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BSc Zdeněk Hošek

Optimization of digital river network and its impact on catchment water management

Optimalizace digitální podoby říční sítě a její dopad na vodohospodářský management povodí

Diplomová práce

Vedoucí závěrečné práce: RNDr. Milada Matoušková, Ph.D.

Praha 2016

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V Praze, 12. 08. 2016

Podpis

Assignment

Title:

Optimization of river network dataset and its use in water management

Aim:

The main aim of the work is to compare existing digital river network datasets and their attributes and propose a method as a tool to allow to merge them into a single dataset. Then additional attributes will be suggested to achieve maximum purpose of the resulting dataset. The results should be useful to a project of river network unification in the Czech Republic initiated by the Ministry of Agriculture.

Suggested methodology:

Firstly, the existing river network datasets will be analysed and their differences identified. Then a primary field survey will be carried out in various locations to verify current state of river network and its representations in existing datasets. During the field survey will be collected supplemental data to allow development of a method which should be applicable without a necessity of field survey. Then the method will be developed based on collected data and survey results. The method will be consequently verified on a selected catchment.

Used methods:

Literature review, Comparison of approaches of other European countries, GIS analysis of existing datasets, Field survey

Used data sources:

Existing river network datasets – ZABAGED, DIBAVOD, CEVT, Other cartographic data from national database, Aerial images, Geological maps, Hydrological data from river administrators and Drainage boards, Water management data from other authorities

Tutor: Signature:

RNDr. Milada Matoušková, Ph.D.

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Abstract

Digital river network dataset is an important source of information in any aspect of water management decision making. It is also a base for modelling or scientific research in many different fields. Development of the dataset in the Czech Republic had been fragmented in a past and as a result three different datasets have been developed that cover the whole of the state's territory. The datasets contain different geometries, different and often conflicting attributes and serve different purposes. Today the time has come that water management decision makers have realised that the situation is no longer sustainable and make effort to merge the datasets into one. The task brings in several technical issues and a potential for severe legal consequences.

The aim of this study is to develop a methodological approach to merging the existing datasets into one. This methodological approach to decision which of the conflicting or different attributes should be adopted is based on assumption that the existing datasets will be merged into one consisting the best of all. Comparison of features in the existing dataset will inevitably lead to many conflicts when it will be necessary to decide which of the considered features should be adopted to the resulting dataset.

The study considers the main purposes which the datasets serve, legal aspects related to river network datasets and compares approaches to digital river network representation in selected European countries. Firstly the existing datasets were analysed and consequently extensive field survey of selected river segments was carried out allowing to identify all the major differences between the existing datasets and their impact on water management, decision making and relevant environmental issues. The field survey included complete detailed reconnaissance of all the selected localities, GPS point identification, photo-documentation a wider area search.

The method consists of a set of questions with possible answer “yes”, “no” or eventually “not applicable”. Each answer has specified numeric value and sum of the values then gives a suggestion whether the considered feature should be adopted or not. The application of the method is based on existing river network datasets and publicly available data including aerial images, Digital Elevation Model and land cover data. The application is possible even without training, although, an experience in the water management field greatly improves the results.

The method was successfully tested on selected catchment of the upper Litavka River where several differences between existing datasets occur. These differences cover all the major types of conflicts.

Abstrakt

Digitální sada dat o říční síti je důležitým zdrojem informací pro široké spektrum činností v rámci

vodohospodářského řízení. Je také základnou pro modely a vědecký výzkum v mnoha různých oblastech. Vývoj datové sady byl v České republice v minulosti rozdělen a výsledkem jsou tři různé paralelně se vyvíjející datové sady, které pokrývají celé území státu. Tyto datové sady obsahují rozdílnou geometrii, rozdílné a často protichůdné atributy a byly vytvořeny pro odlišné účely využití. Proto nadešel čas, kdy si odpovědné vodohospodářské instituce uvědomily, že tato situace je nadále neudržitelná a vyvíjejí úsilí na sjednocení těchto datových sad do jedné. Tento úkol přináší řadu technických problémů a může mít řadu právních důsledků.

Cílem této práce je vytvoření metodického přístupu pro sjednocení existujících datových sad. Tento metodický přístup pro rozhodnutí, který z protichůdných nebo rozdílných atributů by měl být převzat do sjednocené datové sady, vychází z předpokladu, že existující datové sady budou sjednoceny do jedné obsahující to nejlepší z nich. Porovnání jednotlivých prvků v existujících datových sadách nevyhnutelně povede k mnoha konfliktům, kdy bude nutné rozhodnout, který z posuzovaných prvků má být přijat do výsledné datové sady.

Práce vychází z hlavních účelů, pro které je digitální datová sada o říční síti využívána, legislativních aspektů spojených s daty o říční síti, a porovnává přístupy k reprezentaci říční sítě ve vybraných evropských státech. Nejprve analyzuje existující datové sady a následně pomocí rozsáhlého terénního průzkumu vybraných úseků vodních toků identifikuje všechny hlavní rozdíly mezi existujícími datovými sadami a jejich vliv na vodohospodářský management, rozhodování i související environmentální problémy. Tento průzkum zahrnoval kompletní detailní rekognoskaci všech vybraných lokalit, identifikaci GPS bodů, pořízení fotodokumentace a průzkum širšího okolí.

Vyvinutá metoda obsahuje sadu otázek s možnou odpovědí „ano“, „ne“, případně „nelze aplikovat“. Každé odpovědi je přiřazena určitá číselná hodnota a jejich součet dá návrh, zda má být posuzovaný prvek přijat či nikoli. Při aplikaci vychází metoda z existujících datových sad o říční síti a veřejně dostupných dat zahrnujících ortofoto snímky, digitální model terénu a data o krajinném pokryvu. Aplikace metody je možná i bez zaškolení, ale zkušenost v oblasti vodního hospodářství výrazně zlepšuje dosažené výsledky.

Metoda byla úspěšně testována na vybraném povodí horní Litavky, které bylo vybráno z důvodu značného množství rozdílů mezi existujícími datovými sadami, které vystihují všechny hlavní typy problémů.

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Used terms and abbreviations

The following terms are used in the text specifically with the relevant description. Their general use may differ.

Term/Abbreviation	Description
Artificial watercourse	Body of surface water (in specific cases might flow under surface or in pipe) flowing downstream in defined channel. Artificial watercourse channel is by the Czech legislation considered a construction and it doesn't have an administrator but an owner.
ČÚZK	State Administration of Land Surveying and Cadastre – The Czech Office for Surveying, Mapping and Cadastre is an autonomous supreme body of the state administration of surveying, mapping and Cadastre in the Czech Republic. The president of ČÚZK is subordinated only to the prime minister of the Government. The Office has its own account in the State budget of the Czech Republic (The Act n. 359/1992 Coll., 1992). It is the administrator of the ZABAGED database.
DIBAVOD	Digital Base of Water Management Data – database containing several water management related data, maintained by the T. G. Masaryk, Water Research Institute, public research institution.
Drainage Board (DB)	General term including all five major river and basin administrators – Povodi Vltavy, state enterprise, Povodi Labe, state enterprise, Povodi Oh?e, state enterprise, Povodi Moravy, state enterprise, Povodi Odry, state enterprise
GEONAMES	GEONAMES is the database of geographic names of the Czech Republic (CZ) at the level of detail of the Base map of the CZ at 1:10 000 (ZM 10). It is maintained as a seamless database for the entire territory of the CZ in a centralised information system administered by the Land Survey Office. GEONAMES is a part of the surveying information system and is one of information systems of the State administration. GEONAMES contains a complete set of spatial and attribute data on standardized geographic names and names of settlement units (State Administration of Land Surveying and Cadastre, 2016).

Term/Abbreviation	Description
River	Natural body of surface water (in specific cases might flow under surface or in pipe) flowing downstream in defined natural or by man modified channel. All rivers have an administrator, although there are cases when river is divided into reaches and each reach has a different administrator.
River network	A real system of watercourses including natural rivers and artificial watercourses.
River network dataset	A digital dataset representing a real river network. It includes segmented (ZABAGED, DIBAVOD) and unsegmented (CEVT) models.
VÚV TGM, v. v. i.	T. G. Masaryk Water Research Institute, public research institution, funded by the Ministry of Environment
Water Management Authority	In the Czech Republic such authority is represented by special state department within local (NUTS 4) and regional (NUTS 3) councils. There are four major Water Management Authorities in the Czech Republic represented by the Ministry of Agriculture, Ministry of the Environment, Ministry of Transport and Ministry of Defence
Watercourse	Body of surface water (in specific cases might flow under surface or in pipe) flowing downstream in defined channel. It is not defined if such watercourse is a river or artificial watercourse.
Watercourse type	There are three types of watercourses according to national legislation – natural watercourse, main drainage channel and other watercourses. Natural watercourse has assigned administrator while the others are considered property.

1 Introduction

Geographical data in digital form is today a major source of information for environmental and landscape managers on local as well as on national level. It is the same situation in water management field where the major data comes from digital representation of river network. A river network should not be viewed only as some blue lines on the map representing natural rivers. At the times when water resources are precious and rivers are major element of environmental protection it is very important for water management authorities not only to be able to precisely locate any watercourse but also to know what type of watercourse it is and who is its administrator. Such informations are essential for decision making in the field of water and river protection, water and river management, local and landscape management and planning, urban planning and many other activities.

There are currently three different datasets concerning digital representation of river network in the Czech Republic. Although the datasets have the same origin, they have been developed independently for different purposes. However, they all are intended for general use and thus create a complicated situation in water management on all the administration levels. It is therefore desirable to provide only one digital river network dataset which will be state guaranteed for the use in the water management decision making on the state as much as on local administration levels. Such model should also serve as the primary base for hydrological modelling and other research activities.

In order to develop such river network dataset the most suitable way clearly is to combine the three existing models and select from each the best information. The aim of this work is to propose a method for selecting a correct information from conflicting features in the existing river network datasets. The method is based on indicators that were selected throughout extensive field work and comprehensive analyses. The indicators are evaluated for each conflicting case and expressed as numbers. Simple summary of the numbers gives us then single value as a result of which of the conflicting features should be used in the new river network dataset.

Important merit of the method is that the indicators can be identified without necessary field survey which would take too long and be very expensive at the whole country level. The proposed method should thus be applicable from the desk with the use of commonly accessible tools and data. There are however some other aspects of the river network which are perhaps even more important than its correct digital representation. Among these aspects are certainly legal requirements, hydrological and geographical principles and environmentally friendly river management. This work therefore carefully considers such aspects and tries to see rivers and other watercourses as the highly important features of the environment. Also the technical aspects of the actual optimization process, although not the main concern of this work, are taken into perspective.

2 Digital representation of river network

Water is undoubtedly one of the major elements of the environment and there are all the reasons to protect it. Rivers can be understood as geomorphological features of the landscape in which water flows downslope towards the sea. Together with artificially built ponds and reservoirs rivers represent almost all of the surface waters on the territory of the Czech Republic as it is inland country where natural lakes are very few and small. Digital representation of water related geomorphological features is always complicated especially because they are very dynamic. While ponds and reservoirs are mainly affected by man's manipulation that changes water level, the rivers naturally change their course and length. Nevertheless, the digital representation of such features is today extremely important because it provides spatial information essential for all the management, research, monitoring and planning processes applied at local, regional, national and international levels (Colombo et al., 2007).

The importance of correct digital representation of a river network is easily readable. Not only it is essential that the best available river network spatial data are used for any hydrological model, whether it aims at water balance description or at complex prediction of hydrological situation or flood warning. It is also crucial to have the best available spatial and attribute information on rivers when putting into practice legal procedures resulting from management and planning such as complex land and property adjustment, applying farmers financial support schemes, issuing water abstraction allowances and so on.

As an example lets imagine a situation where a small stream flows across a crop field. First, it is important to know, whether the stream is a natural watercourse or an artificially built drainage. If it is a drainage, then it was probably built for the purpose of amelioration of the crop field and thus to land owner should take care of its channel and banks and make sure that it functions well. It is also the owner's legal duty to ensure that no pollutants get into the river into which the drainage flows (The Act n. 254/2001 Coll., 2001). For management and planning purposes stream is a potential source of pollution because the farmer nor the land owner can possibly avoid any polluting fertilizers, pesticides or other substances to reach the watercourse. However, if the stream in question is a natural watercourse it is then protected through European (European Commission, 2000; European Commission, 1991) and national (The Act n. 254/2001 Coll., 2001; Government order n. 262/2012 Coll., 2012) legislation and it is considered an important landscape feature. This not only sets severe limitations to the farmer and land owner but it also means that there must be an administrator for the river, who is responsible for its maintenance and furthermore, the river should be monitored, water quality evaluated and measures taken to achieve goals set by Water Framework Directive. To complicate the situation even further the farmer who is limited in his farming practices may apply to financial reimbursement for loses as he should not cultivate the land within a given buffer to the river channel. The reimbursement is calculated from the area occupied by the river and its buffer.

The above example shows just how important it is to have correct information on river network and its properties. The information affects strongly the farmer, the land owner, local authorities, land and water management planning and, of course, all those interested in hydrological or erosion modelling. Perhaps even more complex is such effect in the urban areas where private land ownership might be burdened by the presence of river.

As the above demonstrates the river network representation and related datasets should include all the necessary attributes to allow public and relevant authorities to use the information for their decision making and planning. Although, there are several ways to present river network, all of such presentations should certainly be based on the same dataset. This basic dataset should contain the basic information which serve as the single foundation for all the additional data directly linked to it.

There are, however, three main datasets concerning river network in the Czech Republic. The National database of geographical features (ZABAGED) contains a river network dataset which is produced by the CUZK - State Administration of Land Surveying and Cadastre (further on called ZABAGED river network dataset); the Drainage Boards are responsible for maintaining the National Register of Watercourses (CEVT) which is based on CEVT river network dataset; the VÚV TGM, v. v. i. maintain the Digital Base of Water Management Data (DIBAVOD) which contains also a river network dataset (further on called DIBAVOD river network dataset). Each of the datasets has been developed over time by different organizations under two ministries – Ministry of the Environment and Ministry of Agriculture. These datasets have some fundamental differences that result from the reasons and purposes for which they have been developed and maintained. Table 1 describes some major characteristics of the considered datasets which should show also some of the main differences that evolved through the time when different purposes were followed during their development.

It is important to also mention that the relation between the Ministries of Environment and

Agriculture was rather complicated at the time of separated development of the different river network datasets, and thus a cooperation on maintaining one river network dataset was not possible.

Table 1: Summary of the main characteristics for the considered river network datasets

River network values	**ZABAGED river network dataset – 2015**	**CEVT river network dataset - 2015**
Number of watercourses	???	125,994
Number of segments	323,338	None
Number of segments after application of the rule dividing only at confluence point	265,220	265,088
Completely the same segments	22,946	
Orientation	From spring downstream	From confluence upstream
Published attributes	ID – of each segment	ID – for the whole river
	FID	ID – for specified sections
	River name	River name
	DIBAVOD ID	DIBAVOD ID
	Catchment ID	River basin
	CEVT ID	Date of last update
	Discharge category – navigable or not	Watercourse administrator
	River type – intermittent or stable	Type of appointment for watercourse administrator
		Beginning of administration (river km)
		End of administration (river km)

There have been some attempts already to resolve this unsustainable situation and produce a single river network dataset. The major problem of all those attempts was that they did not include the essential communication tool which would help to share information between all the organizations responsible for providing data inputs for river network dataset. However, now there is a project lead by the Ministry of Agriculture which aims at bringing all the relevant organizations together and set rules and principles for future administration of the single basic river network dataset, which will be an obligatory base for all further river network representations. The project will inevitably have to include a primary optimization of the existing datasets. It is the aim of this work to provide a simple applicable method for selecting the best data of all the datasets and combining them into a single optimized river network dataset.

2.1 ZABAGED river network dataset

The abbreviation ZABAGED stands for The Fundamental Base of Geographic Data of the Czech Republic, provided by State Administration of Land Surveying and Cadastre. This organization represents independent department financed directly from national budget which is not controlled by ministry, although the Minister of agriculture is the formal highest official. Geographic data from the ZABAGED database, including watercourses and standing waters, are by the law the obligatory cartographic background of any map considering territory of the Czech Republic. The river network dataset has been developed and is maintained within the complete set of geographic data, so it is in accordance with e.g. roads, bridges, and other datasets. The dataset provider, State Administration of Land Surveying and Cadastre, also maintains database of official names for geographic features (GEONAMES), therefore the river names correlates. The provider also guarantees hydrography section under the INSPIRE directive as the national dataset.

The published river network dataset contains the best available geometry, officially recognized river names and other attributes according to Table 1. It represents segmented river network in which segments are divided at all confluence points and also at places where surface channel is replaced by piped channel or where intermittent stream becomes perennial. Because of its geometric quality and importance the river names and geometry should be used as the obligatory base for the future harmonised, unified river network.

The basic approach to ZABAGED river network development contains following rules:

- the line representing a stream or river is a centreline of the river – see Figure 1
- lines are orientated downstream
- spring is where subsurface water permanently appears on the surface forming a channel or where intermittent stream channel is distinguishable on aerial photograph
- river name can differ according to local names (one river may have up to three different names)
- under the standing water body (reservoir, lake, pond etc.) the river network continuity is ensured by straight lines connecting inflow and outflow points and points of confluence when other streams flow into the standing water body – see Figure 1
- the river dataset is incorporated and fully in accordance with the overall national base map in the scale 1:10 000

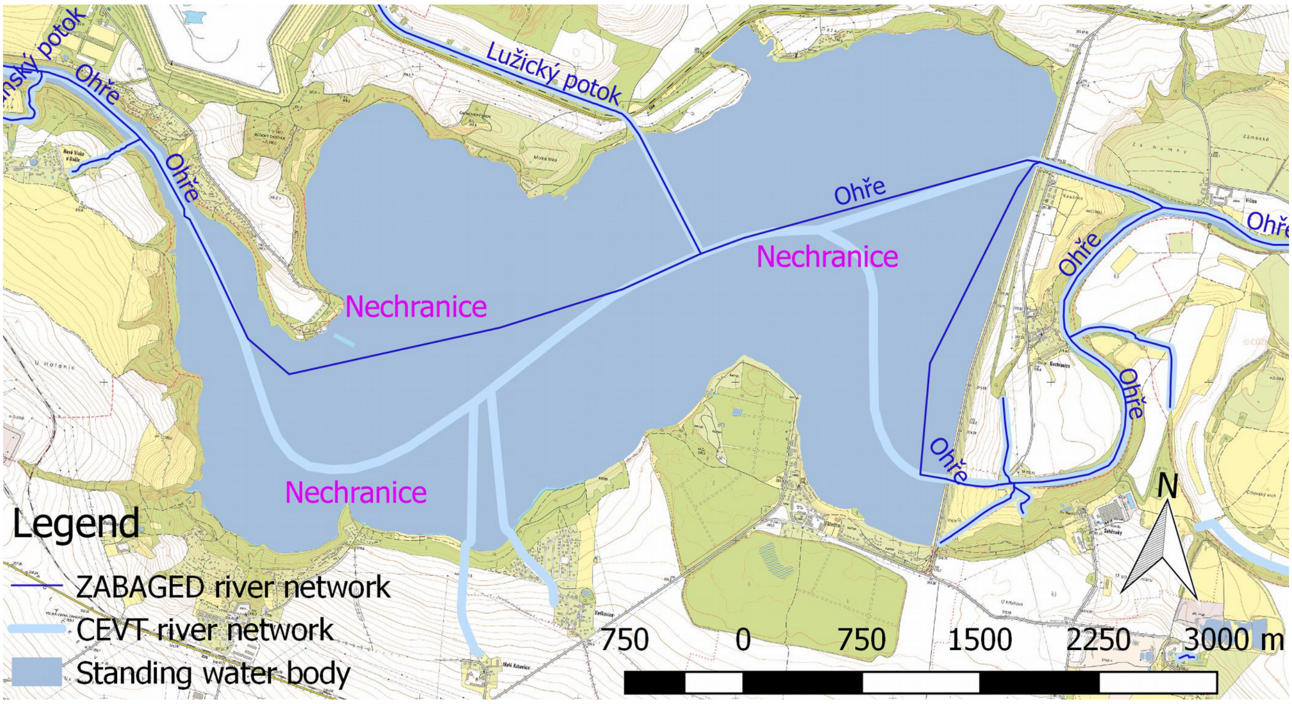

Figure 1: Illustration of the ZABAGED and CEVT concepts of river network datasets specifically under standing water body. While ZABAGED provides the shorter lines connecting inflow and outflow inside the reservoir, CEVT intends to follow original watercourse

2.2 CEVT river network dataset

The abbreviation stands for Central Register of Watercourses, provided by the national Drainage Boards (DBs) (Povodi Vltavy, state enterprise, Povodi Labe, state enterprise, Povodi Ohře, state enterprise, Povodi Moravy, state enterprise, Povodi Odry, state enterprise) on behalf of the Ministry of Agriculture of the Czech Republic. Technically there are five main CEVT databases maintained separately by each DB. Lesy České Republiky, state enterprise (State Forestry) is a major administrator of ordinary watercourses and contributes directly into all five DB's databases. The Ministry of Agriculture then administrates the single CEVT dataset which is a combination of all the DB's river network data.

This model of river network had been developed from the same original dataset that was used as a base for DIBAVOD model (described in chapter 2.3). However, the original model was not suitable for dealing with water management issues that are of major concern to DBs. For instance, DBs consider a river as one entity which is represented in CEVT as a single line. To this single line are linked all other relevant entries as man made objects (weirs, dams, embankments, etc.) stored in one central database for each state enterprise. Also the river management is generally provided for the whole of the river. For such reasons the ZABAGED segmented river network dataset had been ill fit to the purposes and thus the CEVT model have been developed.

Beside river management purposes the mode serves as an important dataset for monitoring river administration and responsible administrators. This purpose is extremely important when dealing with legal issues related to river administration, management and planning.

The basic approach to CEVT river network development contains following rules:

- a river is one single entity with one unique meaningless ID
- one river can have only one name
- lines representing river are orientated from confluence to spring
- every line in the dataset contains information whether the line represents river, drainage channel or other artificial stream
- administration units are represented by different layer fitted to the same dataset
- under the standing water body (reservoir, lake, pond etc.) the river network continuity is ensured by lines that are either straight or follow the original channel geometry while connecting inflow and outflow points and points of confluence when other streams flow into the standing water body – see Figure 1
- the reservoir or pond outflow of the main river or stream is always at the place where the original channel had been, regardless the actual discharge

2.3 DIBAVOD river network dataset

The abbreviation DIBAVOD stands for Digital Base of Water Management Data and the database is maintained by VÚV TGM, v. v. i. - T. G. Masaryk Water Research Institute, public research institution, founded by the Ministry of the Environment.

Although, the DIBAVOD river network dataset played major role in the development of the original river network dataset on which all the other datasets had been based, today the updated version of the dataset is not available for public download (the available version is from 2006). The dataset is now updated according to ZABAGED river network dataset and doesn't provide any further hydrological development or geographical updates on its own. Therefore, the dataset has not been considered for the purpose of this work.

3 River data management

Perhaps the main reason why the river network data development separated at some point in the past is because there exist two major purposes which the data should serve. First purpose could be called scientific because it concerns mostly cartographers and researchers. Such data are focused on geometric and hydrological correctness and are used mainly for map making and as an input into various models. Second purpose is legal and concerns Water Management Authorities and other decision makers. For the legal purposes there is an obligatory dataset called Records of Watercourses (Decree n. 252/2013 Coll., 2013). The Records of Watercourses provide obligatory information about each watercourse under the responsibility of the Ministry of Agriculture.

The following sub-chapters are intended to describe various aspects of river network representation and their impact on legal or scientific issues. Essential attributes that should be assigned to each watercourse or its segments and also basic principles of geometric representation are discussed. Then the review of legal requirements and different approaches to river network representation is provided. It gives the background on which the proposed method for selecting a correct information from conflicting features in the existing river network datasets is based.

3.1 Legal aspects of river network representation

The Czech national legislation defines watercourses as surface waters running by gravity in their channel either permanently or for the prevailing part of the year including water artificially impounded in such channels. They include water in dead-end branches and sections temporarily running below the earth surface in natural cavities or in covered sections (The Act n. 254/2001 Coll., 2001). This definition however, fits also to many artificial channels which are rather considered man made property bound by ownership or as main drainage channels owned by state or other mostly private physical or legal persons. It is always on the Water Management Authority to decide whether the water represents a river or artificial watercourse or main drainage channel (The Act n. 254/2001 Coll., 2001). Such types of watercourses are called a legal types and are just the three – river, artificial watercourse and main drainage channel. The legal type is always assigned to a whole watercourse from its beginning to its end.

The decision whether a watercourse is a river or artificial watercourse or main drainage channel is critical in further dealing and management regarding the particular watercourse as demonstrated in chapter 3. River should always be considered as significant natural feature of the landscape, it should have its administrator which is then responsible for its environmental protection and each river should be included in water management planning according to Water Framework Directive (European Commission, 2000). This holds true even for the rivers that are not defined as main rivers and form surface water body in river category (European Commission, 2000) and for the rivers that have been identified as heavily modified (European Commission, 2000), which means that their natural course had been so affected by human activities that good ecological status cannot be achieved. As a river may for legal purposes be considered also artificial channel that had been built by man but have become an important part of the river network (e.g. Podkrušnohorský přivaděč was built to divert waters from coal mines and supply water for cooling towers in power stations). On the other hand watercourses that are not rivers have generally specific purpose (e.g. supply water for irrigation or to hydro-power station or drain water from crop field) should be managed by their owner. Such watercourses do not fall under Water Framework Directive planning but they should not cause failure to achieve good status of the river into which they flow. Any such watercourse should be authorised by local Water Management Authority and should be treated as a potential source of pollution. These watercourses should also be treated separately in hydrological modelling because they may behave in specific way and have thus different impact on discharges downstream.

It is however important to notice that only legal type is published today within the CEVT river network dataset. This is because it is not an easy task to guarantee the information on watercourse channel modifications or purpose. The artificial type also often combine with natural types and thus become inseparable. For example, originally natural watercourses had often been in the past used for collecting water from artificial drainage systems. Then the channel of such natural watercourse was modified and its banks straightened and reinforced to withstand higher water tables without changing its course and inundating the floodplain which was turned to arable land. So now the watercourse appears to be more the drainage then the natural watercourse as it originally was. These originally natural then drainage channels may also serve as sewage. So the watercourse type is often very difficult to identify.

Another aspect of the watercourse legal type is a watercourse administrator. Only the natural watercourses have their administrator while artificial watercourses should always be considered a legal property with defined ownership. The rights and duties of the river administrator are given by the (The Act n. 254/2001 Coll., 2001) in section 47. The Ministry of Agriculture is the only authority that makes decision on who shall be an administrator for a particular watercourse. The information about river administrators is a part of the record of the watercourses. Furthermore, all the legal decisions regarding watercourse administration and all other water management decisions of the Water Management Authorities are stored in the record of water management decisions according to (Decree n. 414/2013 Coll., 2013). Such record is publicly available and contains also some historical allowances, regulations and permissions regarding water abstraction, waste water discharge and so on.

3.2 Responsible organizations and data sources

In the Czech Republic the main responsibility over watercourses lies on the Ministry of Agriculture which is the main guarantee of the Water Act. The Ministry is also the founder of the Drainage Boards (DBs) and one of the main Water management Authority. DBs are responsible for water management and flood risk management planning and implementation of measures, application of flood protection measures and manipulation on all major reservoirs. DBs are fully responsible for the records of rivers as laid by the (The Act n. 254/2001 Coll., 2001). The Ministry of Environment is mainly responsible for water protection, groundwater monitoring and protection, water bodies designation and assessment and flood risk planning and protection. It is too one of the main Water management Authority. The Ministry is also the founder of the T. G. Masaryk Water Research Institute, public research institution, the producer of the DIBAVOD river network dataset. Other two responsible bodies are the Ministry of Transport, looking after the waterways, and the Ministry of Defence looking after all the watercourses within military zones. The last two ministries are the remaining main Water management Authorities.

In England and Wales the major Water Management Authority is Environment Agency founded by Department for Environment, Food and Rural Affairs which is responsible for water management planning and protection, monitoring, flood risk management on main rivers, and other river protection activities such as river conservation and restoration (Environment Agency, 2014). Other main authority for maintaining river network data is Rivers Agency which is an agency founded by the Department for Infrastructure. The agency is responsible mainly for drinking water infrastructure, sewerage, waterways maintenance, water levels monitoring and flood protection. As the two agencies are concerned mainly about main rivers, there is also the Association of Drainage Authorities, controlled by Environment Agency, which unite local and internal Drainage Boards responsible for ordinary watercourses (Environment Agency, 2014; Environment Agency, 2012). All of these organizations provide data for UK national database in which the river network dataset is stored and published (Environment Agency, 2012).

Another major organization within the United Kingdom that provides a range of hydrological data and studies is The Centre for Ecology and Hydrology. The Centre for Ecology and Hydrology includes the Institutes of Hydrology (IH), Freshwater Ecology (IFE), Terrestrial Ecology (ITE) and Virology and Environmental Microbiology (IVEM). It has its headquarters at Wallingford. The Institute of Hydrology carries out a wide range of hydrological research and consultancy into all aspects of the hydrological cycle, including studies of process and operational hydrology, hydrometry, hydroecology and climate change. It operates experimental catchments across the UK including Plynlimon (in upland Wales), Balquidder (in the Scottish Trossach uplands) and the Cairngorms mountains (Scotland). Here the work has particularly focused on the effects of land use, such as forestry, and on snow. In recent years, emphasis has moved to lowland impermeable catchments where water resources are particularly under pressure. The Institute of Hydrology also maintains The National River Flow Archive and the National Hydrological Monitoring Programme which provides status reports on the hydrological situation in relation to flood and droughts (Acreman and British Hydrological Society, 2000).

In Portugal the whole burden of environmental protection is laid upon the Portuguese Environment Agency (Agéncia Portuguesa do Ambiente). The environmental protection includes all water management activities, water management planning according to Water Framework Directive, Flood protection and also the transitional and coastal waters on the mainland and also on Azores and Madeira islands. As such the Agency is responsible for the river network dataset maintenance and publishing.

The research activities related to water protection are generally provided by the "Istituto da Água, I.P." which is a public research institute. Among such research activities is, for example, a river typology focused on water management planning according to Water Framework Directive. The typology has been applied to the national river network dataset and as a major criterion it uses the river localization within defined geographic areas of Portugal (Ministério do Ambiente et al., 2008). In order to correctly apply the river typology the national river network dataset contains also the location attribute. Such attribute then becomes very important when any water management activity is concerned. The second planning cycle activity according to Water Framework Directive has proved that adding the typology information to the national river network dataset greatly supports the public awareness of the issue.

The United Kingdom's system of river management and protection represents some sort of balanced approach between the two extremes. While the Czech system distributes responsibilities among four ministries and several subordinated organizations, the Portuguese system is fully centralised with almost exclusive responsibility given to the Portuguese Environment Agency. In terms of water management and protection there is an argument that distributed obligations provide some kind of controlled mechanism in which organizations with different responsibilities limit each other in abusing their authority. Such system, however, very complicates production and maintenance of any single national water related dataset.

3.3 Links and relations to other data

The fact that river network dataset is related to other datasets is rather obvious. For example the link between river network and river basins is apparent. Perhaps the best way to see all the important links is to look at the Water Act. It defines in its section 21 all the obligatory records that should be maintained and published. These records are the state guaranteed water related datasets that serve as the base of information for water management decision making. The minimum data range for each record and the responsible organization are set in Decree n. 252/2013 Coll. The list of the records and their description is provided in Table 2.

Table 2: List of water related obligatory records (Decree n. 252/2013 Coll., 2013)

Record	Description
Records of watercourses	Records of all parts of the river network including artificial watercourses, their type and administrator
Hydrological catchments	River basins and sub-basins for all rivers of 4th and higher Strahler order
Records of structures on watercourses	Transversal barriers (migratory cross-sectional obstacles) higher than 1 m, and structures to monitor surface water status
Records of groundwater zones	Groups of groundwater bodies
Records of water reservoirs	Reservoirs and ponds included in the 1 – 3 technical – safety supervision or those owned by state
Records of water bodies including heavily modified water bodies and artificial water bodies	Water bodies as defined by (European Commission, 2000), which serve as the main units for water management planning
Records of surface water quantities	Data on the measured flow and data on the natural flow in watercourses in selected gauging stations and profiles in watercourses
Records of surface water quality	Characteristic values of selected parameters in surface water quality monitoring profiles
Records of groundwater quantities	Data on natural groundwater resources for individual groundwater zones
Records of groundwater quality	Data obtained from the groundwater chemical status monitoring network
Records of the status of water bodies	Status of water bodies is defined by (European Commission, 2000) and consists of chemical and ecological status
Records of ecological potential of heavily modified and artificial water bodies	Heavily modified and artificial water bodies are not assessed on their ecological status but their ecological potential is considered instead

Record	Description
Records of surface water abstraction	Abstractions that are subject to reporting obligation for the physical or legal persons with the relevant abstraction allowance
Records of groundwater abstraction	Abstractions that are subject to reporting obligation for the physical or legal persons with the relevant abstraction allowance
Records of waste water discharges	Discharges that are subject to reporting obligation for the physical or legal persons with the relevant permission to discharge waste water
Records of mine water discharges	Mine water discharges are subject to reporting obligation for the physical or legal persons with the relevant permission to operate mine
Records of accumulation of surface waters in water reservoirs	Accumulation of water in reservoirs is subject to reporting obligation for those permitted to operated reservoirs specified in records of water reservoirs
Records of international river basin districts in the Czech Republic and sub-basins	Basins boundaries result from records hydrological catchments
Records of natural water accumulation protected areas	Areas of important groundwater accumulation
Records of water resources protection zones	Water resources have usually set a protection zone which is proposed by the physical or legal person permitted to abstraction and confirmed by water management authority
Records of surface water resources, which are used or intended to be used as a source of drinking water	This records include all surface abstraction sites or potential sources of drinking water
Records of groundwater resources, which are used or intended to be used as a source of drinking water	This records include all groundwater abstraction sites or potential sources of drinking water
Records of sensitive areas	The whole territory of the Czech Republic is considered sensitive
Records of vulnerable areas	Vulnerable areas are areas with the potentially high threat of eutrophication to surface waters especially from agricultural practice
Records of surface waters used for bathing	Bathing waters are defined and monitored by the regional hygiene authority
Records of surface waters that are or may become permanently suitable for the life and reproduction of indigenous species of fish and other aquatic animals	Such surface waters consist of parts of river network divided between salmon type and carp type waters
Records of hydraulic structures for land amelioration	Only state owned main drainage channels are recorded

Record	Description
Records of flood prone areas	Flood prone areas are divided into active zones of flood risk and zones with potential for flooding to occur in 5, 20 and 100 years

From the records listed in Table 2 can be seen that there are several obligatory records which are closely related to river network. The Records of Watercourses are directly based on river network dataset and they provide obligatory geographical and legal information about each watercourse. The (Decree n. 252/2013 Coll., 2013) also sets the responsible organization for the records keeping. To see all the links and relations however, is not so simple. The best way to find them is to look at hydrography technical document to the INSPIRE directive (INSPIRE Thematic Working Group Hydrography, 2014). The major obligation resulting from the European directive is that all the spatial data should have only one source database and relevant attributes should be shared (European Commission, 2007). So for example if we consider records of reservoirs, one of the attributes is name of a river on which the reservoir is placed. This river name should be extracted form the records of rivers which is official source of river network data. This obligation is intended to prevent unnecessary doubling of data and ensuring that the same data are used.

The above not only supports the necessity of having only one river network dataset but it also places another aspect to it as it should contain all the information that is unique to each watercourses or its reaches and thus can be shared across various records.

3.4 Different approaches to river network representation

It has already been pointed out that river network dataset should serve several different purposes. Each purpose require different attributes and different precision. Some main purposes and their requirements are summarised in Table 3.

The single national river network dataset should in ideal case contain all of those important attributes provided in Table 3. The development of such ideal river network dataset has however some major prerequisites, sources of data must be defined and interconnected and the principles of representation must be set. While the data sources and their connectivity is more of legal issue, the principles of representation are more complex and technical.

Table 3: Summary of some major purposes served by the river network digital dataset and their main requirements

Purpose	Important attributes
Hydrological modelling	Length and shape, network connectivity, Strahler order, flow orientation, topological correctness, open or piped channel, watercourse type

Purpose	Important attributes
Hydromorphology	Watercourse type, administrator, designation of main river, banks, open or piped channel
Water management planning	Watercourse type, legal type, administrator, relation to designated water body, network connectivity, location
Environmental protection	Watercourse type, legal type, administrator, related basin, localization

River channels are not static features in the landscape but they have high levels of dynamism and are very sensitive to changes in flow or sediment yield or changes in bed and bank resistance (Holden, 2008). Perhaps the best way to start dealing with the representation options is to look at legal aspects summarised in the INSPIRE directive guidance document (INSPIRE Thematic Working Group Hydrography, 2014). The document describes not only recommended representation of rivers including the graphics and their required attributes but also provides a detailed overview of the linkages between all other main hydrographical data. However, the document recommendations on graphics and styles are useful only for standard representation of spatial information. The purpose of the representation often requires to adjust it to main attribute accordingly, e.g. representation of different watercourse types.

Perhaps the most important part of digital river network representation is its spatial correctness. Especially in case a private land ownership might be affected by existing watercourse its geometrical precision matters very much. There are several different methods on how to digitally represent a river. It depends mainly on its width and sinuosity and on the level of spatial generalization. In general, the rivers are represented by a centre line which runs in the middle between defined banks. As a major source of spatial data to produce digital river network dataset is commonly used a Digital Elevation Model (Poggio and Soille, 2011). There are several very advanced techniques to produce a digital river network from Digital Elevation Models, however, non of them works well in case of artificially modified channels (Poggio and Soille, 2011; Colombo et al., 2007).

The Land Survey Office is now working on a project of improvement of the hydrological data with the use of Laser Imaging Detection and Ranging (LIDAR) survey method. The method is based on producing precise Digital Terrain Model from which the precise location of watercourses should be readable. The improved Digital Terrain Model in combination with high-spatial resolution satellite and aerial imagery should allow better quantification of river planform geometry (Fisher et al., 2013). The main difficulty, however, related to the production of precise Digital Terrain Models with no bathymetric sensors concerns the absorption of natural (solar) or artificial (LIDAR) electromagnetic radiation in the wetted portion of the river channels (Moretto et al., 2014). Another difficulty of such remote sensing techniques is the recognition of watercourses buried under the surface. Even more complicated are situations around reservoirs' outflow where the identification of the original watercourse against safety spillway is impossible without appropriate documentation. Thus, although, the project should greatly improve the river network geometry and spatial correctness, the problem of artificial watercourses will unlikely be solved. In the whole Europe the natural river network has been historically so heavily modified (Rinaldi et al., 2013; Dufour and Piégay, 2009) that a field survey and project documentation are essential in correct spatial representation of the real river network.

In terms of required attributes the situation is more complicated. Some attributes are no unique for a single watercourse and they would require segmentation of the river network dataset. Such approach is already applied in ZABAGED river network dataset. This approach is however not viable with too many attributes because it would lead to very fragmented segmentation which would be quiet difficult to maintain especially if we consider the expected cooperation between all the relevant organizations. One possible solution to this problem would be the use Arc River Data Model Structure which is a customized GIS - based data repository built on to of ESRI's geodatabase technology (Kim et al., 2015). This system is designed to represent river data in a curvilinear coordinate system to support various types of spatial analyses and to represent multi-dimensional river features through points, lines polygons and volumes (Kim et al., 2015). The use of such structure would greatly improve the usefulness of the river network dataset especially in hydromorphology.

Hydromorphological characteristics of watercourses are important in assessing ecological status or potential of river water bodies (European Commission, 2000). They also play important role in river management planning and protection and help to improve the water quality. In relation to determining ecological status of watercourses and the application of restoration measures various watercourse typologies have been developed (Great Britain and Environment Agency, 2003; Ministério do Ambiente et al., 2008; Kondolf et al., 2003, Langhammer et al., 2012; Kujanová et al., 2016). The watercourse typology then provides a base for development of type specific reference conditions which are in turn a base for finding and applying appropriate restoration measures.

The river classifications are not limited only to ecological status assessment but they have wide range of landscape management implications (Rinaldi et al., 2015). A broad geomorphological characterisation should integrate the landform and fluvial features of valley morphology which combine the influences of climate, depositional history and land use (Rosgen, 1994). The wider the range of watercourse characterisation is included the wider range of decision making it allows. This approach includes management which is not necessarily based on restoration toward reference conditions but also a management focused on human benefits (Dufour and Piégay, 2009).

Hydromorphological data are also the most significant river characteristics when dealing with the so called urban stream syndrome which is the consistently observed ecological degradation of streams draining urban land (Vietz et al., 2016). Typically, channels in established urban catchments are deeper, wider and simpler, with reduced physical habitat (e.g. less mobile bed substrate, fewer bars and riffles, less wood, disengaged floodplains) and altered rates of sediment transport, all contributing to degradation of stream ecosystems (Vietz et al., 2016).

Although, DBs have in their databases several hydromorphology related data, they do not publish them yet, mainly because they have been obtained during various field operations without any methodological approach and they are very dynamic and thus demanding on updates. Nevertheless, with appropriate methodology and with provided suitable structure the DB's may be inclined to publishing of collected hydromorphological data, which would be a great step forward in many ways.

4 Methodology

Following sub-chapters describe in detail each step taken towards the aim of this work, which is development and verification of the method for selecting a correct information from conflicting features in the existing river network datasets. As the result is the methodology it is not itself described here but in results section. It is also important to mention here that the following steps were not all strictly taken in given order but sometimes it was inevitable to return to previous step and repeat some processes. This holds true especially when developing the set of questions on which the method is based. It explained in further detail in the results section.

4.1 Data collection

First essential step was to collect available data and information regarding the existing river network datasets. As explained in chapter 2.3 the DIBAVOD river network dataset was not considered as it does not provide any recent updates to geometry or structure of the river network dataset and as such it will not be included in river network optimization process carried out by the Ministry of Agriculture. Thus only ZABAGED and CEVT river network datasets have been included. Other reason also was in fact that the only available version of DIBAVOD river network dataset is from 2006 and current updates are publicly unavailable. Therefore, only CEVT and ZABAGED river network datasets were collected and considered further in this study. Because the river network datasets are daily updated and modified it was essential to do all the following analyses on data of approximately the same date. After some preliminary testing the final datasets were collected within the second week of January 2016, so they can both be considered valid to the end of 2015.

The ZABAGED river network dataset contained vectorised lines representing segments of rivers as explained in chapter 2.1. Beside the complete geometry for each line the dataset contains attributes shown with their explanation in Table 4.

Table 4: Attributes included in the ZABAGED river network dataset

Original attribute	Explanation
FID_ZBG	Unique ID for each line segment
JMENO	Name of the river if known, otherwise the field is left empty
UTOKJ_ID	Hydrological sequence for each segment provided by the T. G. Masaryk. Water Research Institute
KODPOVODI	Hydrological catchment as provided by the Czech Hydrometeorological Institute
VYDATTOK_K	Code for character of the segment in terms of its flow continuity
VYDATTOK_P	Word description of the flow continuity – generally perennial or intermittent
TYPTOKU_K	Code for type of watercourse
TYPTOKU_P	Word description of the type of watercourse – generally states if the watercourse is in open surface channel or buried and if it is navigable or not
IDVT	Unique ID of the whole river used in CEVT – not provided for all rivers and with no guarantee
Shape_Length	Automatically calculated field for each segment in meters

The CEVT river network datasets contained vectorised lines representing the whole watercourses (no segmentation). CEVT is usually published in two layers, one representing the whole watercourses and the other segmented watercourses with identification of river administration. It is also published with only legal watercourse type (River, Amelioration, Artificial watercourse). The actual watercourse type attribute (see the legend in Figure 2) is not published. However, for the purposes of this project the attribute has kindly be provided by all DBs and as such it was presented in format and graphics as shown in Figure 2. The whole list of attributes for the CEVT river network dataset is provided in Table 5.

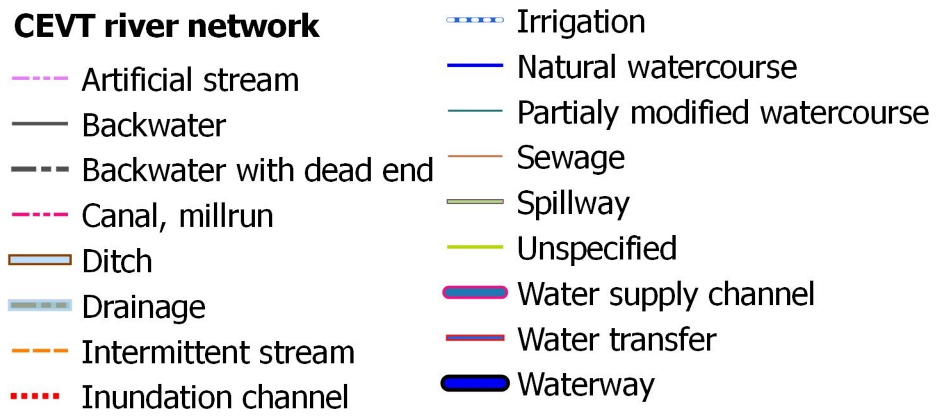

Figure 2: Unpublished types of watercourses as used and graphically represented in map outputs

Table 5: Combined attributes included in CEVT river network datasets

Original attribute	Explanation
IDVT	Unique ID for each watercourse in its full length
NAZEV	River name if known, otherwise replaced by *
JEV_ID	ID of the particular characteristic presented – e.g. unique ID for each segment with different administration
DR_TOK_ID	Code of the watercourse type
DRUH_TOK	Watercourse type – full
TYP_CEVT_ID	Code of the legal watercourse type
TYP_CEVT	Legal watercourse type – River, Amelioration, Artificial stream
JEV_NAZEV	River administrator – filled only for the legal type River
LOKAL_OD	Km of the beginning of particular administration
LOKAL_DO	Km of the end of the administration
KOD_SP	Code for specific administrators
URCENI	Legal setting of the administration – based on legal duty or decision of appropriate authority, the Ministry of Agriculture
POVODI	Basin administrator – Drainage Board

Other important data used in preliminary analyses and for the method development included land cover data obtained from the ZABAGED dataset published in January 2015 as valid to the end of 2014. This dataset contains vectorised layers of the features shown in Figure 3 including their representation format used in map outputs. Further data used were the aerial images provided online by the CUZK and other online map sources and local council's information web sites. For the method application is however necessary to use only official CUZK data and images provided publicly and online.

During the field survey and for the field sites geographic descriptions have also been used data from Contours dataset which is part of the national Topographic database (Land Survey Office 2015). From the contours dataset was created Digital Elevation Model with the Topo to Raster tool incorporated in the ESRI software. The resolution was set to 10 meters.

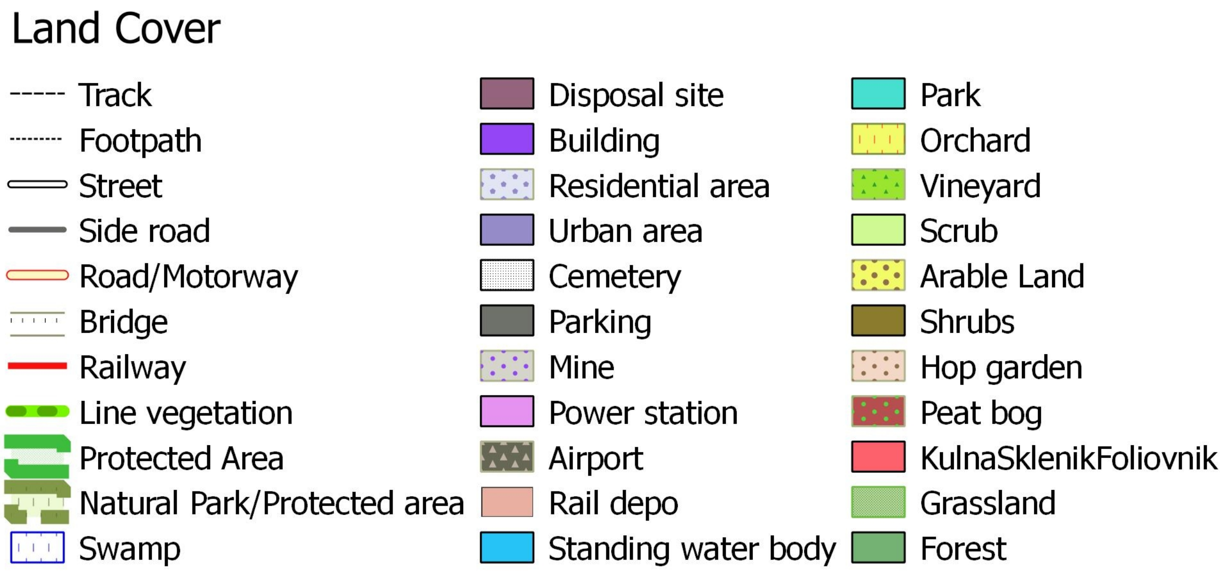

Figure 3: Legend for the land cover in maps

4.2 Data analysis

The second step involved thorough analyses of the river networks including their basic characteristics (see Table 1), structures, principles and purposes. The analyses were based on available metadata profiles of the datasets and included several procedures done by the use of ESRI ArcMap and ArcCatalog software, version 10.2.2. and QGIS software version 2.10.1 – Pisa.

Firstly, the CEVT dataset is a compilation of five datasets provided by the DBs. During the compilation many topological errors were found and therefore a comprehensive topological cleaning had to be induced. Afterwards, it was necessary to produce the same level of segmentation. While ZABAGED dataset was segmented heavily including segmentation at each confluence point and several other “pseudo” segments reflecting other surface features (piped sections of the streams, crossing with reservoirs and change from intermittent to perennial) the CEVT dataset provided unsegmented model where each river was represented as a single feature from confluence to spring. It was thus necessary to modify each model's segmentation to the same level by strictly following the rule of dividing watercourses only in confluence point.

The segment modification was followed by comparison of the two resultant datasets. The confluence points were compared in their position and when the point fell within 10 meters of distance from each other they were considered the same. Only segments between two confluence points identified as the same could also be identified as the same. This logic disregarded the actual geometry of the segments but preferred rather their corresponding identity. Consequently, the segments that could not be related to corresponding segment from the other dataset were searched and marked.

From the analyses described above was developed a categorisation of differences between the two datasets which was then used as a base for the method development.

4.3 The first field survey

The resultant categorisation of differences provided a base for selection of the localities in which field survey was conducted. Firstly, test field surveys had been carried out in two localities (Obecnice and Stará Huť) to obtain information about essential preliminary data preparation and time requirements in the field. The Obecnice locality was later removed from the results as the CEVT dataset went through major update in the locality which completely changed situation. Nevertheless, the survey of the locality help significantly towards preparation and surveying methods. The aim of the field survey was to carry out detailed recognition of the localities in which differences between considered datasets had been found, describe the reality of the current river network and search for clues which should provide ground for decision on similar cases without the necessity of visiting the locality.

After each visit to selected field survey locality the collected field data were carefully assessed and a Catalogue list was created. The Catalogue list contains preliminary data obtained from previous analyses:

- <u>geometry of both considered river network datasets</u>
- <u>river segments, names, IDs and orientation</u>
- <u>type of stream (CEVT)</u>
- <u>stream order – Strahler</u>

physic-geographical data obtained from various electronic resources:

- land cover data (ZABAGED 2014)
- DEM with 10 meters precision (developed during the primary analyses period from 2 meters contours)
- geological data (Czech Geological Survey map 1:50 000)

and the field data:

- GPS of the definition points
- record of existing watercourses and eventually dry channels
- thorough description of the locality
- land cover data evaluation
- river and land management description
- suggestion for a proposed solution to the river network dataset

4.4 The method development

The method of combining the existing river network datasets to produce an optimized river network dataset was developed during the first field survey. Each difference identified during the primary data analyses which was then researched in the field survey was recorded and documented in the Catalogue list see - Appendix 1. From the Catalogue list were extracted all the differences, the surveyed reality, suggested solutions and the management issues noticed and recorded during the field survey. A pattern was searched in the data that would indicate similar differences with similar river and management issues. Firstly, a statistical approach had been considered but it proved inappropriate and difficult to apply. Instead, other physic-geographical features, including DEM, land cover data, land use, geology and slope steepness were included into the consideration. As a result a table was developed in which differences are linked with suggested solution and with criteria for decision.

4.5 Case study area selection

The pre-requirements in the case study area search were that it was small to mid size catchment and there was sufficient amount of differences between the CEVT and ZABAGED river network datasets to demonstrate how the proposed method could be applied. As the best suitable area was chosen the Litavka River upper catchment. Firstly, the catchment was analysed in detail in terms of its physic-geographical characteristics, hydrological characteristics and all the differences in the CEVT and ZABAGED river network datasets were identified. Then, for all the differences, the method of river optimization was applied. This resulted in proposed new river network dataset including proposed changes in the watercourse types. The proposed model was then thoroughly verified in the second field survey. Afterwards, the reliability and functionality of the method was assessed.

5 The upper Litavka River catchment study area

The Litavka River is a main river that springs on eastern slopes of the Brdská vrchovina Hill country under the Malý Tok hill at altitude of 755 meters a. s. l. and is long 54.728 km according to CEVT river network dataset. The average discharge of the river near its confluence with the Berounka river is 2.57 m^3/s and the whole river basin covers area of 629 km^2.

The selected upper Litavka River catchment covers an area of 16.594 km^2 and is located in the Central Bohemia region about 60 km south of Prague Figure 4. Although the Central Bohemia region can generally be considered rich compare to other regions in the Czech republic, this southern part of the region is rather rural and poorer. The catchment area is only scarcely inhabited with the Láz village at its centre. The nearest Water Management Authority is located in Příbram town some 9 km north-east from the village. This relative remoteness form urban areas and authorities gives the area specific character with some lovely remote natural watercourses and some severely damaged and polluted artificial watercourses.

Geologically the area belongs to Barrandium Pluton zone of Bohemian Massif. The catchment area in particular is located on south-eastern slopes of Brdská vrchovina Hill country with mainly Cambrian conglomerate and Ordovician quartzite bedrock - see Figure 5. It lies within the “Tocká vrchovina Hill country” part of the Brdská vrchovina Hill country geomorphological unit of the Brdská oblast Region in the Poberounská subprovince (Balatka and Kalvoda, 2006).For the Brdská vrchovina Hill country are typical steep structural slopes on the edges and forested rounded hill peaks and wide ridges (Demek et al., 1965).

The hills in the area are also an important source of good quality ground water and as such it is protected zone of ground water accumulation.

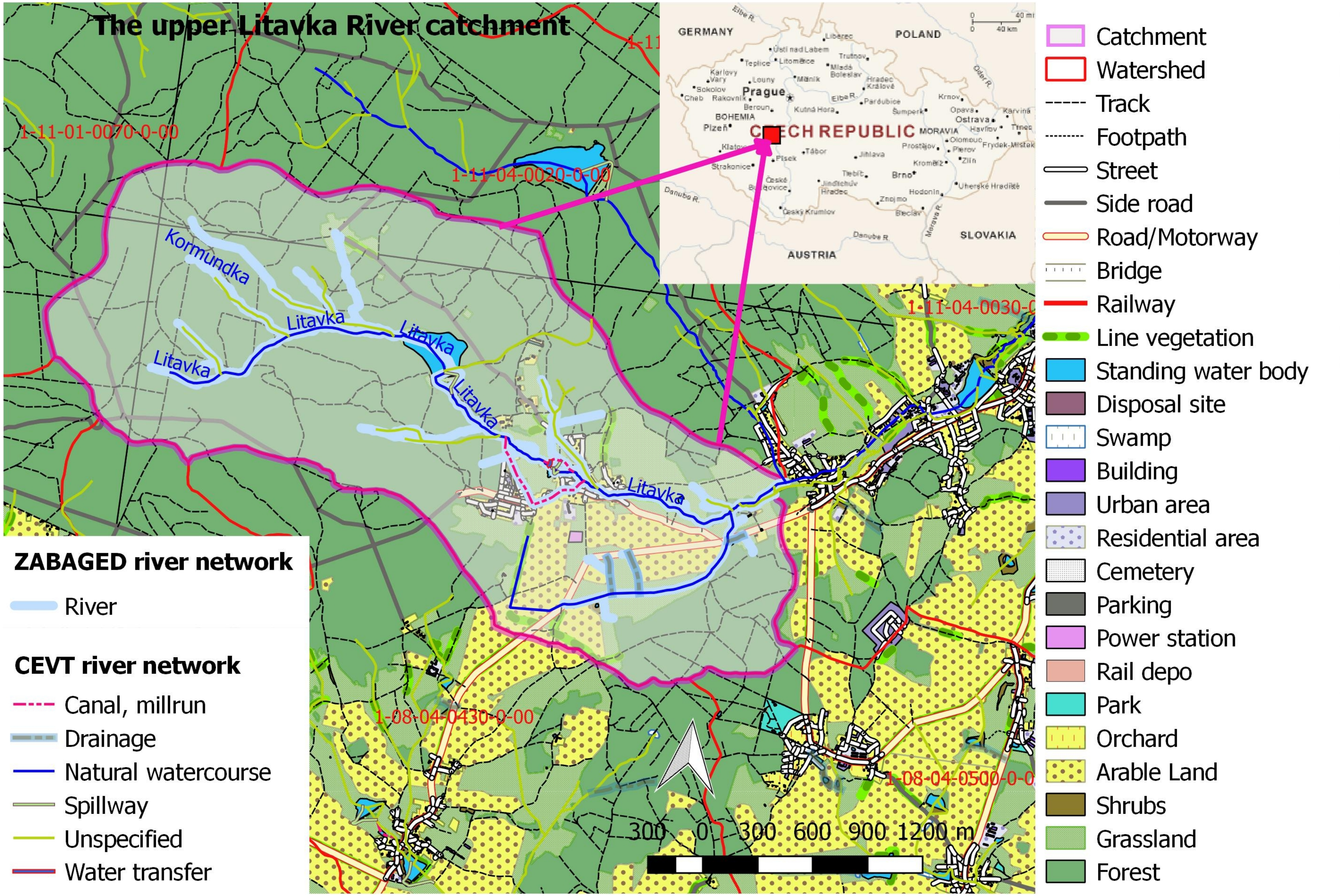

Figure 4: The upper Litavka River catchment in Central Bohemia. Thick light blue lines represent current ZABAGED river network dataset, the multi-coloured lines current CEVT river network dataset with differentiation according to watercourse type

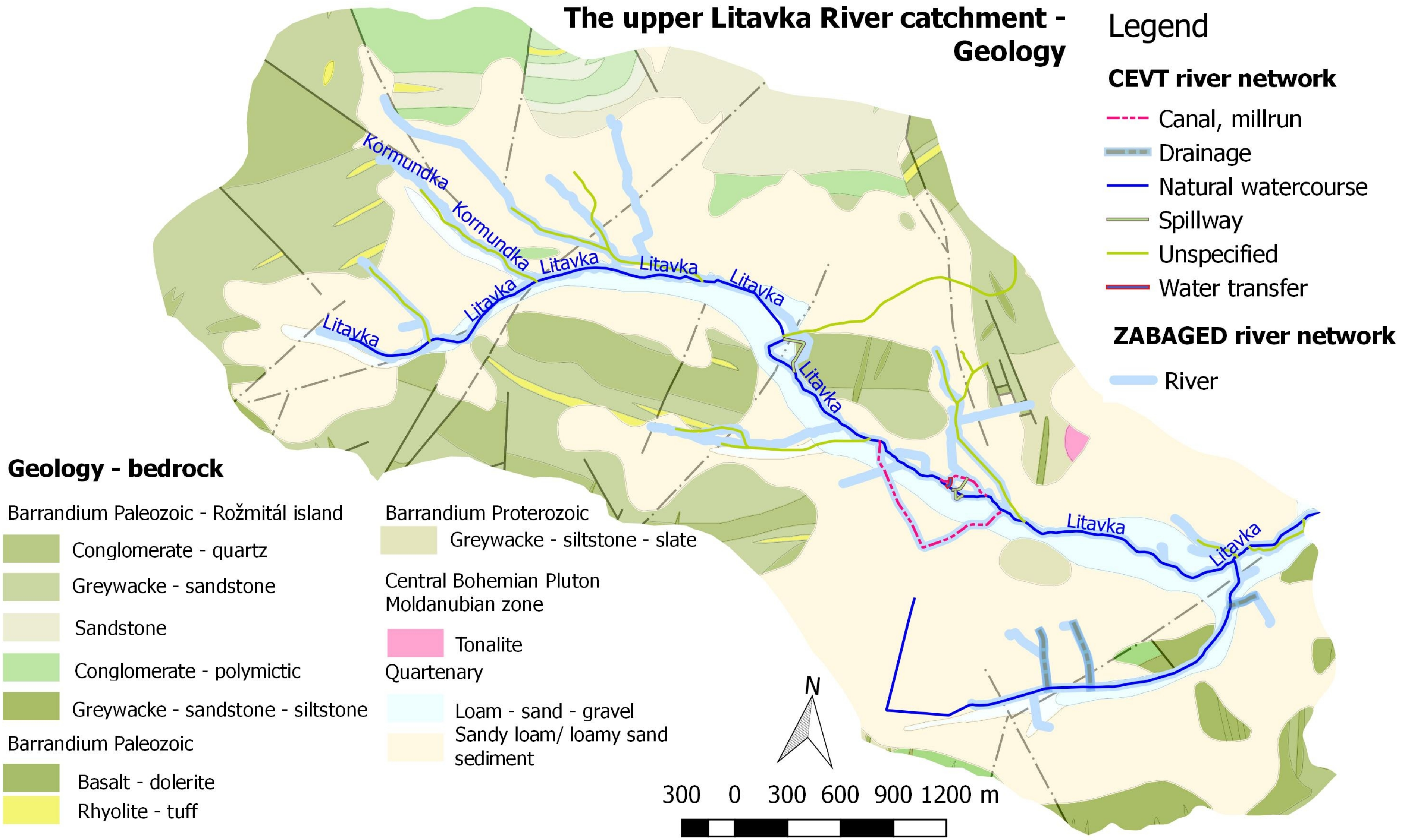

Figure 5: The upper Litavka River catchment geology

In terms of elevation characteristics the catchment can be described as mid to higher altitude with generally gentler slopes, although some slopes have almost mountainous character and can be really steep. The highest point is the Malý Tok hill at 843 m a. s. l. and the lowest point is where the Litavka River leaves the catchment at 556 m a. s. l. The north-western parts of the catchment are the highest with the springs of the Litavka River and some natural tributaries. The slopes in this part are relatively steep but because they are mostly forested the erosion does not represent significant risk. The south-eastern parts of the catchment have gentle slopes and are affected by the artificial drainage systems to improve the arable land. The Digital Elevation Model in Figure 6 was created from 2 m contours obtained from national database ZABAGED with TOPO to RASTER interpolation method (ESRI, 2014). The output DEM has resolution of 10 m^2.

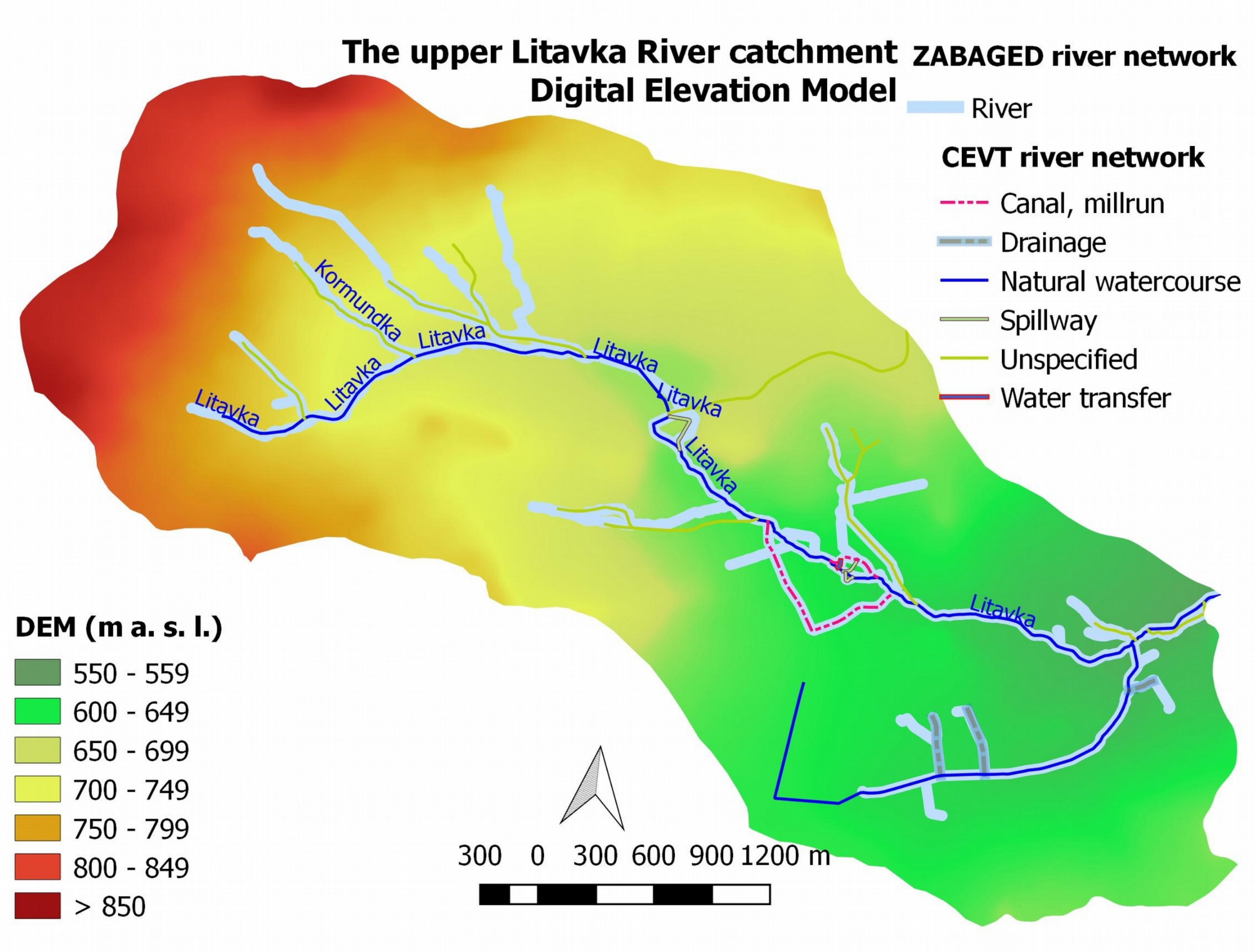

Figure 6: The upper Litavka River catchment - DEM

The soils in the catchment area are mostly Stagnosols (pseudogley) and Gleysols (Czech Geological Survey, 2014). Conditioned by excessive wetness at shallow depth, this type of soil develops gleyic colour patterns made up of reddish, brownish or yellowish colours on ped surfaces or in the upper soil layers, in combination with greyish/bluish colours inside the peds or deeper in the soil profile

(European Commission et al., 2005). The presence of such soils corresponds with the fact that major part of the catchment has gentle slopes under the highest parts and there is generally high groundwater table. Such geological and pedological characteristics define the catchment as water rich unsuitable for intensive farming area.

According to Quitt's (1971) climate classification the spring area belongs to climatic region CH 7, the central part of the catchment belongs to climatic region MT3 and the lower eastern parts of the catchment belong to climatic region MT5. The average annual temperature in the 1961 – 1990 period is 6 – 7 ^{0}C and average annual precipitation in the same period is in the spring area 700 – 800 mm and 600 – 700 in the remaining area (Czech Hydrometeorological Institute, 2016).

The Litavka River is a right hand tributary to the Berounka River within the Elbe River basin. It is a main river according to Water Framework Directive and as such it falls under the administration of the Povodí Vltavy, state enterprise (one of the five Drainage Boards). The hydrological characteristics of the river network in the selected catchment were calculated from both the river network datasets and are summarised in Table 6. These characteristics' calculations were made with accordance to Strahler (2011) suggestion and clearly show the difference of both river network datasets. Such differences have inevitably great effect on the hydrological models but also greatly impact local planning and decision making regarding the water management.

According to biogeographical regionalization by Culek et al. (1996) the catchment belongs to Hercynian sub – province. Major part of the catchment is within the Brdský bioregion and some south-eastern parts are within the Slapský bioregion. Although the area should mainly be forested by natural mixture of beech and coniferous trees the forest consists almost entirely of spruce monoculture.

The area is rural with Láz village at the centre of the catchment. There is virtually no industrial activity and also agricultural activities are rather extensive with mainly pastures for cattle and horses. The land cover of the catchment is enumerated in Table 7 and shown on map in Figure 7.

Because the official CORINE land cover data proved too generalised for the purposes of this study, the land cover was extracted from the national Topographic database (Land Survey Office 2015) published for the year 2014. The data were grouped with the purpose of reflecting river management issues considered further in the study.

Table 6: Hydrological characteristics of the upper Litavka River catchment river network

River network dataset	Strahler stream order	Number of segments	Bifurcation ratio	Total length (km)	Mean segment length (km)	Cumulative mean segment length %	Length ratio %
CEVT	1	16	-	8.484	0.53	40.410	40.410
	2	7	2.286	5.251	0.75	65.420	25.011
	3	18	0.389	4.816	0.27	88.359	22.939
	Unrated – artificial	10	-	2.444	0.24	100	11.641
	Totals	51	-	20.995	0.4475	-	100
ZABAGED	1	35	-	11.648	0.333	48.743	48.743
	2	11	3.182	2.983	0.271	61.225	12.483
	3	25	0.44	6.054	0.242	86.559	25.334
	4	4	6.25	0.602	0.15	89.078	2.519
	Unrated – artificial	19	-	2.61	0.137	100	10.922
	Totals	94	-	23.897	0.2266	-	100

Table 7: The upper Litavka River catchment land cover - extracted from Topographic database valid for the year 2014 (Land Survey Office, 2015)

Land cover group	Proportion of the whole area in %
Coniferous forest	75
Green areas with low vegetation (grassland and shrub)	14
Arable land	8
Surface waters (reservoirs, ponds, pools)	1
Residential areas and infrastructure	2

The catchment was chosen as a field study area for several reasons. It is a catchment with several differences between ZABAGED and CEVT river network datasets probably because of a fact that the upper parts of the catchment were until recently within military restricted zone with no access for civilians. The military zone restrictions not only prevented appropriate updates to river network but they also helped to preserve almost natural state to some of the upper parts of the catchment. It also has variable land cover without much of urban areas yet with small village in its centre. There is a visible lack of control from the Water Management Authority which often leads to an unauthorised changes to channels and streams made by local residents who tend to adjust their environment to their needs without consulting the authorities. As such there are some minor channel modifications and river bank structures in place which alter the river network and go undetected in the existing datasets. The actual comparison between the two datasets within the selected catchment can also be seen in Figure 4.

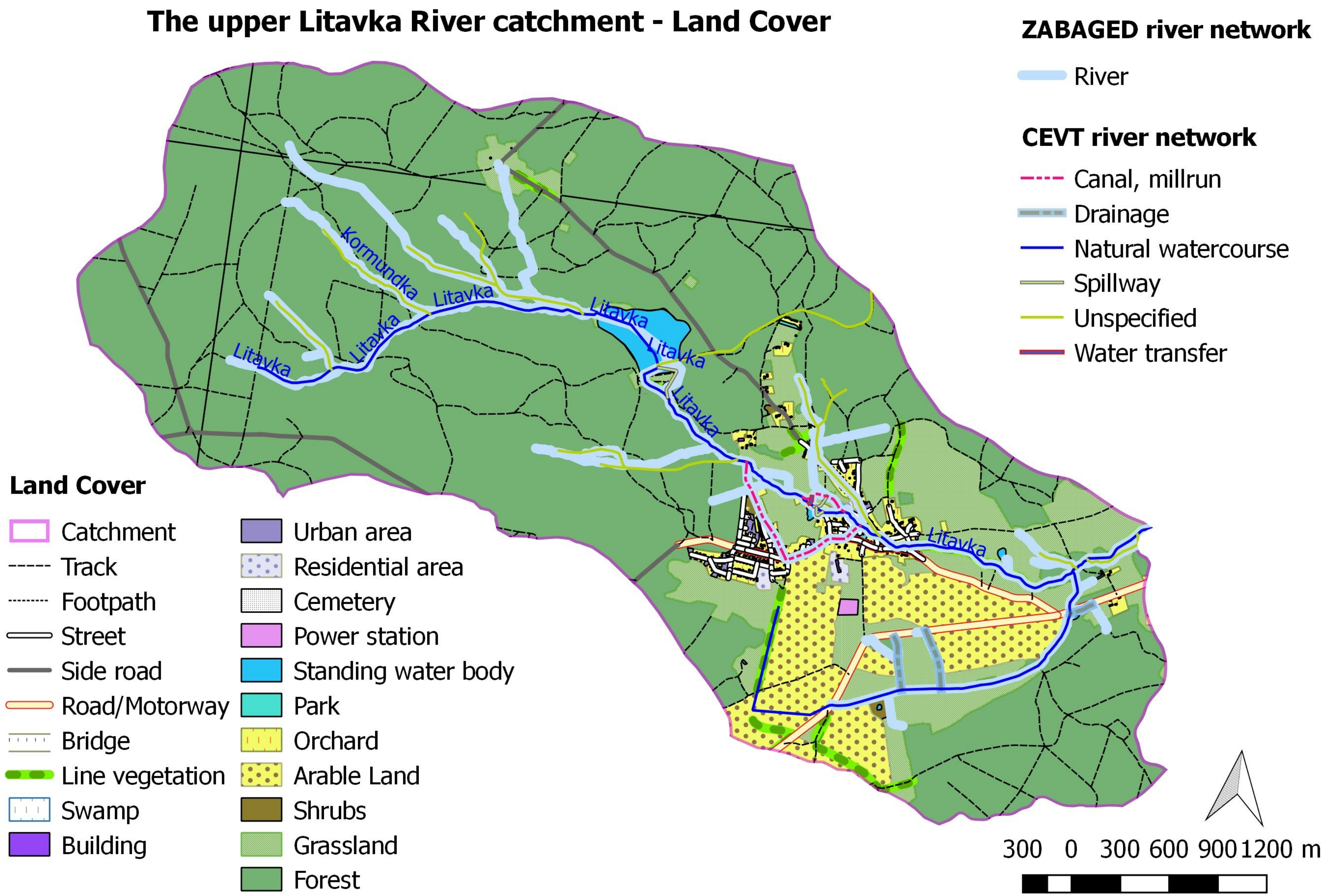

Figure 7: The upper Litavka River catchment - land cover, extracted from the national Topographic database (Land Survey Office 2015)

6 Results

The following chapter provides results in order in which they have been gained. Most of the results are interlinked and dependant on each other.

6.1 Preliminary analyses

Firstly, the original datasets were thoroughly analysed to appreciate the scale of differences between the data. The overall summary of the differences is in Table 1. Following analyses were aimed at identification of typical differences and their localization. From these analyses resulted a list of typical errors provided in Table 8 and list of suggested solutions provided in Table 9.

Table 8: List of typical errors found in ZABAGED or CEVT river network datasets

Errors
River segment exists in ZABAGED only
River segment exists in CEVT only
River segment is extended further upstream in ZABAGED
River segment is extended further upstream in CEVT
Different outflow of the river from water body (pond, reservoir)
River segment flows in different direction
Confluence of river segments in different location
River segment is not in any dataset

Table 9: List of suggested solutions to identified typical errors

Solutions
Remove the river segment from dataset
Add the river segment to dataset
Use current ZABAGED situation
Use current CEVT situation
Develop new situation, existing situations are completely incorrect

After producing the above lists of errors and possible solutions followed comprehensive visual search for various appropriate sites suitable for the primary field survey. These two steps were in fact closely interlinked and each field survey was preceded by complete analysis of the site.

6.2 Primary field survey results

The primary field survey results provide the most important ground for the final method development and the upper Litavka River catchment case study. The primary field survey was carried out in several different periods and the approach continuously evolved as the knowledge and understanding base widened. Thus the methodological steps were not exactly followed one after another and so the results were reached at various stages.

The major intended result of this stage was to develop Catalogue of surveyed sites with some general description of the wider area, detailed description of the found errors, suggested solution with its explanation and a river and environmental management issues which could be used as indicators of similar errors elsewhere. For each locality or area was also provided customized map output with important features and photo documentation. An example of a record in the Catalogue for one of the surveyed sites is in Table 10 in which the locality Vlachovice is described in detail, including some basic locality characteristics and river segments parameters. A map of the locality with taken GPS points and with some images from the obtained photo-documentation is in Figure 8. The complete Catalogue of sites is in Appendix 1 and contains results from field survey of 11 localities where various types of errors had been identified in the preliminary analyses.

Table 10: Example of a record in the Catalogue of sites for locality Vlachovice

Locality	**Vlachovice**					
Locality description	Rural area upstream north of village Vlachovice, bellow and above confluence of the Vlára River and the Sviborka River. Geologically the area belongs to Paleogene Carpathian flysh belt of the Magurian Nappes with mainly claystone, conglomerate and sandstone bedrock. The area is just outside the border of the Bílé Karpaty protected area and hilly, although with mid altitude of 300 – 400 meters above sea level. Forestry and kettle grazing are main farming activities there and overall the environmental management appears rather poor. Meadows are grazed and grass cut to the river banks leaving no space for flood plain. The Vlára and Sviborka Rivers are deeply incised and green waste form the meadows and shrubs are pushed into the channels.					
River (segment)	No name					
Start point ID (down stream)	P13					
Start point coordinates	17°	56'	8.65"	49°	7'	58.81"
Start point elevation	353.8479					
End point ID (up stream)	P15					
End point coordinates	17°	56'	4.38"	49°	8'	8.06"
End point elevation	358.3086					
Type of stream	Canal, millrun					
Left floodplain	Bush					
Right floodplain	Bush					
Error type	River segment exists in ZABAGED only					

Locality	Vlachovice
Situation description	The river segment in question is an old millrun that has not been in use for apparently long time. Its banks and floodplain are mostly covered by shrubs and solitary trees with some grassland and crop fields in near proximity. The channel is dry overgrown by shrubs and high grass and there is a plenty of rubbish around.
Suggested solution	Remove the river segment from dataset
Explanation to suggested solution	The millrun has not been in use for long time and the weir diverting water from the Vlára River is damaged beyond repair. There is no reason to expect reconstruction of the millrun.
Land Use recognition	The area of the millrun floodplain has been left to secondary succession which is clearly identifiable from remotely accessible land cover data. Such conditions suggest that a use of the millrun is no longer required and it is possible to apply a restoration management to the original Vlára river floodplain.

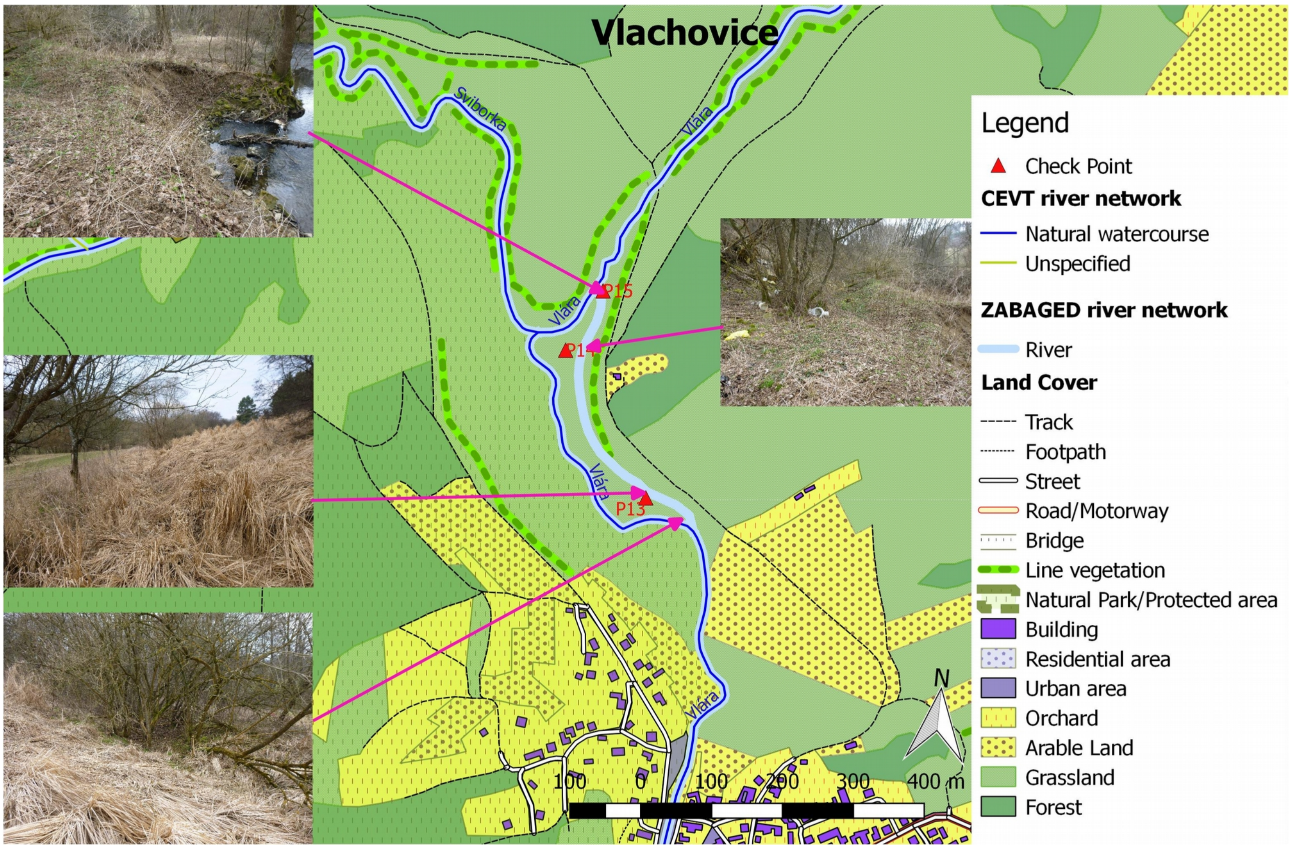

Figure 8: An example of a map from the Catalogue of sites - locality Vlachovice

The results of the primary field survey were analysed in terms of their impact on the list of typical errors (see Table 8) and the list of suggested solutions (see Table 9). The experience of different primary field survey also propagated into changes in Catalogue of sites Appendix 1 and to compositions of base maps created for each locality.

Each of the field surveys was accomplished by filling the Field survey form (see Table 11), recording coordinates of all relevant points for clear spatial identification of the locality and the watercourse in question and obtaining vast photo documentation.

Table 11: Field survey form with description of each obligatory field.

Survey collected information	Description
Locality description	Primary geographical description of the locality including geological data acquired from geological map
River (segment)	Name of the watercourse if given
Start point ID (down stream)	ID of georeferenced survey point used map of the locality and other spatial identification
Start point coordinates	Coordinates of the downstream point of the survey watercourse or its segment
Start point elevation	Elevation of the point acquired from the self-produced DEM
End point ID (up stream)	ID of georeferenced survey point used map of the locality and other spatial identification
End point coordinates	Coordinates of the upstream point of the survey watercourse or its segment
End point elevation	Elevation of the point acquired from the self-produced DEM
Type of stream	Watercourse type defined in the CEVT river network dataset
Left floodplain	Simple description of vegetation type or other land cover or structures identified in the floodplain
Right floodplain	Simple description of vegetation type or other land cover or structures identified in the floodplain
Error type	Error type as used from the list of errors
Situation description	Detailed description of the real situation on the site
Suggested solution	Suggested solution selected from the list of solutions
Explanation to suggested solution	Detailed description of all the possible indicators on which the other similar cases might be solved
Land Use recognition	Detailed description of other possible indicators eventually visible on the aerial images or land cover data

6.3 The method for selecting a correct information from conflicting features in the existing river network datasets

The major required result, the method for selecting a correct information from conflicting features in the existing river network datasets, has been developed during the field survey process and then subjected to severe testing and modifications. The base of the method is in identification of typical conflicting data in the existing datasets and search of indicators identified in the field survey that would help to make correct decision. The indicators collected during the field survey phase are summarised in Table 11. A complete set of characteristics on which the indicators are based, including different managements within surveyed localities is provided in Appendix 2. The ID for each indicator is the same as for GPS points used in the Catalogue of sites, therefore an example and photo-documentation to each indicator can be found there - Appendix 1.

From the indicators and their relations to environmental characteristics of the watercourse and floodplain or the surrounding area have been developed a set of questions (see Table 12). The questions are the foundation of the method application. Each question requires yes or no answer or eventually "not applicable". In turn each answer is numerically evaluated in positive or negative value within the range of -2 to +2. The values for each answer are simply summarised and the resulting value is the suggested solution. Positive value means that the segment in question should be added to the dataset and vice versa. The value for each answer on each question was determined by applying the question to all of the conflicting features in all the surveyed localities and empirically searching for suitable combination of answers and their values. The suggested solutions are based on assumption that the problem arises from conflicting situation when either two segments exist and only one of them can be adopted or when only one segment exist and it is necessary to decide whether to adopt it or not.

Table 12: Set of questions and values of the answers representing the foundation of the method for selecting a correct information from conflicting features in the existing river network datasets

Question	Answer	Value
Is the segment longer than 300 m	yes	1
	no	-1
A visible spillway structure and water abstraction with connection	yes	1
	no	0
	not relevant	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	yes	-1
	no	0
	not relevant	0

Question	Answer	Value
Infrastructure in the way of overland flow not directly interrupting a watercourse	yes	-1
	no	0
	not relevant	0
Water abstraction upstream the watercourse in question	yes	1
	no	0
	not relevant	0
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	yes	-1
	no	0
	not relevant	0
Industrial or residential structure crossing the original watercourse	yes	-1
	no	0
	not relevant	0
Residential or industrial area in proximity to watercourse with expectable connection	yes	1
	no	0
	not relevant	0
Dense river network and high water table area	yes	1
	no	0
	not relevant	0
Steep forested slope	yes	-1
	no	0
	not relevant	0
Connecting watercourse	yes	-1
	no	0
	not relevant	0
The segment geometry appears artificial and is in inhabited area	yes	-1
	no	0
	not relevant	0
Watercourse in thalweg surrounded by agricultural land on steep slope eventually with identifiable source of water	yes	-1
	no	0
	not relevant	0
Watercourse flows into artificial channel	yes	-2
	no	2
	not relevant	0
Channel visible on aerial image	yes	2
	no	-2

Question	Answer	Value
	not relevant	0
Summary	Suggested solution	
Segment	Segment ID	

The application of the method is simple and it supports the expected river network optimization process. The process should be based on combining data from the existing datasets to produce a single dataset using the best information from both. The process inevitably brings the necessity of deciding between two conflicting features. The conflicts correspond with the list of errors provided in Table 8. Practically all of the errors can be translated into a question whether a line segment in either ZABAGED or CEVT dataset should be added to the optimized dataset or not. Such line segment is thus subjected to questions in Table 12 and the answers calculated into a single value. Positive value suggests to add the segment into optimized dataset, negative value suggests the removal of the segment. A simple worksheet application has been produced with pre-defined answers and automatic calculation of the resulting values and suggested solution.

To illustrate the application of the method more clearly there is an example shown in Figure 9. On the map there is an overlay of ZABAGED (thick light blue lines) and CEVT (lines categorized by the watercourse type attribute) river networks. In first case the interconnecting segment exists only in the original ZABAGED dataset. It is thus necessary to decide whether the segment should be added to the optimized dataset or not. Therefore the segment in question is subjected to the questions in Table 12 and if the result is a positive number the segment is recommended to include in the optimized dataset and if negative then removed. The result of this particular case is in Table 13.

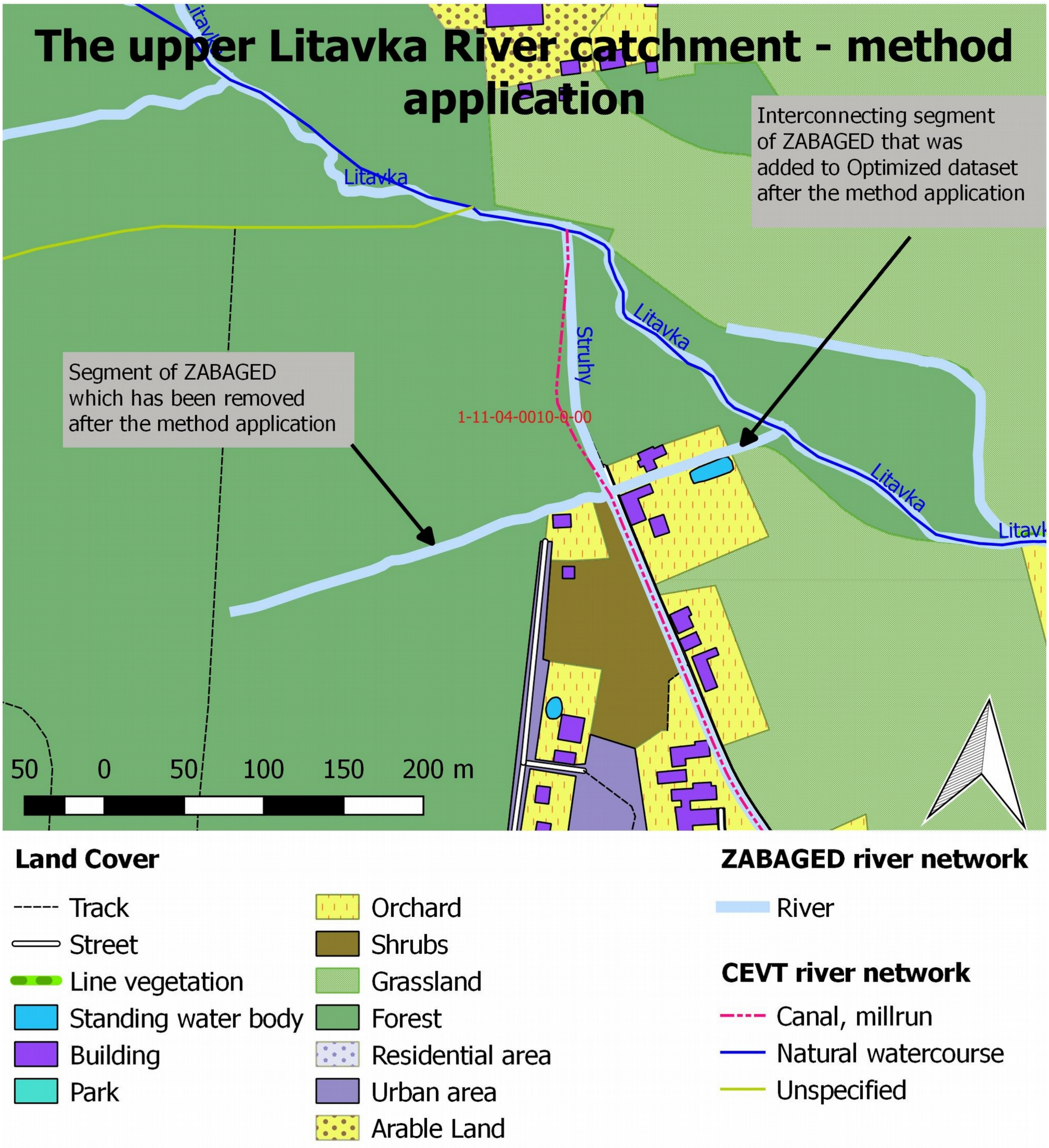

Figure 9: Example of the method application in the case study

As required by the preliminary conditions set in the hypothesis the method does not need any extensive information collection but can be applied with the use of relatively simply available data. When the method was applied to the second segment shown in Figure 9 the result was negative and the segment was recommended for removal.

Table 13: The method application result for a river segment that exists in the original ZABAGED dataset but not in the CEVT dataset. The result suggests to include the segment in the optimized dataset

Question	Answer	Value
Is the segment longer than 300 m	no	-1
A visible spillway structure and water abstraction with connection	not relevant	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	yes	-1
Water abstraction upstream the watercourse in question	yes	1
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	yes	2
Industrial or residential structure crossing the original watercourse	yes	-1
Residential or industrial area in proximity to watercourse with expectable connection	yes	1
Dense river network and high water table area	not relevant	0
Steep forested slope	no	0
Connecting watercourse	yes	2
The segment geometry appears artificial and is in inhabited area	no	0
Watercourse in thalweg surrounded by agricultural land on steep slope eventually with identifiable source of water	no	0
Watercourse flows into artificial channel	yes	-2
Channel visible on aerial image	yes	2
Summary	Add segment	3
Segment ID	Z3644393198190592+1	

Amongst the major disadvantages of the method is that it is not applicable on the structural differences between the existing models. Structural differences as the flow orientation or main outflow from the reservoir are characteristics that cannot be assessed by this method and additional knowledge is necessary. However, supposing the optimization process will mostly be carried out by the DBs experts who are in fact responsible for providing such technical data, this weakness of the method should not prove too limiting. Other limitation of the method is that it cannot deal with watercourses which are not in any of the existing datasets. Although, such events are not expected in large they have occurred few times during the verification stage of the project. Occasion when an unknown stream is found in the field is rare and it must be dealt with separately. The method provides no suggestion to it.

6.4 Case study results

Once the method had been developed into a complete process it was necessary to start with verification. Firstly, the question set was tested on the primary field survey sites. Afterwards, the upper Litavka River catchment was selected as an appropriate case study area through a similar analysis to that carried out in the preliminary stage. When the case study area was selected and described in terms of catchment characteristics (see chapter 5), three conflicting watercourses were chosen for the second part of the verification. In these three cases the method was applied and then the result was confirmed in the field. The result of this first testing is presented in a map in Figure 10. Out of the three watercourses one was correctly recommended for removal and one correctly for adding into the optimized dataset. However, the watercourse, or rather a segment of the watercourse between check points L28 – L29 was recommended was removal incorrectly as it can be seen on the relevant image in the Figure 10.

The first testing showed a specific weakness of the first version of the method and that was a specialization on natural watercourses while lacking in dealing with severely modified or artificial river network. To improve this weakness a question “Watercourse flows into artificial channel” has been added and answer values of the question “Connecting watercourse” have been modified. After the improvement the method was again applied to the three tested watercourses or their segments. This time the result was correct in all cases.

After the first testing and improvement the method was applied to all the conflicting features in the upper Litavka River catchment. The answers and resulting suggestions are completely presented in table in Table 13. After the method application all the results have been verified in field and a complete photo-documentation have been obtained. The verification is presented in table in Appendix 3. Overall 22 conflicting features had been identified and in 21 cases the suggestion produced by the method application proved correct. Only in one case the method failed when recommending for addition of a segment that was found in the field as a remnants of unused artificial drainage channel. It is however necessary to admit that in another 2 cases the results may be questionable because even in the field it proved difficult to confirm the existence or usage of the artificial channels. The usability of the method and shortcomings of the verification are discussed in more detail in the following chapter 7.

Based on the verified results the complete dataset of the optimized river network has been produced. The process of the optimized dataset production followed the principal idea that the best of existing datasets should be combined and the conflicting features should be assessed through the developed method. The guarantee of geometry is CUZK, thus the ZABAGED dataset was taken as the primary input and for all the segments that were found in both datasets was applied the principle that geometry is given by ZABAGED and flow orientation and other topological characteristics are given by the CEVT dataset. When conflicting features were found the method was applied and the result adopted into the dataset. All of the modifications are presented on a map in Figure 11. The map shows the modifications made in each original dataset and the resulting Optimized river network dataset. The optimized dataset contains only the verified results. The final dataset alone is presented in Figure 12 on the land cover background including watercourse categorization based on watercourse type.

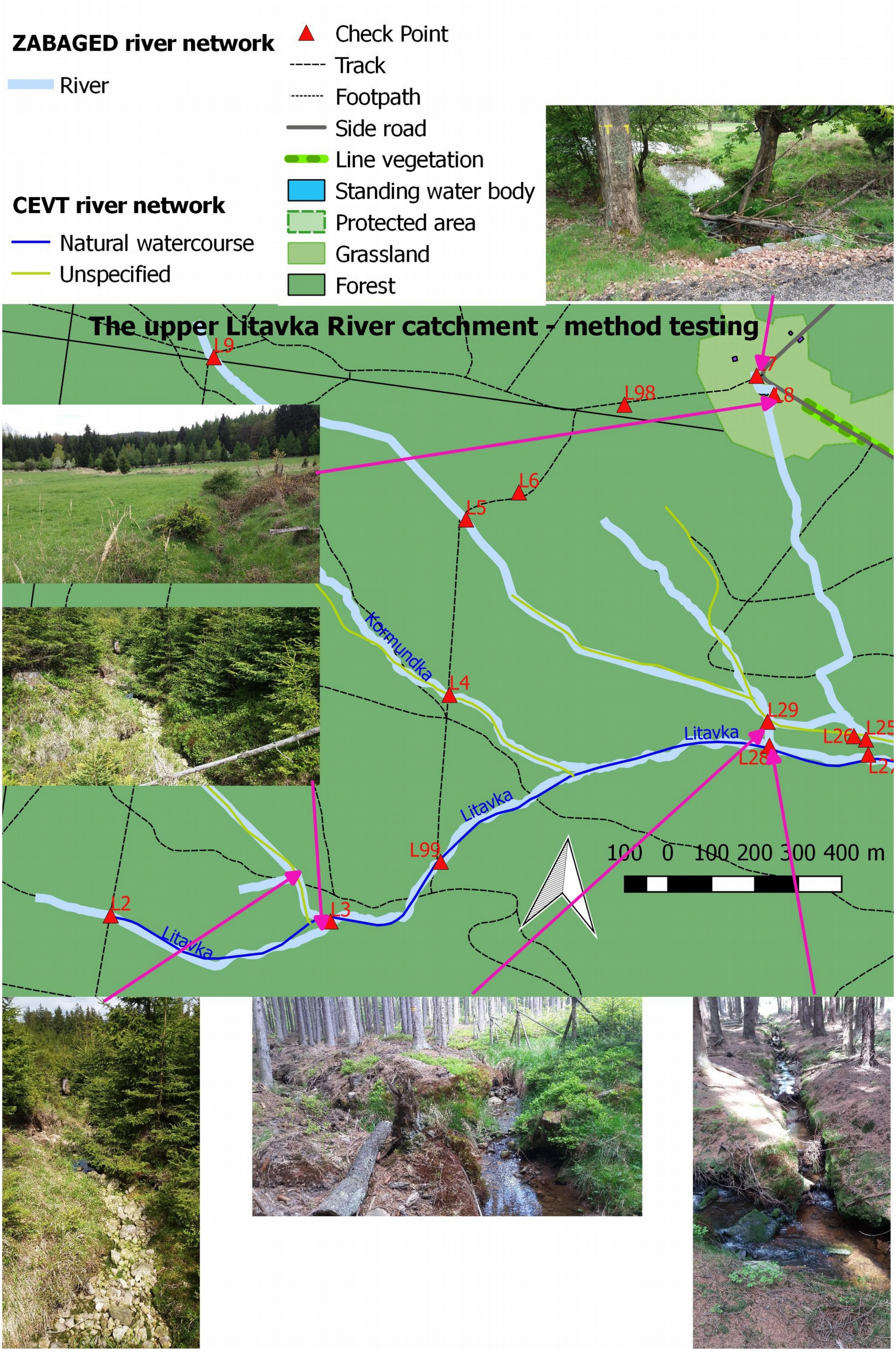

Figure 10: The upper Litavka River catchment - first method testing

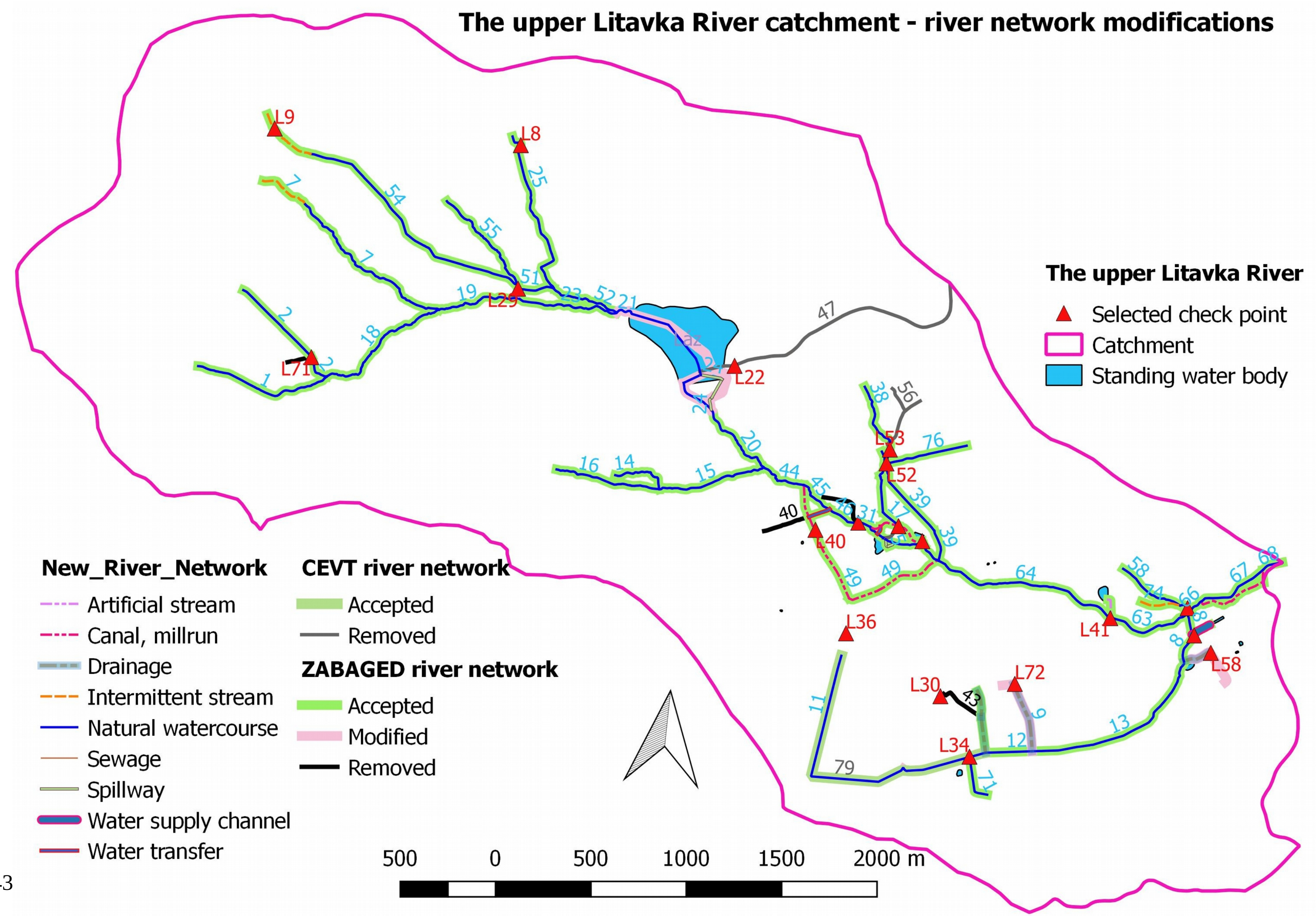

Figure 11: The upper Litavka River catchment - map showing the proposed river network dataset and modifications to original datasets

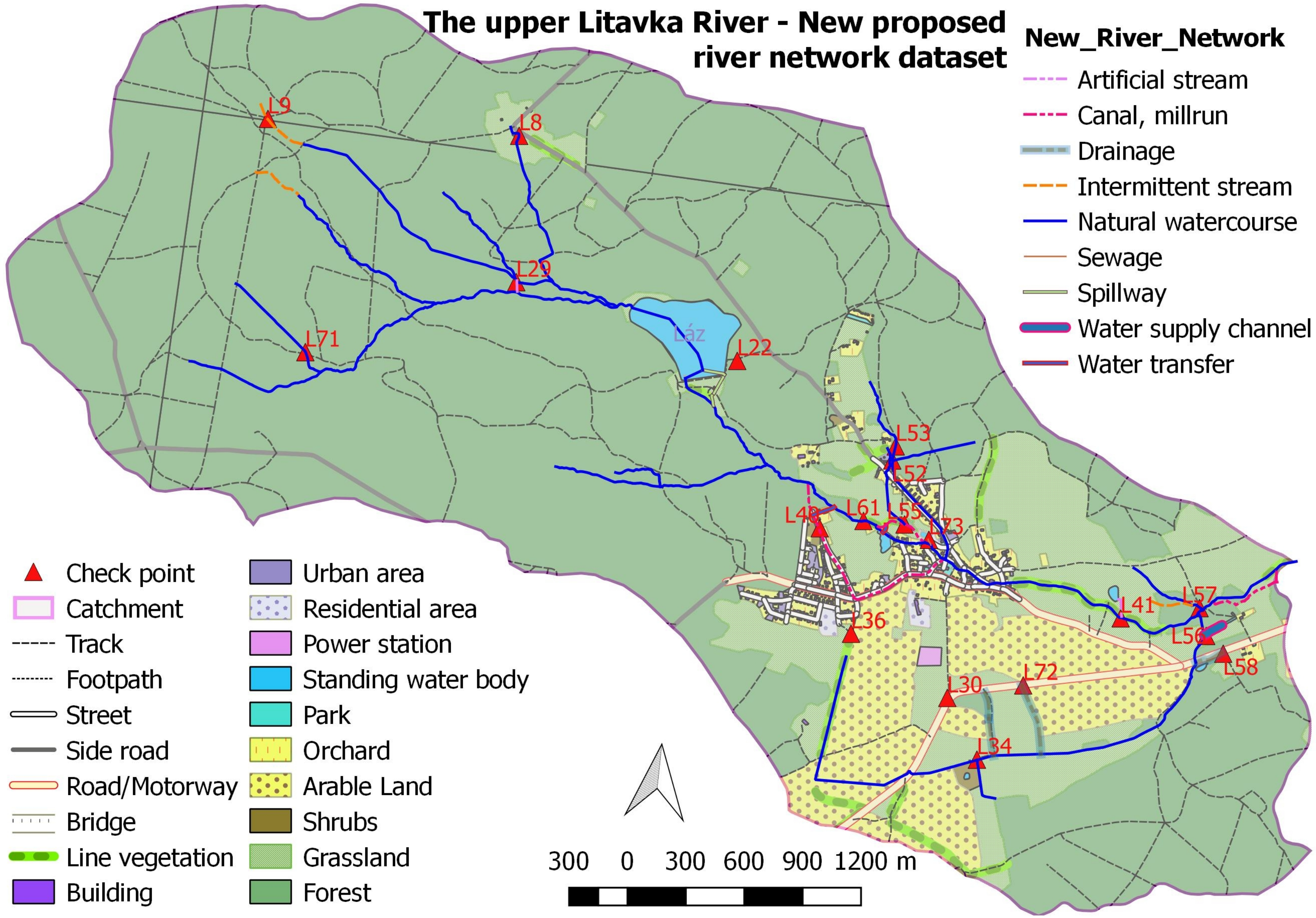

Figure 12: The upper Litavka River catchment Optimized River Network with selected field Check points and land cover. The Optimized dataset is categorized according to watercourse types

7 Discussion

Although it may appear that the results of the method application have been very good, the actual situation is more complicated. The method provided 21 correct solutions for 22 conflicts in the two original datasets. That represents effectiveness of over 95 %. But there are some shortcomings of the method and also some applicability problems that are discussed in following sub-chapters.

7.1 Method application

Perhaps the major shortcoming of the method is a subjectivity of its application. The method presumably allows for significant amount of variability and individualism when answering the questions. It is therefore not for inexperienced person to apply the method and there is a lot of space for different answers by different applicants. Inevitably, the person who knows the area in question will have answered the same questions differently to one who has never visited the area. Also the field experience is essential when applying the method. The method is aimed for use without necessary field work but the person applying it should have some experience with the field so he/she can better assess different aspects of the river network.

Although the above described disadvantage could play a major role in the method application by not well trained personnel, it should not be the case when used within the river network optimization process. The process is overall in hands of experts mainly from the Drainage Boards who all have extensive field work experience.

7.2 Field verification limits

The method verification was based on extensive field work. The verification, however, proved often not as simple. There are many examples where the recognition of a watercourse or its channel in the field is rather complicated. One of the typical situations is described in Figure 13 and Figure 14.

Figure 13: The upper Litavka River catchment - check point L71, inaccessible area of removed segment 4

Figure 14: The upper Litavka River catchment - different view from check point L71, inaccessible area with low GPS signal

The segment in question (see map in Figure 11) was a short first order stream recorded only in ZABAGED dataset and located deep in the forested headwater area of the catchment. It was recommended for removal by the method application. As it can be seen on images above the area is very inaccessible and it is almost impossible to follow the watercourse into which the stream should flow. Even with high quality GPS device the signal gets weak and rather imprecise. In such case to ensure that the stream really is not there and there is also not a channel which would suggest the existence of intermittent stream becomes extremely difficult. The images above show a dry channel into which another stream flows into. It was only later when the whole area was circumnavigated and series of GPS points were taken when it was realised that the found confluence was between the Litavka River and the segment 2. Only this way it was possible to establish that the stream in question does not exist even as an intermittent.

Perhaps even more complicated is situation when a piped watercourse should be located and verified. A typical example is presented by Figure 15 and Figure 16. The location is in the Láz village centre between no name pond and the canal semi-circling the area. While the piped spillway can be located easily the proof that the other spillway – segment 78 does not exist is very difficult to find.


Figure 15: Private land at the place where underground should be connected the no name pond with the canal via piped spillway - check point L55


Figure 16: Spillway from the no name pond in the Láz village centre which connects to canal near the check point L55

Thus while the method itself works well even in these above described complicated situations it is difficult to verify the results. As such the results should be treated with caution and if possible additional information should be gathered before final decision is made.

Very specific results have been gained throughout the field verification in terms of finding new unregistered watercourses. In the forested area of the headquarters of the upper Litavka River catchment were found 4 watercourses which are not registered in any of the existing datasets. Example of such watercourse is shown in Figure 17. As it can be seen it is a perennial watercourse with significant discharge and it certainly appeared to be natural. The fact that it is not registered complicates its protection and basically the owner or administrator of the forest is not bound by the law to respect and protect such unregistered watercourse. These watercourses cannot obviously be discovered by the method application but only in the field. To register such watercourses and include them in the optimized river network dataset unfortunately goes beyond the scope of this work and so they have been ignored. The only what can and will be done is that the relevant DB shall be notified.

Figure 17: Unregistered watercourse in the forested headwater area of the upper Litavka River catchment

7.3 Additional data

The method does not bring any new data to existing datasets, it is aimed only at choosing between conflicting features. The research however indicates that there are many additional information which would be very useful and desirable to present and publish with the official river network dataset. Firstly, the watercourse type is not accessible publicly, as explained in chapter 3.1 whilst it is extremely useful information and actually necessary for the method application. It has been noticed during the field verification that many watercourse types are rather questionable. At the same time however, the type was assumed for the segments which were adopted from ZABAGED river network dataset as they did not have such information. This task proved to be very difficult and the method itself does not provide any help with the type recognition.

Another set of information that could not be verified by the method is concerning flow orientation and topological characteristics of the watercourses. Such information are according the legislation guaranteed by the DBs, however, when ZABAGED segment is added these information are often difficult to verify other than in field. It was attempted to use some GIS method to verify existing and obtain such missing information. For an inspiration a dissertation work was found (Hartvich, 2008) in which the author tried the use of GIS to analyse valley segments orientation. The output of this particular part was that a major impact on the result of an analysis of the valley segment's orientation in GIS has the character and origin of input data. The input data were ZABAGED river network and DEM generated thalwegs. The resulting orientation of generated thalwegs was very different to ZABAGED. The resulting proportion of both directions of thalwegs within north-west

Šumava doesn't show much of significant preferential directions, not even when split into homogeneous segments nor when divided according to joints and following length weighting (Hartvich, 2008).

From the part of the dissertation work was concluded that manually drawn thalwegs represent rather reliable data, but layer of river network (regardless the method of its representation, i.e. whether the rivers are split in joints or divided into homogeneous segments) covers preferential ways only partially. However, there is apparent dissolve due to the impact of very detailed river network, which doesn't correspond in high detail to thalwegs and when applied to larger areas even small error may completely overshadow real river network orientation (Hartvich, 2008). The major problem of this attempt was apparently in fact that ZABAGED dataset contains not only natural watercourses but also several artificial or heavily modified watercourses that do not respect the thalweg orientation. If the watercourse type information was included in the published dataset, it would be possible to filter out the artificial watercourses and the above GIS technique would give probably much better results.

Also important is the watercourse type when calculating the Strahler stream order. The method for calculating it (Strahler, 1957) does not include artificial watercourses and so applying it automatically on real river network provides incorrect results. Again the simplest solution is to filter out all the artificial watercourses and apply the method only on natural watercourses. The hydrological characteristics according to Strahler (2011) are presented in Table 14. There is a major difference visible between the new dataset and both of the existing datasets presented in Table 6.

Table 14: Hydrological characteristics according to Strahler for the upper Litavka River catchment with Optimized river network dataset as an input

River network dataset	Strahler stream order	Number of segments	Bifurcation ratio	Total length (km)	Mean segment length (km)	Cumulative mean segment length (%)	Length ratio (%)
Optimized river network	1	15	-	8.482	0.565	35.604	35.604
	2	8	1.875	2.728	0.341	47.055	11.451
	3	6	1.333	1.046	0.174	51.446	4.391
	Unrated – artificial	39	-	11.567	0.297	100.000	48.554
	Totals	68	-	23.823	0.350	-	100.000

There are several other data which would be very useful to include in the Optimized river network dataset including hydromorphological data, average discharge, bank modifications and so on. Although such data are often difficult to guarantee and update, their use would greatly improve river and landscape management. For example the Water Framework Directive makes “hydromorphic condition” (the physical outcome of the inter-relationship between flow regime and the channel perimeter) a central parameter in spatial and temporal assessment of compliance with EU regulations (Sear and Arnell, 2006). An important part of a process of including additional geomorphological data into national river network dataset should be to work alongside river managers to understand the nature of the questions posed and to educate as to the values and services geomorphology can provide (Sear and Arnell, 2006). Under the current Water Framework Directive aims the geomorphological contribution to river and basin management becomes more feasible (Gregory et al., 2008). Furthermore, the implementation of management procedures has changed with greater public participation prior to decision making (Gregory et al., 2008), which also requires better public awareness. That can hardly be achieved without making river network related data publicly available.

The example how such data may in future eventually be added to published river network dataset is in the activity of The Centre for Ecology & Hydrology under the UK Natural Environment Research Council. The Centre provides several datasets linked to national hydrological datasets mostly as outcomes from their research and mapping activities. As the Centre is a public institution the outcomes are provided as open source. One such dataset is called “Integrated Hydrological Units of the United Kingdom: Groups”. This dataset is part of Integrated Hydrological Units (IHU) of the UK, a set of geographical reference units for hydrological purposes including river flow measurement and hydrometric data collection (Kral et al., 2015). The creation and development of similar dataset in the Czech Republic would however involve a much closer and better coordinated cooperation between the relevant institutions. That would in turn require better cooperation between various ministries responsible for the institutions and for financial support of the research projects.

8 Conclusion

The method's over 95 % successful solutions in conflicting cases seems acceptable and it shows that even such simple method when used with caution can produce required results with minimum costs and within short time. The shortcomings of the method described in chapter 7 however show that the method application is prone to inevitable errors. Such errors nevertheless occur even now and they have to be dealt with continually as they are found. It is extremely important to understand all the problems related to river network published dataset. On one side there are legal issues that limit the use of land or property located near the natural watercourse, on the other there are all sorts of environmental issues that can be pursued only if the watercourse is recorded and publicly recognized.

There is also an output of this work that had not been fully anticipated and is rather surprising. It had not been expected to find several unregistered watercourses which is necessary to include in river network dataset, and it had not been expected to find out how many watercourses have been modified without authorisation. While the discovery of new unregistered watercourses is perhaps related only to forested headwater areas in less inhabited regions, the fact that people tend to modify channels without consideration of their ecological function is a lot more worrying. Especially in rural areas it is not an exemption to find a watercourse channel that has been diverted into a pipe without authorisation and a fence was built over the watercourse to prevent access onto a private land. Such behaviour is, of course, against the law but its enforceability is low and complicated.

It is believed that the River Network Optimization project could uncover several of such problems and bring them into discussion. To deal with such problems it is important that the Optimized river network dataset contains as many hydromorphological and hydrological data as possible. Only by publishing such data their imperfections shall play an important role and that should in turn to enforce their appropriate update. It is however down to Water Management Authorities to consider the data and take appropriate action when the protection of watercourses is at stake.

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Data resources

ZABAGED river network dataset - State Administration of Land Surveying and Cadastre 2015, Department for Administration and Development of data

CEVT river network – Ministry of Agriculture 2015, Department of State Administration of Water Management and River Basin

Topographic data ZABAGED - State Administration of Land Surveying and Cadastre 2015, Topographic database

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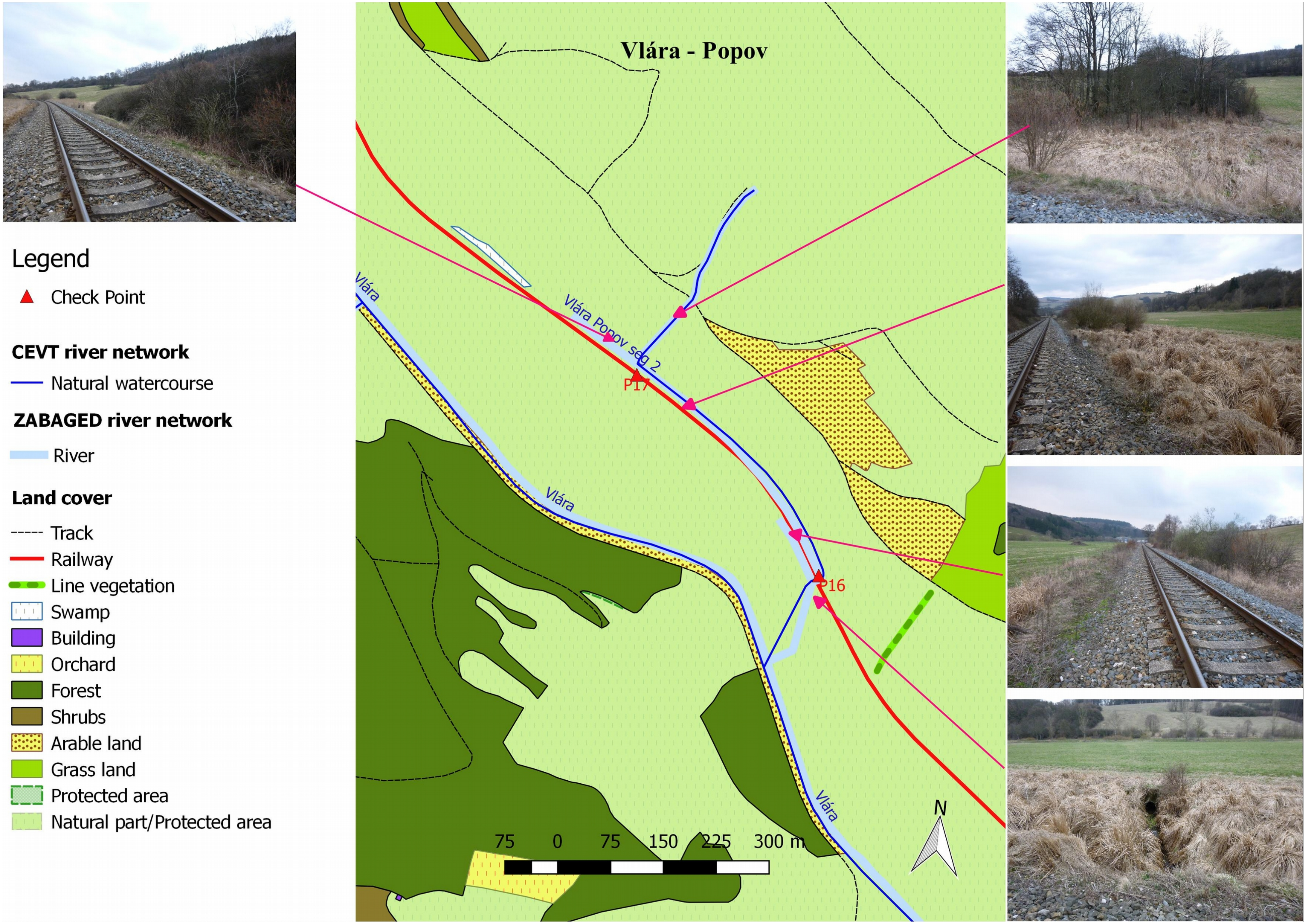
Pedological map of the Czech Republic 1:10 000 - Research Institute for Soil and Water Conservation 2016, Sowac GIS portal, accessed via http://mapy.vumop.cz/

Appendix 1

Locality	**Vlára – Popov**
Locality description	Rural area west of Štítná nad Vláří village in the heart of Bílé Karpaty protected area. Geologically the area belongs to Paleogene Carpathian flysh belt of the Magurian Nappes with mainly claystone and sandstone bedrock. The Vlára River forms rather deeper valley with diverse selection of steep and gentler sloping hills around. The soft sedimentary bedrock, steep slopes, deforestation and farming practises increase the risk of erosion and land slides. This is reflected also along the Vlára River which banks show signs of slope failing and the channel is in places deeply incised. The stream in question is small stream running down the gentler slopes above the Vlára River having no clearly defined channel. However, as it should cross the railway track it is redirected into the drainage channel along the track for 420 meters, then piped under the track and further on it is piped again to flow under the surface directly to the Vlára River.
River (segment)	No name
Start point ID (down stream)	P16
Start point coordinates	17° 56' 39.26" 49° 4' 38.41"
Start point elevation	327.9509
End point ID (up stream)	P17
End point coordinates	17° 56' 25.32" 49° 4' 46.85"
End point elevation	328.4379
Type of stream	Unspecified
Left floodplain	Bush
Right floodplain	Bush
Error type	River segment exists in ZABAGED only
Situation description	There are two river segments in ZABAGED dataset joining the stream which are not in the CEVT dataset. Both segments are short (110 and 95 meters respectively), neither have defined channel and none had water at the time of field survey. Although, the vegetation cover suggests that there may be some water flowing shortly after some rainfall event.
Suggested solution	Remove the river segment from dataset
Explanation to suggested solution	The two segments in question are both apparently dry for most of the year and because of the presence of the railway track there is no possibility for any natural channel formation. They represent only some technical structure designed to prevent deterioration to the railway track by flowing water after a major rainfall event.

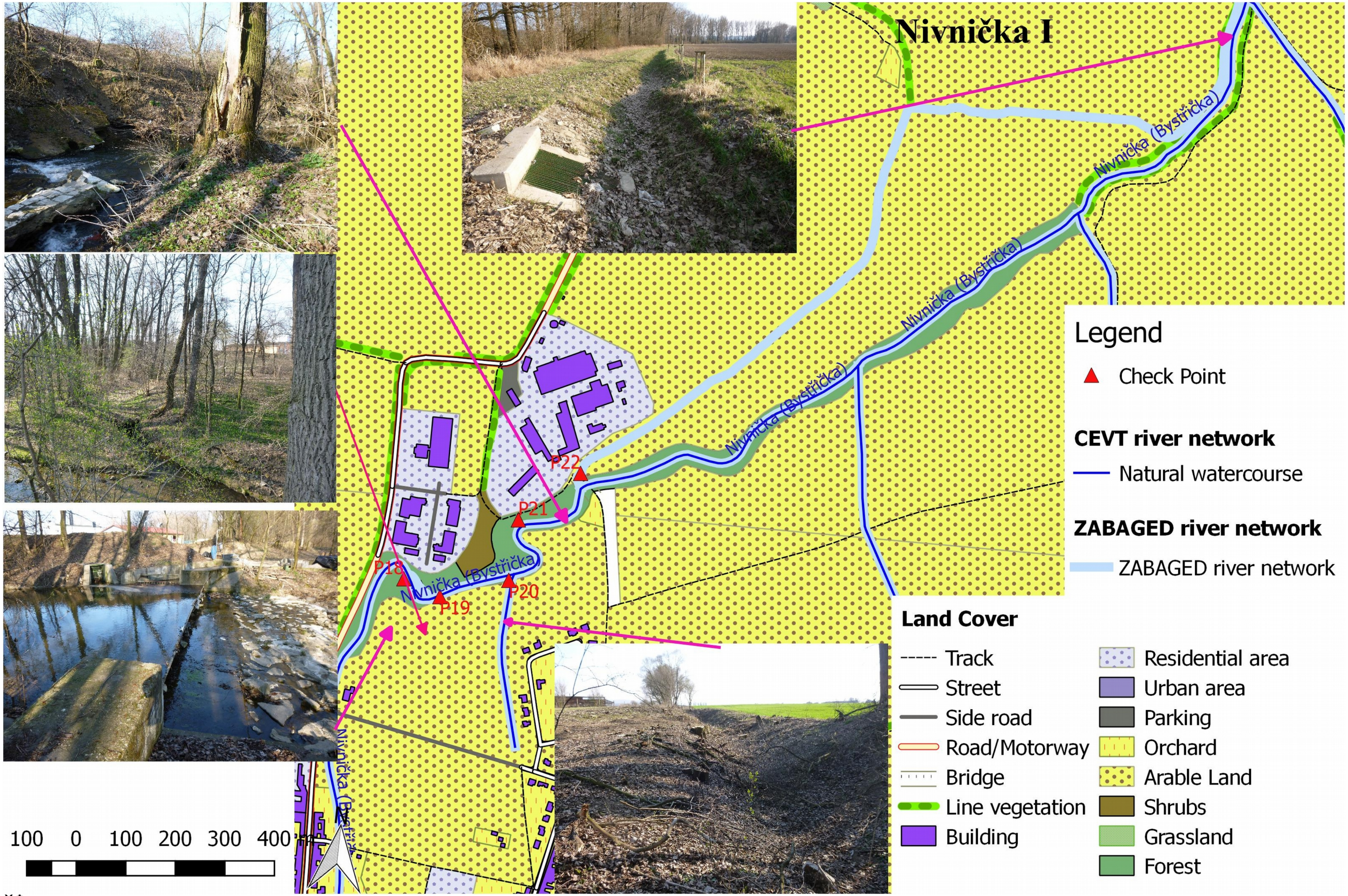
Land Use recognition

From the remote data it possible to clearly identify the railway track, the fact that the main stream is piped under the surface from the track downwards and intensive farming land use is applied in the area. From the two segments length and orientation along the railway it is possible to recognise that they may only serve as a drainage for the track. Such segment should not be included in river network and there can hardly be suggested any improvement to the existing stream management.

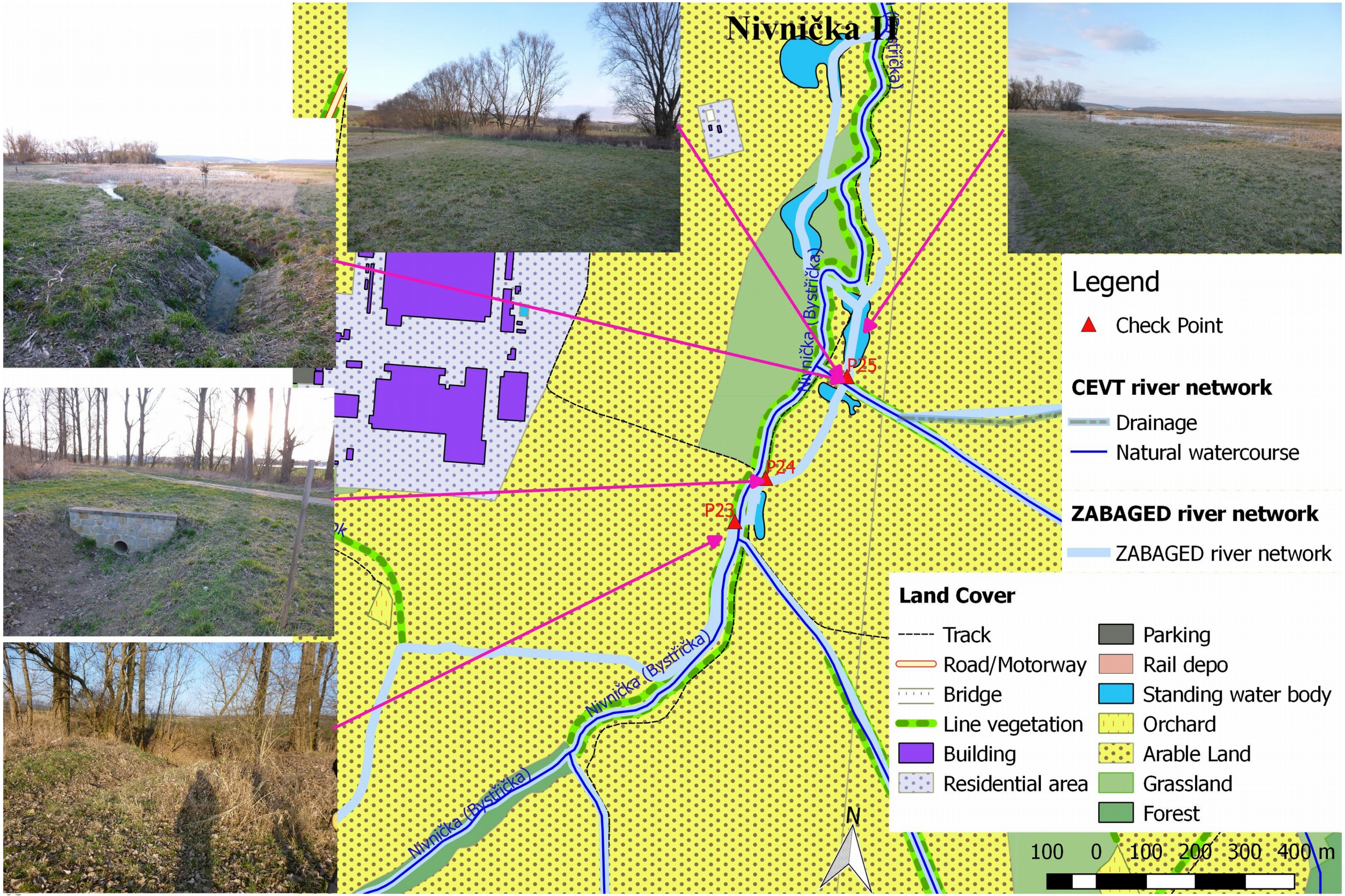

Vlára - Popov
Legend
Check Point
CEVT river network
Natural watercourse
ZABAGED river network
River
Land cover
Track
Railway
Line vegetation
Swamp
Building
Orchard
Forest
Shrubs
Arable land
Grass land
Protected area
Natural part/Protected area
Vlára
Vlára Popov seg 2
P17
P16
75 0 75 150 225 300 m
N

Locality	**Nivnička I**
Locality description	Partially rural and industrial area south of the town Uherský Brod. Geologically the area belongs to Paleogene Nivnicky flysh belt with mainly calcite claystone of the Magurian Nappes with mainly claystone and sandstone bedrock. It is flat low lying area with large crop fields with very intensive farming and several industrial parks. The Nivnička River represents here slow, meandering fourth order (Strahler 2002) stream with plenty of fine sediment to transport. The river is heavily affected by water abstraction for industrial and agricultural purposes and hydro-power generation. On both banks there are significant bank slides.
River (segment)	No name
Start point ID (up stream)	P18
Start point coordinates	17° 38' 24.86" 48° 59' 20.85"
Start point elevation	235.0912
End point ID (down stream)	P23
End point coordinates	17° 39' 42.30" 49° 0' 4.82"
End point elevation	218.9994
Type of stream	Canal, millrun
Left floodplain	Arable land
Right floodplain	Arable land
Error type	River segment exists in ZABAGED only
Situation description	In the ZABAGED dataset there is a canal diverting from the Nivnička River at point P22. The canal is not in the CEVT dataset. The canal exists, however the diversion starts already at point P18 and flows firstly through industrial park and then at point P22 it appears in the crop field where it has artificially made channel. At the point P22 the discharge is significant and appears permanent while at point P23 where it joins the Nivnička River the channel is dry. The loss of water in the channel is due to generally dry conditions in the region and unsuitability of the channel placement. The use of the channel is questionable as the industrial park at the diversion point P18 is not publicly accessible and there is no further use of the canal until its confluence.
Suggested solution	Add the river segment to dataset
Explanation to suggested solution	The canal existence is obvious and there is a significant discharge at certain parts. The acknowledgement of the canal is seen as important for the Nivnička River management because it accounts for, perhaps unnecessary, significant water abstraction.

Locality	**Nivnička I**
Land Use recognition	The water abstraction from the Nivnička River for the canal is difficult to identify even in the field because it is directed into the pipeline across private industrial park. Then the canal is however in open field identifiable from aerial photographs. As it is open mainly farm land it is notable as land feature and there is no reason to doubt correctness of the ZABAGED data. The proximity of industrial parks also suggests illegal water abstraction.

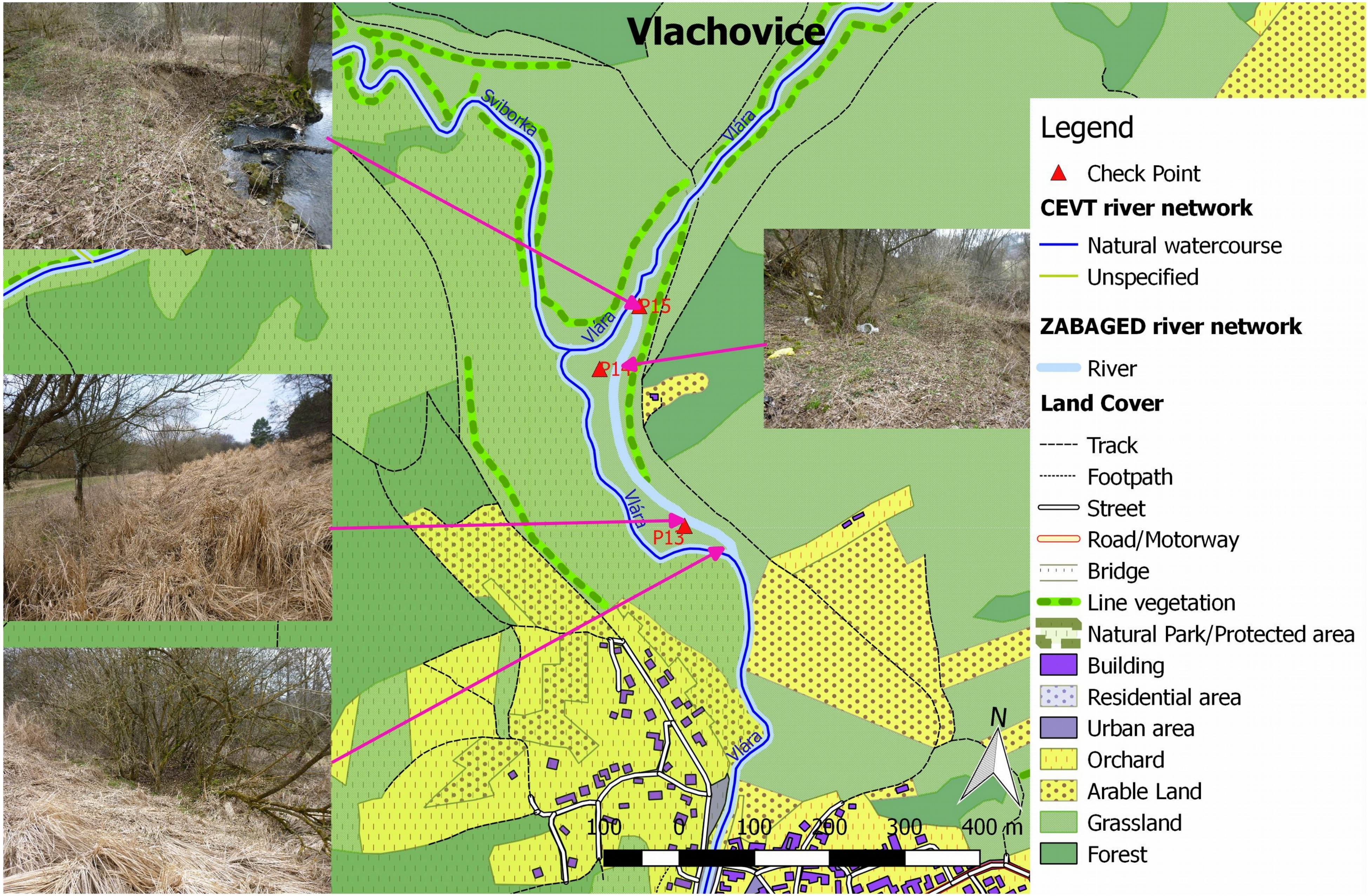

Nivnička I
Nivnička (Bystřička)
Nivnička (Bystřička)
Nivnička (Bystřička)
Nivnička (Bystřička)
Nivnička (Bystřička)
P18
P19
P20
P21
P22
Legend
Check Point
CEVT river network
Natural watercourse
ZABAGED river network
ZABAGED river network
Land Cover
Track
Street
Side road
Road/Motorway
Bridge
Line vegetation
Building
Residential area
Urban area
Parking
Orchard
Arable Land
Shrubs
Grassland
Forest
100 0 100 200 300 400 m

Locality	**Nivnička II**
Locality description	Partially rural and industrial area south of the town Uherský Brod. Geologically the area belongs to Paleogene Nivnicky flysh belt with mainly calcite claystone of the Magurian Nappes with mainly claystone and sandstone bedrock. It is flat low lying area with large crop fields with very intensive farming and several industrial parks. The Nivnička River represents here slow, meandering fourth order (Strahler 2002) stream with plenty of fine sediment to transport. The river here becomes more natural as it flows away from industrial parks of previous locality. In the right hand floodplain there has been realized project for water retention including construction of some ponds and pools and planting suitable vegetation. This have significantly positive effect on the Nivnička River itself.
River (segment)	No name
Start point ID (up stream)	P24
Start point coordinates	17° 39' 44.95" 49° 0' 7.82"
Start point elevation	218.1478
End point ID (down stream)	P25
End point coordinates	17° 39' 52.07" 49° 0' 14.94"
End point elevation	216.7208
Type of stream	Intermittent stream
Left floodplain	Individual trees
Right floodplain	Arable land
Error type	River segment exists in ZABAGED only
Situation description	In the ZABAGED dataset there is a watercourse diverting from the Nivnička River at point P24. The watercourse is not in the CEVT dataset. Although artificial, it could perhaps be rather considered intermittent stream which purpose it to supply water for the recently constructed ponds and pools aiming at water retention in the land. The situation is complicated by the fact that while the watercourses are included in the ZABAGED dataset the ponds and pools are not.
Suggested solution	Add the river segment to dataset
Explanation to suggested solution	The existence of the intermittent stream is essential for the water supply to recently constructed ponds and pools. There are also other structures as culverts and piped outflow which existence is reasonable only if the stream exists.
Land Use recognition	All the watercourses in this particular area have been made to support the original project of building ponds and pools to support water retention in the land. Information about the project are publicly available. Such project could have been authorised only with the knowledge of the relevant River-board Authority and therefore it should be included in the CEVT dataset.

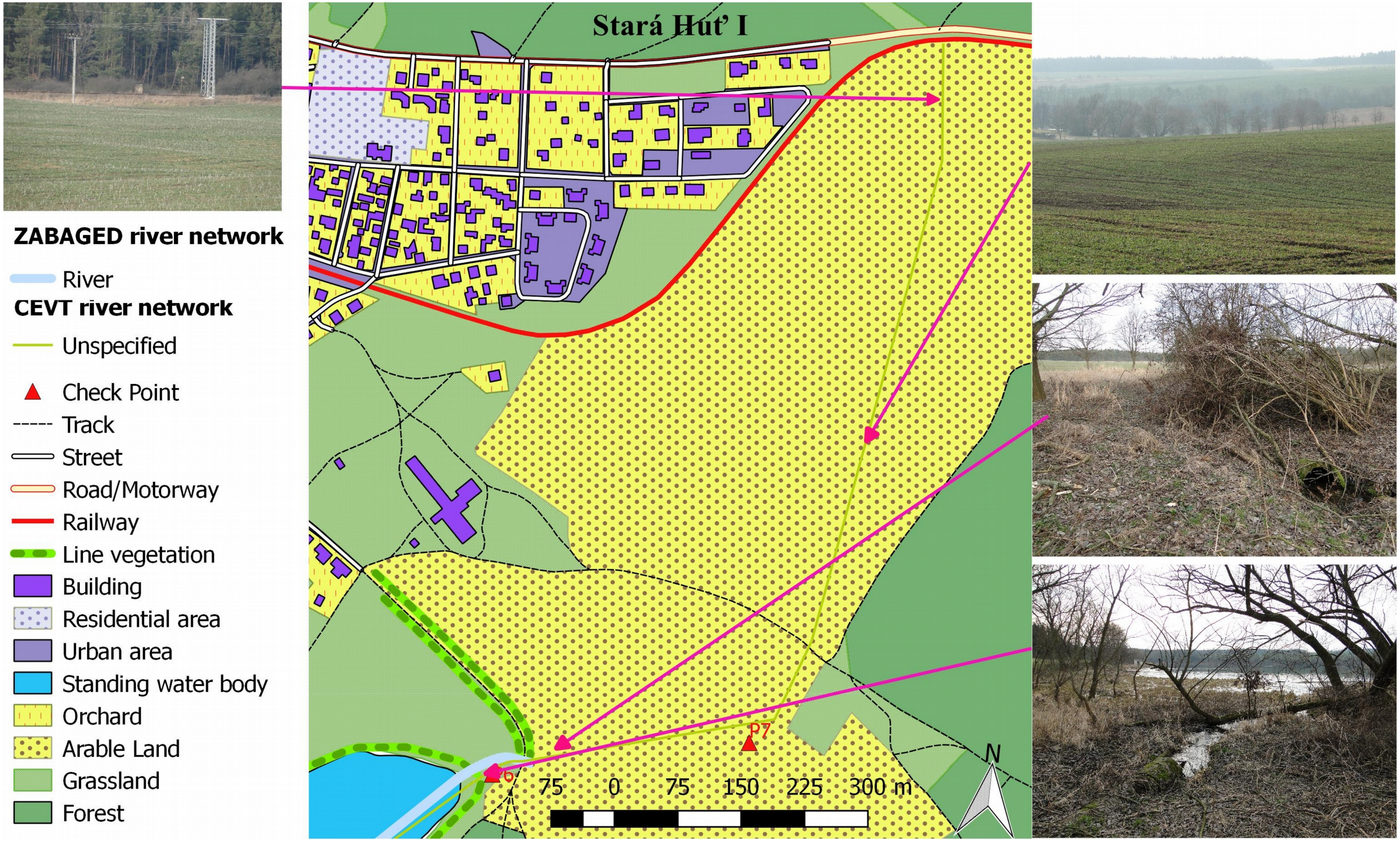


Nivnička II
Nivnička (Bystřička)
P23
P24
P25
N
Legend
Check Point
CEVT river network
Drainage
Natural watercourse
ZABAGED river network
ZABAGED river network
Land Cover
Track
Road/Motorway
Bridge
Line vegetation
Building
Residential area
Parking
Rail depo
Standing water body
Orchard
Arable Land
Grassland
Forest
100 0 100 200 300 400 m

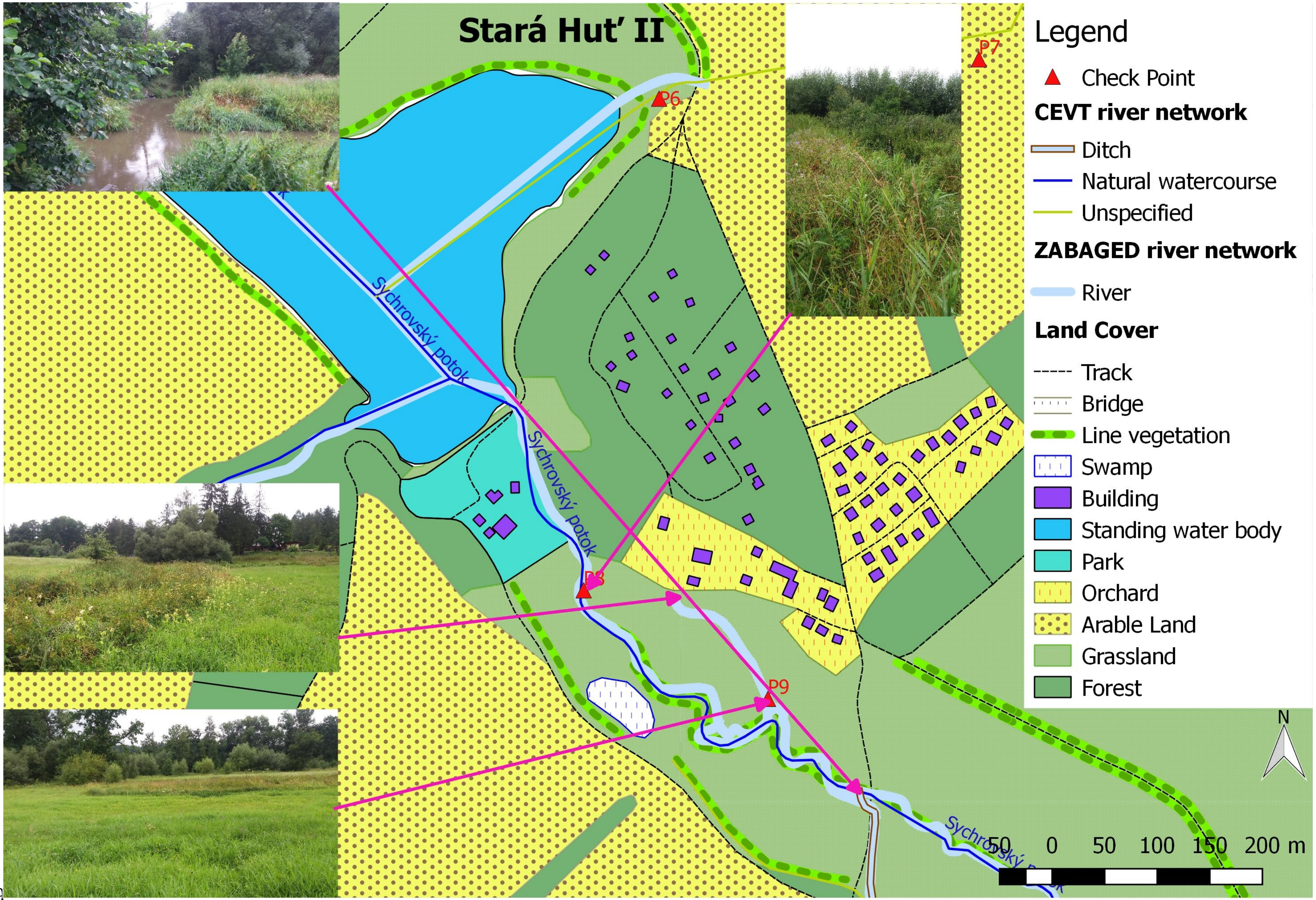
Locality	**Vlachovice**
Locality description	Rural area upstream north of village Vlachovice, bellow and above confluence of the Vlára River and the Sviborka River. Geologically the area belongs to Paleogene Carpathian flysh belt of the Magurian Nappes with mainly claystone, conglomerate and sandstone bedrock. The area is just outside the border of the Bile Karpaty protected area and hilly, although with mid altitude of 300 – 400 meters above sea level. Forestry and kettle grazing are main farming activities there and overall the environmental management appears rather poor. Meadows are grazed and grass cut to the river banks leaving no space for flood plain. The Vlára and Sviborka Rivers are deeply incised and green waste form the meadows and shrubs are pushed into the channels.
River (segment)	No name
Start point ID (down stream)	P13
Start point coordinates	17° 56' 8.65" 49° 7' 58.81"
Start point elevation	353.8479
End point ID (up stream)	P15
End point coordinates	17° 56' 4.38" 49° 8' 8.06"
End point elevation	358.3086
Type of stream	Canal, millrun
Left floodplain	Bush
Right floodplain	Bush
Error type	River segment exists in ZABAGED only
Situation description	The river segment in question is an old millrun that has not been in use for apparently long time. Its banks and floodplain are mostly covered by shrubs and solitary trees with some grassland and crop fields in near proximity. The channel is dry overgrown by shrubs and high grass and there is a plenty of rubbish around.
Suggested solution	Remove the river segment from dataset
Explanation to suggested solution	The millrun has not been in use for long time and the weir diverting water from the Vlara River is damaged beyond repair. There is no reason to expect reconstruction of the millrun.
Land Use recognition	The area of the millrun floodplain has been left to secondary succession which is clearly identifiable from remotely accessible land cover data. Such conditions suggest that a use of the millrun is no longer required and it is possible to apply a restoration management to the original Vlara river floodplain.


Vlachovice
Sviborka
Vlára
P15
P14
P13
Legend
Check Point
CEVT river network
Natural watercourse
Unspecified
ZABAGED river network
River
Land Cover
Track
Footpath
Street
Road/Motorway
Bridge
Line vegetation
Natural Park/Protected area
Building
Residential area
Urban area
Orchard
Arable Land
Grassland
Forest
N
100 0 100 200 300 400 m

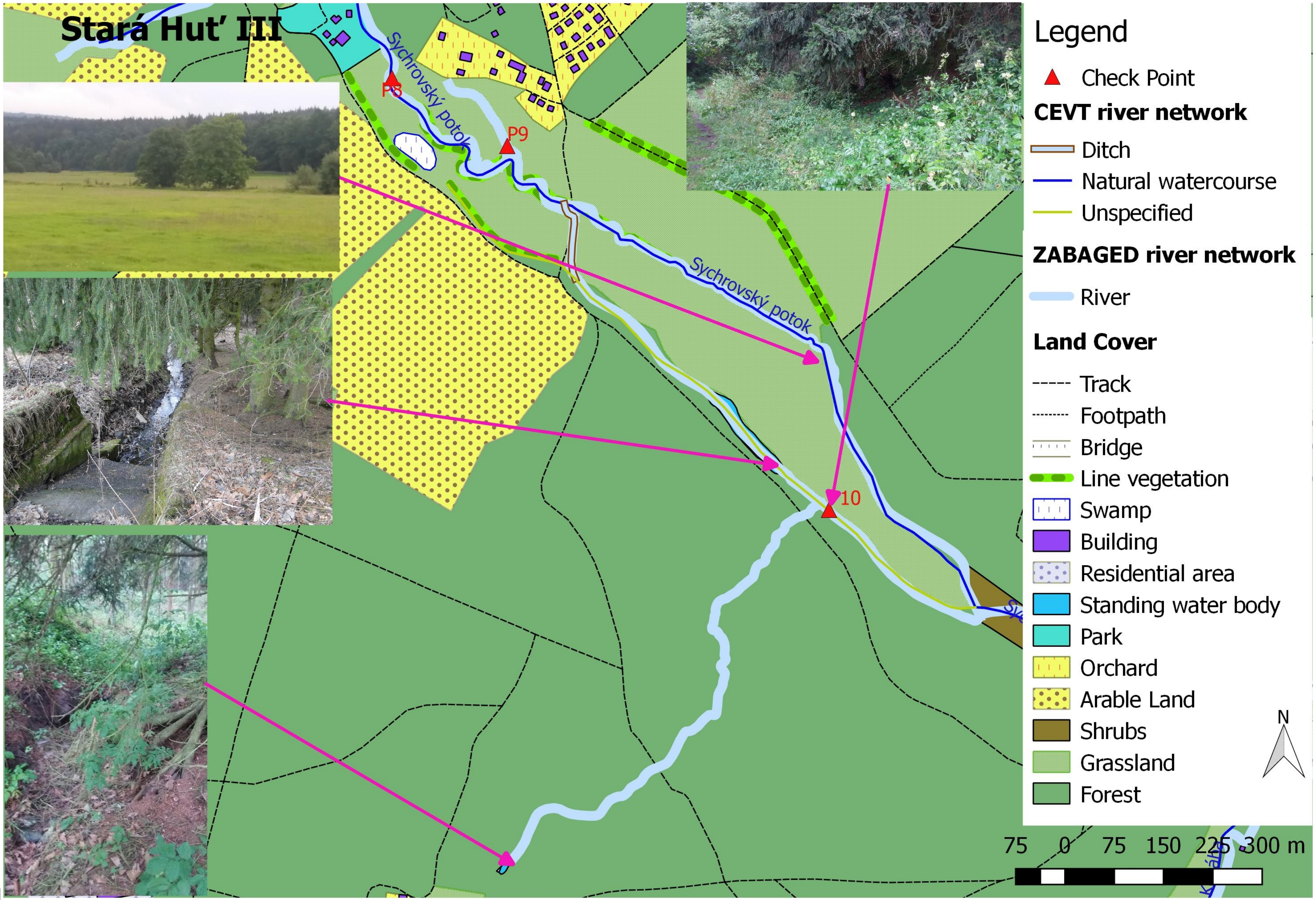
Locality	**Stará Huť I**
Locality description	Rural area south–east of town Stará Huť which used to be heavily industrialized town and is now more of satellite to Dobříš town on the north–west side. The pond Strž was build to supply water to nearby steelworks. Geologically the area belongs to Neoproterozoic part of Barrandium section of the Bohemian massif with greywacke as the main bedrock type. Today the land management is orientated toward popular new housing with family houses being built away from town centres but within reasonable distance to major towns with job opportunities (in this case Dobříš and Prague). The rest of the area is extensively farmed and forested with some attempts for wetlands and river restorations.
River (segment)	No name
Start point ID (down stream)	P6
Start point coordinates	14° 12' 29.76" 49° 46' 39.44"
Start point elevation	343.0016
End point ID (up stream)	P7
End point coordinates	14° 12' 44.56" 49° 46' 42.01"
End point elevation	351.2427
Type of stream	Drainage
Left floodplain	Arable land
Right floodplain	Arable land
Error type	River segment is extended further upstream in CEVT
Situation description	The watercourse in question is originally natural intermittent stream, tributary to pond Strž. It was later piped and directed under surface and used as a main stream for the drainage system of the crop field. The natural source of water represents a swamp across the road and railway track.
Suggested solution	Add the river segment to dataset
Explanation to suggested solution	Although mainly under surface the stream exists and forms main drainage discharge and is significant source for the pond Strž.
Land Use recognition	There is an identifiable source of water for the stream in form of swamp across the road and railway track. From the slope steepness of the crop field it can also be suggested that some drainage system is required to ensure arability.


Stará Huť I
ZABAGED river network
River
CEVT river network
Unspecified
Check Point
Track
Street
Road/Motorway
Railway
Line vegetation
Building
Residential area
Urban area
Standing water body
Orchard
Arable Land
Grassland
Forest
P6
P7
75 0 75 150 225 300 m
N

Locality	**Stará Huť II**
Locality description	Rural area south – east of town Stará Huť which used to be heavily industrialized town and is now more of satellite to Dobříš town on the north – west side. The pond Strž was build to supply water to nearby steelworks. Geologically the area belongs to Neoproterozoic part of Barrandium section of the Bohemian massif with greywacke as the main bedrock type. Today the land management is orientated toward popular new housing with family houses being built away from town centres but within reasonable distance to major towns with job opportunities (in this case Dobříš and Prague). The rest of the area is extensively farmed and forested with some attempts for wetlands and river restorations.
River (segment)	No name – confluence at P9
Start point ID (down stream)	P9
Start point coordinates	14° 12' 38.85" 49° 46' 21.63"
Start point elevation	336.2471
End point ID (up stream)	P8
End point coordinates	14° 12' 29.46" 49° 46' 24.14"
End point elevation	337.3317
Type of stream	Ditch
Left floodplain	Grassland
Right floodplain	Bush
Error type	River segment exists in ZABAGED only
Situation description	Between points P8 and P9 there is high grass bushy area with high ground water table and thus there is some new channel formation at P8. At point P9 should be confluence with stream flowing from cottages nearby. The channel is identifiable and it may function as a sewer drainage.
Suggested solution	Add the river segment to dataset
Explanation to suggested solution	As it has identifiable channel and it flows dispersed cottages and garden houses it may represent a stream with untreated sewers discharge. As such it is important to register it as a part of river network as it may deliver heavily polluted waters.
Land Use recognition	The channel is recognisable on aerial image, it flow from dispersed residential area and it in area of generally high ground water table. As the whole area is difficult to access and different channel are almost indistinguishable it is suggested to accept ZABAGED situation for the rest of the streams in the locality as it has minimum overall effect on river management.


Stará Huť II
Legend
Check Point
CEVT river network
Ditch
Natural watercourse
Unspecified
ZABAGED river network
River
Land Cover
Track
Bridge
Line vegetation
Swamp
Building
Standing water body
Park
Orchard
Arable Land
Grassland
Forest
P6
P7
P8
P9
Sychrovský potok
Sychrovský potok
Sychrovský potok
N
50 0 50 100 150 200 m

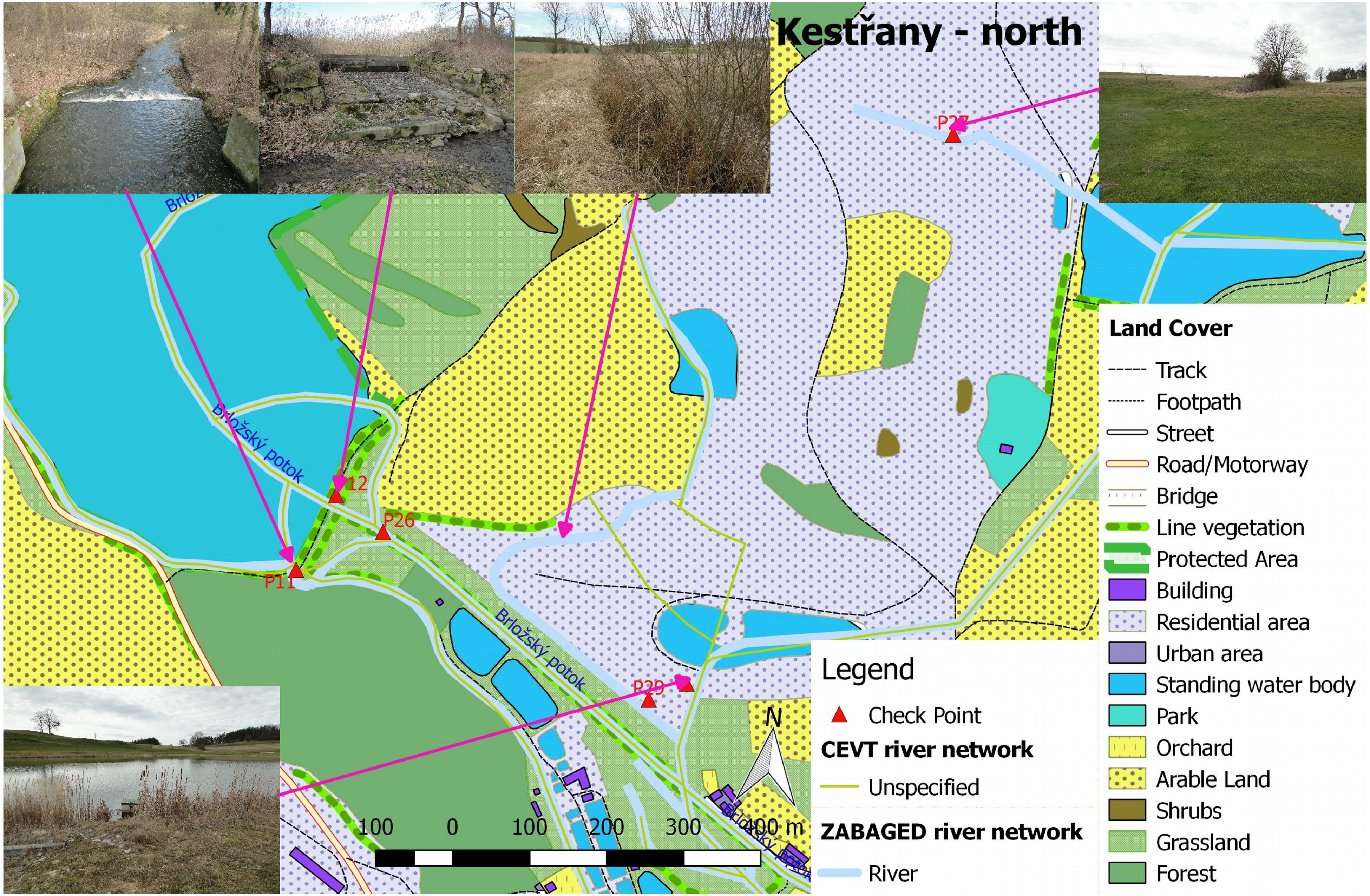
Locality	**Stará Huť III**
Locality description	Rural area south – east of town Stará Huť which used to be heavily industrialized town and is now more of satellite to Dobříš town on the north – west side. Geologically the area belongs to Neoproterozoic part of Barandium section of the Bohemian massif with greywacke as the main bedrock type. This part of the area is only extensively farmed and more forested with some wetlands and free growing bushes.
River (segment)	No name – confluence at P10
Start point ID (down stream)	P10
Start point coordinates	14° 13' 6.93" 49° 46' 6.10"
Start point elevation	333.4416
End point ID (up stream)	
End point coordinates	
End point elevation	
Type of stream	Unspecified
Left floodplain	Bush
Right floodplain	Forest
Error type	River segment exists in ZABAGED only
Situation description	The watercourse in ZABAGED dataset does not exist. There is a sign of some intermittent stream channelisation but it is more of concentrated surface runoff with rill formation
Suggested solution	Remove the river segment from dataset
Explanation to suggested solution	The watercourse does not exists
Land Use recognition	The watercourse in question is completely in forested area on a steep slope with minimum of human influence. Such stream would have to be considered natural and thus management would have to be applied and administrator set. The area is forested with no specified forestry management, the stream length is 840 meters and there are no direct pressures. If questionable the stream existence it appears more reasonable not to register such watercourse.


Stará Huť III
Sychrovský potok
P8
P9
Sychrovský potok
10
Legend
Check Point
CEVT river network
Ditch
Natural watercourse
Unspecified
ZABAGED river network
River
Land Cover
Track
Footpath
Bridge
Line vegetation
Swamp
Building
Residential area
Standing water body
Park
Orchard
Arable Land
Shrubs
Grassland
Forest
N
75 0 75 150 225 300 m

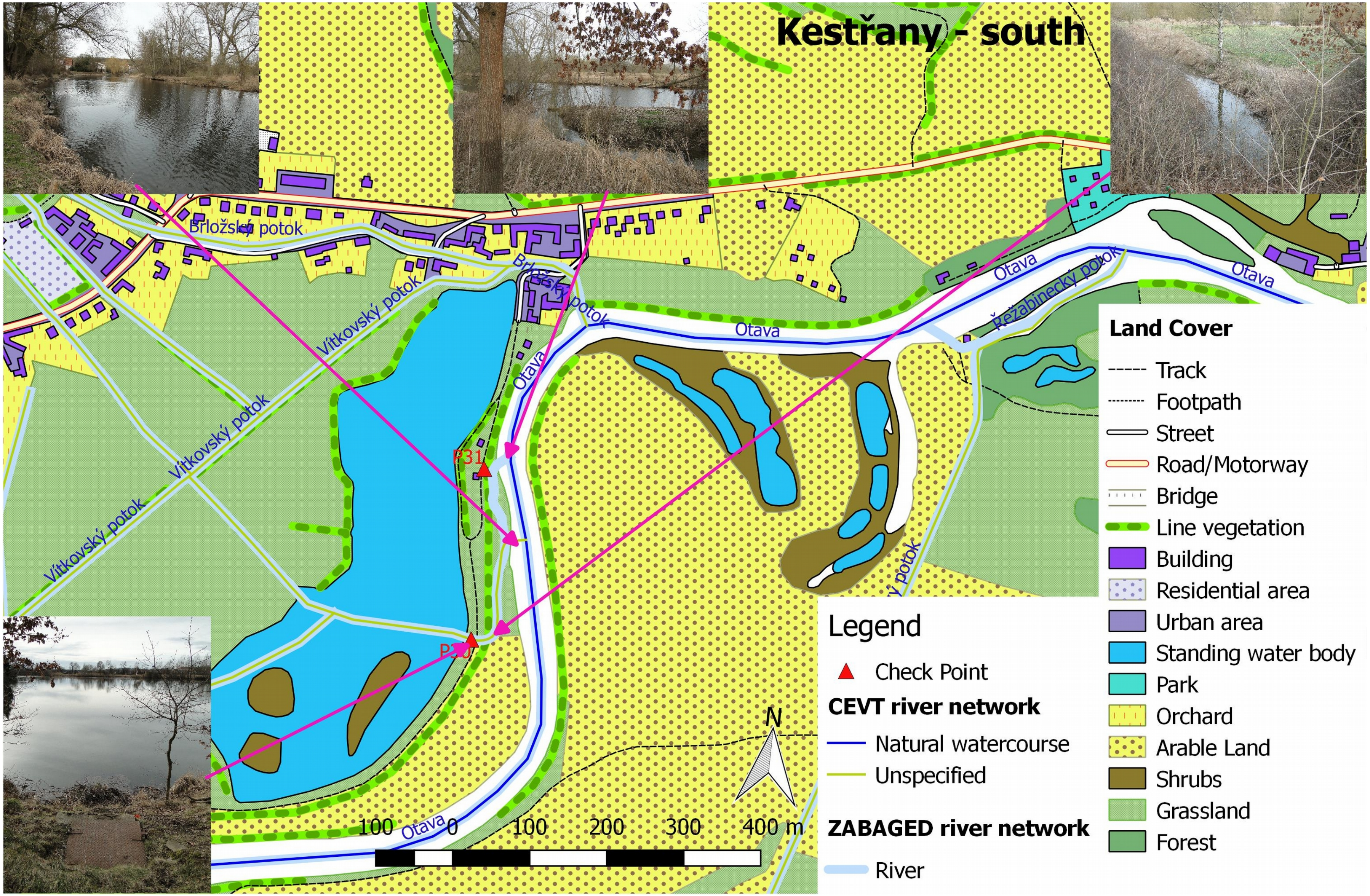
Locality	**Kestřany north**
Locality description	Rural area north of town Kestřeny in southern Bohemia. Geologically it belongs to Moldanubian zone of Paleozoic to Proterozoic part of Bohemian massif with mainly gneiss bedrock, although most of its souther parts lies on fluvial sediments of the Otava River floodplain. The main activities in the area are agricultural with important fisheries. The particular study field is between pond Velký Potočný pond and the town Kestřeny where there are several fish hatcheries and golf resort.
River (segment)	10244979
Start point ID (down stream)	P29
Start point coordinates	14° 04' 25.46" 49° 16' 24.67"
Start point elevation	372.9685
End point ID (up stream)	
End point coordinates	
End point elevation	
Type of stream	Drainage
Left floodplain	Arable land
Right floodplain	Ruderal species
Error type	River segment flows in different direction
Situation description	The watercourse is a drainage main outflow which originally flowed directly to confluence point P29 as in CEVT, but has been redirected when golf course was built as in ZABAGED.
Suggested solution	Use current ZABAGED situation
Explanation to suggested solution	ZABAGED is better updated towards new situation as it changed with the golf course construction
Land Use recognition	The original watercourse has been redirected which can be suggested due to the golf course existence in its original path. Also the area in its right hand floodplain can be considered wetland which suggests that there has been water supply added.
River (segment)	10272361
Start point ID (down stream)	
Start point coordinates	
Start point elevation	
End point ID (up stream)	
End point coordinates	
End point elevation	
Type of stream	Unspecified
Left floodplain	Residential area
Right floodplain	Residential area
Error type	River segment exists in CEVT only

Situation description	The original watercourse was a drainage canal. The drainage system has been directed into the 10244979 channel and this watercourse has bee removed, all due to golf course construction.
Suggested solution	Remove the river segment from dataset
Explanation to suggested solution	ZABAGED is better updated towards new situation as it changed with the golf course construction
Land Use recognition	The original watercourse has been removed due to the golf course existence. The importance of such watercourse is negligible so the update from ZABAGED can be easily accepted.
River (segment)	No name
Start point ID (down stream)	P27
Start point coordinates	14° 04' 25.46" 49° 16' 49.99"
Start point elevation	394.8979
End point ID (up stream)	
End point coordinates	
End point elevation	
Type of stream	Unspecified
Left floodplain	Arable land
Right floodplain	Arable land
Error type	River segment exists in ZABAGED only
Situation description	It is a intermittent watercourse that is piped for last 50 meters before its inflow into a new constructed pond which is not yet in a map. From the new pond the watercourse continues into the Hliněnský pond.
Suggested solution	Add the river segment to dataset
Explanation to suggested solution	The new pond should be taken into consideration and is now visible on the aerial images. It represents an inevitable connection to Hliněnský pond.
Land Use recognition	The existence of new pond suggests there is some inflow and also connection to Hliněnský pond. In such artificially modified landscape ZABAGED appears to be better updated.
River (segment)	Brložský potok
Start point ID	P12
Start point coordinates	14° 04' 25.46" 49° 16' 31.32"
Start point elevation	376.2013
End point ID	P26
End point coordinates	14° 04' 25.46" 49° 16' 30.07"
End point elevation	373.9718
Type of stream	Natural watercourse
Left floodplain	Bush
Right floodplain	Other farmland
Error type	Different outflow of the river from water body (pond, reservoir)

Situation description	The Brložský brook's original channel run through what is now a spillway of the Velký Potočný pond. Today, however, most of the water flows through P11 where water is used to supply fish hatcheries and the rest flow through artificial channel which is then linked to the original channel lower downstream.
Suggested solution	Use current ZABAGED situation
Explanation to suggested solution	It is reasonable to adjust current situation in terms of water flow, because the original channel is no longer in use and water there flow only scarcely.
Land Use recognition	The existence of fish hatcheries suggests there would be significant amount of water abstracted to supply them. Also the outflow structure from the pond is visible on aerial images.

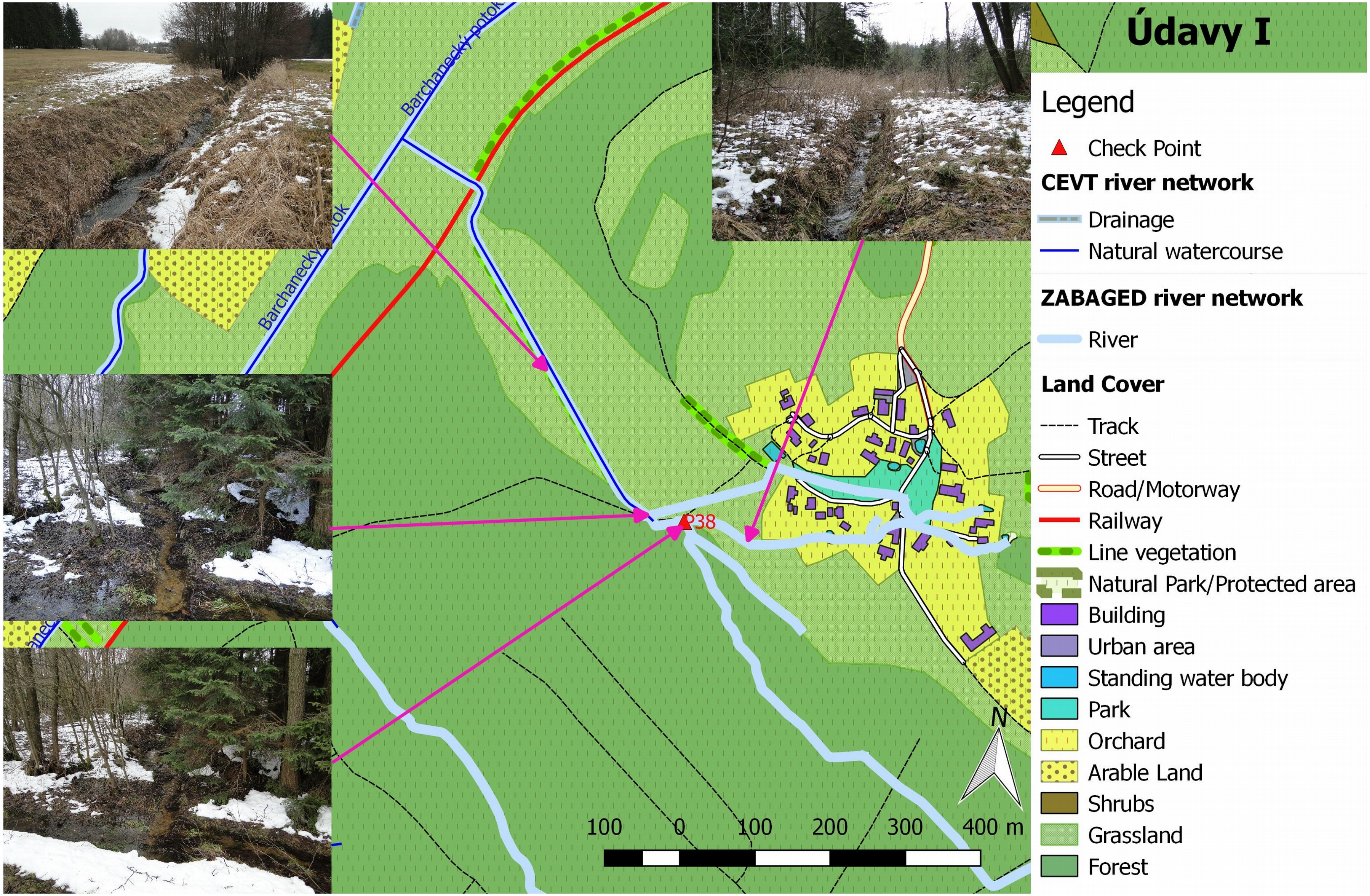

Kestřany - north
Brložský potok
Brložský potok
P11
P12
P26
P27
P29
N
100
0
100
200
300
400 m
Legend
Check Point
CEVT river network
Unspecified
ZABAGED river network
River
Land Cover
Track
Footpath
Street
Road/Motorway
Bridge
Line vegetation
Protected Area
Building
Residential area
Urban area
Standing water body
Park
Orchard
Arable Land
Shrubs
Grassland
Forest

Locality	**Kestřany south**
Locality description	Rural area south of town Kestřeny in southern Bohemia in the Otava River floodplain. Geologically the surrounding area belongs to Moldanubian zone of Paleozoic to Proterozoic part of Bohemian massif with mainly gneiss bedrock. The main activities in the area are agricultural with many ponds used for intensive fish growth. The particular study field is between pond Podvesný and the the Otava River.
River (segment)	10242783
Start point ID (down stream)	P30
Start point coordinates	14° 05' 6.46" 49° 16' 1.67"
Start point elevation	368.3449
End point ID (up stream)	P31
End point coordinates	14° 05' 5.73" 49° 16' 8.85"
End point elevation	368.8547
Type of stream	Artificial stream
Left floodplain	Bush
Right floodplain	Bush
Error type	Confluence of river segments in different location
Situation description	The watercourse is an artificial stream connecting the pond Podvesný with the Otava River. Due to inaccessible terrain the channel almost naturalised and changed its course towards the river.
Suggested solution	Use current ZABAGED situation
Explanation to suggested solution	ZABAGED is better updated towards new situation as it changed over time
Land Use recognition	The watercourse banks are covered by dense bush and the area is swampy almost inaccessible. It is unimportant which situation is adopted and so as a general rule the ZABAGED solution is preferred

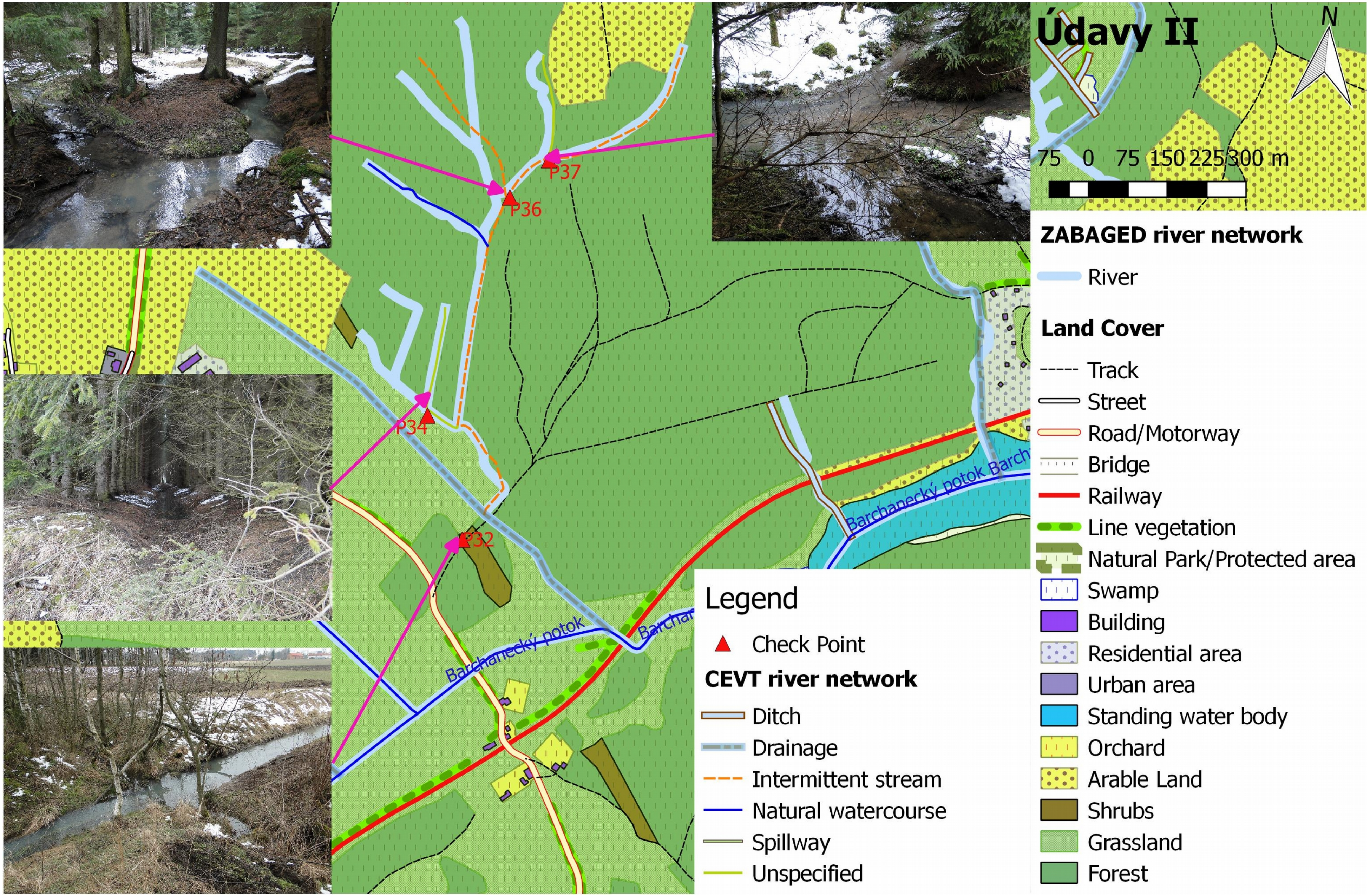

Kestřany - south
Brložský potok
Brložský potok
Vítkovský potok
Vítkovský potok
Vítkovský potok
Otava
Otava
Otava
Otava
Otava
Řežabinecký potok
P31
P30
N
100
0
100
200
300
400 m
Legend
Check Point
CEVT river network
Natural watercourse
Unspecified
ZABAGED river network
River
Land Cover
Track
Footpath
Street
Road/Motorway
Bridge
Line vegetation
Building
Residential area
Urban area
Standing water body
Park
Orchard
Arable Land
Shrubs
Grassland
Forest

Locality	**Údavy I**
Locality description	Highland area inside the Žďárské vrchy protected natural area. The area is mainly forested with some agricultural activities including crop fields and pastures. Geologically the area belongs to diverse region of Bohemian massif between Cretaceous basin of orlicko-žďárský development and hlinská Proterozoic/Cambrian zone with metamorphic bedrock. The area is near the division between Elbe and Danube River basins with very dense river and stream network. This particular locality is north of small Údavy village. Although, mostly countryside the forest and the fields are intensively drained with complicated drainage systems.
River (segment)	No name – not in any dataset
Start point ID (up stream)	P32
Start point coordinates	15° 49' 56.71" 49° 44' 3.78"
Start point elevation	554.1059
End point ID (down stream)	
End point coordinates	
End point elevation	
Type of stream	Drainage
Left floodplain	Grassland
Right floodplain	Arable land
Error type	River segment is not in any dataset
Situation description	The channel is artificially made to drain the crop field. It may dry during the summer period but at the time of the field survey the discharge was significant.
Suggested solution	Add the river segment to dataset
Explanation to suggested solution	It is artificially built drainage channel with significant discharge at wet periods.
Land Use recognition	The watercourse is in open field representing one of many drainage channels in the locality. The existence of this unregistered watercourse suggests that it was built without appropriate consultation with River-board Authority and may even represent illegal structure. Such problem can be identified only by field survey.
River (segment)	Right hand tributaries at P34
Start point ID (up stream)	P34
Start point coordinates	15° 49' 56.71" 49° 44' 11.13"
Start point elevation	554.4105
End point ID (down stream)	
End point coordinates	
End point elevation	
Type of stream	Drainage
Left floodplain	Forest
Right floodplain	Grassland
Error type	River segment exists in ZABAGED only

Situation description	The right hand tributaries to existing drainage channel are apparently just artificial extensions dry for most of the year. They fill with water during extremely wet period but they still don't contribute significantly to the river network.
Suggested solution	Remove the river segment from dataset
Explanation to suggested solution	Insignificant structural depressions that don't contribute to river network
Land Use recognition	There is dense drainage network in the locality and the additional short channel should not be identified as watercourses. Unless important in terms of river management, these channel should be removed from the river network model.
River (segment)	10123209, 10123210, 10123211, 10123212
Start point ID (up stream)	P33
Start point coordinates	15° 59' 55.43" 49° 44' 10.44"
Start point elevation	553.5750
End point ID (down stream)	P37
End point coordinates	15° 50' 0.65" 49° 44' 27.66"
End point elevation	560.8597
Type of stream	Drainage
Left floodplain	Forest
Right floodplain	Forest
Error type	River segment exists in ZABAGED only
Situation description	All of the watercourses are natural streams including the one extra in ZABAGED which is not in CEVT.
Suggested solution	Add the river segment to dataset
Explanation to suggested solution	The extra ZABAGED watercourse form part of natural river network.
Land Use recognition	As it is in the natural area, although the forest is commercial, all the watercourses should be considered natural, as long as there is no indication of artificial drainage construction. Additional watercourses from ZABAGED should be added as they may represent significant contribution to the river network. There is no need for additional river management settings.


Údavy I
Legend
Check Point
CEVT river network
Drainage
Natural watercourse
ZABAGED river network
River
Land Cover
Track
Street
Road/Motorway
Railway
Line vegetation
Natural Park/Protected area
Building
Urban area
Standing water body
Park
Orchard
Arable Land
Shrubs
Grassland
Forest
Barchanecký potok
P38
N
100 0 100 200 300 400 m

Locality	**Údavy II**
Locality description	Highland area inside the Žďárské vrchy protected natural area. The area is mainly forested with some agricultural activities including crop fields and pastures. Geologically the area belongs to diverse region of Bohemian massif between Cretaceous basin of orlicko-žďárský development and hlinská Proterozoic/Cambrian zone with metamorphic bedrock. The area is near the division between Elbe and Danube River basins with very dense river and stream network. This particular locality is south of small Stružinec village.
River (segment)	Several segments not in CEVT + 10173202
Start point ID (up stream)	P38
Start point coordinates	15° 49' 58.15" 49° 43' 24.96"
Start point elevation	568.8460
End point ID (down stream)	
End point coordinates	
End point elevation	
Type of stream	Unspecified
Left floodplain	Forest
Right floodplain	Residential area
Error type	River segment exists in ZABAGED only
Situation description	There are several watercourses above the P38 point of confluence where CEVT dataset ends a single watercourse.
Suggested solution	Add the river segment to dataset
Explanation to suggested solution	All the ZABAGED watercourses should be added as artificial streams because they represent network of highly polluted streams into which sewerage drains. The segments at forest may be considered natural although perhaps intermittent.
Land Use recognition	The watercourses in the village connects several small ponds or garden pools and there is no waste water treatment plant. All of this suggests that these watercourses exist as artificial and heavily polluted. The streams in the forest represent only extension to the stream 10173202 and therefore it is insignificant. It may be added as intermittent stream.


Údavy II
N
75 0 75 150 225 300 m
P37
P36
P34
P32
Barchanecký potok
Barchanecký potok Barch
Barchan
ZABAGED river network
River
Land Cover
Track
Street
Road/Motorway
Bridge
Railway
Line vegetation
Natural Park/Protected area
Swamp
Building
Residential area
Urban area
Standing water body
Orchard
Arable Land
Shrubs
Grassland
Forest
Legend
Check Point
CEVT river network
Ditch
Drainage
Intermittent stream
Natural watercourse
Spillway
Unspecified

Appendix 2

Error ID	Error type	Description	Source of error	Suggested solution	Management	Indicators
P12	Different outflow of the river from water body (pond, reservoir)	The Brložský brook's original channel run through what is now a spillway of the Velký Potočný pond. Today, however, most of the water flows through P11 where water is used to supply fish hatcheries and the rest flow through artificial channel which is then linked to the original channel lower downstream.	Unsuitable approach in CEVT	Use current ZABAGED situation	The existence of fish hatcheries suggests there would be significant amount of water abstracted to supply them. Also the outflow structure from the pond is visible on aerial images.	A visible spillway structure and water abstraction with connection
P13	River segment exists in ZABAGED only	The river segment in question is an old millrun that has not been in use for apparently long time. Its banks and floodplain are mostly covered by shrubs and solitary trees with some grassland and crop fields in near proximity. The channel is dry overgrown by shrubs and high grass and there is a plenty of rubbish around.	ZABAGED not updated, original channel still visible on aerial image	Remove the river segment from dataset	The area of the millrun floodplain has been left to secondary succession which is clearly identifiable from remotely accessible land cover data. Such conditions suggest that a use of the millrun is no longer required and it is possible to apply a restoration management to the original Vlara river floodplain.	Secondary succession taking place with shrubs and ruderal species covering the riparian zone

Error ID	Error type	Description	Source of error	Suggested solution	Management	Indicators
P16	River segment exists in ZABAGED only	There are two river segments in ZABAGED dataset joining the stream which are not in the CEVT dataset. Both segments are short (110 and 95 meters respectively), neither have defined channel and none had water at the time of field survey. Although, the vegetation cover suggests that there may be some water flowing shortly after some rainfall event.	Unnecessary detail in ZABAGED	Remove the river segment from dataset	From the remote data it is possible to clearly identify the railway track, the fact that the main stream is piped under the surface from the track downwards and intensive farming land use is applied in the area. From the two segments length and orientation along the railway it is possible to recognise that they may only serve as a drainage for the track. Such segment should not be included in river network and there can hardly be suggested any improvement to the existing stream management.	Infrastructure in the way of overland flow not directly interrupting a watercourse

Error ID	Error type	Description	Source of error	Suggested solution	Management	Indicators
P18	River segment exists in ZABAGED only	In the ZABAGED dataset there is a canal diverting from the Nivnička River at point P22. The canal is not in the CEVT dataset. The canal exists, however the diversion starts already at point P18 and flows firstly through industrial park and then at point P22 it appears in the crop field where it has artificially made channel. At the point P22 the discharge is significant and appears permanent while at point P23 where it joins the Nivnička River the channel is dry. The loss of water in the channel is due to generally dry conditions in the region and unsuitability of the channel placement. The use of the channel is questionable as the industrial park at the diversion point P18 is not publicly accessible and there is no further use of the canal until its confluence.	CEVT has not been updated correctly	Add the river segment to dataset	The water abstraction from the Nivnička River for the canal is difficult to identify even in the field because it is directed into the pipeline across private industrial park. Then the canal is however in open field identifiable from aerial photographs. As it is open mainly farm land it is notable as land feature and there is no reason to doubt correctness of the ZABAGED data. The proximity of industrial parks also suggests illegal water abstraction.	Water abstraction upstream the watercourse in question

Error ID	Error type	Description	Source of error	Suggested solution	Management	Indicators
P24	River segment exists in ZABAGED only	In the ZABAGED dataset there is a watercourse diverting from the Nivnička River at point P24. The watercourse is not in the CEVT dataset. Although artificial, it could perhaps be rather considered intermittent stream which purpose it to supply water for the recently constructed ponds and pools aiming at water retention in the land. The situation is complicated by the fact that while the watercourses are included in the ZABAGED dataset the ponds and pools are not.	CEVT has not been updated correctly	Add the river segment to dataset	All the watercourses in this particular area have been made to support the original project of building ponds and pools to support water retention in the land. Information about the project are publicly available. Such project could have been authorised only with the knowledge of the relevant River-board Authority and therefore it should be included in the CEVT dataset.	Bodies of standing surface water in the proximity to watercourse with expectable direct connection
P27	River segment exists in CEVT only	It is a intermittent watercourse that is piped for last 50 meters before its inflow into a new constructed pond which is not yet in a map. From the new pond the watercourse continues into the Hliněnský pond.	CEVT has not been updated correctly	Add the river segment to dataset	The existence of new pond suggests there is some inflow and also connection to Hliněnský pond. In such artificially modified landscape ZABAGED appears to be better updated.	Bodies of standing surface water in the proximity to watercourse with expectable direct connection
P29	River segment flows in different direction	The watercourse is a drainage main outflow which originally flowed directly to confluence point P29 as in CEVT, but has been redirected when golf course was built as in ZABAGED.	CEVT has not been updated correctly	Use current ZABAGED situation	The original watercourse has been redirected which can be suggested due to the golf course existence in its original path. Also the area in its right hand floodplain can be considered wetland which suggests that there has been water supply added.	Industrial or residential structure crossing the original watercourse

Error ID	Error type	Description	Source of error	Suggested solution	Management	Indicators
P6	River segment exists in CEVT only	The watercourse in question is originally natural intermittent stream, tributary to pond Strž. It was later piped and directed under surface and used as a main stream for the drainage system of the crop field. The natural source of water represents a swamp across the road and railway track.	Piped channel invisible form aerial image	Use current CEVT situation	There is an identifiable source of water for the stream in form of swamp across the road and railway track. From the slope steepness of the crop field it can also be suggested that some drainage system is required to ensure arability.	Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water
P901	River segment exists in CEVT only	The original watercourse was a drainage canal. The drainage system has been directed into the 10244979 channel and this watercourse has bee removed, all due to golf course construction.	CEVT has not been updated correctly	Remove the river segment from dataset	The original watercourse has been removed due to the golf course existence. The importance of such watercourse is negligible so the update from ZABAGED can be easily accepted.	Industrial or residential structure crossing the original watercourse
P38	River segment exists in ZABAGED only	There are several watercourses above the P38 point of confluence where CEVT dataset ends a single watercourse.	CEVT does not contain enough detail	Add the river segment to dataset	The watercourses in the village connects several small ponds or garden pools and there is no waste water treatment plant. All of this suggests that these watercourses exist as artificial and heavily polluted. The streams in the forest represent only extension to the stream 10173202 and therefore it is insignificant. It may be added as intermittent stream.	Bodies of standing surface water and residential area in proximity to watercourse with expectable connection

Error ID	Error type	Description	Source of error	Suggested solution	Management	Indicators
P32	River segment is not in any dataset	The channel is artificially made to drain the crop field. It may dry during the summer period but at the time of the field survey the discharge was significant.	CEVT and ZABAGED not updated correctly	Add the river segment to dataset	The watercourse is in open field representing one of many drainage channels in the locality. The existence of this unregistered watercourse suggests that it was built without appropriate consultation with River-board Authority and may even represent illegal structure. Such problem can be identified only by field survey.	Unsuitable example
P33	River segment exists in ZABAGED only	All of the watercourses are natural streams including the one extra in ZABAGED which is not in CEVT.	CEVT does not contain enough detail	Add the river segment to dataset	As it is in the natural area, although the forest is commercial, all the watercourses should be considered natural, as long as there is no indication of artificial drainage construction. Additional watercourses from ZABAGED should be added as they may represent significant contribution to the river network. There is no need for additional river management settings.	Dense river network and high water table area
P34	River segment exists in ZABAGED only	The right hand tributaries to existing drainage channel are apparently just artificial extensions dry for most of the year. They fill with water during extremely wet period but they still don't contribute significantly to the river network.	Unsuitable approach in ZABAGED	Remove the river segment from dataset	There is a dense drainage network in the locality and the additional short channels should not be identified as watercourses. Unless important in terms of river management, these channels should be removed from the river network model.	The segment geometry appears artificial and is in inhabited area

Error ID	Error type	Description	Source of error	Suggested solution	Management	Indicators
P9	River segment exists in ZABAGED only	Between points P8 and P9 there is high grass bushy area with high ground water table and thus there is some new channel formation at P8. At point P9 should be confluence with stream flowing from cottages nearby. The channel is identifiable and it may function as a sewer drainage.	CEVT does not contain enough detail	Add the river segment to dataset	The channel is recognisable on aerial image, it flows from dispersed residential area and it is in area of generally high ground water table. As the whole area is difficult to access and different channels are almost indistinguishable it is suggested to accept ZABAGED situation for the rest of the streams in the locality as it has minimum overall effect on river management.	Dense river network and high water table area
P10	River segment exists in ZABAGED only	The watercourse in ZABAGED dataset does not exist. There is a sign of some intermittent stream channelisation but it is more of concentrated surface runoff with rill formation	Unnecessary detail in ZABAGED	Remove the river segment from dataset	The watercourse in question is completely in forested area on a steep slope with minimum of human influence. Such stream would have to be considered natural and thus management would have to be applied and administrator set. The area is forested with no specified forestry management, the stream length is 840 meters and there are no direct pressures. If questionable the stream existence it appears more reasonable not to register such watercourse.	Steep forested slope

Error ID	Error type	Description	Source of error	Suggested solution	Management	Indicators
P30	Confluence of river segments in different location	The watercourse is an artificial stream connecting the pond Podvesný with the Otava River. Due to inaccessible terrain the channel almost naturalised and changed its course towards the river.	CEVT has not been updated correctly	Use current ZABAGED situation	The watercourse banks are covered by dense bush and the area is swampy almost inaccessible. It is unimportant which situation is adopted and so as a general rule the ZABAGED solution is preferred	Connecting watercourse
		Specific indicator usable in every case			Not management related	Channel visible on aerial image
		Specific indicator usable in every case			It is an important management issue if the watercourse flows into an artificial watercourse. It allows for better recognition of likelihood of a watercourse existence	Flow into artificial channelisation

Appendix 3

Question	Answer	Value	Answer	Value	Answer	Value
Is the segment longer than 300 m	no	-1	no	-1	yes	1
A visible spillway structure and water abstraction with connection	not relevant	0	not relevant	0	not relevant	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0	no	0	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	no	0	no	0	no	0
Water abstraction upstream the watercourse in question	no	0	no	0	no	0
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	no	0	no	0	yes	2
Industrial or residential structure crossing the original watercourse	no	0	no	0	no	0
Residential or industrial area in proximity to watercourse with expectable connection	no	0	no	0	no	0
Dense river network and high water table area	no	0	yes	1	no	0
Steep forested slope	yes	-1	no	0	no	0
Connecting watercourse	no	0	yes	2	no	0
The segment geometry appears artificial and is in inhabited area	yes	-1	yes	-1	no	0
Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water	no	0	no	0	no	0
Watercourse flows into artificial channel	no	2	no	2	no	2
Channel visible on aerial image	no	-2	no	-2	yes	2
Summary	**Remove segment**	**-3**	**Add segment**	**1**	**Add segment**	**7**
Segment	Z3553524776435712		Z3554038696116224		Z3554008463572992	

Question	Answer	Value	Answer	Value	Answer	Value
Is the segment longer than 300 m	yes	1	no	-1	no	-1
A visible spillway structure and water abstraction with connection	not relevant	0	not relevant	0	not relevant	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0	no	0	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	yes	-1	yes	-1	yes	-1
Water abstraction upstream the watercourse in question	no	0	no	0	no	0
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	no	0	no	0	no	0
Industrial or residential structure crossing the original watercourse	no	0	no	0	no	0
Residential or industrial area in proximity to watercourse with expectable connection	no	0	no	0	no	0
Dense river network and high water table area	no	0	no	0	no	0
Steep forested slope	no	0	no	0	no	0
Connecting watercourse	no	0	no	0	no	0
The segment geometry appears artificial and is in inhabited area	yes	-1	yes	-1	yes	-1
Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water	no	0	no	0	no	0
Watercourse flows into artificial channel	no	2	yes	-2	yes	-2
Channel visible on aerial image	no	-2	no	-2	no	-2
Summary	**Remove segment**	**-1**	**Remove segment**	**-7**	**Remove segment**	**-7**
Segment	C10265066		Z7322322		Z7437485	

Question	Answer	Value	Answer	Value	Answer	Value
Is the segment longer than 300 m	yes	1	yes	1	no	-1
A visible spillway structure and water abstraction with connection	not relevant	0	not relevant	0	not relevant	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0	no	0	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	yes	-1	no	0	no	0
Water abstraction upstream the watercourse in question	no	0	no	0	no	0
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	no	0	yes	2	no	0
Industrial or residential structure crossing the original watercourse	yes	-1	yes	-1	no	0
Residential or industrial area in proximity to watercourse with expectable connection	yes	1	yes	1	no	0
Dense river network and high water table area	no	0	no	0	no	0
Steep forested slope	no	0	no	0	no	0
Connecting watercourse	no	0	no	0	no	0
The segment geometry appears artificial and is in inhabited area	yes	-1	no	0	no	0
Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water	yes	2	no	0	no	0
Watercourse flows into artificial channel	no	2	yes	-2	no	2
Channel visible on aerial image	yes	2	yes	2	no	-2
Summary	**Add segment**	**5**	**Add segment**	**3**	**Remove segment**	**-1**
Segment	C10256279		Z456487142950266+4		Z3644290001534976+1	

Question	Answer	Value	Answer	Value	Answer	Value
Is the segment longer than 300 m	no	-1	no	-1	yes	1
A visible spillway structure and water abstraction with connection	yes	1	no	0	not relevant	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0	no	0	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	no	0	no	0	no	0
Water abstraction upstream the watercourse in question	yes	1	no	0	no	0
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	yes	2	yes	2	no	0
Industrial or residential structure crossing the original watercourse	no	0	yes	-1	no	0
Residential or industrial area in proximity to watercourse with expectable connection	no	0	yes	1	no	0
Dense river network and high water table area	no	0	no	0	no	0
Steep forested slope	no	0	no	0	no	0
Connecting watercourse	yes	2	yes	2	no	0
The segment geometry appears artificial and is in inhabited area	no	0	no	0	no	0
Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water	no	0	no	0	no	0
Watercourse flows into artificial channel	no	2	yes	-2	no	2
Channel visible on aerial image	no	-2	no	-2	no	-2
Summary	**Add segment**	**5**	**Remove segment**	**-1**	**Add segment**	**1**
Segment	Z3644497854464000		C10261476		C10241773	

Question	Answer	Value	Answer	Value	Answer	Value
Is the segment longer than 300 m	no	-1	yes	1	no	-1
A visible spillway structure and water abstraction with connection	not relevant	0	not relevant	0	not relevant	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0	no	0	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	no	0	yes	-1	yes	-1
Water abstraction upstream the watercourse in question	no	0	no	0	yes	1
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	no	0	no	0	yes	2
Industrial or residential structure crossing the original watercourse	no	0	no	0	yes	-1
Residential or industrial area in proximity to watercourse with expectable connection	no	0	no	0	yes	1
Dense river network and high water table area	no	0	yes	1	not relevant	0
Steep forested slope	no	0	no	0	no	0
Connecting watercourse	no	0	no	0	yes	2
The segment geometry appears artificial and is in inhabited area	no	0	no	0	no	0
Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water	no	0	no	0	no	0
Watercourse flows into artificial channel	no	2	no	2	yes	-2
Channel visible on aerial image	no	-2	no	-2	yes	2
Summary	**Remove segment**	**-1**	**Add segment**	**1**	**Add segment**	**3**
Segment	C10267035		Z3643658104471552		Z3644393198190592 +1	

Question	Answer	Value	Answer	Value	Answer	Value
Is the segment longer than 300 m	no	-1	yes	1	no	-1
A visible spillway structure and water abstraction with connection	not relevant	0	not relevant	0	yes	1
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0	no	0	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	no	0	no	0	no	0
Water abstraction upstream the watercourse in question	no	0	no	0	no	0
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	no	0	no	0	yes	2
Industrial or residential structure crossing the original watercourse	no	0	no	0	no	0
Residential or industrial area in proximity to watercourse with expectable connection	no	0	no	0	no	0
Dense river network and high water table area	yes	1	yes	1	no	0
Steep forested slope	yes	-1	yes	-1	no	0
Connecting watercourse	no	0	no	0	no	0
The segment geometry appears artificial and is in inhabited area	yes	-1	no	0	yes	-1
Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water	no	0	no	0	no	0
Watercourse flows into artificial channel	yes	-2	no	2	no	2
Channel visible on aerial image	yes	2	yes	2	yes	2
Summary	**Remove segment**	**-2**	**Add segment**	**5**	**Add segment**	**5**
Segment	Z3644317633609728		Z7321348+1		Z1611582022878586	

Question	Answer	Value	Answer	Value	Answer	Value
Is the segment longer than 300 m	no	-1	no	-1	no	-1
A visible spillway structure and water abstraction with connection	no	0	not relevant	0	not relevant	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0	no	0	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	no	0	yes	-1	no	0
Water abstraction upstream the watercourse in question	no	0	no	0	no	0
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	no	0	no	0	yes	2
Industrial or residential structure crossing the original watercourse	no	0	yes	-1	yes	-1
Residential or industrial area in proximity to watercourse with expectable connection	no	0	no	0	no	0
Dense river network and high water table area	no	0	no	0	no	0
Steep forested slope	no	0	no	0	no	0
Connecting watercourse	no	0	no	0	no	0
The segment geometry appears artificial and is in inhabited area	yes	-1	yes	-1	yes	-1
Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water	no	0	no	0	no	0
Watercourse flows into artificial channel	no	2	yes	-2	yes	-2
Channel visible on aerial image	yes	2	no	-2	yes	2
Summary	**Add segment**	**2**	**Remove segment**	**-8**	**Remove segment**	**-1**
Segment	Z3658575364751360		Z3583205433147392		Z3583205433147392	

Question	Answer	Value	Answer	Value
Is the segment longer than 300 m	no	-1	no	-1
A visible spillway structure and water abstraction with connection	no	0	no	0
Secondary succession taking place with shrubs and ruderal species covering the riparian zone	no	0	no	0
Infrastructure in the way of overland flow not directly interrupting a watercourse	no	0	no	0
Water abstraction upstream the watercourse in question	no	0	no	0
Bodies of standing surface water in the proximity to watercourse with expectable direct connection	yes	2	yes	2
Industrial or residential structure crossing the original watercourse	no	0	no	0
Residential or industrial area in proximity to watercourse with expectable connection	yes	1	no	0
Dense river network and high water table area	no	0	no	0
Steep forested slope	no	0	no	0
Connecting watercourse	no	0	no	0
The segment geometry appears artificial and is in inhabited area	no	0	no	0
Watercourse in talweg surrounded by agricultural land on steep slope eventually with identifiable source of water	no	0	no	0
Watercourse flows into artificial channel	no	2	no	2
Channel visible on aerial image	yes	2	yes	2
Summary	**Add segment**	**6**	**Add segment**	**5**
Segment	Z3623215872081920		Z3652767579111424	

Appendix 4

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L71	40	Remove segment	Remove segment		No visible confluence, no right hand tributary

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L29	70	Add segment	Add segment		Segment used in first testing of the method with fail result. After the method adjustment the result is correctly to add the segment
L8	25	Add segment	Add segment		Segment correctly assessed during the first testing. The channel is very deep and overgrown by vegetation but the flow appeared permanent, fed from the pond. The photograph was taken just on the dam of the pond.

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L22	47	Remove segment	Remove segment		The segment is represented by artificially built channel which is now dry with evidence that it has not been used in last 10 years – There were found trees in the channel that were older than 10 years. Also there is no source for the channel.
L58	3	Remove segment	Remove segment		Drainage system connected to piped private drainage detailed network which works only for draining the agricultural land after rainfall. It should not be part of the river network.

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L72	9	Remove segment	Remove segment		Dry ditch by the road connected to an open drainage channel. The ditch is part of the road infrastructure and should not be part of the river network.
L36	79	Add segment	Add segment		The channel starts at this point with deep standing water as a source, cover by dense vegetation. Artificial look of the channel is given by modifications, it functions as a drainage, although natural watercourse perhaps had existed there.
L55	17	Add segment	Add segment		Natural watercourse that is piped under the private land and runs through pastures mostly under surface.

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L61	41, 42	Remove segment	Remove segment		No sign of any channel. There are however some drainage pipes bringing water into the Litavka River. Those are however not a main drainage system.
L73	26	Add segment	Add segment		Piped sewage from the open swimming pool towards the river. There is no waste water treatment.
L55	78	Remove segment	Remove segment		There is no sign of connection between the pond and the main drainage channel at the located place. The spillway is upstream.

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L53	56	Add segment	Remove segment		At the place of confluence is dry deep channel with no sign of flowing water. The channel appears to represent old drainage system which has not been in use for years now. Even the existing channel is overgrown by vegetation and hardly visible in the field.
L53	59, 77	Remove segment	Remove segment		Field search proved that the downstream watercourse does not exist any more thus this watercourse has nowhere to flow and is automatically considered non existent.

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L52	76	Add segment	Add segment		Forest stream of almost equal discharge as the other watercourse with which it confluences
L40	75	Add segment	Add segment		Piped watercourse diverted from canal running through private property connecting to the Litavka River
L40	40	Remove segment	Remove segment		Wet land with no visible channel in inaccessible area

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L9	54	Add segment	Add segment		Established channel with permanent flow at the check point L9
L41	73	Add segment	Add segment		Artificial channel discharging water from a private pond back to Litavka river. There is also a piped water transfer from river to the pond, but that is not on any map.

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L57	74	Add segment	Add segment		There are signs of developed channel and it is in an area with very high ground water table. It is recommended to add such watercourse as intermittent because there is no justifiable argument to remove it.
L30	43	Remove segment	Remove segment		Some channel formation appears but it is dry. There is a potential source across the road where there is a pasture with some water accumulation at lowest point connected to the channel via culvert under the road. It could eventually work as a drainage in wet season but for most of the year the channel is dry.

Check Point	Segment ID	Method Application Result	Field Result	Photo Documentation	Notes
L56	72	Add segment	Add segment		Vegetation cover channel with weir and dry open channel supplying water to nearby private pond.
L34	71	Add segment	Add segment		Small watercourse flowing in channel completely covered by vegetation but with significant discharge. Appears to be natural.