection

ABSTRACT

Acquisition of primary spatial data (geodata) in the form of a field survey (i.e. direct contact of the surveyor with the observed object or phenomenon of the real world) can undoubtedly be described as the most demanding method of their acquisition in terms of time and financial costs. However, in the past ten years, there has been a sharp turnaround in the field of mobile mapping. With the introduction of smartphones and laptops (tablets), countless applications for field data collection have been developed. Combined with Open Source tools, mobile data collection activities have become widely available to both professionals as well as the general public. One of these applications is QField. It is a multi-platform mobile GIS designed primarily for Google Android, Apple iOS, and Microsoft Windows platforms. Its user interface is strikingly similar to that of the QGIS desktop app, giving the false impression that the mobile app is part of it. However, it is stand-alone software developed by an Open Source solutions group, OPENGIS.ch, whose compatibility with the desktop application is ensured by another element, a plugin.

The aim of this paper is therefore not only to introduce the reader to some of the functionalities of this mobile application, including its advantages and pitfalls, but also, and most importantly, to critically evaluate its usability in practice. This is done by combining the experience of other authors of case studies with our own experience, gained in the performance of tasks arising from the activities of T. G. Masaryk Water Research Institute.

INTRODUCTION

The QField application, intended for mobile mapping of objects and real-world phenomena (collection of spatial data directly in the field via a mobile device), ranks among typical representatives of Open Source Software (OSS). It is distributed under the GNU Public Licence (GPL) version 2 and above [1]. This means that under this licence, the application can not only be used for free, but its source code is also freely available, which can be further modified (which greatly strengthens the user's control over running processes). Closely related to this is the expansion of software configuration options and partial functionalities; in this way, even more specific user requirements for the final product can be met with zero or completely minimal costs for acquisition or operation.

As for the other indisputable advantages resulting from the OSS principle, we must emphasize the strong support of the user community in the form of educational videos placed, for example, on YouTube or user discussion forums (Github, Stack Overflow, Reddit, etc.). OSS are also characterized by being multi-platform or having the ability to run the required process on more than one platform (in the sense of operating systems or hardware platforms). However, in the case of multiplatform software, it cannot be automatically assumed that the software will work on all available platforms [2].

Fig. 1. Linking the mobile application with other geotechnologies

QField is currently available for:

- Google Android platforms – recommended version 9 and above (https://play.google.com/store/apps/details?id=ch. opengis.qfield),
- iOS (https://apps. apple.com/app/ qfield-for-qgis/id1531726814),
- Microsoft Windows (https://qfield.org/get_latest/?platform= windows).

Other platforms are only available in the beta version, e.g. Linux (https:// qfield.org/get_latest/?platform=linux) and MacOS (https:// qfield.org/get_latest/?platform=macos) [3].

Usually, easy data transfer is ensured, i.e. data storage usually in open formats. In the case of QField mobile GIS, the data formats of the QGIS and GDAL data providers are supported. The most common formats are Geopackage, Shapefiles, MBTiles, TIFF, JPEG2000, or specifications or standards created for the needs of GIS technologies and interoperability – WMS, WFS, Simple Features for SQL (however, this list is far from complete).

The application is developed using programming languages C++, QML, Java, Perl, and Shell scripts. A brief history of its development is shown in *Tab. 1*. However, not all versions of the application are listed here, only those with major changes [1].

The use of the mobile application must be preceded by the preparation of its environment. This phase includes several sub-tasks, such as selection of background maps, addition of other thematic layers that are necessary for the needs of the field data collection itself, setting of their symbology and labels of their elements; last but not least, there is creation of the target layer (or layers), to which new records will be collected. Functionalities that can be used for individual actions will be described in detail below. First of all, it should be emphasized that

Tab. 1. QField mobile app development history as of 2019 [4]

Date	Version	New features, improvements
28/03/2019	1.0.0 Matterhorn	
03/10/2019	1.2.0 Matterhorn	Value Relation widget, login dialog, support for snapping using expressions
03/03/2020	1.4.0 Olavtoppen	Welcome screen with recently opened projects, portrait mode, split layer elements, native camera and gallery usage, antenna height correction
18/08/2020	1.6.0 Qinling	Multi-editing of layer elements, dynamic configuration of image names
20/10/2020	1.7.0 Rockies hits the stage	Coordinate search, filters in the Value Relation widget, new fancy QML and HTML widgets, improved geometry editing features and an extensible legend
24/02/2021	1.8.0 Selma	Manual digitization, improved widget forms, using data from external GNSS receivers without any third-party applications
05/04/2022	2.0.0 Arctic Fox	Integration with QFieldCloud BETA
13/10/2022	2.4.0 Ecstatic Elk	Release for versions for the iOS platform
04/04/2023	2.7.0 Heroic Hedgehog	Audio recording option
30/05/2023	2.8.0 Insightful Indri	Version available as of 11/07/2023

for these purposes it is more than appropriate to use the QGIS desktop application environment and tools, for several reasons. The first and most important argument is the high compatibility of both software. This is mainly caused by the fact that the developers of the QField mobile application used the same libraries (summary of procedures, functions, constants, and data types) that QGIS uses. From the point of view of basic data manipulation, whether previous or subsequent, this solution appears to be very practical. Another reason for this connection is the interlacing with other geotechnologies. These can be, for example, data management and data storage systems – PostgreSQL, SQLite and their extensions for supporting geographic objects (PostGIS, SpatiaLite) or tools for providing geodata (GeoServer, QGIS Server) (*Fig. 1*) [5].

For custom data transformation between desktop and mobile application (and reverse synchronization of changes), the QField developers created a plug-in to QGIS QFieldSync. This is available in the plugin repository and can be installed in QGIS directly via the Plugin Manager. The project in compressed *.qgz format prepared in the desktop application environment contains information about the configuration of individual layers and background maps. Before data transformation itself, the project must be converted to XML format *.qgs, which is compatible with the requirements of the mobile application itself. Thanks to the plug-in module, everything (project and input data) is stored in one folder, which is transferred to the mobile device. The transfer is provided in two ways; from the repository or using QFieldCloud (*Fig. 2*) [1]. During application testing, the fee was set for his service, so we were forced to proceed with manual import (until an adequate equivalent cloud or other solution is found).

An acceptable solution to this problem appears to be the use of the PostgreSQL database system connection and its extension for spatial data, PostGIS. The solution methodology proposed for mobile mapping of the road cadastre inventory of the city of Piacenza in Italy seems quite promising. Even though it is built exclusively on free and Open Source Software without the QFieldCloud service, it complies with official national requirements [12, 13]. The basic principle is the correct setting of the configuration file pg_service.conf. Thanks to this connection, online data availability is ensured and one of the limiting factors – the memory capacity of the mobile device – is eliminated, especially when taking more extensive photo documentation or when using multiple background maps [1].

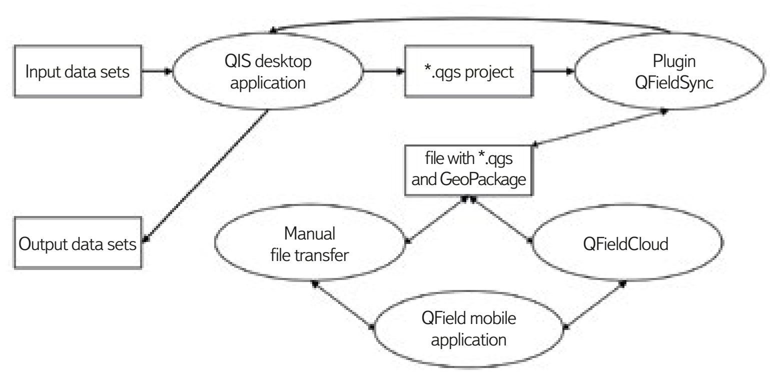

Fig. 2. Data transformation between desktop and mobile application

PREPARATION OF WORK AREA

The initial phase of the process includes the configuration of input data, i.e. not only background data (raster and vector), but also empty data sets into which new information about the object of interest of data collection will be collected.

In the case of background vector layers, the main things to deal with are their symbology, adjustment of the displayed legend, visibility in individual display scales, and labels of elements (Labels). In the QGIS environment, all the mentioned attributes are configured in the layer properties (Properties > Symbology). As for the underlying raster layers, there are two options. The first is the use of already prepared XYZ tiles – OpenStreetMap, Google Maps (e.g. satellite images are very often used), Mapy.cz, etc. If the users require their own specific background data, they must be processed into the project in MBTiles format (Processing Toolbox > Raster tools > Generate XYZ tiles /MBTiles/). This format only supports tile data (both vector and raster). A spherical Mercator projection is required for their presentation. The files can be internally compressed and optimized, producing views that adhere to the MBTiles specification [6]. A typical example of the use of this format in our conditions is, for example, a background layer from processed remote sensing data or reference map materials of the State Administration of Land Surveying and Cadastre (Basic maps, Orthophoto maps).

For empty data sets, in addition to the basic configuration of their styles, their data model is also set – in simple terms, requirements for the form and range of information about the object of interest. The data model must be defined before the start of the collection – its modification during collection is undesirable and (during subsequent synchronization) will often cause terminal complications, making subsequent geoprocessing impossible. Data layers populated through a mobile application are vector by default. It always depends on the user's intent; only the basic geometry types are available, i.e. point, line, and polygon.

An indispensable base is the definition of the default attributes of the vector layer (their name and data type). The available data types vary according to the format specification. In QGIS, the data types listed in *Tab. 2* are available.

Tab. 2. Examples of available data types [7]

Data type	Description
Integer	Integer
Real	Decimal
Text (String)	Text string; can be sorted
JSON (JavaScript Object Notation)	A standard text format for representing structured data based on JavaScript object syntax
Date	
Date/Time	
BLOB (Binary Object)	A collection of binary data stored as a single entity, usually images, audio, or other multimedia objects
Boolean	A data format with only two possible values (usually "TRUE", or "FALSE")

Individual attributes behave differently depending on their type (numeric, text, etc.). A summary of the data types used for a specific vector data set can be obtained from the source fields tab in the layer properties (Properties > Fields). When editing, their limits should not be exceeded, e.g. string length, range of values, or entering an incorrect expression. The behaviour of attributes (both in the desktop and mobile application) can be regulated and further specified using the attribute form in the layer properties (Properties > Attributes Form). In general, the configuration of individual attributes could be divided into several sections, namely basic settings, widgets, restrictions, and default values (*Fig. 3*)

Basic settings

In the first section of the basic setting of the attribute (*Fig. 4*), the parameters for its display are dealt with, regardless of its data type. The Alias parameter adds a title to the attribute (without string length restrictions, with diacritics and spaces), which often makes it easier for the user to navigate, especially in the case of attributes with similar or unclear names. Another important parameter is the Editable checkbox. By default, editing the fields of this attribute

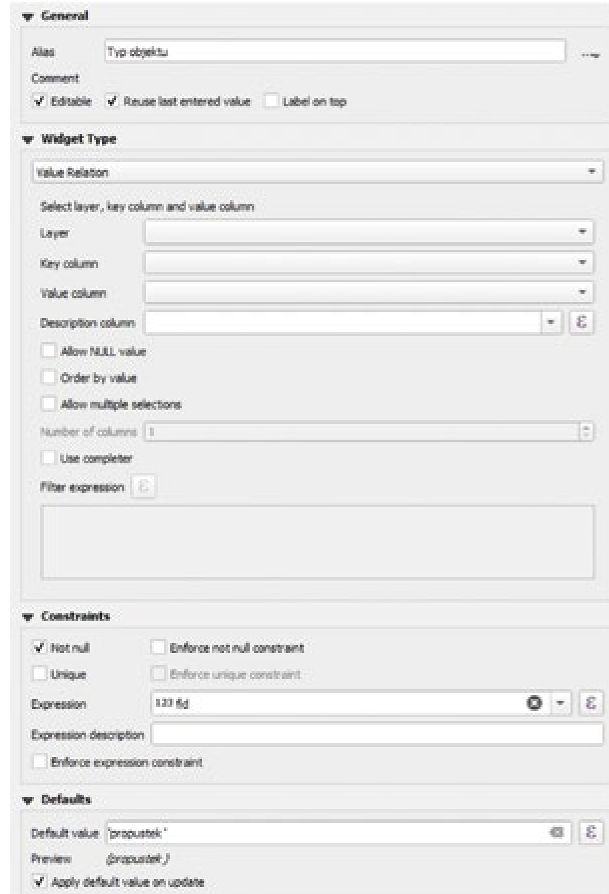

Fig. 3. Data layer attribute form

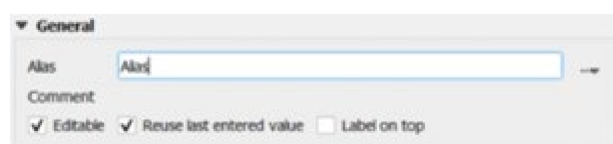

Fig. 4. Basic attribute settings

is allowed. If the checkbox is unchecked, it is not possible to insert new data and edit existing data. A relatively useful function in the field of mobile data collection is remembering the last entered value (checking the Reuse last entered value checkbox).

Widgets

Widgets allow you to configure specific forms with certain behaviour and appearance for different data types. In the following text, we will proceed from simpler to advanced variants of widgets.

The simplest widget is Text Edit. It is the basic type of editing window for text strings, while the only alternative to its extension is the use of a multi-line variant (*Fig. 5a*). Selecting the Hidden widget hides the name and content of the attribute in the detail of the element. The Checkbox field (*Fig. 5b*) writes the values that will be checked into the attribute, while their definition is required in advance. Using a checkbox is convenient for deciding between

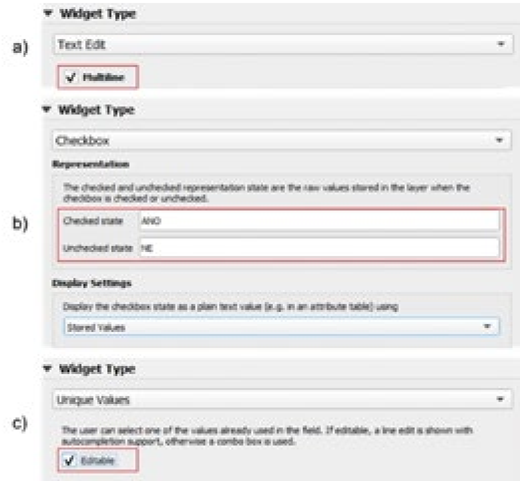

Fig. 5. Widgets – Text Edit (a), Checkbox (b), Unique Values (c)

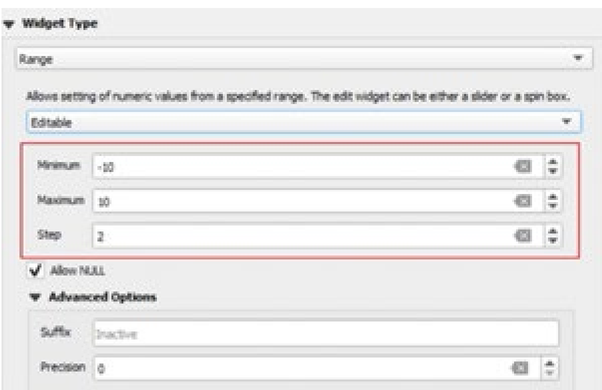

Fig. 6. Widgets – Range

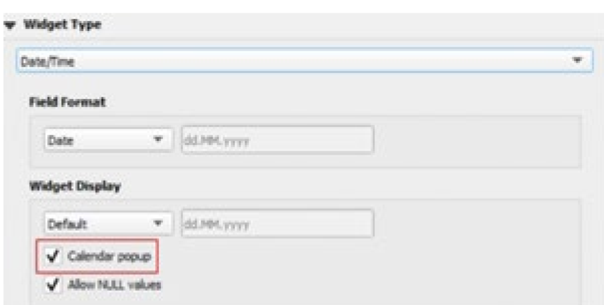

Fig. 7. Widgets – Date/Time

two states. Through Unique Values, the content of the drop-down list is generated in the attribute (based on the values already entered), from which you can choose during editing. If this parameter is also set as editable (*Fig. 5c*), the inserted text will be automatically supplemented according to the possibilities of the drop-down list.

For numeric data types, the permitted range of values (Range), i.e. minimum and maximum values, can be determined. It is possible to choose between a classic editable window and graphic tools, specifically a slider or a spin box (*Fig. 6*).

Attributes containing Date or Date/Time can be inserted in many formats, or the user can insert their own format template. As for graphic elements,

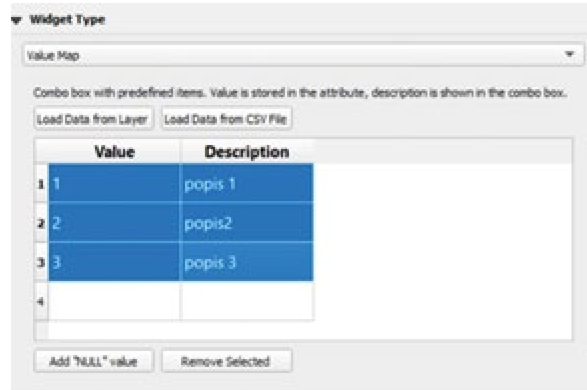

Fig. 8. Widgets – Value Map (domain)

Fig. 9. Constrains of attribute values

Fig. 10. Default value configuration example – timestamp

the attribute can be supplemented with a pop-up window with a calendar (*Fig. 7*), from which the desired data is subsequently selected.

The Value Map widget could essentially be described as a domain or codebook. The attribute is edited by selecting values from the drop-down list (*Fig. 8*). Its items are inserted and edited directly in the widget settings. Two parameters are used for their definition – Value, Description; the description is used during editing, the value is displayed in the resulting attribute table of the layer. As for a more extensive codebook, there is an option to import it from a text file. It is also possible to import values from an attribute of another dataset.

The UUID generator (Universal Unique Identifier) is used exclusively by the data type. The text is filled in automatically. This is a unique identifier composed of a combination of letters and numbers.

A big trend in recent years is that multimedia files (e.g. photographs, audio recordings, and videos) are often attached to the collected attributes about the object of interest. In this case, it is advisable to use the Attachment widget. The attribute of the data type text string can contain an absolute or relative path to a file or a URL (Uniform Resource Locator), which can be displayed directly as a hyperlink based on this configuration. It is possible to set a preview for images and web pages. More about the possibilities of inserting multimedia files will be presented in the practical examples below.

Constraints

Constraints can affect the range of attribute values (*Fig. 9*). For example, the requirement to fill in the attribute (checked checkbox – Not null) ensures that the attribute is filled with data. If the attribute is not filled, the user is notified of this fact and the element record can be saved. In the event that the attribute values are strictly required by the user and it is necessary to prevent the storage of an empty attribute, the next level of this measure is to check the Enforce not null constraint checkbox. Checking the uniqueness of the record works on a similar principle (check boxes – Unique, Enforce unique constraint). Expressions can also be used to set controls for specified values. Based on predefined user-defined functions, expressions offer a powerful way to manipulate attribute value, geometry, and variables to dynamically change style, geometry, content, and more.

Default values

The attribute default values configuration section (Defaults), if it is not underestimated, can represent a fairly wide range of actions during data collection – it is advisable to pay sufficient attention to it precisely in cases where the content of the attribute is determined by a rule. An example is the use of a so-called time stamp, calculation of the geometry of an element (length, area) or coordinates. Compound expressions (*Fig. 10*) are very often used to determine default values [7].

Object to transfer water

Id	Name	Alias	Type	Type name	Length	Precision	Comment
0	ID		double	Real	0	0	
1	TYP_OBJEKT	Typ objektu	QString	String	30	0	
2	ROZM_TVAR	Rozměry D / ŠxV (cm)	QString	String	50	0	
3	MATERIAL	Materiál konstrukce	QString	String	50	0	
4	FOTO	Foto	QString	String	250	0	
5	POZNAMKA	Poznámka	QString	String	250	0	
6	EDITOR	Editor	QString	String	30	0	
7	DATUM	Datum sběru	QString	String	30	0	
8	TVAR_VTOK	Tvar na vtoku	QString	String	20	0	
9	TVAR_VYTOK	Tvar na výtoku	QString	String	20	0	

Characteristic points on road network

Id	Name	Alias	Type	Type name	Length	Precision	Comment
0	fid		qlonglong	Integer64	0	0	
1	ID	ID záznamu	double	Real	0	0	
2	TRIDA	Třída cesty	QString	String	50	0	
3	SKLON	Sklon	QString	String	50	0	
4	TER_KONFIG	Terénní konfigurace	QString	String	50	0	
5	POD_ODVOD	Podélné odvodnění	QString	String	50	0	
6	PR_ODVOD	Příčné odvodnění	QString	String	50	0	
7	POVRCH	Povrch cesty	QString	String	50	0	
8	FOTO	Foto	QString	String	250	0	
9	POZNAMKA	Poznámka	QString	String	250	0	
10	EDITOR	Editor	QString	String	30	0	
11	POSKOZENI	Poškození (v úseku cesty)	QString	String	250	0	
12	DATUM	Datum sběru	QString	String	30	0	

Significant changes on road network

Id	Name	Alias	Type	Type name	Length	Precision	Comment
0	fid		qlonglong	Integer64	0	0	
1	TYP_BODU	Typ bodu	QString	String	30	0	
2	PREKAZKA	Překážka přítoku vod	QString	String	250	0	
3	FOTO	Foto	QString	String	250	0	
4	POZNAMKA	Poznámka	QString	String	250	0	
5	EDITOR	Editor	QString	String	30	0	
6	PRISLUSENS	Příslušenství lesní cesty	QString	String	250	0	
7	DATUM		QString	String	30	0	

Fig. 11. Data models

QFIELD MOBILE APP CONTROL

The control of this mobile application is intuitive – in the event that a carefully set project is already in the desktop application, there should be no complications when collecting data in the field.

The following text is dealing with the manual version of the project import used so far. After transforming the prepared project with the QFieldSync plugin (into the required format), the entire folder (uncompressed) is then moved to the storage of the mobile device (via a USB cable, Google Drive, Dropbox, etc.). It must have a specific location: <drive>:/Android/data/ch.opengis.qfield/files/ (this location is necessary to successfully run the project in the application). There can be multiple folders containing different projects – their number is limited only by the capacity of the user's mobile device.

After starting the mobile application, the local file, the Imported projects folder is opened and after selecting the desired project, the appropriate project file is selected. After it is loaded, the data is displayed in a way that corresponds to its display in the desktop application. The contents of the project (map legend), including background maps, are called up by the main menu icon in the upper left corner. After double-clicking (or long-pressing on the required layer), a pop-up window will appear with a menu, thanks to which you can, for example, control the visibility of individual layers, show or hide element labels, expand or hide legend items, or zoom in on a given layer and display a list of all layer elements.

Digitization of new and adjustment of the position of existing elements in the field can only be started after switching on the editing mode in the main menu and after selecting the required vector layer. At the moment when editing starts, a crosshair appears in the middle of the map field, which must be set in the centre to the desired site. This can be done in two possible ways. The first is a manual site search according to the background map. The second approach, more often used to locate a point, uses the user's location – it is important to have location permission on the mobile device for the application. Confirmation for creating a new element is the green "plus" button in the lower right corner of the map field. Subsequently, a field with predefined attributes will appear to be filled. This procedure of entering elements with "point" geometry is the basis for the creation of two others (line and polygon) when edges are formed between the entered vertices. The "minus" button in the lower right corner is used to cancel an incorrectly placed point. For these geometries, the element is terminated or cancelled with the icons at the bottom of the screen.

It is not necessary to be in edit mode to edit attributes. By double-clicking on the selected element on the map, its attributes are displayed. If there are multiple elements from other layers at the given site (overlapping), all of them will be listed in the menu. Then one or more elements can be selected. After this selection, it is necessary to press the icon for editing the attributes, then the required actions can be performed [1].

CASE STUDIES

QField mobile application for spatial data collection has found its application in many industries in recent years. The most numerous examples include archaeology, tourism, spatial planning, landscape design, and agriculture.

For example, it was deployed during data collection in an open area during an archaeological survey at sites near Rome, while the possibility of creating spatial queries from two or more tables was especially valued. Thanks to the minimization of the amount of stored data, the process of data collection in the field was significantly shortened [8].

German urban planners have also decided to deploy this application to document the state of urban structure for more effective planning. The collected data are further processed and made available in the ALKIS® information system through other Open Source Software (QGIS, PostgreSQL, and PostGIS). Due to the positive experience with 2D data, their next defined goal became the third dimension in terms of digital elevation models and 3D building models [9].

The possibilities of mobile mapping were also assessed by Romanian geographers who collected data on the movement of tourists in large cities (Oradea, Timişoara, Cluj, and Bucharest). In this study, several mobile applications were compared (QField, Geopaparazzi, and Survey123), while in the case of QField, the possibility of preparing dynamic forms and their flexibility according to user requirements were evaluated positively [10].

On the Pacific island of Tonga, an agricultural landscape was mapped using QField. The collection of data was characterized by a relatively large working group of acquirers; therefore, unlike the previous mentioned applications, no direct connection to the database system was used. The authors of the study describe in particular the advantages of using QFieldCloud (currently used for a set fee), consisting primarily of a simple way of unifying data collected by different groups at the same time. Only after this synchronization was the data forwarded to the database for further processing [11].

Within our organization, the application was deployed for the following activities:

Analysis of changes in the water regime of land and watercourses in Krkonoše National Park caused by the road network

The main goal of this project is to make it possible to analyse the influence of the road network (including related drainage facilities) on the water regime, especially on total runoff, in the entire area of Krkonoše National Park. QField was chosen for data collection in the field as part of the sub-goal – the creation of spatial datasets, which map in detail the road network in the national park, including related drainage facilities and also the network of watercourses of all orders. Basic requirements were the ability to collect data in parallel on multiple devices, the addition of multiple multimedia files to one element, and the presence of specific background data. Since the work on the project took place before a fee for the service was set, the unification of the obtained data was done through QFieldCloud.

Data models (*Fig. 11*) were designed for three point layers: objects for transferring water (culverts, fords, bridges, mountain inlets, etc.), characteristic points on the road network (road, forest road for wood removal /1L and 2L/, forest track /3L/, technological line /4L/, pedestrian path /technically modified/, footpath /trodden only/, boardwalk, etc.) and significant changes to the road network (beginning or end of the road, clear break in the vertical alignment or saddle, clear change of surface, change of longitudinal drainage, forest path equipment, obstruction/diversion of water inflow, etc.).

During implementation of the field investigations, the data model was modified based on user requirements. It was therefore necessary to harmonize the resulting stages in the environment of the QGIS desktop application. Within Krkonoše National Park, around 2,000 point objects were mapped and described at four selected sites.

Creation and filling the register of all outlets on the Elbe watercourse from Brandýs nad Labem to Mělník — pilot project

The goal of this pilot project was to map wastewater outlets on a selected section of the important Elbe watercourse and identify the objects with existing records with the intention of obtaining an overview of registered and unregistered outlets. The contracting entities were the Ministries of the Environment and Agriculture.

Here, the mobile application played a completely different role than in the previous case. The task was to make the results of already conducted field data collection available to users of mobile devices (e.g. to verify the status of mapped objects). Unlike the parallel web map application, it was based exclusively on Open Source technologies (desktop application QGIS and its plug-ins, QField). It is therefore not about developing your own mobile map application, but about configuring a so-called project that is imported into the QField application environment and made available to users there.

During the actual project configuration, emphasis was placed not only on the appropriate setting of symbology and addition of other thematic layers, background maps and numerous photo documentation, but in particular on their linking, placement in directories, and conversion into a suitable format for import into the QField application. Currently, the application only displays the results of the field survey on the background map of aerial photography (Google Satellite – Google Maps) with the highlighting of water bodies and the addition of the names of some thematically important surrounding objects or, for easier orientation, on the OpenStreetMap basis. Due to the planned expansion of the mobile application use by the possibility of collecting new data, the imported package also includes an empty test layer with pre-prepared items and dials in which new records can be written. The content of the map application can also be supplemented with other vector and raster data sets according to requirements.

EVALUATION AND CONCLUSION

Testing of one of the many mobile applications for spatial data collection has been ongoing at TGM WRI since mid-2022. The reason for choosing a mobile application based on the principles of Open Source technology was mainly the fact that related segments of architecture (especially the QGIS desktop application) are already fairly widespread in the community of GIS users.

After initial difficulties, especially with the compatibility of ESRI product formats, which are still preferred within our organization, it was possible to achieve results in field data collection of comparable quality to the products of commercial providers of GIS tools. An essential milestone for testing the QField application was the end of the beta version and the subsequent set fee of the QFieldCloud service, which fully covered the requirements for collecting and backing up data taken by a large number of devices at the same time. Simultaneously, it was intended for relatively safe synchronization of the obtained data. Due to the uncertainty of whether enough potential users will be willing to include the new application in their activities, we decided on a temporary solution of manually moving the transformed data from the desktop application directly to the mobile device storage. In the future, we intend to respond to this situation in the form of our own cloud solution or a direct connection to a separate database.

Similar to other mobile GIS, the QField application has its limitations and pitfalls. For example, an unstable Internet connection significantly slows down the loading of background layers and increases the inaccuracy of the position of targeted objects (this can be eliminated by integrating a GNSS antenna or importing data from GNSS receivers). Another limitation is the impossibility of using WMS services when collecting data in the field. The application is quite demanding on the mobile device battery.

In any case, the above-mentioned successful deployments of the QField mobile application within the framework of two implemented orders demonstrate its high potential. It is an interesting possibility to use one of the many geoinformation technologies, with minimal costs for its acquisition and high flexibility in meeting user requirements.

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This article was translated on basis of Czech peer-reviewed original by Environmental Translation Ltd.

DOI: 10.46555/VTEI.2024.01.002

ISSN 0322-8916 (print), ISSN 1805-6555 (on-line)

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Weisshuhn flume in Žimrovice

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Keywords: Weisshuhn flume — hydrometric measurements — HEC-RAS — MIKE 11

ABSTRACT

The CHMI Ostrava branch has repeatedly had the opportunity to measure water flumes, mostly during verification measurements of minimum residual flows, measurements for structural wear, or revision of flow measurement curves. As part of these measurements, it was a very valuable experience to get to know these undoubtedly very interesting waterworks, which are often also technical monuments. Part of these activities included measurements and subsequent modelling of Weisshuhn flume in Žimrovice. This article summarizes and comments on the partial results of these activities. One of the tasks was to determine the critical points in terms of water losses in the Weisshuhn flume. Although these phenomena do occur, the numbers are not significant, as illustrated by the results of measurements and modelling. Different types of devices were used for the measurements; mostly ADCP devices, namely RDITeledyne StreamPro, SonTek RiverSurveyor M9, and SonTek Teledyne RS5. MIKE 11. HEC-RAS hydraulic models were used to simulate steady and unsteady flow.

INTRODUCTION

We classify water flumes among the anthropogenic constructions that had a great influence on shaping our cultural landscape in the past centuries [1]. It goes without saying that it is necessary to care for flumes not only from the conservation point of view, but also from the point of view of hydrological and hydraulic aspects. The primary function of flumes is water transport and the subsequent use of water energy for specific purposes. In the past, it was mainly in mills, sawmills, factories for processing of textile raw materials, and paper mills. Transfer can take place within the basin, but we often come across flumes that transfer water between several basins.

The Harappan culture was the first in history to engage in the construction of flumes, in the Bronze Age, but their construction continued even further – through the Roman period and the Middle Ages until the onset of the industrial revolution [2]. The precision and quality of the construction of these important hydrological structures still fascinate us today because many medieval projects still fulfil their function; for example, the channels within the Třeboň system, the surroundings of Pardubice (Opatovický kanál, Zminka), and Poodří PLA [3].

Flumes, as artificially constructed water channels, increase the density of the river network, influence the flow regime of water and sediments, groundwater conditions, and also vegetation. It should be noted that flumes are anthropogenic landforms that can be classified as the initial stage of channelization of watercourses in our country [1].

Many years have passed since the beginnings of the flume construction, and therefore the flumes may be in an inoperable condition; in the event that we would like to restore their function, it is necessary to assess their technical condition. Restoring the function of flumes is becoming relevant due to extreme climatic fluctuations in the form of long dry periods or intense floods. They could be restored in order to improve the discharge in watercourses in dry season, or, after consideration of the flume capacity, they could also be used to transfer flood discharges [3].

In the Jeseníky Mountains, the energy of watercourses has been used since ancient times by means of flumes, which were often supplemented by a system of small water reservoirs. Interesting constructions in this location include, for example, Hanušovický flume, the flumes in Horní Morava and Krupá, as well as the flumes in the Černá Opava basin. One of these flumes, in Nízký Jeseník, is the flume in Žimrovice, the so-called Weisshuhn flume [3].

Carl Weisshuhn (1837–1919), a well-known entrepreneur and builder, is responsible for several important buildings in Opava district and Silesia. In the second half of the 19th century, he became famous for building bridges, viaducts, mountain railways, and standard railways. In 1891, he built a 3.6 km long flume bringing water to the newly built paper mill in Žimrovice. Water flows into the flume from the left bank above Weisshuhn weir, situated on the meander of the Moravice river, and flows around the rocky slopes below Kozí hřbet. The flume route is led through three tunnels carved in the rock and two aqueducts crossing the tributaries of the Moravice – Kamenný stream and the nameless stream. The flume channel is rectangular and trapezoidal in shape, 4–5 m wide, and originally lined with stones, while part of it is built in bedrock. At the end of the flume there is an outlet for ice and mud [4, 5].

To start with, the paper mill included one grinding mill with five horizontal grinders, one turbine, and one paper machine. At the beginning of its operation, the paper mill was able to produce up to 8,000 kg of paper per day. At that time, water flowed through Žimrovice flume to the paper mill at a speed of 4 m^3 per second, which doubled the output to almost a thousand horsepower [6].

Žimrovice paper mill developed significantly at the turn of the 19th and 20th centuries, when Weisshuhn received a permit to float wood that was harvested from the forests growing around the Moravice river [6]. In favourable hydrological situations, especially during spring snowmelt or autumn rains, the wood (in the form of a metre-long log stripped of the bark) was floated up to Weisshuhn raft at Kozí hřbet and from there to the factory [7].

An interesting fact is that between the railway station in Hradec nad Moravicí and Žimrovice paper mills, Weisshuhn also had a 4,100 m long narrow-gauge line built around the Moravice river from Weisshuhn weir to the paper mills, which was referred to as "Pifka". This line was mainly used to transport old paper from Hradec railway station to Žimrovice [8].

Wood was floated by the flume until 1966; however, the plant was nationalized in 1946 and since then the operators have changed several times. The flume has remained functional and water intended for the production of electricity flows through it, supplying the still functioning paper production [3]. *Fig. 6.* shows a map showing the area of interest.

Fig. 1. Discharge measurement using ADCP RDI StreamPro, Weisshuhn flume in Žimrovice, 8th January 2024 (Photo: J. Unucka)

Field work and measurements

For a better understanding of the influence of the flumes on the landscape (and more specifically on its hydrological regime), apart from the literature search, it was necessary to carry out field measurements and survey. At Weisshuhn flume in Žimrovice (Žimrovice flume), both field mapping and surveying of objects (geodetic GNSS, total station) were carried out, as well as hydrometric measurements – a hydrometric propeller was used as well as a water flow meter (OTT MF Pro) and acoustic devices (ADCP Teledyne RDI StreamPro, SonTek River Surveyor M9 and, in 2024, also the new RS5 and finally also the ADV SonTek FlowTracker2). With the help of these data, it is possible to carry out subsequent analyses in hydraulic models, which enable 1D/2D simulations of steady and unsteady flow and offer rich possibilities for visualizing the results, including partial data exports to the GIS environment. Field measurements, together with subsequent analyses and simulations, allow us to better understand and specify the effects of these constructions on the water regime in the landscape, for example water transfers during floods or, conversely, the influence of flumes in periods of drought [9].

In order to improve the quality of the input topographical and altimetric data for the subsequent schematization of hydraulic models, a geodetic survey of selected sections and objects of the Žimrovice flume was carried out. These measurements were carried out using a total station and a dual-frequency measuring GNSS (Global Navigation Satellite System), which can be used to target objects with very high positional accuracy. In places where hydrometric measurements were carried out, cross sections were also measured using GNSS and a total station. SonTek RiverSurveyor M9 and RS5 ADCP devices also offer the possibility to use GPS data in RTK mode.

The measurement of profile velocities was used for the parameterization and calibration of hydraulic models and the construction of measuring flow curves. Thanks to measurements with hand-held or float devices in several determined

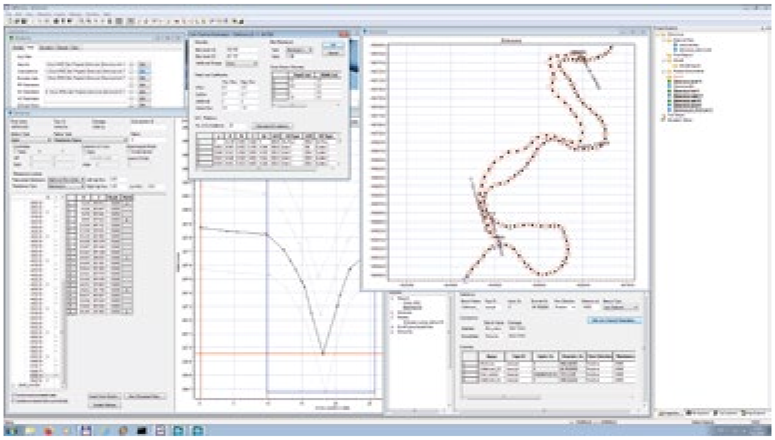

Fig. 2. Example of schematization of the main river Moravice and Weisshuhn flume, MIKE 11 hydraulic model

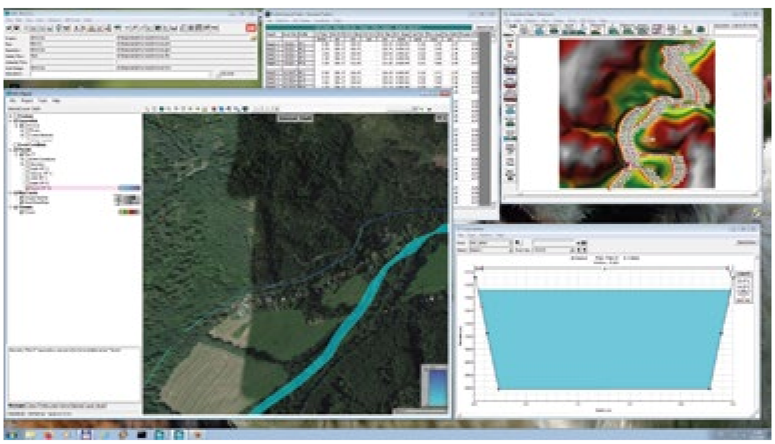

Fig. 3. Example of schematization of the main river Moravice and Weisshuhn flume, HEC-RAS hydraulic model

cross sections downstream, we were able to analyse the drop in Q and, based on these drops, the condition of the flume was assessed in terms of possible leaks and water losses. Despite its age, this flume proved to be in very good condition, and it is admirable how well it was built for its time, when engineering resources and tools were limited. The Q measurement outputs can be evaluated in the Results section in *Figs. 4* and *5*.

Hydrological modelling

Hydrological (or mathematical) modelling is undoubtedly a tool that is practically indispensable nowadays. Using specialized software, we are able to simulate various scenarios without having to interfere with the real environment. For the needs of the simulation, including the influence of technical structures and water transfers (water distribution works, unloading), it was necessary to choose such software tools that allow simulating also these types of hydrological and hydraulic systems. The HEC-HMS software was used as part of the rainfall-runoff modelling, which is a program that was developed by the US Army and is undergoing continuous development and improvement [3]. HEC-RAS and MIKE 11 were chosen from software tools that focus on the movement of water in riverbeds, whether natural or artificial (hydraulic models in general). All of these program resources mentioned above are FEMA/NFIP industry standards. The MIKE 11 schematization was subsequently imported into the HEC-RAS model, so that the geometric and hydraulic (e.g. roughness of the riverbed) parameters of the schematizations were identical in both models. A big advantage of both models is the possibility to parametrize losses and leaks using the so-called Leakage coefficients.

RESULTS

Figs. 4 and *5* show that the losses caused by seepage are not essential in terms of endangering the immediate surroundings or the functionality of the flume itself. We can say that the work has not lost its hydrological and hydraulic significance even after many years. The output is not only the measured and simulated hydraulic parameters of the flume, but also a partial evaluation of the state of the technical structure. Furthermore, on the basis of the obtained results, we can compare and analyse the extent to which the outputs from hydraulic model simulations are usable, in this case specifically the HEC-RAS and MIKE 11 models. It should be emphasized that, despite the complicated hydraulic conditions, the outputs from the models are very accurate and approach the actual measured flow rate *in situ*. For further evaluation of hydrological-hydraulic parameters and the significance of the flume during the flood or drought period, further measurements and then simulations in HD models can be carried out, which will help to better understand and define the significance of these structures in the landscape.

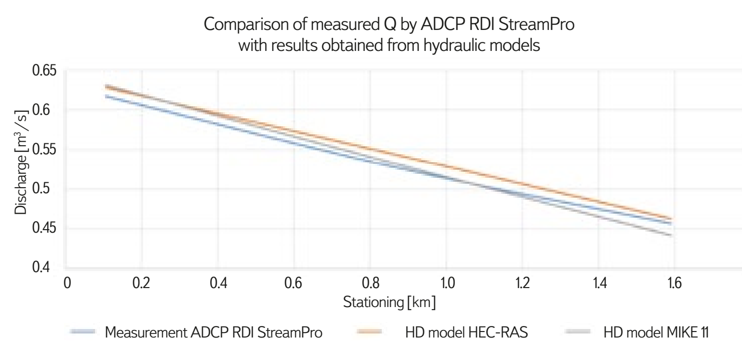

Fig. 4. Comparison of measured and simulated discharge during low flow episodes

We can compare both graphs, where the Q values are measured and then simulated for lower water bearing on the first one, and the same was done for higher water bearing on the second one (*Fig. 5*)

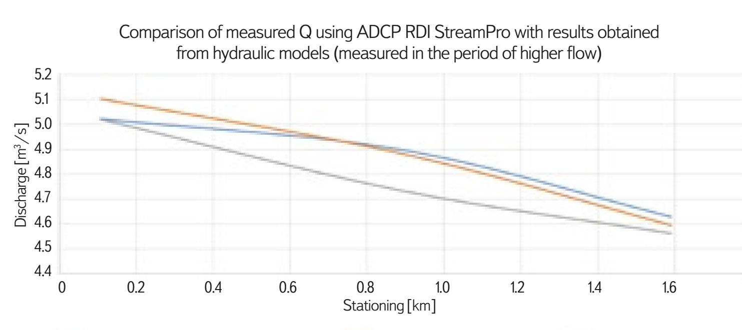

Fig. 5. Comparison of measured and simulated discharge during high flow episodes

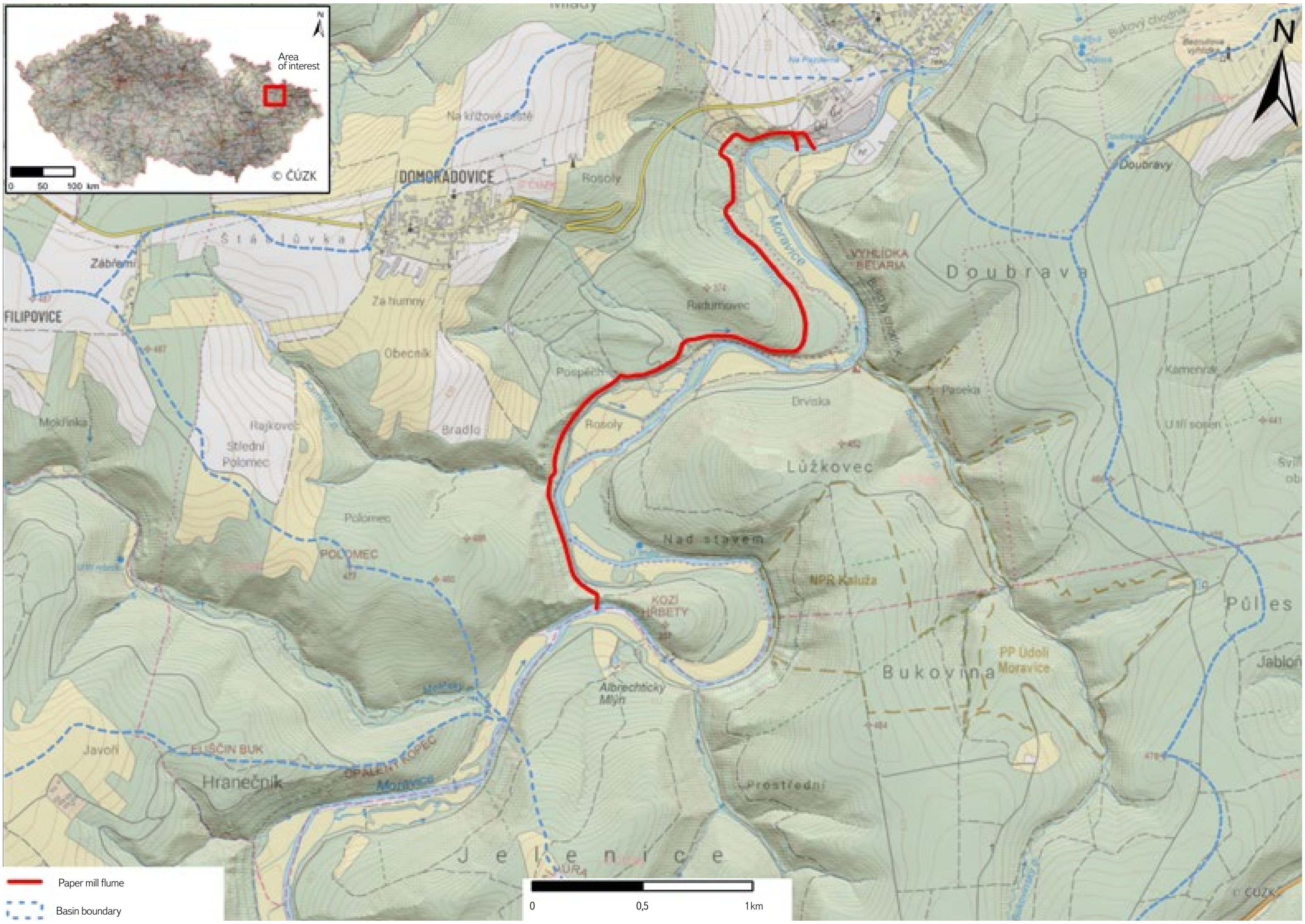

Fig. 6. Location of the pilot area

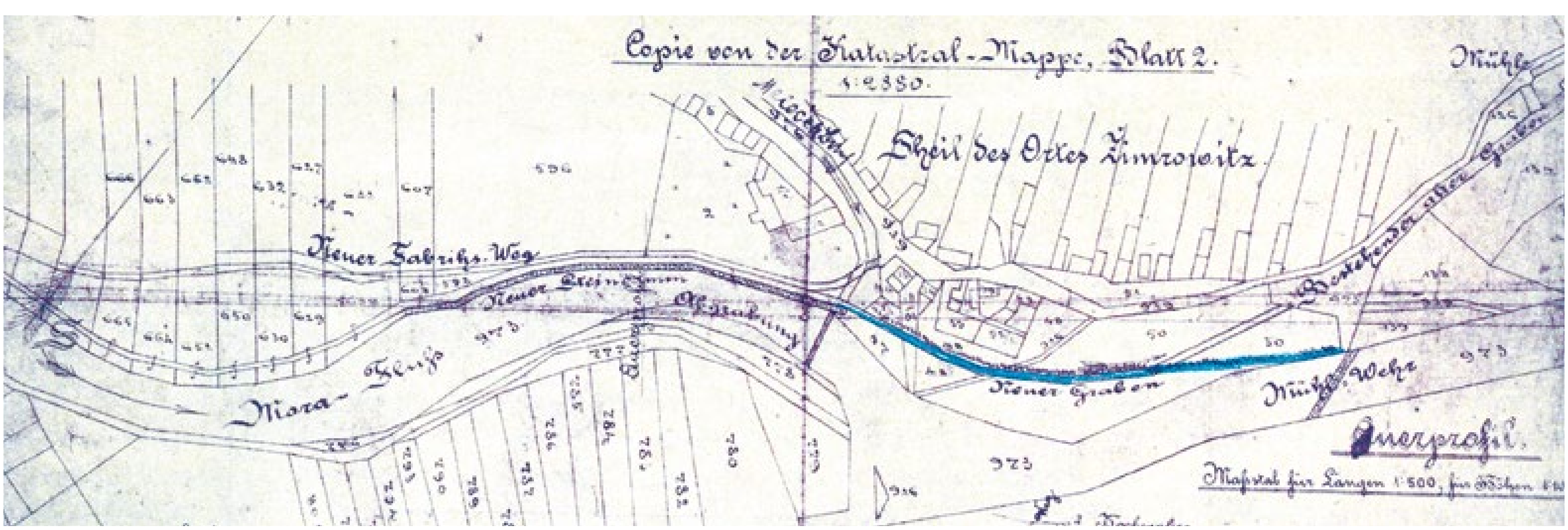

Fig. 7. Historical map of Weisshuhn flume

CHMI Ostrava plans to continue researching old water management structures in the landscape, as they are undeniably interesting works not only from a historical and construction-technical point of view [10], but also hydrological (water transfer) and ecological (refugia or biocorridors for plant and animal species which are tied to aquatic and transitional habitats). Partial results for specific locations are most often presented as part of the regular Vodní mlýny (Water Mills) conference, which is organized by the museum in Ústí nad Orlicí under the leadership of PhDr. Radim Urbánek. The authors hope that a more comprehensive publication will be created in time.

Although the measurement of flow rates and the modelling of hydraulic processes in the flumes is quite specific, the work done so far at various locations (Žimrovice, Hanušovice, Žďárský stream, Javorka, Ploskovický stream, etc.) points to the fact that appropriately selected instrumentation and software make it possible to obtain usable results.

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This article was translated on basis of Czech peer-reviewed original by Environmental Translation Ltd.

ISSN 0322-8916 (print), ISSN 1805-6555 (on-line)

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Interview with Ing. Petr Kazda, Director of Partnership Environmental Foundation

Do you know Tree of the Year, Planting for the Future, and the Adapterra Awards? And do you know what an Open Garden is? Do you use Greenways? All this and much more is related to the Partnership Environmental Foundation in Brno, whose director since 2019 has been Ing. Petr Kazda. Why is climate change a challenge for him that can bring us new opportunities?

Mr. Kazda, you studied administration and management at the Faculty of Economics and Administration at Masaryk University in Brno. You started your professional life right after your studies in the organization you now manage. Do you remember the moment you decided to work for the Foundation?

Thanks to my external cooperation with Lipka in Brno, I had the opportunity to get to know the projects supported by the Partnership Environmental Foundation as the beneficiary. At that time, I put the Foundation on the imaginary list of my possible future employers. I gradually got to know the whole breadth of its activities. For example, thanks to travelling in the Romanian Carpathians, in which the Romanian partner of the Foundation supported the interpretation of local heritage; the Czech Foundation forms the international Environmental Partnership Association with other foundations in Slovakia, Poland, Hungary, Romania, and Bulgaria.

What was the first project you participated in at the Foundation?

I joined the coordination of the Cyclists are Welcome national certification. The head of the Greenways foundation programme at the time, Juraj Flamik, and the ambassador of foreign relations and tourism expert Daniel Mourek transferred this certification to the Czech environment based on German and Austrian experience. The aim of the project was to create a supporting network of high-quality facilities for cyclists on the main cycling routes, often leading through river valleys. Hotels, guesthouses, restaurants, and other tourist destinations were thus preparing for the specific needs of this clientele. The cyclists themselves provided professional support in equipping the facilities at these places and also became promoters of certification in their clubs.

You have been working at the Foundation since 2005. Can you compare what the Foundation was like when you joined it and what it is like today?

There are many differences. From a small organization with fifteen employees based in several offices in the centre of Brno, it is now a respected partner in the field of adaptation of landscape and urban areas to climate change with more than fifty employees, its own educational facility, and a laboratory of adaptation measures – Open Gardens. In this green oasis below Špilberk Castle in Brno, the Partnership Environmental Foundation is based together with organizations such as Frank Bold and Friends of the Earth Czech Republic.

In 2019, you took over the Foundation from Miroslav Kundrata, who had led it for 25 years. It must have been a challenge for you to take over the organization from a person who made a significant contribution to its development.

Miroslav gave me a lot of space to gradually implement changes in management; together we prepared the Foundation for strategic planning with the involvement of all colleagues. It was a good procedure that prepared one well for handing over the management of the organization after so many years. Miroslav remains at the Foundation in the position of Strategic Director and founder of a number of programmes – from the Tree of the Year and Planting the Future to the Open Gardens and now the Partnership for Sustainable Recovery of Ukraine.

From a team of three in 1993, the organization has expanded to 53 permanent employees who have been helping in the implementation of more than 3,500 projects. Is there still room or potential for further growth?

Foundation programmes are evolving and changing. Last year, the project Živá půda, led by our colleague Zuzana Benešová, experienced the most dynamic development. The project offers advice for landowners, generating and rating of lease agreements, and is behind the creation of the Platform for Regenerative Agriculture. The farmers who are involved present the principles and proven practices of arable land management that lead to its restoration and thus support the restart of landscape functions.

A significant step for the foundation was the launch of the Partnership for Sustainable Recovery of Ukraine. This programme seeks out, connects, and also educates local leaders from Ukrainian cities, municipalities, universities and media during weekly internships in the Czech Republic. The most pressing internship topics are waste, water management, and power engineering. The goal of the programme is to strengthen the absorptive capacity for quality, sustainable projects of the local Ukrainian administration and to support a bottom-up transformation of the environment and adaptation as a cross-cutting theme of all investments. Thanks to the internships, the first partnerships and specific supplies of technology from Czech companies are created. The programme is based on Miroslav Kundrata's experience from the 1990s; thanks to the Foundation, a number of Czech civil society leaders and mayors completed similar internships in Western Europe and the USA.

You participate in the support of cross-border projects. Is the Foundation's ambition to expand its activities beyond the borders of the Czech Republic?

We want to continue to strengthen the European reach. From Brno, we coordinate the European Tree of the Year survey. People from our individual programmes are involved in the activities of transnational associations from the Climate Alliance to the European Cyclist's Federation. In Brussels, we „share" colleague Adam Holub with the European Landowners Organisation.

In addition to supporting external projects, the Foundation also has its own projects. As an example, I will mention the very successful Adapterra Awards project and the Tree of the Year project, which is very popular among the public.

Do you have a project hidden on the back burner, so to speak, that you would like to implement, but for some reason it has not been possible? Alternatively, what new projects can we look forward to in the future?

We are following the process of implementing the EU Nature Restoration Law into national policies. I suppose it will give us more room for cooperation with farmers. In municipalities, it will increase their awareness of the impacts of farming in the agricultural landscape and ways of managing water, and thus also the awareness of the link between the health of the surrounding landscape and the quality of life in villages. We are therefore preparing a fund for the recovery of the Czech landscape, which will provide both assistance and support to smaller municipalities, the transfer of good practice, and financial support for such innovative projects that would not receive support from SEF or NCA CR.

What do you see most as an appreciation of your work and the work of your team?

The answer follows from the name of the Foundation. One of our values is healthy partnerships. They are manifested in the trust of our supporters, philanthropists, as well as beneficiaries. In the implementation of their and our projects, the involvement of the public is essential. Simultaneously, it does not work without trust and openness of municipalities, cities, and regions. The appreciation is these partnership ties, which make it possible to have the impact in local communities and their immediate surroundings.

In your latest newsletter, you speak, among other things, about the way our country is able to implement changes in the landscape, such as widening rivers, returning wetlands to nature, and so on. Why are changes in the public space of urban areas so much more complicated?

This does not apply in general. It depends on local conditions, the complexity of ownership relationships, the state of complex land improvements and so on. When improving the quality of public space in cities and towns, it is necessary to include adaptation measures in the investment: natural cooling of the space with water, evaporation through greenery, water capture and its retention for later irrigation. It is important to choose the right composition of trees, taking into account the future development of the site – for example, traffic needs, further development in the vicinity, and maintenance requirements. Solving conflicts with technical networks can be difficult.

What does climate change mean to you as Foundation Director?

Last year the Director of TEREZA, Educational Centre in Prague, Petr Daniš, published the book *Klima je příležitost* (*Climate is an Opportunity*). It's the same for me. Climate change accentuates the need to restore the functions of our landscape, its water regime, and improve the quality of life in urban areas. It creates pressure for efficient and decentralized energy solutions, for saving resources. It brings a new perspective on externalities – for example, how a new production hall mitigates or worsens the effects of climate change. In general, the entire area of green construction is a huge opportunity, strengthened by efforts to mitigate and adapt functionally to the impacts of climate change – from the use of recyclates to water management and on-site recycling and reuse to island energy solutions.

In connection with climate change, we read on your website that increased temperatures can even affect the taste of Czech beer due to the effect on the quality of hop cones. This is certainly bad news for many Czechs. ☺

We are not yet sure if their impact could also be an improvement in taste. ☺ In any case, for many patriots and consumers of these products, it will be balanced by the increasing quality of Czech and Moravian wines.

Mr. Kazda, thank you very much for the interview.

Ing. Josef Nistler
Mgr. Zuzana Řehořová

Ing. Petr Kazda

Ing. Petr Kazda was born in Brno on 27th April 1981. While studying at the Faculty of Economics and Administration of Masaryk University, he assisted externally in Lipka, a school facility for environmental education. This experience guided him professionally into environmental organizations. He started working on Greenways at the Partnership Environmental Foundation. In the 1990s, this grant and assistance programme supported the creation of multifunctional trails for transportation and recreation, both in natural river corridors and, for example, on defunct railways. The Foundation allocated these activities to its subsidiary Partnership, o. p. s., which Ing. Petr Kazda led for seven years. The company is still behind projects such as the Moravian Wine Trails, the Elbe Trail, and Cyclists are Welcome certification. He became the CEO of the Partnership Environmental Foundation in 2019.

Water infiltration will help with heat, drought, and floods

New predictions of climate change impacts in the Czech Republic show that rainfall will increase slightly in the future. However, in combination with the expected increase in temperature, evaporation will be higher, which will lead to long-term water shortage. Forecasts also say that rainfall will be distributed differently during the year, which in practice means that long periods of drought will alternate with sudden torrential rainfall. But this is nothing new. In the Czech Republic today, there is already a lack of water; it lies on the main European watershed, and we are therefore highly dependent on rainwater. In the past, unfortunately, we have modified cities and the countryside in such a way that rainwater was quickly diverted away – by channelling watercourses, by farming methods, and by creating sewers. Adaptation measures to climate change in the field of water management can significantly increase the sustainability of water resources, reduce the risk of floods, and ensure water even in times of drought.

Water in the city will improve the microclimate

Urban dwellers are the most affected by weather extremes, such as heat waves or torrential rainfall causing local floods. The reason is the lack of greenery and water, the excess of paved surfaces, and the rapid runoff of water through the sewers, which during torrential rains causes overloading of wastewater treatment plants and, hence, water pollution. In order to limit these phenomena, it is crucial that the rainwater is retained at the point of impact. Infiltration and water retention measures can prevent sewers from overflowing during torrential rain in urban areas, ensure sufficient water for urban greenery, and improve the microclimate.

There are many ways to deal with water retention in the urban areas. In Roudnice nad Labem (*Fig. 1*), for example, they have invested in the reconstruction of streets and not only added more parking spaces, but, thanks to the design of the architectural studio, they also built a system of blue-green infrastructure. Local streets are lined with rain gardens. These capture surface water and allow it to gradually seep into the subsoil. In addition, they planted a number of trees, which allowed the water to soak in, and used permeable material on paved areas.

Fig. 1. Rain gardens line the pavements and roads in Roudnice nad Labem (Source: Nadace Partnerství – Adapterra Awards, photo: V. Herout)

It is not always possible to hold all the water in the ground at once, so a combination with retention reservoirs is suitable. Thanks to them, the rainwater runoff will be slowed down, both into the sewage system, which will not get overloaded, and into the surrounding greenery. They have been put it into practice, for example, in the Suomi Hloubětín residential district in Prague (*Fig. 2*). Retention reservoirs are located under apartment buildings. Surplus water from these cisterns then flows through outdoor distribution systems into the infiltration areas, open shallow ditches with an infiltration function, and only then does the rest of the water travel to the central infiltration pond and from there through the overflow to the newly meandering Rokytka stream.

Fig. 2. Below Suomi Hloubětín, there are infiltration meadows where water from retention reservoirs flows to (Source: Nadace Partnerství – Adapterra Awards, photo: V. Herout)

Semi-natural restoration of watercourses and anti-flood measures

Slowing down water runoff is a task not only for the urban environment, but also for watercourses and agricultural landscapes. In the last century, the regulation of watercourses into narrow straight channels was popular, which means that even low intensity rainfall or snow melt can cause significant problems in the form of floods and inundations. Today, the trend is exactly the opposite – to restore watercourses in a semi-natural way. Natural and semi-natural watercourses slow down the flow of water, enabling regulated overflow, and thus reduce the risk of floods.

A number of successful watercourse restorations have been carried out by Morava River Basin Management; among them is the project to widen the bed of the gravelly Bečva river (*Fig. 3*). The main goal of modifying the watercourse was to reduce the deepening of the riverbed, to widen it, to allow water to spill into the floodplain even at lower flows, and to facilitate the conditions for the movement of ice, which accumulated in the riverbed and caused winter floods. Thanks to restoration of part of the river, it was possible to increase the level of flood protection in three adjacent villages – Černotín, Skaličky, and Ústí. Simultaneously, the wide and branching nature of the river enables

Fig. 3. Widening of the Bečva river allowed the creation of gravel bars (Source: Morava River Basin Management)

Fig. 4. A polder protects Němčany from floods – inlet to the reservoir in the foreground (Source: Nadace Partnerství – Adapterra Awards, photo: V. Herout)

the transition of surface water to groundwater. In this way, the landscape can store water for the dry season.

Slowly draining water is a sign of a healthy landscape. In particular, the landscape of South Moravia – but also other areas in the Czech Republic – suffer from drought due to large areas of intensive agriculture. The arid landscape cannot absorb water in the event of rainfall. Water runs off the surface, taking the most fertile topsoil with it, resulting in less organic matter in the soil and less fertile fields. The rapid runoff of water over the surface again causes floods. An effective solution to these problems are semi-natural anti-flood measures.

Flood protection has been implemented, for example, in Němčany (*Fig. 4*). Thanks to a series of eleven consecutive semi-natural measures, the village is protected from flood, which it had had to deal with for a long time. On the slope above Němčany, water is gradually retained by biocorridors, anti-erosion barriers, and ditches created along the road and across the opposite slope. The water that is not retained flows via a runoff channel into a grassy river bed and further through a dry polder into a reservoir with a constant level. When the water level is higher, the water is diverted from the polder through a side safety overflow and subsequently from the reservoir into the local watercourse, which ensures a regulated and safe water flow in the village.

Additional examples of good practice can be found in the freely accessible database at www.adapterraawards.cz.

Nominations for successful solutions for the sixth year of the Adapterra Awards competition are currently underway. You can join too.

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ISSN 0322-8916 (print), ISSN 1805-6555 (on-line)

Watermills and windmills as a meeting place

There were many attempts in the past to establish a holiday of Czech mills, which could be related to the holiday of St. John of Nepomuk or even lesser-known saints such as St. Senan or St. Vinok. Therefore, our colleagues Rudolf Šimek (for watermills) and Jan Doubek (for windmills) agreed to organize a joint event for the anniversary of the creation of the legendary mill emblem on 13th May 1116. They also invited archivist and molinologist Jan Škoda to cooperate and approached the owners of several mills to see if they would support the event. There was a wave of very positive reactions, so they decided to organize a big event called Mill Open Day, which will take place on Saturday 11th May this year.

They were inspired by the mill open days which are organized in surrounding European countries, but also elsewhere in the world. For example, in Austria last year the of Mill Open Day was held for the first time and 61 mills took part in it. The purpose of the Czech event is to make people aware of the fact that watermills and windmills are one of the most important inventions of mankind and to open to the public many normally inaccessible buildings with their often very interesting stories. As the organizers emphasize, it will be up to the property owners how they want to present their mill. As part of the event, the mills that are open to public can, for example, reduce the entrance fee, diversify the tour, or show otherwise inaccessible areas. However, the mills that are normally closed or rarely accessible will be the most interesting for the visitors.

During March, Rudolf Šimek and Jan Doubek gathered interested water and wind millers and created a filter in the databases www.vodnimlyny.cz and www.povetrnik.cz, which now contains mills that will participate in the event. In addition to the above-mentioned websites, the event is also promoted on the Milujeme vodní mlýny (We love watermills) Facebook group, where approximately three thousand members are already discussing the mills. Both organizers of the event have a common motto: "Let's make the mills a place to meet and talk, just as they were in the old days."

Fig. 1. Watermill in Slup (Photo: R. Šimek, 2017)

Anyone interested in participating in the Mills Open Day on 11th May 2024 can contact its organizers directly:

Mgr. Rudolf Šimek – watermills
✉ info@vodnimlyny.cz

Ing. Jan Doubek – windmills
✉ doubek.mlyny@vetrnemlyny.info

Everyone is cordially invited.

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ISSN 0322-8916 (print), ISSN 1805-6555 (on-line)

Fig. 2. Manor Mill in Starosedlský Hrádek (Photo: R. Šimek, 2017)

Fig. 3. Satran's Mill in Vepřek (Photo: R. Šimek, 2021)

Fig. 4. Whole-wooden windmill of German type, Starý Poddvorov (Photo: J. Doubek, 2020)

Fig. 5. Windmill of Dutch type, Kuželov (Photo: J. Doubek, 2017)

Fig. 6. Small windmill with a turbine, Václavovice (Photo: J. Doubek, 2019)

Obr. 1. The Elbe river in Děčín, the Thun-Hohenstein castle and the Tyrš bridge arch (Photo: D. Fiala)

The Czech Republic chairs the International Commission for the Protection of the Elbe River for the next three years

In Magdeburg on 16th January 2024, the handover ceremony took place of the presidency of the International Commission for the Protection of the Elbe River (ICPER). The Czech Republic took over from the Federal Republic of Germany for the next three years. Ing Tomáš Fojtík, who is Director of T. G. Masaryk Water Research Institute (TGM WRI), was appointed as the new president with the agreement of the contracting parties. The TGM WRI employees are internationally recognized and long-term leaders, spokespeople, and members of working groups and expert groups, who significantly participate in the Commission's activities and direction. This fact underlines the significance and importance of this research organization of the Ministry of the Environment as well as the actual research. Since the ICPER establishment in 1990, Ing. Tomáš Fojtík is the fifth president of the Commission from the Czech Republic.

The task of the new president will be to support the activities of working groups and expert groups within the ICPER, especially in the implementation of the EU Water Framework Directive and the Floods Directive. He will also focus on the issue of sediments and nutrients and the development of the International Elbe Monitoring Programme, the International Elbe Warning and Alarm Plan, and the Special International Elbe Monitoring Programme for monitoring water quality in the event of an extreme hydrological situation.

Ing Tomáš Fojtík says to his appointment: "For me, the appointment to the position of the ICPER president is a great honour, but also a commitment. International cooperation has always been important to me, because only through it can we contribute to the overall improvement of the environment. Our efforts in this area should have no boundaries because water does not know them either."

Although this year ICPER only organizes internal events, in 2025 it is planning to hold two important water management events aimed at the general public as well. The first is the International Elbe Forum, which will be held in Ústí nad Labem on 2–3 April 2025. The Elbe Forum aims to support the compilation of the International Management Plan for the Elbe River Basin District and at the same time contributes to mediating planning results and their implementation. Since 2013, the Forum has also been used for the implementation of the Floods Directive and the elaboration of the International Flood Risk Management Plan for the Elbe River Basin District. The second important event, which will take place in 2025 under the Czech Republic's presidency, is Magdeburg Seminar on Water Protection. It was first held in Magdeburg in 1988, and since 1992 it has been held alternately in the Czech Republic and Germany. Over the years, it has gained a reputation as one of the most important professional and scientific events in the field of water protection in the Elbe basin. The attractiveness of the seminar is evidenced by the number of active participants. In 2023 alone, 190 interested parties from the Czech Republic and Germany accepted the invitation. The Magdeburg Seminar on Water Protection 2025 will be held on 8–9 October.

Obr. 2. The Magdeburg Cathedral on the sandstone rock Domfelsen, which forms the dreaded rapids in the Elbe river (Photo: D. Fiala)

Author

Ing. Josef Nistler
Source: www.ikse-mkol.org/cz/

ISSN 0322-8916 (print), ISSN 1805-6555 (on-line)

ICPER was founded on 8th October 1990. In addition to the Czech Republic and the Federal Republic of Germany, the founding and contracting parties also include the European Union, which was a contracting party to the ICPER until 30th April 2004; that is, until the date of the Czech Republic's entry into the European Union on 1st May 2004. The main goals of ICPER activities are water use, primarily enabling drinking water from bank infiltration and agricultural use of water and sediments, achieving the most natural ecosystem possible with a healthy abundance of species and, last but not least, permanently reducing the load on the North Sea from the Elbe basin.

VTEI/2024/2

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A scientific bimonthly journal specialising in water research. It is included in the List of peer-reviewed non-impacted periodicals published in the Czech Republic.

Volume 66

VTEI.cz

Published by: Výzkumný ústav vodohospodářský T. G. Masaryka, veřejná výzkumná instituce, Podbabská 2582/30, 160 00 Praha 6

Sources of photographs for this issue:
VÚV TGM, 123RF.com, shutterstock.com, doc. RNDr. Jan Unucka, Ph.D., Mgr. Daniel Fiala, Mgr. Rudolf Šimek, Ing. Jan Doubek, Vojtěch Herout

Graphic design, typesetting and printing:
ABALON s. r. o., www.abalon.cz

Number of copies: 400.
Since 2022, the VTEI journal has been published in English at https://www.vtei.cz/en/

The next issue will be published in April 2024.
Instructions for authors are available at www.vtei.cz

ISSN 0322-8916
ISSN 1805-6555 (on-line)
MK ČR E 6365

WATER ELEMENTS IN THE LANDSCAPE (NOT ONLY) AS FEEDERS FOR ANIMALS

Aquatic and semi-aquatic transitional ecosystems are an important element in the landscape, not only from the point of view of the dynamics of water circulation in the landscape, but also biodiversity. In addition to the direct influence on vegetation and plant communities (the so-called trophic and hydric series of geobiocenology and forest typology), they have a significant function regarding the occurrence of ecotones (transition zones), biocentres, biocorridors, and interaction elements in the landscape. Many species of invertebrates are closely bound together with vegetation to these transitional ecosystems. And if we look away from this professional framework, it is extremely important if there are enclaves in the landscape in dry periods that function as feeders for animals and also as elements that improve the microclimate and the local climate. Camera trap images from the Czech Republic, Slovakia, and other European countries show how attractive these feeders are for forest animals and wild animals. It is interesting to observe the daily course of these visits, when red deer, roe deer, and fallow deer, wild boar, as well as smaller (badgers, foxes) and larger (wolves, bears) animals alternate in practically regular rhythms. The importance of small water bodies in the landscape is far greater than we often realize in today's hectic times. It is therefore not surprising that the importance of these permanent or even periodic water bodies in the landscape is also emphasized by the team of authors under the leadership of Otakar Štěrba in the book Říční krajina a její ekosystémy (River landscape and its ecosystems) (2008). Among other things, the book mentions that what we observe in the landscape of the Czech Republic on a small scale is the equivalent of the African Okavango Delta and similar systems on a larger scale.

Text and photo provided by doc. RNDr. Jan Unucka, Ph.D.

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