

## HYDROMORPHOLOGICAL METHOD AND GIS TOOLS WITH A WEB APPLICATION TO ASSESS A SEMI-NATURAL URBANISED RIVER

Dawid BEDLA<sup>1\*</sup>, Wiktor HALECKI<sup>2\*</sup>, Karol KRÓL<sup>3</sup>

<sup>1</sup>*Department of Ecology, Climatology and Air Protection, University of Agriculture in Krakow,  
al. Mickiewicza 24/28, 30-059 Kraków, Poland*

<sup>2</sup>*Department of Hydrology, Meteorology and Water Management, Faculty of Civil and  
Environmental Engineering, Warsaw University of Life Sciences, ul. Nowoursynowska 166,  
02-787 Warsaw, Poland*

<sup>3</sup>*Department of Land Management and Landscape Architecture, University of Agriculture in Krakow,  
ul. Balicka 253c, 30-149 Kraków, Poland*

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### Highlights:

- ▶ Plugin CraftMap is a tool to publishing web application of hydromorphological features.
- ▶ River habitat survey is an appropriate method for a new developed public urban park.
- ▶ GIS technique may be use to semi-urbanized river, green space and landscape planning.
- ▶ Web application integrates hydrological habitat assessment and GIS technique.

**Abstract.** River valleys are an essential element of urban space, and play an important role in the functioning of the natural environment and the recreation of city dwellers. Moreover, blue-green infrastructure facilitates healthy urban living. New technologies can contribute significantly to dissemination of messages of environmental protection. We discuss adaptation of the RHS method for presenting interactive data for river channels. Our assessment was focused on three parameters: habitat area, structure and conservation. The main parameters were described using selected indicators linked to natural and anthropogenic factors. The habitat modification score showed that the physical state of the Drwinka River was obviously modified, and the habitat quality assessment rated the stream as hydromorphological class III. The web application showed that the proposed method is suitable for creating realistic visual effects, and indicates greening areas against degraded areas.

**Keywords:** green-blue infrastructure, hydromorphology, interactive visualisation, landscape management, river park, urban ecosystems.

### Introduction

The contemporary diversity of valleys and riverbeds is the result of enduring processes occurring in entire river basins and in the channels themselves (Liu et al., 2019a). When assessing their condition, particular attention should be paid to the course and form of the channel, the width and depth of the cut, the type of bank and the channel bottom, and the flood plain (Mokwe-Ozonzeadi et al., 2019). Valleys and river channels in the natural or slightly transformed state caused by human activity

(Halecki et al., 2019) are characterised by typical faunal and floral assemblages, as well as high variability in hydrological (Mor et al., 2019) and physiographical conditions (Halecki et al., 2018a). The species diversity of river valleys and riverbeds is generated directly by, among other factors, heterogeneity in hydrological features and soil conditions, and indirectly by flooding episodes and anthropogenic modifications (Anim et al., 2019; Yan et al., 2019). River valleys also play a role as ecological corridors, especially in valuable ecosystems, such as alluvial forests, alder forests, meadows, pastures, wetlands, peat bogs, and

\*Corresponding author. E-mails: [d.bedla@ur.krakow.pl](mailto:d.bedla@ur.krakow.pl); [wiktor@mailmix.pl](mailto:wiktor@mailmix.pl)

oxbow lakes (Jankowski, 2001). Well-developed urban river valleys are designated for silence, seclusion, relaxation, leisure, and sport for local residents. To determine the level of anthropogenic pressure on river valleys, an evaluation of their natural attributes should be carried out (Operacz et al., 2018, Spilková & Rypáčková, 2019). In addition, appropriate management of the river valley allows for the display of natural elements and the surrounding architectural and urban ecosystem (Guo et al., 2019; Miao et al., 2019; Kaleta et al., 2019). All these factors have become important for people engaging in leisure activities near waterfronts. In addition, an adequate quality of the surface water, without odours and noise, is required by society (Bernat, 2010).

In recent years, interactive forms of mobile applications have been commonly accepted, especially for using online resources (Król, 2015b; Zhou et al., 2019). Basic websites have been replaced by applications co-created by producers, who have collaboratively developed content available on the internet (Bruns, 2009). These changes have been accompanied by dynamic development of web cartography, geo-visualisation, as well as an increase in the availability of geoinformation web services (Iosifescu-Enescu et al., 2010). “Mashup websites”, which combine thematic data with a map made available by geodata providers, are commonly recommended (Yu et al., 2008). In addition, visualisation of spatial data has become diverse, and has adopted advanced forms. Users often create and share their own ideas. This is a result not only of technological development, but also of the expectations of users who are eager to participate in the process of co-creating and improving mapping applications (Flanagin & Metzger, 2008). Digital cartographic resources, applications, and internet services are constantly being developed, which allow for incorporation of interactive maps in an automated way (Gonzales et al., 2009).

Pro-environmental education can be implemented by web applications based on scientific knowledge. The main objective of this study was to use RHS method to construct a new approach in landscape design of urban park. Moreover, our goal was to disseminate on-line browser to integrate GIS technique and field study for urban park.

The aim of the study was to assemble a new approach in landscape design of urban park. Moreover, our goal was to disseminate on-line browser to integrate GIS technique and field study for urban park. The River Habitat Survey (RHS) method (Szozkiewicz et al., 2012) was used for the field research, which was based on: (i) development of a web application for monitoring the watercourse in valuable natural areas in the urban agglomeration; (ii) identification of vegetation types in the riverbed and covering the banks and an area within 50 m from the bank top; (iii) calculation of indicators, such as Habitat Modification Score (HMS) and Habitat Quality Assessment (HQA); and (iv) spatial evaluation and analysis using GIS and hydro-morphological characteristics of the reference site.

## 1. Materials and methods

### 1.1. Characteristics of the research area

The geographical and administrative area of Kraków is located in the central-western part of the Małopolska Province in the south of Poland (Figure 1). The area of the city is 326.85 km<sup>2</sup>, and the population, according to 2018 data, is 769,498 (Central Statistical Office, 2018). Kraków has a moderate climate, which is characterised by frequent weather changes. The average annual air temperature is 8.7 °C. The hottest months are July and August, with an average temperature of 18–19 °C. From November to March, the average monthly temperature drops below 0 °C. Winter lasts about 70 days, summer about 100 days, spring about 62 days, and autumn about 64 days. The average annual precipitation in Kraków is 679 mm/m<sup>2</sup>. The maximum rainfall occurs in July, with about 100 mm/m<sup>2</sup>, and the lowest precipitation is in January or February (Institute of Meteorology and Water Management – National Research Institute, 2016). A characteristic of this area is the frequent occurrence of days with very warm weather with precipitation (during the year this is about 34 days). In the geological context, the sediments of the Kraków agglomeration originated in the Miocene Sea (Kondracki, 2011).

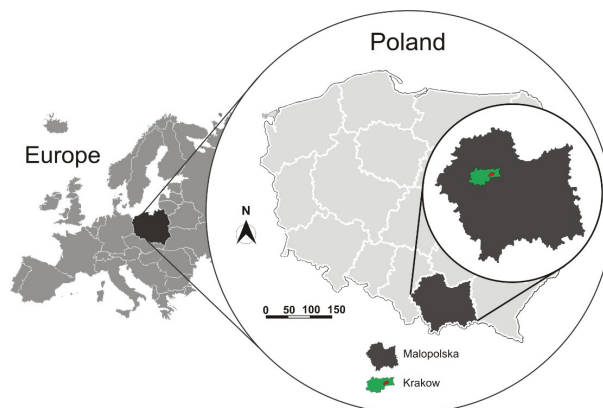


Figure 1. Location of the Drwinka River in Kraków

The Drwinka River, 5.9 km in length, is a tributary of the Drwina Długa, which, in the city of Kraków, flows into the Vistula. The stream has the legal status of a municipal river park. The upstream is characterised by high naturalness, interesting terrain, and erosional gorges. In addition, the stream is characterised by high variability of the pebble and cobble substrate (Antosiewicz, 2005). Three types of soils occur in the area of the Drwinka Valley: acidic, gley, and industrial. Acid brown soils are commonly found in the southern part of Kraków, on sandy formations with a pH not exceeding 5.0, in areas exposed above the bottom of the watercourse. Physical attributes were measured at sites on a uniform section not impounded by weirs.

Three basic plant communities have been identified in the valley of the Drwinka River. The first group includes black alder (*Alnus glutinosa*), grey alder (*Alnus incana*),

European ash (*Fraxinus excelsior*), white willow (*Salix alba*), common oak (*Quercus robur*), European white birch (*Betula pendula*), Norway maple (*Acer platanoides*), and European elder (*Sambucus nigra*). The second group consists of fallow communities: dry sandy grasslands (Sedo-Scleranthetea) and thermophilic xerothermic communities (Trifolio-Geranietea). The third group includes garden plots and orchards, which dominate in the southern part of the Drwinka Valley. Most of the plant communities are well maintained.

## 1.2. Fieldwork and data handing

The research site was located on the Drwinka River in the Piaski Nowe estate in Kraków. Fieldwork was carried out in a completely visible channel, on the right bank. The geographical coordinates of the first spot check were 50°00'890"N and 19°58'74"E, while of the last were 50°00'891"N and 19°58'972"E (Figure 2). The RHS form was filled in during the research survey, after adapting it to Polish abiotic river types. Four sections were covered: (A) background map-based information; (B) field survey details; (C) predominant valley form; and (D) number of riffles, pools, and point bars. The other side of the RHS form contained detailed characteristics of each of 10 control spot-checks (10×50 m along the river). Before the start of the study, a site was established at the top of the watercourse, and subsequent spot-checks at regular 50 m intervals. This part of the survey involved three sections of the RHS form: (E) physical attributes; (F) bank-top use and vegetation structure; and (G) channel vegetation. The third stage of the RHS field form consisted of four sections: (H) land use within a 50 m wide area of the bank top; (I) bank profiles; (J) extent of trees and associated features; and (K) extent of channel features. The last stage of fieldwork consisted of a synthetic description of the whole 500 m site, involving all natural morphological elements and anthropogenic modifications occurring in the

riverbed, but not recorded during the reporting of control spot checks, including description of the valley, land use, bank spot checks, tree stands and morphological elements accompanying them, channel dimensions, and valuable elements of the river environment. The last stage of the research was an assessment of the hydromorphological state of the Drwinka River.

## 1.3. Calculation of indicators for ecological quality

The RHS system allows collection of over 400 parameters based on hydromorphological features (Zieliński et al., 2012). Using the indicators HMS and HQA (Szozkiewicz et al., 2009), the river was classified into one of five hydromorphological status classes in accordance with the requirements of the European Union Water Framework Directive 2000/60/EC (WFD).

HMS describes the total degree of anthropogenic changes that affect the hydromorphology of the watercourse, including all transformation structures recorded in the RHS method. The indicator includes such parameters as: number and degree of environmental impact of particular types of structural modification (culverts, weirs, bridges, etc.) and downstream changes in the river (resectioning, trampling of riverbanks by people, reinforced banks, embankments, etc.); and poaching of the banks and the bottom of the channel (Szozkiewicz & Gebler, 2012). The HMS index reaches values in the range from 0 to 100. An analysed site characterized by small modifications to hydromorphological features has a low HMS value. On the other hand, high HMS values indicate strong hydromorphological modification of the watercourse (Szozkiewicz et al., 2009).

HQA describes the diversity of natural morphological elements of the watercourse and river valley. The indicator includes such parameters as: flow types (free fall, chute, broken standing waves, unbroken standing waves, rippled, upwelling, smooth, and no perceptible flow);

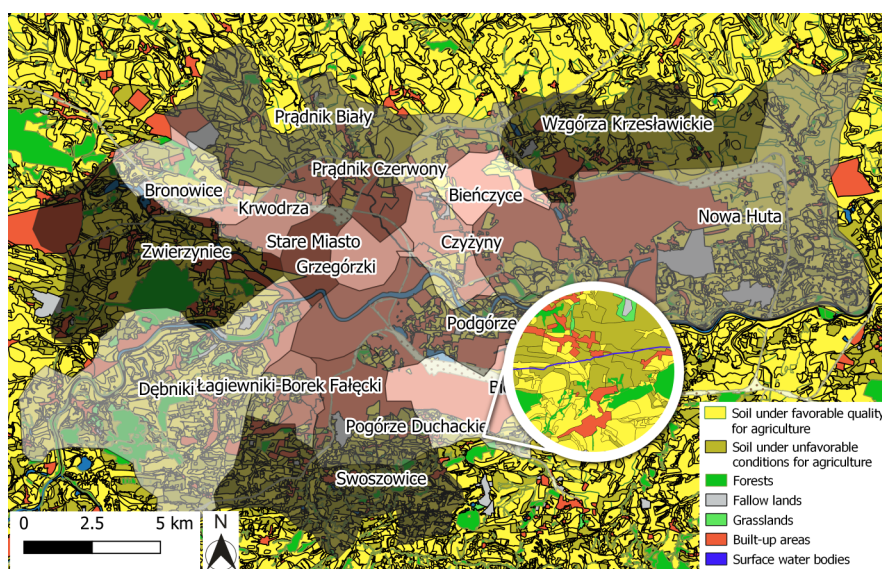


Figure 2. The study site based on soil and agricultural maps (soil classification is described in the text)

bottom material (bedrock, boulder, gravel, sand, mud/silt, clay, peat); natural morphological channel elements (bedrock, exposed boulders, un/vegetated mid-channel bars, mature islands, natural accumulation, beaver ponds); natural morphological elements of the banks (eroding or stable earth cliffs, un/vegetated point bars, and un/vegetated side bars); coastal vegetation, meanders, groups of aquatic plants (liverworts and mosses, submerged broad-leaved, submerged linear-leaved, floating leaved (rooted), amphibious, submerged broad-leaved, and submerged fine-leaved plants); land use within the 50 m wide transect from the top of the bank (deciduous/mixed forests, coniferous forests, wetlands); tree stands and morphological elements (overhanging boughs, exposed bankside roots, underwater tree roots, fallen trees, coarse woody debris); and valuable natural elements of the river environment (braided/side channel, leafy debris, natural reservoir, marsh, and bog). The HQA index reaches values in the range from 0 to 136; however, in Polish rivers these values usually range from 15 to 80. The RHS method was chosen because it meets the requirements of the WFD (2000). After analysing the natural and anthropogenic elements present in the watercourse, the indicator values, as well as the quality of the water, were comprehensively assessed for the Drwinka River. The perspective of performance was determined on the basis of a comparison between the current state of the structure and function of the habitat and future impacts.

#### 1.4. Conducting research using spatial analysis methods

Research using the RHS method is multi-stage and requires appropriate materials and equipment: a field form, spot-check key, geodesic staff, camera, and GPS. The first stage of the research consisted of an analysis of the topographical background, orthophotomaps, aerial photographs, and generally available GIS data. The analysis was carried out to assess the anthropogenic pressure on the river valley. Based on human modification of the river valley, three land-use groups – urban, agricultural, and semi-natural – were determined. Each land-use group was located within a 100 m wide and 500 m long site adjacent to the river valley, and covered more than 25% of the area.

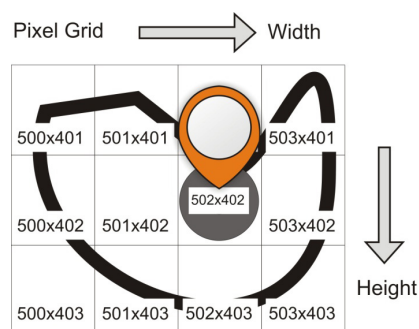


Figure 3. Scheme of placement of points of interest (POI) on the map using the “width” and “height” attributes of the pixel position (draft)

#### 1.5. Technological concept – prototype of mobile applications

It was assumed that the graphic form of the component could be raster maps presented in a dynamic and interactive way. To create the application, the CraftMap plug-in was chosen, which is a tool for publishing web applications of environmental data (Król, 2015a, 2016). It uses jQuery JavaScript, HTML and CSS programming languages, and is free for non-commercial use.

The points of interest (POIs) were located on a raster basis with the position of attributes “width” and “height” presented in each pixel (Figure 3). POIs are interactive and can provide multimedia information. The view is displayed at the user’s request in a pop-up window. Tool functionality was extended in order to combine multimedia information with the indicated check point in the river park. The main drawback of such a solution is the need to manually programme the location of information points, which requires interference in the source code. CraftMap provides smooth browsing of raster graphics; however, it does not enable an interactive approximation of the map view using smooth zoom. The application was created using CraftMap based on one image (in the raster file form). Navigation is connected to graphical user interface in a pop-up window (Figure 4). Raster resolution and file compression are prone to decrease the quality of attributes generated with CraftMap. It also depends on the raster type file and the graphic method of presenting the

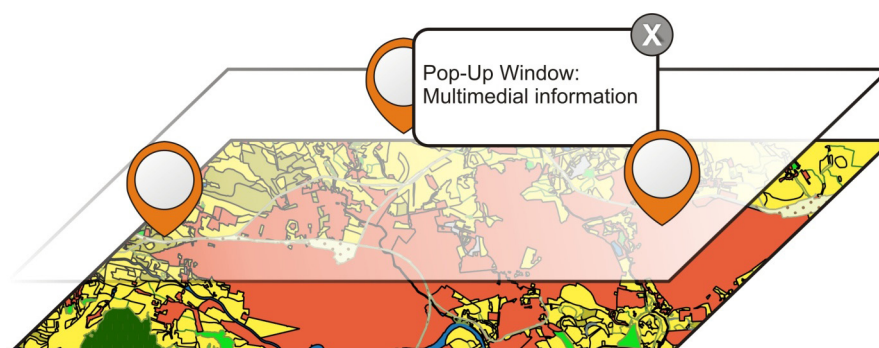


Figure 4. Scheme of points of interest (POI) implementation on a layer performed with the CraftMap script (overview draft)

colour and scale of the map. Therefore, the usability of the application is determined by the quality of the graphic background and the scope of information assigned to the raster.

## 2. Results

### 2.1. Assessment by the River Habitat Survey method

To assess the natural values of the Drwinka River, the British RHS method was adapted to Polish abiotic river types (Figure 5). The floodplain area of the valley dominates in the 500 m site, with a lack of natural river terraces. There were five riffles, five pools and plunge pools, four unvegetated point bars, two mid-channel vegetated point bars, and an eroding earth cliff. There were no artificial features, such as weirs, sluices, deflectors or outfalls.

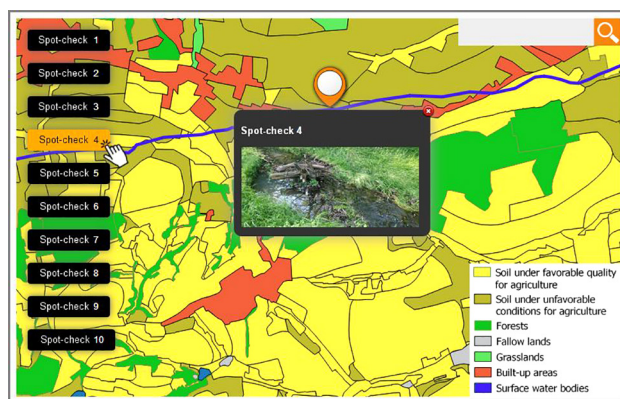


Figure 5. Interactive presentation of the spot checks in the Drwinka River Park in Kraków using CraftMap (soil classification is described in the text)

#### Spot check 1

In the first control spot check, the left bank was made of sand and gravel, while the right bank was of earth. The natural morphological element noted for the left bank was a meandering bend not covered by vegetation, and for the right bank an eroding undercut (photo 1). The flow type was rippled and the material of the bottom was sand. There were no modifications to the channel bottom and no natural morphological elements. In the 5 m wide transect from the top of the left and right banks, there were shrubs, and the vegetation cover of the top and slope of both banks was of a uniform structure. The channel vegetation types were liverworts, mosses, and filamentous algae.

#### Spot check 2

Both banks were made of soil (humus layer), and the bed was multi-faceted. The natural morphological element of the left bank was an unvegetated point bar. Within the analysed control cross section, smooth flow dominated, and the material of the bottom was sand. The natural morphological element of the bottom was an unvegetated mid-channel bar. In the 5 m wide transect from the top of the left and right banks, there were shrubs, and the top

and slopes of both banks were covered in vegetation of a uniform structure. The channel vegetation was dominated by submerged linear-leaved species.

#### Spot check 3

In this spot check, the left bank was made of earth (humus layer), and reinforced with a fascine fence. The flow was dominated by unbroken standing waves, and the stream bottom consisted of a boulder pressed into the bottom of the channel. In the 5 m wide transect from the top of both banks, there were shrubs, and the summit and slopes of both banks were overgrown with vegetation of a uniform structure. The channel vegetation was dominated by liverworts, mosses, and submerged linear-leaved plants.

#### Spot check 4

This control spot check found that the left bank was of earth (humus layer), and reinforced with a fascine fence. A rippled flow predominated, and the stream bottom consisted of boulders pressed into the channel. In the 5 m wide transect from the top of the left and right banks, there were numerous trees, and the top and slopes of both banks were overgrown with vegetation characterised by a uniform structure. The channel vegetation was dominated by liverworts, mosses, and submerged linear-leaved species.

#### Spot check 5

In this spot check, the left bank was of earth (the humus layer), while the right bank was a reinforced artificial ford. There was a natural side bar in the stream bed (photo 4) formed of fragments of trees and branches. A rippled flow predominated, and the material of the stream bottom was boulders pressed into the bed. In the 5 m wide transect from the top of the left and right banks, there were shrubs, and the top and bank face were overgrown with vegetation of a uniform structure. The channel vegetation was dominated by liverworts, mosses, and submerged linear-leaved and filamentous algae.

#### Spot check 6

The stream banks were built of earth (the humus layer). In the stream bed, there was an unvegetated mid-channel bar, and remnants of the fascine fence reinforcements (photo 5). Smooth flow dominated, and boulders formed the bottom material. In the 5 m wide transect from the top of the left and right banks, there were trees and shrubs, and the top and slopes of both banks were covered with vegetation of a uniform structure. In the stream bed, submerged linear-leaved and filamentous algae predominated.

#### Spot check 7

The material of the stream banks was earth (the humus layer). A natural element was an eroding earth cliff (right bank). Smooth flow predominated, and boulders were pressed into the bottom of the stream bed. In the bed, there was an unvegetated mid-channel bar. In the 5 m wide transect from the top of the left and right banks,

there were trees and shrubs, and the top and slopes of both banks were overgrown with vegetation of a uniform structure. The channel vegetation was dominated by liverworts, mosses, and submerged linear-leaved and filamentous algae.

#### Spot check 8

In this spot check, the banks were reinforced with a fascine fence. Smooth flow prevailed and a boulder was the bottom material. In the 5 m wide transect from the top of the left and right banks, there were numerous trees and shrubs, and the top and slope of both banks were overgrown with vegetation of a uniform structure. The channel vegetation was dominated by liverworts, mosses, and submerged linear-leaved and filamentous algae.

#### Spot check 9

In this spot check, the bank material was earth (the humus layer). The natural element on the right bank was an eroding earth cliff. In the 5 m wide transect from the top of the left and right banks, there were shrubs, and the bank faces and tops were covered with vegetation of a uniform structure. The flow was dominated by riffles, and the bottom material was boulders. The channel vegetation was dominated by liverworts, mosses, and submerged linear-leaved.

#### Spot check 10

In the last spot check, the banks were reinforced with a fascine fence. The flow was dominated by riffles, and the bottom material was boulders. In the 5 m wide transect from the top of the left and right banks, there were shrubs, and the top and slopes of both banks were covered with vegetation characterised by a uniform structure. The channel vegetation was dominated by liverworts, mosses and submerged broad-leaved, submerged linear-leaved, and filamentous algae.

## 2.2. Physical attributes

Characteristics of the basic morphological parameters and control spot checks showed that in the Drwinka River, both banks in all sites were of earth, but there were also fascine fence reinforcements. The dominant material of the bottom, such as gravel and cobble, and sand in three control spot checks, was evidence of recent management. The flow type in the watercourse, according to the RHS methodology, was classified as rippled (no waves) and smooth (no eddies). In the case of natural morphological elements of the watercourse, only vegetated mid-channel bars, point bars, eroding earth cliffs, and coarse woody debris were observed. Vegetation within 5 m of the right and left bank tops consisted mainly of shrubs. Bank faces, however, were covered with only structurally simple vegetation. In the channel, liverworts, mosses and submerged linear-leaved and filamentous algae occurred. Within 50 m of the left and right bank tops, numerous shrubs, tree stands (mainly alder), and wetlands were registered.

Across the site there was a suburban area. On the left-side bank, broadleaf woodland was noted, while the right side was dominated by scrub and semi-improved grassland. Morphological elements accompanying trees were uncovered and underwater roots and woody debris. Banks tops were mostly trampled or partly reinforced by fascine fence. No valuable natural elements were recorded on the test site and no invasive plants were found. In many places, municipal waste, originating probably from the neighbouring settlements, was noted.

## 2.3. Indices of hydromorphological features

The data collected from field research were used to determine the hydromorphological features of the watercourse. The presence of natural elements and their diversity were a measure of the naturalness of the river habitat. The indicator of naturalness from the HQA is presented in Table 1. HQA was determined on the basis of the analysis of natural elements recorded in the RHS field form (Figure 6). For downstream, the natural elements that had the strongest influence on HQA values were from four categories: flow type (smooth and rippled); other morphological elements (woody debris, underwater tree roots, piles of leaves, etc.); aquatic vegetation; and unvegetated or vegetated point bars. The overall HQA score was 46 from the analysis of the above parameters: flow type – 7; channel substrate – 2; channel features – 4; bank features – 5; bank vegetation structure – 5; point bars – 3; in-stream channel vegetation – 8; land use within 50 m – 0; trees and associated features – 7; and special features – 5.

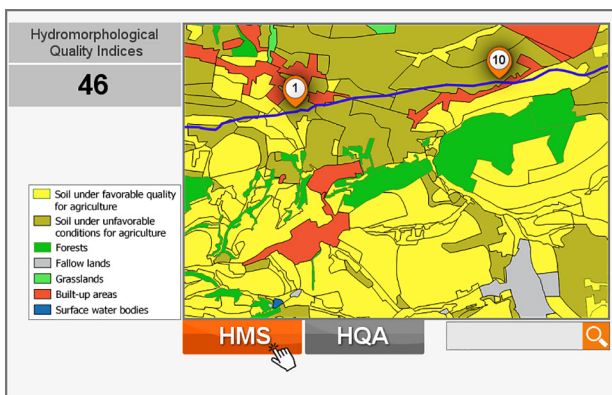


Figure 6. HMS and HQA indices (soil classification is described in the text)

Table 1. The HMS score for a reference site (adopted from: Environment Agency, 2003)

		Score per site
Modifications not recorded at spot-checks	Culvert	8
	Reinforcement to bed	6
	Reinforcement to banks	2
Modifications at spot-checks	Reinforced whole banks	1
	Reinforced top only	2

Based on the index value obtained from HQA, the stream was classified as moderately natural. As in the case of the naturalness assessment of the river habitat, field studies made it possible to collect data on anthropogenic pressure such as reinforcement.

The HMS conversion rate was determined based on the analysis of all forms of anthropogenic changes recorded in the RHS form (Table 2). For the “Drwinka River Park”, elements of two parameters had the strongest influence on the index value: bank modifications (reinforcements, trampling by local citizens); and changes to the channel (fascine fence reinforcements) and bottom (boulders, cobbles) caused by human activities. The HMS score was 19; the most important contributory factor was modification of the banks and channel – 16, and material introduced to the stream bottom – 3. On the basis of the HMS index, the Drwinka River was classified as obviously modified. Based on the HQA and HMS values, as well as assessment criteria used in the RHS method, water quality class and hydromorphological features of the Drwinka River were determined. The results are presented in Table 3.

Table 2. The HQA score for a reference site (adopted from: Environment Agency, 2003)

Parameter	Score per site
Flow type	0–13
Bank material	0–10
Natural elements of the river channel	0–18
Natural elements of the river banks	0–31
Bank top vegetation structure	0–12
Material deposition	0–2
Channel vegetation types	0–12
Land use within 50 m of banktop	0–14
Extent of trees and associated features	0–19
Extent of channel features	0–5

### 3. Discussion

Assessment of natural resources usually involves more than one type of environment, and is performed using organisms naturally occurring in local habitats such as rivers. The scoring system is a simplified technique that determines the condition of the river, and helps forecast ecological threats. Interactive presentation of environmental data on land use and water resources in urban ecosystems can have an educational and informational role in river park conservation, leading to protection of the local landscape in settlement areas. This proposed tool may be used for creating detailed databases of hydromorphological features, and can be fully implemented in long-term environmental management. The environmental assessment also considered the value of green open space in the city area.

#### 3.1. Advantages and disadvantages of the River Habitat Survey method in the city

The RHS method can be used to assess natural values on the basis of hydromorphological features of watercourses. In Poland, this system is used in monitoring and protecting river valleys, watercourse restoration, calibration of biological methods, and to assess hydromorphological features of rivers according to the WFD. In addition, it meets the requirements of the European Committee for Standardization (Boon et al., 2010). The river valley appraisal can be complemented by characterisation of elements of the abiotic factors, which increases the attractiveness of the surveyed object (Stachura et al., 2014). Vegetation as ecological indicators for stream restoration success is often based on the study of habitat types (Zarzycki, 2009). Based on inventory and assessment of natural habitats, we can obtain information on location of river valleys with priority habitats, and map the distribution and conservation of natural habitats (Obidziński & Żelazo, 2009; Heasley et al., 2019). Rivers with high appraisal values are characterised by a large number and high diversity of natural

Table 3. Hydromorphological scoring system based on categories for describing the physical state of the river channel semi-natural includes pristine channels (Jusik & Szoszkiewicz, 2009)

			Semi-natural	Predominantly unmodified	Obviously modified	Significantly modified	Severely modified
			HQA scoring				
			57	50–56	37–49	30–36	<30
Semi-natural	HMS scoring	0–2	I	II	II	III	IV
Predominantly unmodified		3–8	II	II	II	III	IV
Obviously modified		9–20	III	III	III*	IV	IV
Significantly modified		21–44	III	IV	IV	IV	V
Severely modified		45	IV	IV	V	V	V

Note: \*category scored for Drwinka River.

morphological elements (Szozkiewicz et al., 2009). A disadvantage of the RHS method is the failure to take into account the third WFD criterion, i.e. the average flows typical of a given watercourse occurring over the long-term (Ioana-Toroimac, 2018). The RHS method is most often used in assessing small- or medium-sized watercourses, where access to both banks is possible. Using HQA, it is difficult to assess components dominating the bottom and bank material, coastal vegetation structure, and vegetation type (Windsor et al., 2019). HMS is not related to optimal water resource allocation under the constraint of biological and hydrochemical elements, and, therefore, the results obtained using the RHS method are not fully reliable (Raczyńska et al., 2012). According to Osowska and Kalisz (2011), the RHS method is useful for assessing composition and abundance of benthic invertebrates, ichthyofauna, the relationship between river waters and groundwater, continuity of the watercourse, water body, thermal conditions, oxygenation and salinity, acidification, and biogenic substance content.

The riverbed should be visible. Partial visibility of the riverbed may be caused by the presence of rheophilic vegetation and planktonic algae (Szozkiewicz et al., 2012). The use of another method, Hydromorphological Features Monitoring of Rivers (MHR), can be used to avoid these problems. The MHR method is performed solely on the basis of four hydromorphological features: the hydrological regime, river continuity, river channel morphology, and the floodplain valley form (Ilnicki et al., 2011). The RHS method allows for appropriate assessment of urban rivers and river valleys subject to anthropogenic pressure (Hamerla & Pierzchała, 2016). According to Trząski and Mana (2008), the RHS method is useful for preliminary assessment of the natural values of rivers and river valleys of small watercourses. In addition, the RHS method should be applied to watercourses flowing through urban ecosystems. According to Szozkiewicz et al. (2009), the RHS method consists of assessment and classification of the ecological status of the watercourse in terms of hydromorphological features. Our results showed that areas adjacent to the Drwinka River influenced HMS and HQA indices (Tables 1, 2).

Our field study carried out using the RHS method classified the ecological condition of the Drwinka River as class III (see Table 3). A few natural morphological elements were observed along the entire length of the test section, which significantly reduced the score. The HQA score of 46 indicates a moderately natural stream. However, the HMS score of 19 resulted mainly from the reinforcement of the banks by fascine fences and the previous strengthening of the stream bottom with boulders. Mobile applications may prove to be a great support in assessing the values of river parks (Figure 5). This app presents a forecast for riverbed regeneration. To obtain relevant and reliable results, it is necessary to check the accuracy of data during and after field work.

### 3.2. River park on the Internet – information for local communities

Currently, there is a strong emphasis on development of green infrastructure (Møller et al., 2019) and ecosystem services (Speak et al., 2018). Another challenge is the effective management of water resources (Al-Jawad et al., 2019). The development of social and economic sectors (Artmann et al., 2019; Kim, 2019) and the need for information on disasters, e.g. floods (Bazan-Krzywoszańska et al., 2019), have stimulated the development of interactive tools. The results of field surveys can be disseminated in an attractive way using public and free computer techniques and tools. For the citizen, their greatest potential is in their application in the development of green infrastructure (Escobedo et al., 2019; Leonard et al., 2019), including interactive planning models (Vakilifard et al., 2019). Many mobile applications help in rational environmental management. Today's computer applications are user-friendly, and many are open-source web applications (Sanaa et al., 2019). As the culmination of field studies and various spatial analyses, we recommend the use of a web application to present and disseminate data, results, and conclusions from research. Our results suggest that GIS techniques have a unique ability to support web applications. Most of the described text functions can be configured to show hydromorphological features (Figure 6).

### 3.3. Evaluation of the natural quality of the river valley in the city

The concept of a smart city can have a significant impact on the comfort of people's lives. Social awareness depends on the consciousness of individuals, and is shaped by the influence of social processes integrating and synthesising available information (Chung et al., 2018; Bazan-Krzywoszańska et al., 2019). This is also related to the human impact on the surrounding environment (Halecki & Gąsiorek, 2015). The latest scientific achievements are aimed at combining land-use change and land cover with the potential for ecosystem services, both important for water quality (Verawaty et al., 2019). Tsoukalas and Makropoulos (2015) indicated that the potential of an area to provide regulating ecosystem functions decreases over time. Residents of larger cities and all who visit them regularly may consider installing an appropriate application for monitoring the state of the environment (Teixeira et al., 2019). Such applications are especially relevant for river systems, because the morphological features of a river do not undergo rapid changes if it is protected (Karahan et al., 2014).

Many web tools can be used for effective management in the city to protect the aquatic environment (Andersson-Sköld et al., 2018). Web applications for assessing water status and quality may be helpful. In intensively urbanised areas, these applications may show habitat features. Our application can be applied to solutions that refer to real-time monitoring of water pollution, and mobile technology



may be particularly useful in tackling this problem. However, because of their fluctuation and dynamics, physical parameters are difficult to obtain in aquatic ecosystems (Tian et al., 2019; Tong et al., 2019). Physical models are suitable for creating realistic and synthesised assessments (Gong et al., 2016; Zischg et al., 2018), especially to evaluate the quality of built-up areas (Li et al., 2019; Liu et al., 2019b). Our proposed application can be helpful for developing a large number of interactive assessments. A similar approach based on long-term hydrological data has been presented by Yang et al. (2015), and may be applicable to development of urban forestry and greening (Song & Wang, 2016), both providing important ecological services (Verawaty et al., 2019).

In recent years, there has been an increase in public interest in the threats to ecological systems, as well as an increased interest in various forms of social awareness (Allawi et al., 2019; Halecki et al., 2018b). Ecological modelling is an extremely useful tool to manage the environment. However, despite improvements, existing algorithms are still computationally expensive, which leads to time-consuming processes that are impractical for urban green managers and for application in field infrastructure for open green space (Escobedo et al., 2019). We present a new implementation of a selected set of mobile tools, directly referring to mutual interactions in space thanks to manually coded procedures and algorithmic optimisation. This study, based on hydromorphological features of a semi-natural urbanised river, provides a clear perspective on complex systems for assessing surface water values and corresponding indicators. Sharing information via web applications can increase ecological awareness and the interest of local communities in environmental protection at the local (urban) scale.

#### 3.4. Recommendations for the future

We recommend that results of the RHS method and tests based on biological indicators should be combined. Our findings are similar to those of Czerniawska-Kusza and Szoszkiewicz (2007) for the biological and hydromorphological features of the Mała Panew river. The results obtained by two different methods showed that the RHS is based on appraisal of habitat naturalness and physical modifications of the river. However, biological methods based on macro-invertebrate assemblages should also be considered, together with chemical characteristics of water quality. Czerniawska-Kusza and Szoszkiewicz (2007) unequivocally stated that a full presentation of the ecological status of rivers and river valleys require both methods simultaneously.

In addition, there should be a focus on introducing minor changes to watercourses, for example vegetation recovery in river channels (Kijowska & Wiejaczka, 2011). Small rivers or streams in the green infrastructure may be considered ecological corridors in the watercourse valley (Rozenau-Rybowicz & Baranowska-Janota, 2007). Effective planning designations for conserving river parks

have tremendous potential for local societies and residents. Development of vegetation in the Drwinka Valley may benefit local biodiversity (Halecki, 2017). It is difficult to identify a well-preserved stream or river, and to categories other aspects of water management. Although local communities can contribute to the presentation and dissemination of ready-made tools for green infrastructure, our application, enriched with hydromorphological features, is characterized by an individual approach to the user. We also recommend the use of our web application for sustainable river management. Moreover, we recommend avoiding the strengthening of river channels with solid anthropogenic materials such as concrete side banks. Revetments of natural elements are essential for increasing water retention in urban areas.

#### Conclusions

Expansion of cities with contextualised human–nature interactions in newly developed land is the target of government-oriented urban planning. The reason for maintaining the remaining largely unexplored areas is the preservation of valuable heterogeneous local environments. However, these semi-natural fragments have been pushed over to marginal unfavorable sites, while favorable sites have been replaced by agriculture and rapid urban growth and development. The hydromorphological features of the stream we studied was rated as class III. The RHS method is based on the inventory of well-defined elements of the river environment, and is precise and repeatable. It is suitable for assessment of small- and medium-sized watercourses to investigate the relationship between land use, water flow, and channel management in the urban agglomeration. The assessment of the hydromorphological features of the Drwinka River using the RHS method shows that this technique should be performed for inventory of engineering works as a preliminary exploratory survey of rivers. Moreover, identification of vegetation types in the riverbed and covering the banks and an area within 50 m from the bank top can be investigated. Several techniques and computer tools can be used to create interactive websites devoted to the issues of environmental protection. Therefore, we may calculate indicators, such as habitat modification score (HMS) and habitat quality assessment (HQA). Web applications can, therefore, have a special impact, particularly on the younger generations, by fulfilling an educational function through properly tailored messages. Users can apply content created in the interface, which is consistently shaped in the field, and input details and modify its functionality with their own ideas. Dedicated methods can be used not only for generating realistic static images, but also for tracking spatial analysis of the river channel. Hence, web cartography can be helpful for hydromorphological assessment in urban area. The detailed database may also be useful in long-term environmental management. Because the application integrates hydromorphological features and GIS techniques, decision-makers who

use it can alleviate a number of threats to the river. Consequently, researchers can prepare preliminary drafts of environmental data important for nature conservation by processing data on water resource management. Future solutions may include specification of benchmark sites as river parks in the urban area.

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