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Dear readers, friends and colleagues,

on the following pages you will be presented the contents and results of the Erasmus Intensive Programme of the academic year 2003/04 which was organised and hosted by the Department of Physical Geography and Geoecology of the Charles University in Prague under the title of "Management and Protection of Water Recources in Transition Countries".

In the framework of the EU-SOCRATES/Erasmus activities, Intensive Programmes (IP) are designed as "short programmes of study (10 days to 3 months) which bring students and staff from universities in different participating countries together in order to work on a specific thematic issue in a multinational surrounding and take profit from extraordinary teaching and learning conditions as well as from the variety of scientific approaches to the subject under consideration." Intensive Programmes require an academic coordination by one of the partner universities.

Given this definition, there are two key features Erasmus Intensive Programmes have to fulfil: First of all, there's the need for partner universities from different countries which are willing to dedicate part of their time to the exchange of teaching methods and scientific approaches on a multinational level. Secondly, a thematic issue is needed which is of common interest for these partners. Additionally, you need an institution that is willing to organise and coordinate the whole enterprise from the academic point of view.

Already in 1994, such a partnership developed and grouped itself around one common scientific interest: the "Geography of Water". Throughout seven years, two IP-cycles and six residential seminars in different countries coordinated by Prof. Pierpaolo Faggi (University of Padua), the subject of "Water" being such a multifaceted scientific object of international concern on the level of both, human and physical geography, proved to be the perfect nucleus to group around it an extremely enriching and continuously growing European partnership. With the end of the second cycle in 2001 it had to be decided if the IP should be continued or not. There were two aspects which accompanied the decision taking process: The existing group's desire to upgrade its regional knowledge – especially with regard to the various dynamics connected with the European adhesion process – and its profound wish to build up further contacts with universities from Transition Countries. The group then resolved to apply for a new cycle, putting the focus on the subject of "Water Management in Transition Countries". The task of academic coordination of the new cycle was handed over to the University of Mainz.

Until today, we're very happy that the Charles University of Prague, being an official member of the IP-partnership already since the year 2000, in the person of Dr. Milada Matouskova did not hesitate to declare its disposition to be the host and organiser of the first Intensive Programme of the new cycle. On behalf of the whole IP-group we would like to take this occasion to once again express our deepest gratitude to the Charles University of Prague for supporting the IP-activities and providing all the technical equipment, the premises and in particular the staff, which is necessary to organise such a challenging enterprise. Especially we want to point out Dr. Milada Matouskva's and the rest of the organising committee's fabulous effort, work and personal engagement. As you will see on the next pages, we owe her and her staff a successful and - especially from the academic viewpoint – extremely fruitful seminar.

Prof. Dr. Volker Heidt
University of Mainz
Department of Geography
Coordinator of the Intensive Programme
"Water management in transition countries"

Dear readers and colleagues,

it is a great pleasure for us to greet you while you are opening the second issue of the Journal of Czech Geographic Society, Volume 109, No. 2. We would like to inform you about a special geographical event: *"7th European Seminar on the Geography of Water"*. This seminar took place at the Department of Physical Geography and Geoecology, Faculty of Science, Charles University in Prague from 22nd to 31st August 2003.

In this Volume of the Journal you will find the main outputs of the Seminar as well as some basic information about participating universities. We had the pleasure to welcome teachers and students from 8 foreign universities, namely from: University of Cagliari (Italy), University of Mainz (Germany), University of Padua (Italy), University of Pécs (Hungary), University of Sevilla (Spain), University of St. Etienne (France), University of Udine (Italy) and University of Tartu (Estonia).

The main topic of the new cycle of the Intensive Program ERASMUS is *"Water Management in Transition Countries"*. As a subject of the 2003 Seminar in Prague was chosen "The management and protection of water resources in central Europe".

In the beginning, the participants were introduced into the past and present development in the field of hydrology, water management and water protection in the Czech Republic, particularly in connection with the social-economical development, transformation process and preparation for the entrance in the EU. Lectures to the given topic were provided by both the department staff and the experts from organizations and companies dealing with hydrology, water management and water protection.

After the introduction lectures, the participants were divided into three thematic groups in accordance with the three major issues of the IP Seminar in Prague: I) Floods and flood protection, II) Water quality and restoration of water ecosystems and III) Lakes and water reservoirs. The Working Group activities played a very important role in the Seminar programme. Based on information from lectures, field observations, literature, field excursions and discussions with experts, the members of each working group were supposed to produce a final conclusion, which was presented at the end of the Seminar and now published in this Volume of the Journal.

Water-related research activities of participating Universities were an indivisible part of the Seminar, and their short review is published at the end of this Journal as well. Another important part of the IP Seminar was the poster session, where the students had an opportunity to present their own research projects, diploma and Ph.D. theses. During the presentation of the posters, a constructive and fruitful discussion took place.

The Seminar could not have taken place without a keen support of various collaborators and contributors. I would like to thank to all of them. First of all, to the main coordinator of the IP Erasmus, Prof. Dr. Volker Heidt, and his colleague Brigitte Leicht, M.A. from the Johannes Gutenberg University Mainz. Secondly, to the Vice Dean of the Faculty of Science of the Charles University in Prague, Asis. Prof. Dr. Luděk Sýkora, Ph.D. Furthermore to the representatives of the Department of Physical Geography and Geoecology, Prof. Dr. Jan Kalvoda, Dr. Sc. and Asis. Prof. Dr. Bohumír Janský, Ph.D. A heartfelt thanks are due to all the participants of the Seminar for their enthusiastic cooperation and creativity as well as for their eagerness to share and compare their experience from different places in Europe. They created a very friendly, cooperative and pleasant atmosphere regardless of their hard work during the Seminar. And, last but not least, I would like to express my gratefulness to all the colleagues from the Organising Committee.

Dr. Milada Matoušková, Ph.D.
Charles University in Prague
Department of Physical Geography and Geoecology
Head of the Organising Committee of the IP Erasmus 2003
"Water management in transition countries"

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JAN DAŇHELKA

AUGUST 2002 FLOOD IN THE CZECH REPUBLIC: METEOROLOGICAL CAUSES AND HYDROLOGICAL RESPONSE

J. Daňhelka: *August 2002 Flood in the Czech Republic: Meteorological Causes and Hydrological Response.* – Geografie – Sborník ČGS, 109, 2, pp. 84–92 (2004). – The paper describes synoptic situations that resulted in heavy precipitation over the SW Bohemia in August 2002. Spatial and temporal distribution of precipitation and its effect on the flood development is explained. Flood peak flows return period reached very high values in the Vltava River catchment and couldn't be largely affected by reservoirs within the catchment. Nevertheless the role of Vltava River Dam Cascade is mentioned as well as the flood forecasting during the flood. We show also some similarities and differences between 2002 and some historical flood.
KEY WORDS: Flood – Vltava River – August 2002 – Czech Republic.

Introduction

Flood in the Czech Republic in August 2002 was extreme event from many points of view. First of all it was the hydrological and meteorological extreme, but flood affected also daily life of many people in Bohemia and central Europe.

If we lived in medieval times the chronicle writers would probably started their describing of that flood with sentence: "There was no such flood since the times of Noah". This sentence is the evidence of lost of the historical memory. Because of rare occurrence of great floods people usually couldn't keep it in memory for period longer than is the life of one generation. Unfortunately the longer period between floods leads to change in human behavior in the floodplain and on the riverbanks. It's closely connected to increasing vulnerability of human society and activities to catastrophic floods such as the one in 2002.

The previous catastrophic flood in the Czech Republic occurred in the Odra River and Morava River catchments in July 1997. The experience in flood forecasting and management from that event was extremely valuable and saved many human lives and property during 2002 flood.

The evaluation of the flood causes, development and consequences is crucial for possible next improvement in hydrometeorological service as well as in the other phases of the flood management.

Meteorological causes of August 2002 flood

Flood was caused by two periods of heavy precipitation following in very short interval of time.

The first precipitation period occurred in south Bohemia from 6th to 8th of August. A casual pressure low absorbed wet air mass from the Mediterranean and moved very slowly from the northern Italy in northeast direction in those days. Because of windward effect and orographic increase of precipitation there were observed daily rainfall amounts 80–150 mm in two consecutive days in Novohradské hory Mts. That represents highest daily precipitation ever observed in that area. The spatial extend of the maximum precipitation field was relatively limited to the highest parts of the Novohradské hory Mts. and could not caused major flood in the larger scale. The most important thing for the next development of the flood was the saturation of nearly the whole Vltava River catchment where fell mostly from 40 to 100 mm during that period.

More than 280 mm of water fell in Pohorská Ves and Staré Hutě during approximately 60 hours from 6th to 8th of August. That was 1.5–2 times higher than the value of two days precipitation with 100-year return period in that area and led to extreme flood in Malše River catchment. Similar rainfall amounts observed in Austrian part of the mountains caused extreme flood on smaller stream and rivers in the Dyje River catchments in the same time.

Another pressure low reached the central Europe after only about two and a half day without precipitation. The low was formed over the Atlantic Ocean and moved to the Mediterranean where it deepened and absorbed wet air. It continued then in northern direction to the central Europe where the pressure low center stop its movement. In comparison to the previous cyclone this ones trajectory was situated more to the north and therefore not only south part of Bohemia but nearly the whole area of the Czech Republic was affected by heavy precipitation.

It rained over the Vltava River catchment from Sunday August 11th to Tuesday August 13th. Main precipitation field was formed into the shape of wide strip trough the Bohemia in north-south direction and did not move its position significantly during the whole period. Because of anticlockwise rotation of the wind in the cyclone the wet air flowed to Bohemia from the north. That caused strong windward effect on northern slopes of Czech mountains. It was very strong mainly in the Krušné hory Mts. (Ore Mts.) – German meteorological station (about 2 km from the Czech border) recorded 312 mm of rainfall in 24 ours on 12th of August what is the highest daily precipitation amount ever recorded in Germany. Similarly in the highest parts of Jizerské hory Mts. automatic raingauge in Knajpa recorded daily amount of 278 mm on August 13th. So extreme rainfalls even they were spatially very limited caused "flashflood-like" response of the smaller stream in those areas.

Strong windward effect caused increase of precipitation also on the north slopes of Krkonoše Mts., Šumava Mts., Novohradské hory Mts., Brdy Hills and Českomoravská vrchovina Hills.

Mostly from 80 to 200 mm of rainfall fell in the Vltava River catchment during the second precipitation period. It accorded to 200–300 % of the value of 100-year precipitation for three days period in the south part of the Vltava River catchment.

The MAP (mean areal precipitation) for the whole Vltava River catchment (27 039 km^2) during the first precipitation period was 69.0 mm while during the second period it was 110.7 mm. All together from 6th to 13th of August 2002 the MAP value was 184.1 mm. That represents the volume of water of 4.98 km^3 (1.87 km^3 during the first precipitation period and 2.99 km^3 during the second one; Fig. 1).

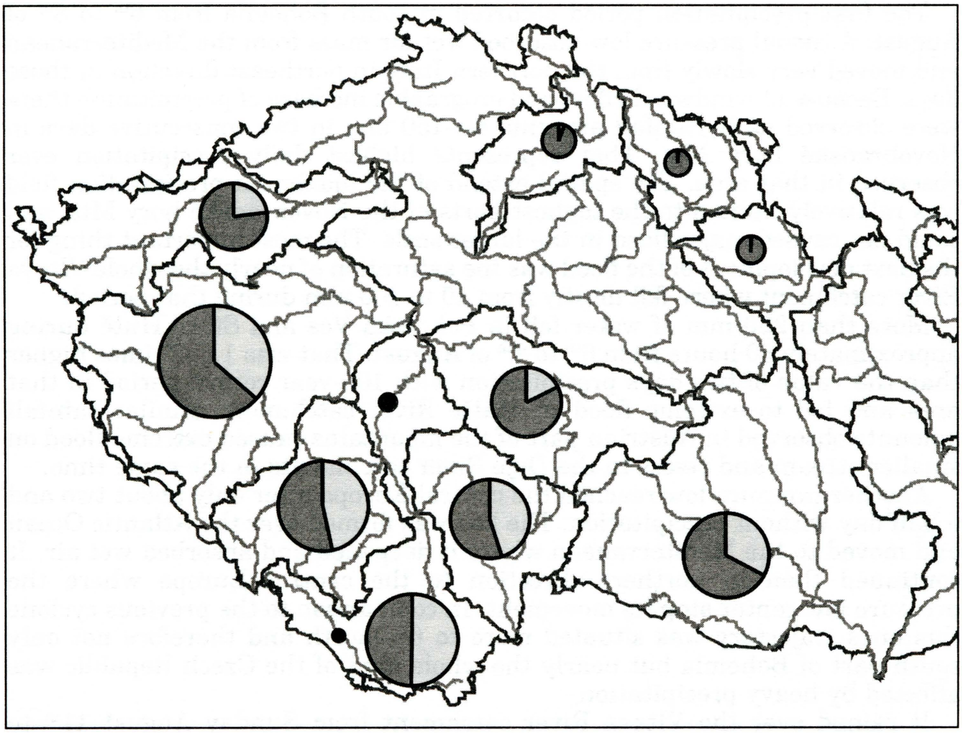

Fig. 1 – Precipitation volumes for selected catchments. Explanations: circle area corresponds to the volume of felled precipitation; light gray – 1st precipitation period; dark gray – 2nd precipitation period.

From the historical records we know about at least similar if not higher rainfall amounts in particular precipitation events in Bohemia. The crucial for the response of the rivers was the repeating of extreme precipitation in very short period of one week. The first precipitation fully saturated the most of the catchment the second one led to fast and high runoff.

Hydrological characterization of flood

In the response to two precipitation periods there were observed two peaks in hydrographs of the most of the rivers in the Vltava River catchment.

The first precipitation event in August 2002 caused extreme flood in the catchment of Malše River and in the Austrian part of the Dyje River catchment. Some minor flood occurred in the Lužnice, Otava, upper Vltava and Berounka River catchments where in some particular profiles discharges reached levels of 1–20 years floods (on tributaries of the Otava River up to 50 years flood).

Malše River and Vltava River downstream Malše River inflow were the most affected. The peak flow return period was estimated to more than 500 years there. Smaller mountainous streams in Malše River catchment (as Černá Brook) were the only streams where the peak flows of the first flood event were higher than the peaks of the second one. The flood wave was transformed downstream in Orlík reservoir on the Vltava River; therefore

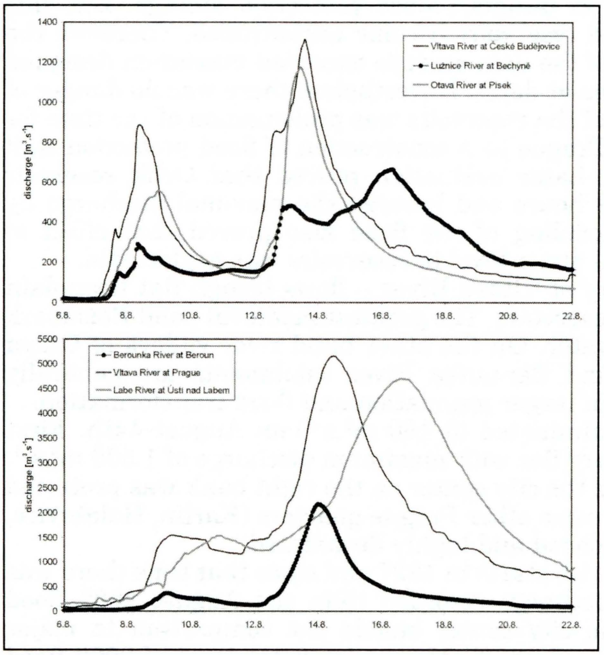

Fig. 2 – Discharge hydrographs of selected rivers and profiles; time on axis x, discharge (m^3.s^{-1}) on axis y.

there was no significant damage in Prague and central Bohemia. But the floodwater fulfilled the reservoirs before the second flood peak.

Very steep and high rising limbs of hydrographs were typical for the second flood episode. The reason was already mentioned; it was the high saturation of the soil and catchment.

Peak flows of south Bohemian rivers occurred mainly on August 13th. The return period of flood was generally bigger than 100 years but in some cases it reached statistical values of more than 1 000 years. Table 1 lists values for main selected profiles while figure 2 shows the discharge hydrographs in main water gauges in Czech Republic.

Table 1 – Peak flow characteristics for selected profiles.

Profile	River	Date	Water level [cm]	Discharge [m^3.s^{-1}]	Return period [years]
Roudné	Malše	8. 8.	446	562	200-500
České Budějovice	Vltava	8. 8.	548	888	500-1000
Heřmaň	Blanice	8. 8.	272	191	50-100
Roudné	Malše	13. 8.	465	695	>1000
České Budějovice	Vltava	13. 8.	652	1310	>1000
Bechyně	Lužnice	16. 8.	640	666	500-1000
Heřmaň	Blanice	13. 8.	427	443	>1000
Písek	Otava	13. 8.	880	1180	500-1000
Lhota	Radbuza	13. 8.	432	360	200-500
Štěnovice	Úhlava	13. 8.	513	398	1000
Plzeň	Berounka	13. 8.	799	858	100-200
Koterov	Úslava	13. 8.	371	459	>1000
Beroun	Berounka	13. 8.	796	2170	500-1000
Prague	Vltava	14. 8.	782	5160	500
Mělník	Labe	15. 8.	1066	5050	200-500
Ústí nad Labem	Labe	16. 8.	1196	4700	100-200
Podhradí	Dyje	14. 8.	476	343	200
Vranov	Dyje	14. 8.	378	364	100

Very important for flood protection activities in Prague was the development on the Vltava River dam cascade. The flood protection storage of the reservoirs there is sufficient for transforming the minor floods. Accordingly operation of the reservoirs fully transformed the first flood episode. Next extensive emptying of reservoirs provided approximately 118 mil. m^3 of free space what was the double of designed flood protection storage. But this storage was quickly filled and reservoirs became uncontrolled. Therefore the water level in all reservoirs of the dam cascade exceeded maximum designed levels and caused big damages at dams. Nevertheless there was no danger of dam collapse. The main role of the reservoirs was prolongation of the time for flood protection activities in Prague as a construction of flood protection wall and inhabitants evacuation. Later evaluation proved that Orlík reservoir delayed the peak flow by 18 hours and lowered the maximal discharge by 800 $m^3.s^{-1}$ (about 20 %). Modeling of the flood also proved that effect of different operation and initial water level in reservoirs was neglectable.

Lužnice River – a tributary of Vltava River – flows trough flat floodplain with lot of ponds and small reservoirs. The greatest medieval pond Rožmberk stored about 60 mil. m^3 of water. On the other hand river valleys of Otava River upper Vltava River and Berounka River catchments are generally narrow with no possibilities of larger inundation and flood transformation.

Vltava River in Prague culminated (5 160 $m^3.s^{-1}$) on August 14th. First flood wave of the flood was very flat with maximum discharge of 1 500 $m^3.s^{-1}$. During the second flood wave the city center on the right bank was protected by flood protection wall. But some other Prague quarters (Karlín, Holešovice, Kampa, Radotín etc.) were flooded and highly devastated.

Prague water level time series starts in 1827 and since that time there was no higher water stage or discharge recorded than the August 2002 flood (Fig. 3). Flood marks in the city center enable the comparison to major historical floods (1784, 1845 and 1890). Maximum water level of 2002 flood was 55 cm higher than 1784 level, 75 cm higher than 1845 level and 120–140 cm higher than 1890 level. Because of hydraulic condition of the valley and may be some change in that the level difference between 1890 and 2002 levels reached up to 300 cm in Karlín.

There was no comparable flood in last two centuries. From historical chronicles we know that the last comparable or possibly greater flood flooded Prague in summer 1432. Another fact visible from figure 3 is that there was nearly no significant flood in twentieth century and especially since forties. That affected the historical memory of Prague's inhabitants as well as the lack of experience of hydrologists and the lack of suitable flood data available for calibration of the hydrological forecasting system.

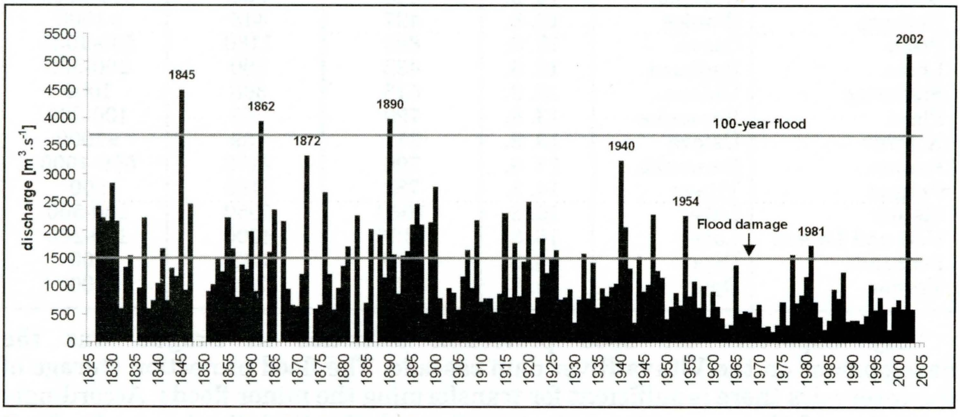

Fig. 3 – Time series of floods of Vltava River at Prague; time on axis x, discharge ($m^3.s^{-1}$) on axis y.

Vltava River inflows the Labe (Elbe) River about 50 km downstream from Prague. Area of the confluence and Labe River flood plain in the central Bohemia is very flat and provides great inundation storage. Therefore, in spite of another tributaries, the peak flow discharge decreased from Prague to Ústí nad Labem where Labe (Elbe) River culminated with discharge of 4 700 $m^3.s^{-1}$ on 16th of August.

Hydrological and meteorological forecasts

Meteorological and hydrological forecast is under the responsibility of the Czech Hydrometeorological Institute (CHMI) in the Czech Republic. For this purpose there is Central Forecasting Office (CFO) in Prague and six Regional Forecasting Offices (RFOs). Every forecasting office has meteorological and hydrological part.

For meteorological forecasting the actual data (from satellites, radars, ground meteorological stations, vertical profiles) and meteorological model outputs are used. The main sources for quantitative precipitation forecast (QPF) are local models of German weather service (DWD) and model ALADIN computed in the CHMI.

QPF forecast for the first precipitation period wasn't successful because of underestimation of expected precipitation by meteorological model. Therefore the forecast was about 30 mm in the mountainous areas in the south Bohemia for 6th and 7th of August while measured precipitation exceeded 100 mm on some stations in both days. On the other hand the QPF forecast for the second precipitation period was quite accurate as shown in figure 4. Meteorologist

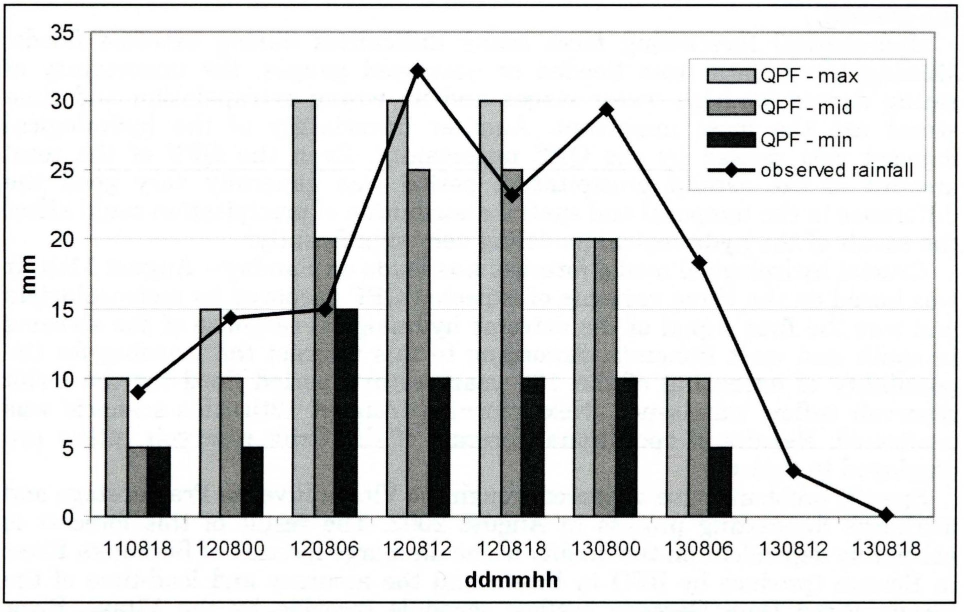

Fig. 4 – Three variants of quantitative precipitation forecast (QPF) of 6 hours amounts for S and SW Bohemia compare to observed precipitation. QPFmax (light gray) – maximal variant, QPFmid (middle gray) – middle variant, QPFmin (dark gray)– minimal variant. Time in 6 hours time step (ddmmhh) on axis x, precipitation (mm) on axis y.

prepared three possible variants of QPF that was used accordingly to count three variants of hydrological forecast.

CFO is responsible for the issuing of warnings and alerts for the dangerous hydrometeorological situations. All together 7 warnings and 14 alerts (most of them for heavy precipitation and floods) were issued during August 2002. Hydrological forecasting office of CFO issued 70 information reports on the flood recent and expected development during both flood episodes. All the reports were distributed using the standard risk management lines and directly send to some another institutions (f.e. Czech Government, Crisis Managements of Czech Republic and some districts, Ministry of Agriculture, Ministry of Environment, Czech TV, Czech Radio Broadcasting, Czech Press Agency, River Authorities etc.). All the reports were published on CHMI web for public.

Hydrological forecast is made using two methods in the Labe (Elbe) River catchment. The first one is daily (morning) manual method of according discharges and travel times. The method uses measured discharge data in the upstream profiles and rating curves. Hydrologist based on the precipitation and his experience estimates the inflow from the area between gauging profiles. The disadvantage of this method is the relatively short lead-time of the forecast – only from 6 to 24 hours in the condition of Czech part of the Labe (Elbe) River catchment – and it could be used only for few forecasting profiles.

To provide longer lead-time of the hydrological forecast is necessary to use rainfall-runoff modeling. Therefore the hydrological forecasting system AquaLog for Labe (Elbe) River catchment with Sacramento rainfall-runoff model is used to produce continuous forecast with lead-time of 48 hours. The advantage of the model is also the possibility of forecasting smaller catchments and streams and the possibility of multiple runs using different variants of QPF. Every CHMI regional office operates its competent part of the system.

Hydrological forecasting faces many difficulties during extreme floods. Missing input data from flooded or destroyed gauges, the uncertainty of rating curves for high water stages and its wrong extrapolation and time stress are the most important. Another uncertainty of the hydrological forecast was caused by the QPF uncertainty. Even the QPF of the total amount of the second precipitation period was generally very good the difference in the temporal and spatial distribution of precipitation could affect the result of the hydrological modeling very significantly.

Crucial hydrological model forecast was made on Sunday – August 11th. It was based on the three variants of expected QPF prepared by meteorologists and was the first signal of the extreme hydrological response of the streams in south and west Bohemia. According to this forecast the warning for the possibility of exceeding of the 100 years return period flood for the Orlík reservoir inflow was issued. Next morning (August 12th) this scenario was confirmed. Results of operational forecast of the Orlík reservoir inflow are displayed in figure 5.

Specific problems have appeared trough the Vltava River in Prague stage and discharge forecasting process in August 2002. The result of this forecast is absolutely dependent on the quality of the discharge forecast of Berounka River in Beroun (produce by RFO in Plzeň) and the accuracy and lead-time of the Vltava River Dam Cascade outflow schedule (provide by the Vltava River Authority). Both of these inputs were highly uncertain. Therefore only a short lead-time estimation of water stages of Vltava River in Prague should be made. The estimation of the peak flow stage was underestimated at the beginning but

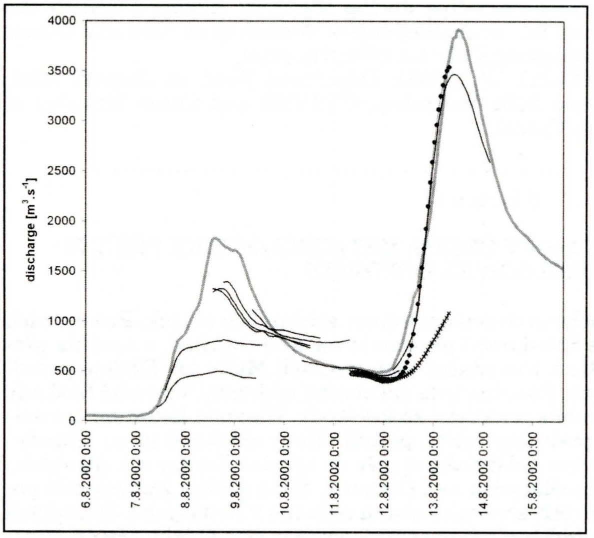

Fig. 5 – Hydrological forecasts (black) based on QPF for Orlík Reservoir inflow compared to later evaluated inflow (gray). Not correct QPF affect the hydrological forecast of the first flood episode. Uncertainty of hydrological forecast according to QPF scenarios (see fig. 4) during the second flood episode is documented by two variants QPFmax (circle line) and QPFmin (crossed line). Time on axis x, discharge ($m^3.s^{-1}$) on axis y.

was elaborated later on. Water stages and discharges of Labe (Elbe) River in Mělník and Ústí nad Labem were forecasted very accurately with the lead time of first forecast of the peak flow more than 2,5 day before it occurred.

Conclusion

Results of the after flood evaluation proved that flood in August 2002 was an extreme event in the meaning of precipitation amounts as well as in the meaning of peak flow discharges in the rivers. Most important was occurrence of two consecutive cyclones bringing extreme precipitation to the same area – the Vltava River catchment – within one week. Highest rainfall amounts were recorded in Novohradské hory Mts. and Šumava Mts. Totally about 5 km^3 of water fell on the Vltava River catchment in both precipitation episodes.

Flood in the streams had two flood peaks according to precipitation episodes from which mostly the second one was higher. First flood episode affected mainly Malše River, where return period of the peak flow reached values of 500 years. Second flood episode affected the most of the Vltava River catchment with peak flows return periods of 100 to 1 000 year.

In comparison to historical floods in Prague the 2002 flood was the biggest flood from those reliable documented and its return period was estimated as 500 years. But the extremity of flood decreased downstream from Prague and on the Labe (Elbe) River.

Hydrological forecasting is very difficult during extreme floods because of input data missing and its uncertainty. Nevertheless the issued forecasts had mostly good quality and were useful in flood protection management.

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Shrnutí

SRPNOVÉ POVODNĚ ROKU 2002 V ČESKU: METEOROLOGICKÉ PŘÍČINY A HYDROLOGICKÉ ODPOVĚDI

Povodeň v srpnu 2002 byla způsobena dvěmi epizodami extrémních srážek. První z nich spojená s tlakovou níží, která se ze Středozemí přesunula na severovýchod, a zasáhla především Novohradské hory. Zde došlo k rozvodnění toků v povodí Malše (až 500leté povodně), následně Vltavy a rakouské Dyje. Povodeň byla zachycena nádržemi Vltavské kaskády a na dolním toku Vltavy tak nezpůsobila prakticky žádné škody. Hlavním faktorem pro další vývoj povodně ale bylo nasycení prakticky celého povodí Vltavy srážkami první epizody.

V krátkém odstupu došlo k postupu další tlakové níže do střední Evropy a k dlouhodobému setrvání s ní spojeného srážkového pásu nad Čechami. Silné srážky zasáhly celé povodí Labe s nejvyššímu úhrny na návětří severních svahů zejména v Krušných a Jizerských horách a na Šumavě. Vzhledem k předchozímu nasycení vyvolaly tyto srážky extrémní povodně na naprosté většině toků v povodí Vltavy.

V jižních Čechách vypadlé srážkové úhrny dosáhly celkově za obě epizody v extrémech až 400–450 mm. Přitom na povodí Vltavy celkově vypadlo okolo 5 km^3 vody, které způsobily povodně s dobou opakování 100 až 1 000 let. Vltavská kaskáda povodeň mohla transformovat pouze částečně a v Praze tak byla povodeň hodnocená jako 500letá. Přitom překonala všechny historicky dochované povodňové značky. Následné mohutné rozlivy ve středních Čechách pak měly za následek zploštění povodňové vlny, tak že v Ústí byla povodeň hodnocena již jen jako 100letá.

Předpovědi srážek v průběhu první vlny nebyly úspěšné, naopak druhá srážková epizoda byla předpověděna velmi přesně. Hydrologické předpovědi narážely na komplikace způsobené výpadky vstupních dat a jejich nejistotou, přesto většinou měly dobrou kvalitu a byly užitečnou informací pro protipovodňová opatření.

Obr. 1 – Srážkové objemy vypadlé na vybraná povodí. Plocha kruhu odpovídá celkově vypadlému objemu srážek; světle šedě srážky první epizody, tmavě šedě srážky druhé epizody.

Obr. 2 – Hydrogramy průtoků ve vybraných tocích a profilech; na ose x zobrazen čas, na ose y průtok v m^3.s^{-1}.

Obr. 3 – Historický řada povodní na Vltavě v Praze; na ose x zobrazen čas, na ose y průtok v m^3.s^{-1}.

Obr. 4 – Tři varianty předpovědi srážek (QPF) pro jižní a jihozápadní Čechy v šestihodinovém intervalu a porovnání s pozorovanými srážkami. QPFmax (světle šedá) – maximální varianta předpovědi, QPFmid (středně šedá) – střední varianta, QPFmin (tmavě šedá) – minimální varianta. Osa x – čas v šestihodinovém kroku (ddmmhh), osa y – srážky (mm).

Obr. 5 – Operativní hydrologické předpovědi (černě) přítoku do nádrže Orlík na základě předpovědi srážek a porovnání s vyhodnoceným přítokem (šedě). Nepřesná předpověď srážek pro první povodňovou epizodu ovlivnila úspěšnost hydrologické předpovědi. Závislost nejistoty hydrologické předpovědi na variantních předpovědích srážek (viz obr. 4) druhé povodňové epizody je dokumentována dvěmi předpověďmi QPFmax (kroužkovaná čára) a QPFmin (křížkovaná čára). Na ose x je zobrazen čas a na ose y průtok v m^3.s^{-1}.

(Author is with Czech Hydrometeorological Institute, Central Forecasting Office, Na Šabatce 17, 143 06 Praha, Czechia; e-mail danhelka@chmi.cz.)

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JAKUB LANGHAMMER

WATER QUALITY CHANGES IN THE ELBE RIVER BASIN

J. Langhammer: *Water Quality changes in the Elbe River Basin.* – Geografie Sborník ČGS, 109, 2, pp. 93–104 (2004). – In the course of the 90s, the Czech part of the Elbe river basin underwent a significant change in the quality of surface water. After a long period of intensified pollution hitting the peak at the end of the 80s, reduced amount of emissions from main industrial and municipal sources led to a lower pollution load of the Elbe and its principal tributaries. The scope and speed of such water quality changes is unprecedented in the Czech as well as in the European perspective. Decrease in the pollution level is however spatially limited to the Elbe river and its main tributaries. Further reduction of emission load will not result in corresponding decline of water pollution. This is due to different evolution of rivers of different sizes, but mainly to insufficient decrease of pollution load in the headstream areas of the river basin. It is this area of small watercourses that has to be in the centre of attention because without its radical changes it isn't possible to ensure permanent improvement of water quality in the Elbe and its tributaries.
KEY WORDS: Hydrology – water quality – pollution – modelling – Elbe.

1. Introduction

Changes in water quality occurring in the 90s in the Czech part of the Elbe and in a large area of its river basin belong among the most significant environmental changes not only in the national, but also in European context. Focused efforts caused by international pressure and changes in political situation at the turn of the 90s resulted in projects aiming at remediation of main sources of industrial and municipal pollution of the Elbe and its main tributaries. These actions were responded by fast and significant decrease in the Elbe pollution load as indicated by most of monitored parameters, and by overall improvement of its environmental state.

However, changes in water quality of the Elbe river basin have been spatially quite differentiated. This paper looks at the internal structure of the process and different dynamics of water quality changes in watercourses with different size of structure and geographical position. Assessment is focused on main load indicators of organic substances and nutrients. Mathematic models help simulate variable scenarios of further Elbe water quality development based on the expected emission load of the river basin.

2. Material and Methods

2. 1. Methodology

Analytical assessment is based on two main methodological procedures – standard geostatistical assessment and applied mathematic modelling.

Geostatistical assessment was employed to analyse developments of surface water quality in the hydrographical network of the Czech part of the Elbe river basin, to analyse pollutant emissions in the aquatic environment, and spatial relations using the geographic information systems (GIS).

Analyses of the Elbe river basin emission load was supported by a database of recorded sources of sewage emissions of the State Water Management Balance (the SVHB). To perform spatial analysis using GIS the digital Water Management Map and the data from the CORINE landcover geodatabase were used.

Assessment of the Elbe quality state and development of its individual aspects was based on data provided by monitoring of surface water quality in profiles of the state network administered by the Czech Hydrometeorological Institute (CHMI). We selected 141 profiles for the analyses, representing individual river basins in terms of geographical location, physical and geographic conditions, social and economic use and river basin structure size, water volume and prevailing character of pollution sources. Assessment was based on the time period 1990–1999 and covered parameters of BOD-5, COD, $N\text{-}NH_4$, $N\text{-}NO_3$ and total phosphorus.

2. 2. Study area

The Elbe river basin covering over 50 000 km^2 concentrates pollution load almost from whole Bohemia showing high concentration of population, industry and agriculture. The Elbe itself is marked by many significant direct pollution sources because favourable geographical conditions in the past led to long-term natural concentration of inhabitants, intensive agricultural production and establishment of many industrial plants since the mid of the 19th century (Fig. 1).

In the course of the first and mainly the second half of the 20th century, the Elbe as well as other big rivers in Europe showed a dramatic rise in pollution according to all monitored indicators due to high concentration of anthropogenic activities. The peak load was reported in the 70s and 80s and most of big rivers in Western Europe underwent a similar process. They, however, were exposed to significant changes from the end of the 60s aimed at stopping further contamination and return to original natural structure. In case of the Elbe, problems stayed unresolved for many years and in the 70s and 80s when European rivers like Rhine, Saale, Mosel etc. showed significant decrease in pollution and new rehabilitation of natural ecosystems, the Czech Republic suffered the highest historical pollution load of rivers.

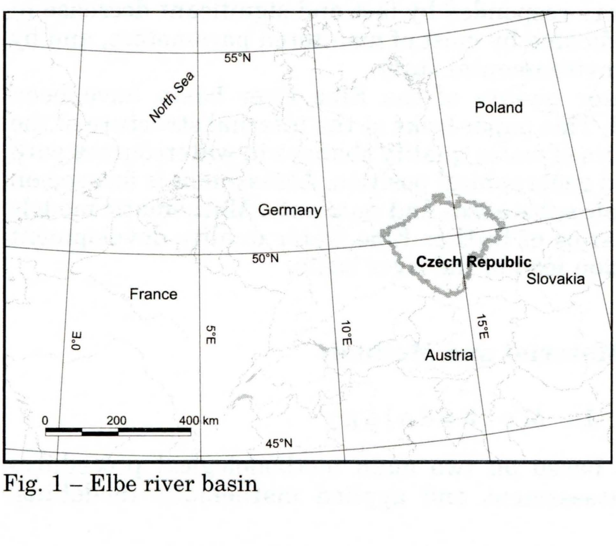

Fig. 1 – Elbe river basin

Dramatic changes in water quality of the Elbe and its river basin came in the 90s. Social changes and opening to international cooperation after 1989 resulted in adoption of fundamental measures to remedy ecological damage. Under coordination of international and national programmes, in particular the International Committee for the Elbe Protection and Projects Elbe I and II, the biggest pollution sources were eliminated and water quality in the Elbe quickly improved.

3. Results

3. 1. Spatial Distribution of Pollution Sources

The Czech part of the Elbe river basin is characterised by high concentration of anthropogenic activities representing current sources of surface water pollution, i.e. mainly urban and industrial complexes distributed along the whole river and its tributaries. Many of them and particularly chemical plants belong among the biggest direct pollution sources in the Czech Republic and Europe.

Spatial concentration of point emission sources in the Elbe river basin copies distribution of main cities and industrial zones. This is also documented by a map of point emission sources (Fig. 2) made on the basis of spatial combination of the SVHB database and the Digital Water Management Map. Along the Elbe river basin, there are 1600 recorded point pollution sources while the most significant emission sources located mainly along large watercourses are concentrated into so called emission areas, i.e. areas of concentrated substance deflation of emissions from point sources to watercourses with similar characteristics of the structure of pollution sources and emitted pollutants.

Besides the sources concentrated in the key areas, there are almost 1 400 recorded point emission sources with annual volume of emitted sewage water over 1 000 m^3. Such local industrial and municipal point emission sources, often drained to recipients with low water volume, affect the already high pollution load transferred from headstream to downstream areas and multiplied by non-declining load from nonpoint pollution sources.

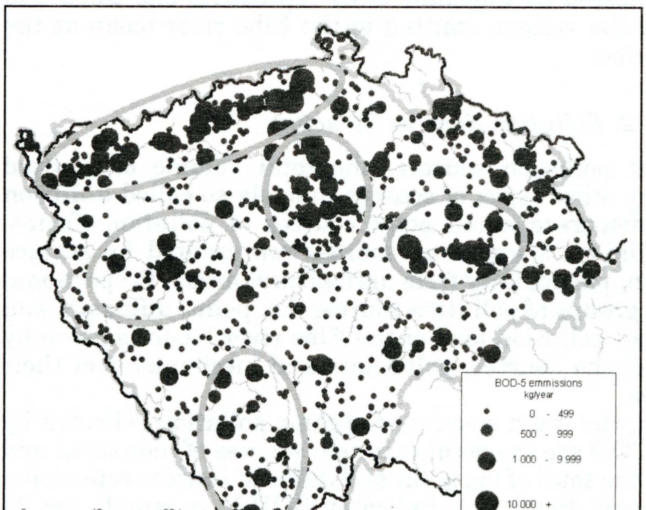

Fig. 2 – Main emmission areas. BOD–5 emmissions (kg/year)

3. 1. 1. Development of Pollutants Emissions

In the course of the 90s, the Elbe river basin experienced a significant decrease

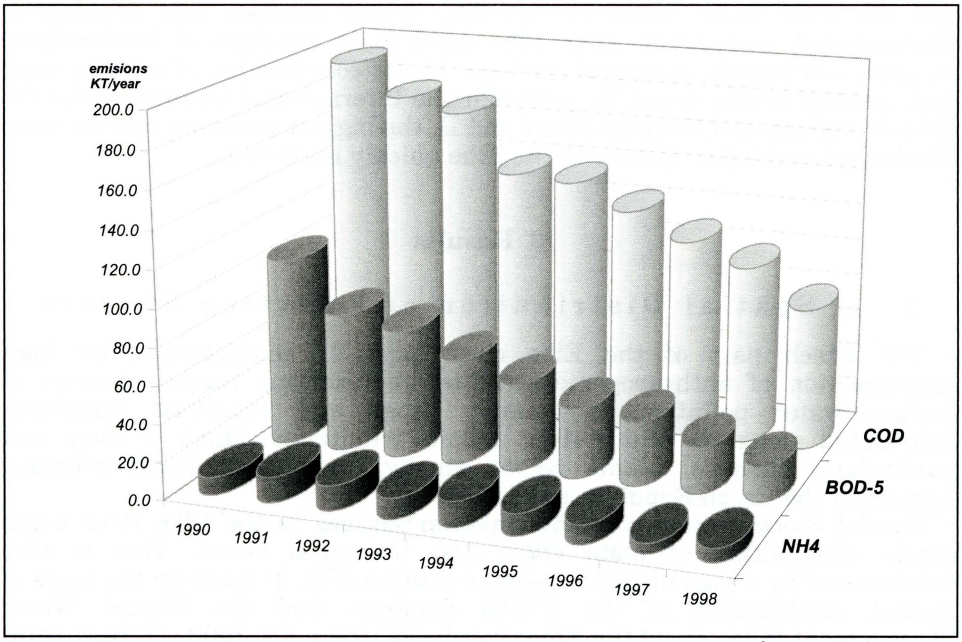

Fig. 3 – Decreasing pollution load from point sources

in pollutants emission volume from recorded point pollution sources. Construction and intensification of sewage treatment plants in big industrial and communal emission sources resulted in radical fall of emissions according to parameters reflecting this type of pollution load (Fig. 3). The indicator of organic pollution, BOD-5, showed reduction of overall recorded emissions from 1990 to 1999 down to one fifth of original volume. Emissions volume at the end of the 90s as reflected by indicator COD represents one third and indicator NH_4 one half of the volume emitted to the Elbe river basin at the beginning of the same period.

3. 1. 2. Pollution Sources Structure

Besides recorded point pollution sources, the total volume of emitted pollutants is comprised by other types of sources, namely so-called diffusion sources represented by dispersed small point sources of pollution (farms, small settlements, landfills etc.), and area sources represented by surface runoff from the river basin, particularly from agricultural areas. Proportional participation of the main groups of pollution sources, i.e. point, diffusion, and area sources, in the overall pollution load of the Elbe river basin is given by different characteristics of the sources, pollutants and mechanisms of their transport to surface water.

In the Elbe river basin, the main sources of organic pollution reflected by indicators of BOD-5 and COD are the point emission sources of industrial and municipal character, and the total of big point and diffused sources represents the majority of the balance. Regarding indicator BOD-5, it stands for 95 percent of the total load and COD represents 75 percent (Fig. 4).

Similar proportions are characteristic for the total phosphorus – almost 60 percent is produced by recorded point sources, 35 percent by diffused sources,

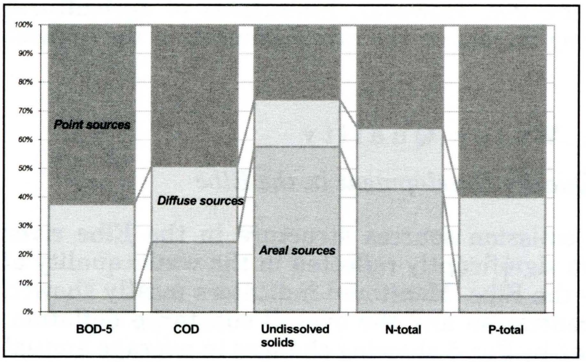

Fig. 4 – Pollution sources structure

and only 5 percent by area sources. The issue of phosphorus transport is quite complicated and therefore these values shall be interpreted taking into account that different authors achieve different final values of the indicator, e.g. Jurča a kol. (1997), or Behrendt and Nesměrák (1996).

Pollution load of the Elbe river basin by whole nitrogen and undissolved substances is mostly generated by transport from area and diffused sources. Regarding total nitrogen, load from area sources represents almost 45 percent of the total amount emitted in the Elbe river basin and jointly with diffusion sources stands for 65 percent of total emissions. This parameter is however comprised by two indicators of different origin and transport mechanism, i.e. by $N\text{-}NH_4$ and $N\text{-}NO_3$. While $N\text{-}NH_4$ shows clear dependence on point pollution centres, $N\text{-}NO_3$ load is generated mostly by area sources.

The indicator of undissolved substances is most closely related to nonpoint sources and general erosion processes. In terms of this parameter, 65 percent of emitted load is generated by area sources that together with diffusion sources represent 75 percent of substance deflation.

3. 1. 3. Changes in Pollution Sources Structure

The structure and participation of main emission sources in the overall Elbe river basin load isn't constant. Significant changes in water quality of the Elbe and its main tributaries occurring in the 90s were accompanied by radical changes in the source structure. Structural development of emissions is mostly marked by fast decline of point sources impact. Regarding industrial sources, the pollution volume emitted at the end of the 90s represented only one sixth of the amount detected at the beginning of the period. Decline in volumes emitted by municipal sources was significantly slower due to the lack of sewage plants in large settlements at the Elbe downstream in the 90s. Nevertheless, emissions even in this respect were reduced in the period down to 1/3 of the original volume.

To the contrary, emissions generated by diffusion and area sources don't show any significant drop and have increasingly decisive impact on surface water quality in the Elbe river basin.

While the impact of industrial and municipal load sources is falling at different speed on the Elbe itself and other big watercourses in the Czech part of the Elbe river basin, small watercourses don't show such significant changes. They are mostly influenced by diffused small sources, e.g. municipalities lacking sewage systems or sewage treatment plants, farms, smaller businesses etc. The majority of peripheral river basins is subject to increasing impact of area sources, particularly of surface runoff from agricultural areas. The balance volume of pollution in the examined river basins isn't falling despite relatively significant reduction of fertilizers application in agriculture in the 90s. However, limitations of agricultural activities haven't had almost any impact on the areas generating the highest volumes of pollution.

3. 2. Water Quality

3. 2. 1. Water Quality Development in the Elbe

Changes in emissions and emission sources structure in the Elbe river basin occurring in the 90s were significantly reflected in the water quality of the main river of the system – the Elbe. Monitored indicators mostly showed decline in river pollution concentration and the overall substance deflation. This development is documented by Fig. 5 showing changes in average annual organic pollution concentrations according to BOD-5 in the longitudinal profile of the Elbe. From the mid 90s, the critical load level was continuously cut down in the Elbe midstream and downstream, and at the end of the period water of the whole stream reached the level achieved at the turn of the 90s only in the Elbe upstream.

In the 90s, the Elbe generally showed visible decrease in concentration and substance load according to selected water quality parameters, particularly those reflecting load from point pollution sources. This concerns indicators reflecting the overall contamination in COD, BOD-5 and $N\text{-}NH_4$ indicators. Mainly in the second half of the 90s, they showed radical decline of the Elbe river basin load due to dramatic cuts of big industrial and municipal sources emissions.

The process of contamination by total phosphorus is different. In the 90s, this indicator reflecting the load volume caused by industrial and mainly municipal point sources showed not only stagnation, but also contamination increase in certain areas. Slow increase in phosphorus load doesn't concern only the Elbe, but also partial river basins of its tributaries. This situation is caused by increased phosphorus emissions by municipality sources and lack of sewage treatment plants in small and medium size villages and their technical state. In terms of the total balance, decrease in phosphorus emissions caused by big industrial and municipal sources at the Elbe and its main tributaries didn't absorb increased load from the whole river basin.

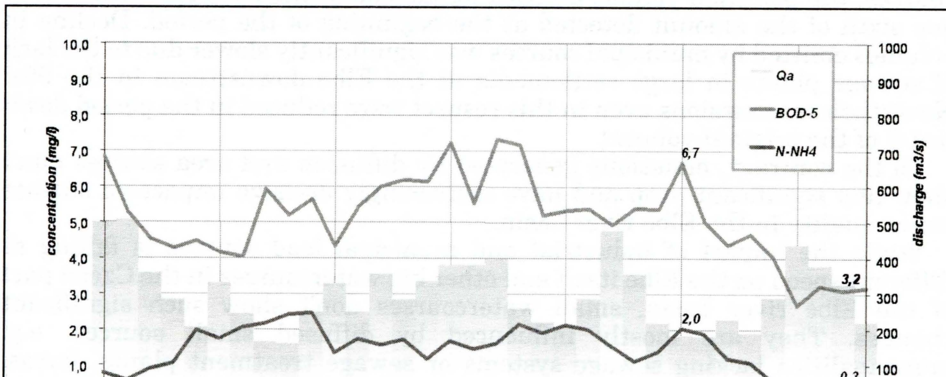

Fig. 5 – Pollution concentrations decrease in Elbe river at Děčín

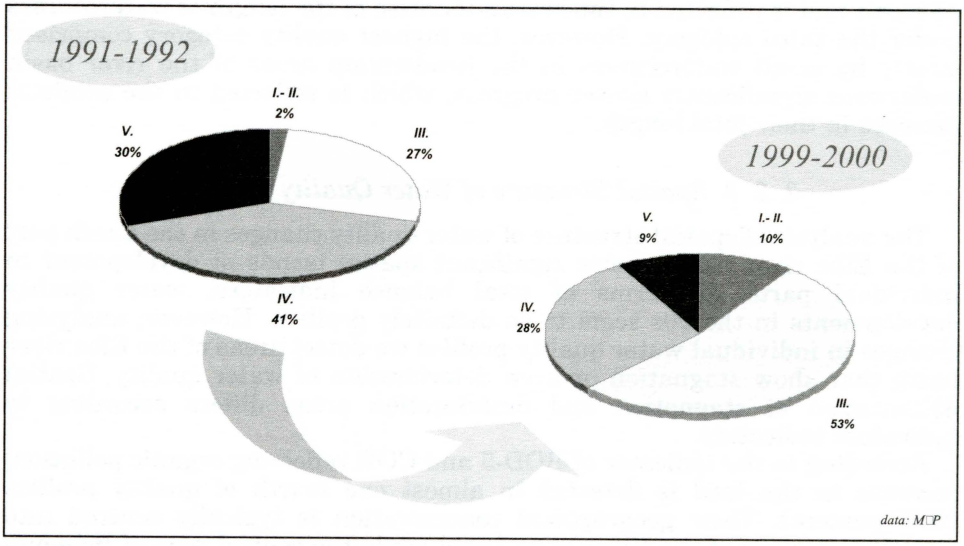

Fig. 6 – Overall water quality changes in Elbe river basin

Indicators reflecting pollution load from area sources, mainly indicators of N-NO_3, didn't show any significant quality changes in the 90s. Supply of nutrients from source surfaces didn't fall despite evident suppression of agricultural activities and fertilizers application in the 90s.

3. 2. 2. Water Quality Changes in the Elbe River Basin

Changes in water quality weren't recorded only in the Elbe, but positive improvements, although of different intensity, involved the whole river basin. The overall quality of watercourses of the Czech part of the Elbe river basin, expressed in quality categories (Fig. 6), was significantly improved. Comparing the number and total length of watercourses included in one of five quality categories at the beginning and in the end of the 90s, three tendencies emerge:

- There are significantly less watercourses classified in the two worst quality categories. Watercourses reaching such a strong pollution level in 1991–92 represented in total 71 percent of the hydrographic network, while in 1999–2000 it was only 37 percent.
- In comparison with the beginning of the 90s, the number of sections of watercourses classified in the third category as polluted water doubled.
- The length of watercourses sections classified in the two best categories increased by 8 percent. It is a positive trend, but a relatively small change against the overall scope of quality changes.

Data on overall water quality changes in watercourses of the Elbe river basin (Min. of the Environment 2001) provide a comprehensive picture of the river basin and the internal structure of changes in individual river basin parts. The sections falling under the fourth and fifth category at the turn of the 90s were mostly on big rivers, on the Elbe and its main tributaries that are subject to big industrial pollution sources. Improvement of water quality resulting from construction and intensification of sewage treatment plants at such sources shifted water quality in recipients by one or two categories upwards and is reflected in the overall increase of the length of watercourses under the third category. However, the highest quality category comprised mostly by small watercourses in the headstream areas of the river basin underwent significantly slower progress, which is reflected in the minimal increase in their total length.

3. 2. 3. Spatial Structure of Water Quality Changes

The analysis of spatial structure of water quality changes in the Czech part of the Elbe river basin shows significant spatial trends of development in individual parts. In terms of total balance indicators, water quality developments in the 90s seem to be definitely positive. However, analysing changes in individual water quality profiles we detect areas of the Elbe river basin that show stagnation or even deterioration of water quality. Spatial delimitation of stagnation and deterioration areas differs according to individual indicators.

According to the indicator of BOD-5 and COD reflecting organic pollution, increase in the load is detected in almost one fourth of quality profiles (22.7 percent). Their geographical concentration is typically centred into boundary regions of the Elber river basin while the central part of Bohemia including Prague region records decrease of pollution (Fig. 7).

The indicator of nitrate pollution shows different spatial trends of pollution load evolution. The overall balance of nitrate pollution load is stagnating and

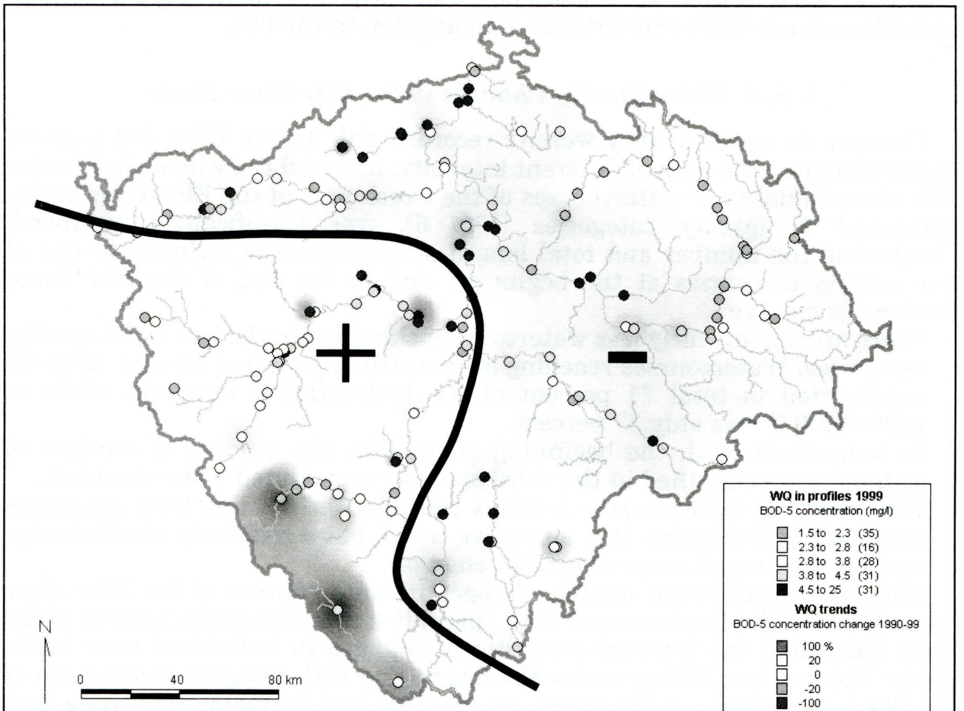

Fig. 7 – Changing patterns of water quality in Elbe river basin, BOD-5. + ... rise of concentrations, - ... decrease of concentrations. WQ in profiles 1999, BOD-5 concentration (mg/l). WQ trends, BOD-5 concentration change 1990-99.

regional comparison doesn't show any significant decrease in overall pollution either. Almost one third of water quality profiles suffer quality deterioration while remaining profiles development is marked by stagnation and minimum concentration decline. It is worrying that concentration rise occurs in already burdened areas classified under 3rd and 4th water quality categories.

Overall spatial trend in nitrate concentration development points to deep problems of links between agriculture and water quality. Globally, the 90s saw a significant suppression of agricultural activities in the Czech Republic, but it didn't result in expected decrease in nutrients and mainly nitrates load. Decline related to agriculture limitation and fertilizers application was set off by intensified activities of economically stronger entities. Unlike in case of industrial and municipal sources, here the decline isn't brought by systematic changes. Further economic upsurge of agricultural entities facilitated for example by future EU subsidies is likely to result in increased use of fertilizers and effective pesticides and deterioration of water quality in small and medium watercourses.

4. Discussion

Radical reduction of emissions in the mid 90s caused fast and significant decline of the Elbe river basin pollutants load. After reaching certain level it however seems that further emissions reduction won't have the same response of falling concentration of main monitored pollutant indicators in rivers. It isn't clear whether and how further water quality improvement in the Elbe river basin can be achieved in the future.

Answers can be found through structurally differentiated view of water quality changes and tools of mathematical modelling. Geostatistical analyses of links between river basin geographical location, its size and water volume, and water quality changes clearly points to differences in development of watercourses belonging to different classes. The majority of positive changes occurred on the biggest watercourses influenced by large industrial and urban point pollution sources. Medium watercourses influenced mostly by local industry and settlements are undergoing a very variable process often directly linked to the overall regional economic situation. The slightest changes, often of a negative character, were detected in small watercourses in agricultural areas.

There are more explanations of highly asymmetric load decline of the Elbe river basin in the 90s, differing by various classes. The fact that most activities aiming at water quality improvement were focused on the biggest rivers had economic, technological and political motives.

Measures to reduce emissions from point sources, i.e. construction or intensification of sewage treatment plants, although economically demanding, are easy to adopt from the technical point of view, and ensure relatively high effectiveness against the invested value. To quickly eliminate the massive volume of pollution leaving the Czech Republic through the Elbe at the beginning of the 90s, remediation of big direct industrial and municipal emission sources on the Elbe and its main tributaries was the only solution. Interest in increased water quality of the Elbe wasn't expressed only by the Czech Republic, but also by Germany and the EU who monitored how remediation of emission sources on the Elbe was reflected by pollution decrease in North Sea, and therefore financially supported construction and modernisation of sewage treatment plants in the first half of the 90s.

On the other hand, smaller watercourses still suffering from local industrial and municipal pollution are less visible and mostly outside the interest of general public and international institutions. These courses, representing the largest part of the Elbe hydrographic network, were subject to massive riverbed modifications, channelization, and melioration in the past and lost their natural abilities to eliminate load caused by anthropogenic activities. Financing of construction and reconstructions of sewage treatment plants in municipalities and industrial facilities in these areas is far more complicated and takes longer. What's more, small and medium watercourses are highly influenced by nonpoint pollution sources difficult to reduce and eliminate without an integrated package of economic, legal, executive and technical measures with a long-term effectiveness.

Processes occurring in the Czech part of the Elbe river basin are analogical to those happening on European rivers. Assessment of water quality in European rivers performed by the European Environment Agency (EEA 2002) shows similar links between watercourse classes and their quality. Regarding total phosphorus and nitrogen, the highest average concentration is detected on the smallest watercourses as in the Czech part of the Elbe river basin. The larger the river basin area and average long-term discharge, the higher the overall water quality and dynamics of pollution decline.

5. Conclusion

The results of analysis of water quality state and developments in the Czech part of the Elbe river basin in the 90s, and the processed development prognosis have shown that increasing differences between water quality in the Elbe and its tributaries currently represent the main problem for further water quality improvement in the given area.

Decrease in pollution level of the Elbe in the 90s doesn't result from positive development of the whole river basin, but only from activities along the Elbe itself and the main tributaries. At the beginning of the 21st century, the majority of hydrographic network of the Czech part of the Elbe river basin, mainly small watercourses in peripheral areas, still remain exposed to high emissions from local industrial and municipality pollution sources and agricultural production.

Point pollution sources underwent radical quality changes in the 90s, which however doesn't apply to diffusion and area sources of surface water pollution. Non-declining emission volume from diffused agricultural and small municipal sources, distributed by the network of devastated small watercourses, hinders natural retention and elimination of pollutants. The areas of small watercourses thus should be at the centre of future attention because permanent improvement of downstream water quality can't be achieved without changes of the headstream area.

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Shrnutí

ZMĚNY KVALITY VODY V POVODÍ LABE

V průběhu 90. let došlo v české části povodí Labe k zásadnímu obratu ve vývoji kvality povrchových vod. Po dlouholetém nárůstu úrovně znečištění došlo díky snížení emisí z hlavních průmyslových a komunálních zdrojů k poklesu úrovně zátěže Labe i jeho nejdůležitějších přítoků. Rozsah a rychlost těchto změn v kvalitě vody je bezprecedentní jak v rámci ČR, tak i v evropském měřítku.

Pokles úrovně znečištění však je však omezený víceméně pouze na Labe a jeho hlavní přítoky. Velká část drobných vodních toků, zejména v zemědělské krajině i nadále trpí nadměrným znečišťováním z průmyslových a komunálních zdrojů, stejně jako intenzivní zemědělskou výrobou.

Pro další pokračování poklesu znečištění Labe bude rozhodující dokončení eliminace emisí z komunálních zdrojů a postupné snižování zátěže, přinášené do Labe jeho přítoky. Tyto v současné době představují bilančně bezkonkurenčně největší zdroje látkových vnosů do toku Labe. S výjimkou Vltavy a Bíliny, které jsou pod vlivem silných bodových zdrojů je kvalita vody většiny z nich ovlivňována plošnými a difúzními zdroji znečištění. Na rozdíl od bodových zdrojů znečištění, které v průběhu devadesátých let prodělaly kvalitativní skok, v oblasti difúzních a plošných zdrojů znečištění povrchových vod k analogickému vývoji nedošlo. Neklesající objem emisí z rozptýlených zemědělských i drobných komunálních zdrojů, odváděných sítí zdevastovaných malých vodních toků, neumožňuje přirozenou retenci a odbourávání znečišťujících látek. Vodní toky jsou díky tomu vystaveny silné zátěži často již od svých pramenných úseků, přičemž celkově vysoká intenzita využití krajiny působí na postupně rostoucí zátěž celého říčního systému.Celková postupná rehabilitace stavu přírodní sféry povodí Labe je procesem s podstatně delším časovým horizontem, než představuje náprava kvality jeho vodní složky. Realizované modely a prognóza vývoje ukázaly na limity v procesu zlepšování jakosti vody prostřednictvím omezování emisí z bodových zdro-

jů znečištění. Další pokles znečištění vody v Labi i při důsledné aplikaci moderních čistících technologií a dodržování emisních limitů může přinést již jen dílčí zlepšení jakosti vody.

Těžiště prací na rehabilitaci kvality vody v toku se proto bude muset přesunout z vlastního koryta toku do jeho celého povodí. Při pokračující eliminaci zátěže z přímých bodových zdrojů bude pro další snížení znečištění vody nezbytný komplexní přístup k řízení kvality vody v povodí, podchycení a eliminace rozptýlených drobných bodových zdrojů znečištění a posilování přirozených funkcí říčních ekosystémů, včetně jejich postupné revitalizace.

Obr. 1 – Povodí Labe
Obr. 2 – Hlavní emisní oblasti povodí Labe (emise v kg/rok)
Obr. 3 – Pokles emisí znečištění z bodových zdrojů, osa x – roky, osa y – emise (tisíce tun/rok)
Obr. 4 – Struktura zdrojů znečištění. Podíly (ve sloupci odspodu): plošné zdroje, difúzní zdroje, bodové zdroje; sloupce (zleva): BSK5, CHSKCr, nerozpuštěné látky, Ncelk, Pcelk
Obr. 5 – Pokles koncentrací znečištění v profilu Labe–Děčín. Osa x – roky, osa y – vlevo koncentrace (mg/), vpravo průtok (m^3/s).
Obr. 6 – Změna tříd jakosti povrchových vod v povodí Labe
Obr. 7 – Změna prostorové struktury kvality vody povodí Labe v ukazateli BSK5. + – nárůst koncentrací, - – pokles koncentrací. Body – jakost vody na profilech v roce 1999, koncentrace BSK5 (mg/). Plošně – změna kvality vody v ukazateli BSK5 v období 1990-99.

*(Author is with Charles University in Prague, Faculty of Science, Department of Physical Geography and Geoecology, Albertov 6, 128 43 Praha 2, Czechia;
e-mail: langhamr@natur.cuni.cz.)*

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MILADA MATOUŠKOVÁ

ECOHYDROLOGICAL MONITORING OF THE RIVER HABITAT QUALITY

M. Matoušková: *Ecohydrological monitoring of the river habitat quality.* – Geografie Sborník ČGS, 109, 2, pp. 105–116 (2004). – Complex ecohydrological methods are of principal significance when evaluating the state of water ecosystems and they give also decisive information for their restoration. New approaches in the evaluation allow a broader view at the water ecosystem. The ecohydrological state of a stream is determined by a set of hydromorphological characteristics of the river channel, of its runoff, by hydrochemical and hydrobiological condition of water, by the character of bank and riparian belts and transformation of the floodplain. The new European Water Framework Directive (2000/60/EC) underlines the significance of ecohydrological methods. In the paper is represented a method of ecomorphological evaluation of streams habitat quality and its application on the model study area of the Rakovnický Brook.
KEY WORDS: ecohydrological monitoring – river habitat – river training – hydromorphology – vegetation belt – riparian zone – water basin.

1. Introduction

From the beginning of the eighties, efforts have come up to develop an objective and complex evaluation method of the ecological state of watercourses. Classical approaches of streams quality evaluation are based on hydrochemical and hydrobiological methods. These methods are not replaceable in the case of determining the pollution degree of surface waters. Their joint negative attribute is concentration on watercourse bed. These methods obviously provide indirect information also on processes taking place within the whole basin. Quality of surface waters is also closely connected with hydromorphological characteristics of watercourse beds, especially with the degree of anthropogenic modifications, the character of riparian belt along streams, the sediment and runoff regime, and land use.

Since the end of the nineties of the twentieth century, tendencies to form new complex analyses have increased which would reflect the total, so called ecological, or ecohydrological condition of streams.

Complex ecohydrological methods are of principal significance when evaluating the state of water ecosystems and they give decisive information for their restoration. The ecohydrological state of a stream is determined by a set of hydromorphological characteristics of the river channel, of its runoff and suspended sediment load regime, by hydrochemical properties of surface water and by hydrobiological conditions in the stream channel, by the character of bank and riparian belts along streams, by anthropogenic transformation of its floodplain. It is indirectly influenced by physical-geographical and social-economic conditions of the whole basin.

The new European Water Framework Directive (2000/60/EC) underlines the significance of ecohydrological methods. Watercourses are evaluated according to an ecological statute, which is determined by biological, hydromorphological and physical-chemical parameters. The Water Framework Directive is aimed both at the state of the streambed and at its riparian belt. The ecological state of water ecosystems is classified in the Directive by three degrees: high, good and fair. Individual degrees are described only in a general way, as it is problematic to specify and to quantify the properties of ecosystems in different regions of Europe. For that purpose, evaluation procedures and water streams typologies are elaborated in different countries.

2. Aims and methods

The aim of this research was to elaborate a method fitted for ecohydrological monitoring of small streams and its verification and application on the model study area. It includes analyses of the existing evaluation ecohydrological approaches. Principal for elaboration of these method were also studies on fluvial-morphological characteristics of natural or near-natural streams.

The great majority of existing evaluation approaches concern watercourses of higher orders according to the classification by Strahler (Strahler 1957). For instance the LAWA method (DWVK, LAWA 1996) was created for the needs of area evaluation and mutual comparison of ecological structures of water streams in the whole Germany. It is extended by the BfG Koblenz method (LAWA 1998), formulated and used within the Elbe (Labe) project in pilot segments of the Elbe (Labe) River in Germany and in the Czech Republic. This method is used for evaluation of ecological state of so-called significant watercourses with a channel larger than 10 m. Another of the methods, "Ecological evaluation streams" by Niehoff (1996), was also created for middle to large basins.

Ecological principles of evaluation are also discussed in the study "A Guide to HABSCORE Field Survey Methods and the Completion of Standard Forms" (NRA 1995). The HABSCORE system was elaborated as a tool for evaluation of watercourses state from the viewpoint of protection of salmon streams. Method "River Habitat Survey" (NRA 1992, 1995) was created on the basis of the evaluation "River Corridors Survey" (NRA 1992, 1995). This method covers a complex of evaluation parameters, e.g. fluvial-morphological characteristics of stream bed and stream banks, a flow type, character of stream bank vegetation and of riparian zone, land use in the riparian belt in 50 m along the stream, but the evaluation system was not elaborated.

Several studies based on ecological principles have been elaborated in the USA and Canada. For example – evaluation of river habitat ecosystems "Rapid Bioassesment Protocols For Use in Streams and Wadeable Rivers" (Barbour 1999), which is a part of the complex biological monitoring of rivers. This method is used as a national standard for ecological evaluation of watercourses.

In the Czech Republic only a few ecohydrological studies have been published. A study concerned with multicriterial analysis of watercourses was elaborated by Šindlar (Šindlar 1998) and used for the needs of the Ministry of the Environment of the Czech Republic – Water Ecosystems Restoration

Programme. An applied ecological study was preceded within the project on the Bilina river basin (Havlík et al. 1997).

3. Ecomorphological evaluation of the stream habitat

Only little attention has been up to now paid to small streams. For the reason of absence of suitable method for small streams, within the framework of the research project GAUK "Water Quality Research in the Berounka River Basin" (Langhammer, Matoušková 1999) and work on Ph.D. Thesis "Ecohydrological monitoring as a basis for restoration of streams" (Matoušková 2003) the method of ecomorphological evaluation of stream habitat quality was elaborated.

This method is an instrument for evaluation of stream ecomorphological state in free countryside as well as in urban areas. It is based on a combination of field investigation, processing of available data and maps. The water ecosystem is understood here as a larger territory, which is formed by individual mutually interconnected zones. It is therefore not bound only to the riverbed. The unit of the highest order is the basin, and then there are delimited zones of the flood plain, of riparian belts and of the stream channel.

The method of ecomorphological monitoring is composed of several separate evaluated parameters that get mutually integrated during the evaluation. It includes the analysis of fluvial-morphological features of the channel, of the anthropogenic transformation of the hydrographical network, of the quality of surface water, of the state of bank vegetation, of the land use in riparian belt and of selected ecohydrological features of the basin (Tab 1). The ecomorphological evaluation is based on the so-called "potential natural state" which is the state of the stream that is formed during the given physical-geographical development of the given area without significant negative anthropogenic impacts in the landscape. Nevertheless, it is not the "historical" state of the stream in the untouched natural landscape.

Ecomorphological mapping is done in determined segments, which are homogenous or heterogeneous in dependence on the size of the basin. In the case of small watercourses (catchments area < 100 km^2), it is suitable to perform the mapping in segments of constant length. The recommended segment length is 100 m or 200 m depending on the accuracy, requirements, and purpose of the mapping. In the case of larger basins (catchments area >100 and < 500 km^2), it is suitable to perform the ecomorphological mapping in segments of varying length, with the emphasis laid on their qualitative homogeneity. Length of individual segments lies within the range of 500–1000 m. Each segment of the watercourse is delimited exactly on the map and marked numerically. Their mutual non-overlapping must be guaranteed. For the field mapping, spring and autumn periods are favourable. Investigation of hydromorphological structures of the bed should be performed during low flow. Mapping results are recorded in a working form of the ecomorphological evaluation, in maps, and subsequently processed to obtain their digital form, and finally evaluated using a spreadsheet editor and represented in thematic layers of GIS.

Individual parameters are classified by a score in the interval < 0; 5>. The values of partial parameters are calculated on the basis of the worst registered value that is on the principle of maximum or on the basis of the prevailing, so-called dominating value or with the help of arithmetic average.

Tab. 1 – Ecomorphological parameters

Ecomorphological zone	Main ecomorphological parameter	Partial ecomorphological parameter	Evaluation (point P / verbal V)
Stream channel	Fluvial-morphology and meandering	Type of river valley	V
		Meandering	V, P
		River bed (character and shape)	P
		Deepening of river channel	P
		Accumulation structures	P
	Longitudinal profile	Existence of steps	P
		Channelization	P
		Riffles and pools	P
		Type of water flow	P
		Degree of depth variability	P
		Man-made changes in outflow	P
	Cross section profile	Type of cross section	P
		Depth (average)	V
		Degree of length variability	P
		Type of river training	P
	River bed	Character of substrate	V
		Type of bed training	P
		Substrate diversity	P
		Microhabitats	P
	Bank structures	Vegetation	P
		Type of bank structures	P
		Unstableness of banks	P
	Water quality	Hydrochemical parametres	P
		Hydrobiological parametres	P
		Sewage outfalls	V
Vegetation belt		Existence of riparian belt	P
		Character of riparian belt	P
		Retention of riparian belt	
Flood plain		Land use in flood plain	P
		Flood control measures	P
		Retention potential of flood plain	P
Water basin		River training	P
		Susceptible to erosion	P
		Land cover	P
		Drainage areas	P
		Retention areas	P

The evaluation is done on the basis of additive principle. All ecomorphological zones have the same importance for determination of the so-called ecomorphological state, which is calculated as the arithmetical average of the evaluated ecomorphological zones. The ecomorphological state is then classified on the basis of assignment of numerical result into one of the defined ecomorphological classes.

4. The model study area

The model area for application of the described method was the Rakovnický Brook basin, which corresponds to the requirements of anthropogenic transformation of the hydrographical network and of the stream order. At the

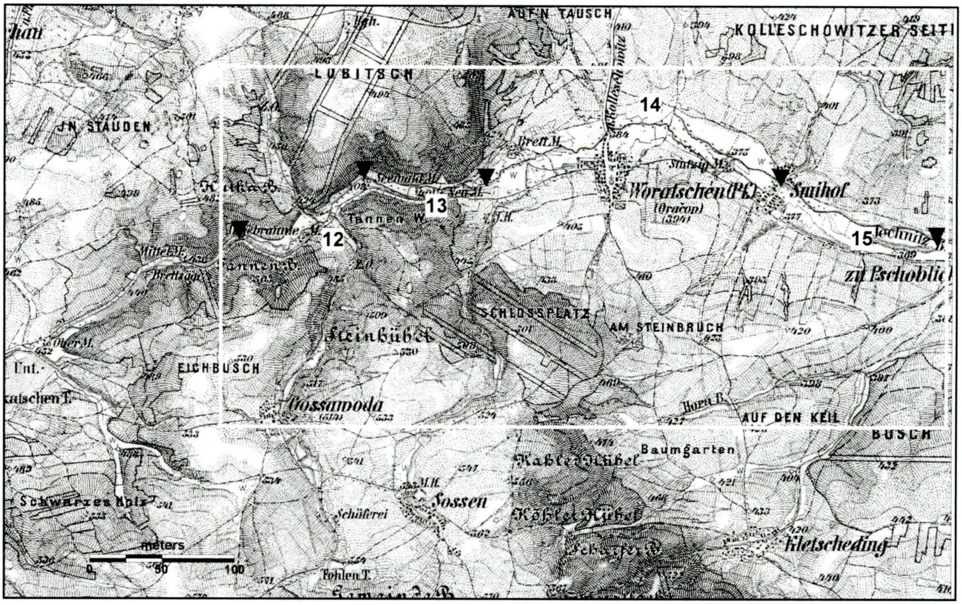

Fig. 1 – Historical map of the Rakovnický Brook. Delimitation of ecomorphological segments for comparing analysis, III. Military mapping from 1879. Source: Map collection, Charles University in Prague.

same time, a sufficient quantity of monitored input data and of other information was available for the given territory.

The Rakovnický Brook is a left affluent of the Berounka River, into which it mouths at the 63.3 river kilometre. The drainage area is 368.14 square km and the length of the main stream is 47.37 km. The mean long-term discharge at the middle part (Rakovník gauging station) is 0.67 $m^3.s^{-1}$, at the brook mouth then 0.86 $m^3.s^{-1}$ (in the evaluated period 1970–2001). The stream passes through two geologically different units. In the north-western part prevail Permian-Carboniferous formations; Proterozoic slates and spilites dominate the south-eastern part. These geological structures condition the geomorphologic features of the relief and determine the basic features of the hydrographical network, which has been in many segments anthropogenically transformed. The stream training works has affected more than one third of the basin. Stream channels in this basin have been further transformed in connection with the flood control measures, with urbanization and sewerage system outfalls, with crossing of streams by communications, etc. The oldest stream training was done in the 14th century when building mills and millraces, then in the 16th and 17th century when building a system of ponds at the upper and middle part of the Rakovnický Brook. These oldest stream-works are now conceived positively, as they are very well integrated into the landscape and give it its specific scenery (Fig. 1).

The total modification of the hydrographical network is 44.6 %, which is above average when compared with the national percentage of modified watercourses (28.4 % according to the *Ministry of Environment ČR, 1995*). The straightening and shortening of streams is largely predominating, as well as deepening and stabilization of water channels mainly by quarry stones. An analysis of runoff conditions proved a dependence of changes in the runoff

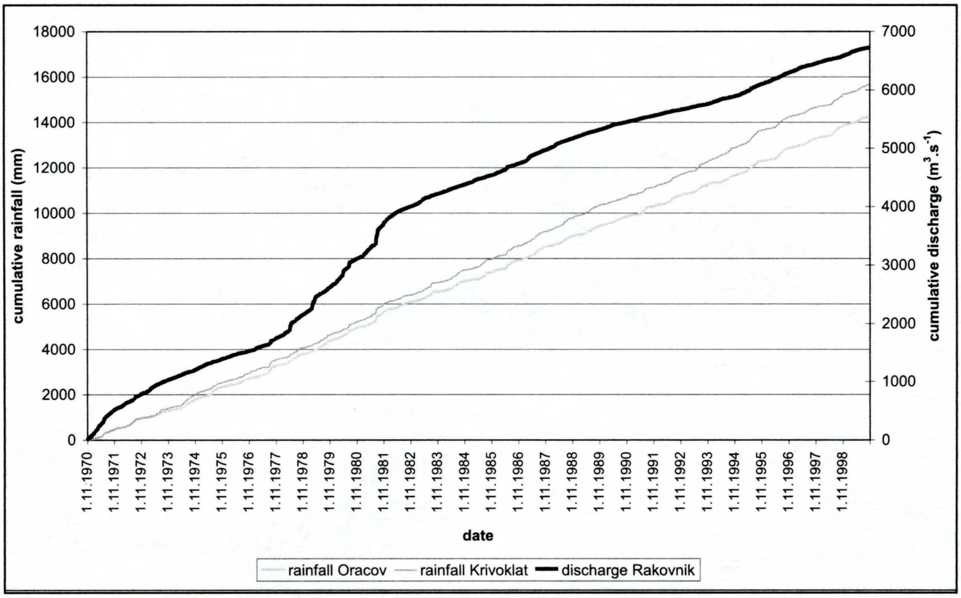

Fig. 2 – Simple mass curves of Qd and daily rainfall in the period 1970–1999. Data: ČHMÚ. The Qd mass curve proves that in the period 1978–81 there was an increased runoff, which corresponds to the period of realization of amelioration measures in the basin. The mass curve of total rainfall manifests a gradual increase in the whole monitored period 1970–1999. In the years 1990–93, there was on the contrary a decrease in the course of the Qd mass curve, which might be due to a poorer maintenance of the amelioration system. All three segments of the Qd mass curve of 1972–77, 1982–89, 1994–99 are parallel.

regime, especially its speeding-up, on the amelioration measures of the land and on training of streams (Fig. 2).

5. Ecomorphological analysis

Ecomorphological monitoring was done in the whole length of the main course that is in 47.37 km. In total, 46 length heterogeneous segments were delimited. Field mapping was done in three basic zones: in the stream channel, in its riparian belts and in its floodplain. The ecomorphological state of the course and of its larger background can be characterized as anthropogenically influenced. A relatively high part (23.4 %) from the total course length represents strongly anthropogenically-influenced segments (IVth ecomorphological degree (ES, Fig. 3). This situation is alarming especially in the source region where reclamation measures have been done. The course length has been shortened; the channel was artificially lined by concrete prefabricated blocks and quarry stones. Riparian belts are insufficiently developed and cannot fulfil their protective function. In addition, fields immediately close to the stream channel are intensively cultivated. Strongly anthropogenically influenced regions include also the stream segment between Oráčov and Pšovky villages at the middle reach as well as the area in the suburb and in the agglomeration of the Rakovnik town.

Only 7.7 % of the total length of the Rakovnický Brook was classified as natural that is by the first ecomorphological degree. It is the area of the upper

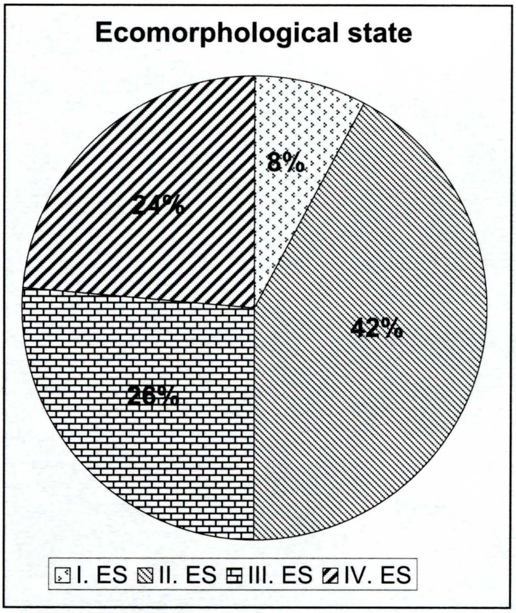

Fig. 3 – Ecomorphological state of the Rakovnický Brook. The graph shows the ecomorphological state of the Rakovnický Brook evaluated on the basis of three monitored zones: the watercourse channel, the riparian belts and the floodplain. I. ES – natural state, II. ES – slightly anthropogenically influenced, III. ES – anthropogenically influenced, IV. ES – strongly anthropogenically influenced.

course between the Krty and Jesenice pound systems and two segments in the lower course in the Křivoklátsko Protected Landscape Area. These territories should be specially protected. Ecohydrologically significant from the protection viewpoint are also the segments classified as the second ecomorphological degree (IInd ES), that is only slightly anthropogenically influenced, which represent 42.4 % of the total course length (Fig. 3). They are situated mainly in the territory of the Křivoklátsko Protected Landscape Area. Especially thanks to this significant part of the IInd ES, the model basin of the Rakovnický Brook can be characterized as intermediate anthropogenically influenced in comparison with other streams in the Czech Republic passing through a landscape with strong agricultural and industrial impacts (Fig. 4). Strongly anthropogenically influenced segments (IVth ES) are situated at the middle course of the Rakovnický Brook in the agglomeration of the Rakovnik town (Fig. 5).

When evaluating the basin zone, regions possibly endangered by negative anthropogenic activities, especially by intensive farming on agricultural lands, were identified on the basis of intersection of individual evaluated factors that is anthropogenic transformation of the hydrographical network, the soils erosion risk, the land cover structure, and the ecological potential of soils resources. The endangered regions are situated at the upper course of the Lišanský Brook, then in the watershed of the Kolešovický Brook, in the source region of the Rakovnický Brook and of its right effluents, the Petrovický, Černý and Jalový Brooks, and then in some partial areas in the Ryšava catchment (Fig. 6). In these regions it would be useful to take anti-erosion measures. Sufficiently large riparian belts should be created along watercourses.

The ecomorphological analysis makes it clear that rehabilitation of streams and of riparian belts should be oriented mainly into the spring area and middle course classified by the IVth ecomorphological degree, where the stream is passing mostly through agricultural landscape. A total renaturalisation of the course should be done there. It means above all to create sufficiently large riparian belts, to back the development of natural fluvial-morphological structures of the channel that would help to increase the bio- and geodiverzity of its habitat. It is also necessary to plant or to restore the bank and the riparian vegetation. Within individual communes

Fig. 4 – Natural part of the Rakovnický Brook in the Protected Landscape Area Křivoklátsko.

Fig. 5 – Strongly anthropogenically influenced segments (IVth ecomorphological degree) at the middle course of the Rakovnický Brook in the agglomeration of the Rakovnik town.

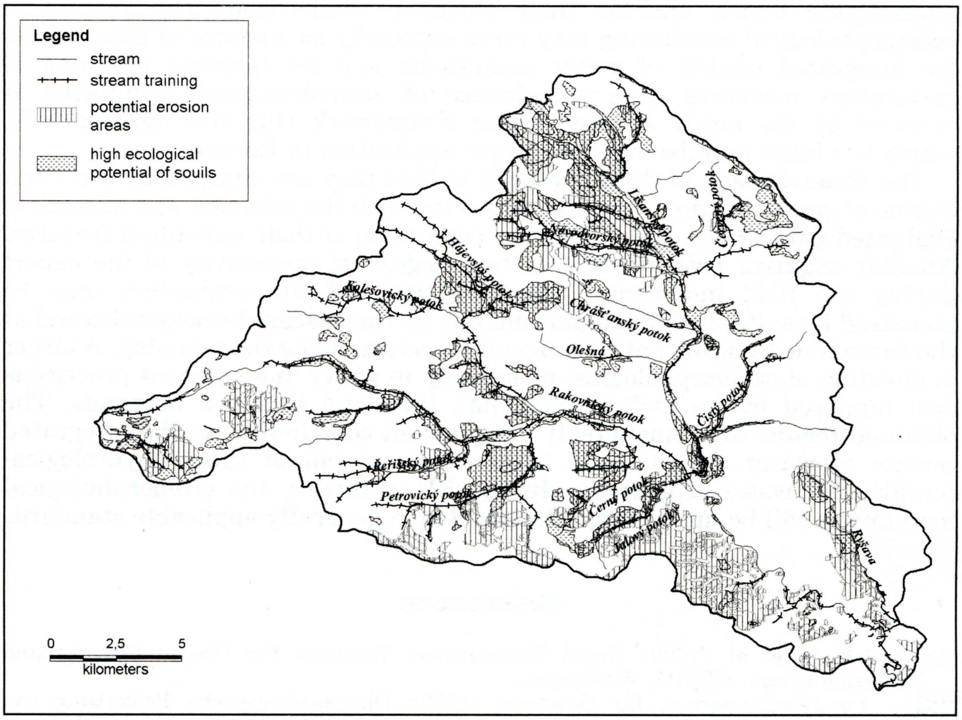

Fig. 6 – Map of the Rakovnický Brook basin. The map shows regions, which are endangered by negative anthropogenic activities, especially by transformation of the hydrological river network and high soils erosion risk.

and in the territory of the town of Rakovník, in the segments classified as the IVth ecomorphological degree, the so-called partial restoration should be done. It means mainly to prevent an excessive pollution of the watercourse, to proceed to biotechnological modifications of the channel and to restore bank or riparian vegetation.

6. Conclusion

Application of the method of ecomorphological monitoring in the model basin of the Rakovnický Brook has confirmed the possibility to identify anthropogenically-influenced segments of watercourses and basin areas fitted for possible restoration measures. This method has brought good results also when used and tested in the Habrový Brook (Garkischová 2002) and the Košínský Brook basins (Bicanová 2002). Stříbrský (2002) compared in his degree work two methods – the BfG Koblenz one (LAWA 1998) and the method of ecomorphological monitoring (Matoušková 2002) on several model segments of Rakovnický Brook. The obtained outputs are similar, which documents the objectivity of the method of ecomorphological monitoring.

An incontestable advantage of the ecohydrological evaluation of water ecosystems is a complex view on streams. It is important to take into account the ecological situation of a larger background of the stream, possibly of the whole basin, as a basic hydrographical unit. The obtained outputs are mostly quantifiable which enables their objective comparison. The results of ecomorphological monitoring may serve especially as a source of information for integrated control of water ecosystems and for targeted planning of restoration measures. The significance of ecohydrological monitoring is stressed by the newly adopted Water Framework Directive (2000/60/EC), which is a basic impulsion for its larger application in Europe.

The disadvantage of these methods is that they are charged by a certain degree of generalization, which is connected with the selection and number of evaluated parameters and with score evaluation of their individual features. Another negative property is a certain degree of subjectivity of the expert during the field monitoring. The objectivity of the evaluation may be increased by suitably defined parameters, by their clear characteristic and at the same time by sufficient training of the person doing the mapping. A larger application of ecomorphological monitoring in water management practice is still hindered by its high professional, time and financial demands. The obtained results are undoubtedly a significant contribution to the integrated control of water streams and to an improvement of the ecohydrological condition of water ecosystems. In the EU countries, the ecomorphological monitoring will be, in its simplified version, a generally applicable standard.

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Shrnutí

EKOHYDROLOGICKÝ MONITORING KVALITY PŘIROZENÉHO PROSTŘEDÍ ŘEK

Ekohydrologický monitoring je novým nástrojem pro hodnocení stavu vodních toků. Získané výstupy poskytují rozhodující informace pro integrovanou ochranu vodních toků a jejich revitalizaci. Ekohydrologický stav vodního toku je určen souborem hydromorfologických charakteristik koryta, odtokovým a splaveninovým režimem, hydrochemickými vlastnostmi vodního média a hydrobiologickými poměry v korytě toku, charakterem břehových a doprovodných vegetačních pásů podél vodních toků, antropogenní transformací údolní nivy. Nepřímo je ovlivněn fyzickogeografickými a socioekonomickými poměry celého povodí.

Převážná většina hodnotících přístupů se věnuje vodním tokům vyšších řádů podle Strahlerovy klasifikace. Nově formulovaná metoda ekomorfologického monitoringu drobných vodních toků je nástrojem pro ekohydrologické hodnocení v intra- a extravilánech. Je založena na kombinaci terénního průzkumu a zpracování distančních dat. Vodní ekosystém je zde chápán jako širší území, které je tvořeno jednotlivými vzájemně propojenými zónami. Prostorovou jednotkou nejvyššího řádu je povodí a dále jsou vymezeny zóny údolní nivy, doprovodných vegetačních pásů a koryta vodního toku. Tato metoda zahrnuje analýzu fluviálně-morfologických charakteristik koryta, antropogenní transformace hydrografické sítě, jakosti povrchové vody, stavu břehové vegetace, využití ploch podél vodních toků a vybraných ekohydrologických charakteristik povodí.

Modelovým povodím pro aplikaci dané metody bylo zvoleno povodí Rakovnického potoka, které splňuje vstupní požadavky týkající se antropogenní transformace hydrografické sítě, velikostního řádu povodí a zároveň dostatečného množství vstupních dat. Ekomorfologický stav Rakovnického potoka a jeho připřežní zóny je možno označit za antropogenně ovlivněný. Relativně vysoký podíl (23,4 %) z celkové délky toku zaujímají silně antropogenně ovlivněné úseky (IV. ekomorfologický stupeň, ES). Tento stav je již znepokojivý v pramenné oblasti, kde došlo k melioračním úpravám hydrografické sítě. K silně antropogenně ovlivněným oblastem náleží i střední tok Rakovnického potoka. Pouhých 7,7 % z celkové délky toku bylo klasifikováno jako přírodní, tj. I. ES. Jedná se o oblast horního toku mezi Krtskou a Jesenickou rybniční soustavou a o úseky v CHKO Křivoklátsko. Tato území by měla být předmětem zvláštní ochrany. V rámci hodnocení zóny povodí byly identifikovány oblasti potenciálně ohrožené vůči negativním antropogenním činnostem, především intenzivnímu obhospodařování zemědělských ploch.

Metoda ekomorfologického monitoringu přinesla rovněž dobré výsledky při její aplikaci v několika dalších modelových povodích při řešení diplomových prací na PřF UK v Praze a ČVUT v Praze (Bicanová 2002, Garkischová 2002, Kovář 2002, Stříbrský 2002).

Výsledky ekomorfologického monitoringu mohou sloužit zejména jako zdroj informací pro integrovanou ochranu vodních ekosystémů a pro cílené plánování revitalizačních opatření v krajině.Význam ekohydrologického monitoringu zdůrazňuje nově přijatá Rámcová směrnice ochrany vod (2000/60/EC), která je základním podnětem pro jeho širší aplikaci v Evropě.

Obr. 1 – Historická mapa Rakovnického potoka. Vymezení ekomorfologických úseků pro porovnávací analýzu, III. Vojenské mapování z roku 1879. Zdroj: Mapová sbírka, Univerzita Karlova v Praze.

Obr. 2 – Jednoduché součtové čáry Qd a denních srážek v období 1970–1999. Data: ČHMÚ. Součtová čára Qd prokazuje, že v období 1978-81 došlo ke zvýšenému nárůstu odtoku, což odpovídá době, kdy byly realizovány hydromeliorační opatření v povodí. Součtové čáry srážkových úhrnů vykazují v celém monitorovaném období

1970–1999 pozvolný nárůst. V letech 1990-93 došlo k naopak poklesu v průběhu součtové čáry, což může souviset s omezením údržby meliorací. Všechny tři segmenty součtové čáry průtoků 1972-77, 1982-89, 1994-99 jsou rovnoběžné.

Obr. 3 – Ekomorfologický stav Rakovnického potoka. Graf znázorňuje celkový ekomorfologický stav Rakovnického potoka vyhodnocený na základě třech monitorovaných zón: koryta vodního toku, doprovodných vegetačních pásů a údolní nivy. I. ES – přírodní stav, II. ES – mírně antropogenně ovlivněný, III. ES – středně antropogenně ovlivněný, IV. ES – silně antropogenně ovlivněný.

Obr. 4 – Přírodní úsek Rakovnického potoka na území Chráněné krajinné oblasti Křivoklátsko.

Obr. 5 – Silně antropogenně ovlivněné úseky (IV. ekomorfologický stupeň na středním toku Rakovnického potoka v intravilánu města Rakovníka.

Obr. 6 – Mapa znázorňuje oblasti potenciálně ohrožené negativní antropogenní činností, především na základě antropogenní transformace hydrografické sítě a erozního ohrožení půd.

*(Author is with Charles University in Prague, Faculty of Science, Department of Physical Geography and Geoecology, Albertov 6, 128 43 Praha 2, Czechia;
e-mail: matouskova@natur.cuni.cz.)*

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BOHUMÍR JANSKÝ, MIROSLAV ŠOBR

GENETIC CLASSFICATION OF LAKES IN THE CZECH REPUBLIC

B. Janský, M. Šobr: *Genetic classification of lakes in the Czech Republic.* – Geografie – Sborník ČGS, 109, 2, pp. 117–128 (2004). – The paper provides genetic classification of lakes in the Czech Republic. We separate lakes to two groups - natural and anthropogenic origin. The genetic classification is based on the classification of lakes according to the way of origination of the lake basin while the geomorphologic viewpoint prevails: glacial lakes, fluvial lakes, karst lakes, lakes dammed-up by landslides, organogenous lakes and anthropogenic lakes. As the anthropogenic lakes we may regard all the water bodies which originated as a consequence of the human activity - mining of mineral resources.
KEY WORDS: glacial lakes – fluvial lakes – karst lakes – lakes dammed-up by landslide – organogenous lakes – anthropogenic lakes.

1. Introduction

In comparison to the world's lakes, the lakes in the Czech Republic are of far smaller size and volume dimensions. They are located prevailingly in the protected natural regions – national parks, protected landscape areas and natural preserves. They deserve attention especially with respect to the maintenance of ecological stability of the protected area, preservation of the characteristic habitats, ecosystems, etc. Therefore, they are extraordinarily valuable and unique natural complexes. The objective of the thesis is to outline the geographical layout of the individual types of lakes in the region of the Czech Republic with the specific focus on the anthropogenic lakes.

The renowned German limnologist of the beginning of 20th century, F. A. Forel, presented the definition of lake that is quoted in the specialised geographical or limnology literature (Forel 1901): "Standing stagnant water mass that is located in a recess in the earth's surface enclosed on its perimeter without a direct connection to sea is generally referred to as lake". Accordingly, in Forel's opinion, each standing water accumulation without a direct connection to sea irrespective of its size is lake. It implies then that also puddles as well as ponds and marshes belong to lakes. Therefore, Forel (1901) distinguishes "the lakes in more specific sense", ponds and marshes.

Lakes in more specific sense are deep in that extent that the surface ripple does not affect its bed and due to their depth shore vegetation does not reach the bed (with the exception of shallow-water areas). Lakes are then the water accumulations with the deepest areas not grown with any vegetation. This definition may be applied for the conditions of the Czech Republic especially as regards the lakes of organogenous type.

On the basis of the analysis of information of the sources of the specialised literature and with a view to the specific conditions of the Czech Republic, we have laid down our own definition of lake: Lake is a natural depression in or under the earth's surface, permanently or temporarily filled with water without a direct connection to sea. In contrast to ponds and minor water basins, lakes cannot be easily drained off. As opposed to shallow standing waters such as minor waters (poodles and pools), ponds, and organogenous and fluvial lakes, as far as deep lakes are concerned, the surface ripple does not affect their bed and the shore vegetation does not reach to the beds due to their depth. The deepest areas are not therefore grown with the water vegetation.

2. Present stage of geographical reseach of lakes

A number of geographers seated in Prague dealt with the research of lakes in our country as well as abroad. This tradition was established by the professor Václav Švambera, who performed the systematic mapping of the glacial lakes in Šumava Mts. In the thirties, the lakes in Šumava and karst areas in Slovakia were dealt with by Karel Kuchař and Josef Kunský. In the post-war period, Václav Král, Eduard Kříž and other authors dealt with research of the lakes in the High Tatras. In the years 1972-75, Bohumír Janský performed the first geomorphologic and limnology research of Mladotické Lake dammed-up by landslide.

After ninety years which have passed since the last researches of the lakes in Šumava made by Švambera, we have decided to resume them. By means of modern equipment the limnology studies of three glacial lakes Prášilské, Plešné and Laka have been drawn up within the Master's thesis by A. Zbořil (1996), T. Vránek (1999), and M. Šobr (1999).

Due to the support of the Grant Agency of Charles University, the project "Lakes in the Czech Republic" has been completed which has been intended to create an extensive study on our lakes including their genetic classification. In the years 1999 to 2002, we have worked out the analysis of number of lakes of natural origin including the water accumulations originated due to the human activity in the whole region of the Czech Republic. The work has not included the dam reservoirs and ponds. The inventory of the lakes has shown that there are almost 700 water accumulations the majority of which are of fluvial, organogenous and especially origin. Within the stage of the research, we have especially dealt in detail with fluvial lakes on the middle course of Labe in the Czech territory between Pardubice and Mělník and three deserted Labe arms have been the subject of the limnology studies (Šnajdr 2002, Klouček 2002, Chalupová 2003). All the mentioned works have been focused on the analysis of the hydrologic regime, water quality, the sediments as well as the biological revitalisation of water bodies. Apart from the fluvial lakes, we have commenced also the research of the organogenous lakes. The first study on the subject has been the work on Mechová jezírka in Jeseníky Mts. which has been completed in the thesis by Oulehle (2002). Besides the general monography conception, he especially focused on the geochemical development of the upland bogs.

The previous works have been followed by the latest extensive project supported by the Grant Agency of the Czech Republic "Atlas of Lakes in the Czech Republic". The final result should be the Atlas of Lakes in the Czech Republic which is supposed to be published in the year 2005.

Fig. 1 – The Černé Lake – glacial lake situated in the central part of the Šumava Mts. (foto M. Šobr)

3. Glacial lakes

There are six glacial lakes in the Czech Republic, situated in the central part of Šumava (Černé – Fig. 1, Čertovo, Plešné, Prášilské and Laka Lakes) and Krkonoše Mts. (Mechové Lake). The lakes in Šumava Mts. are the vestiges of the regress of glaciers of Würm age which at that time surrounded the hill-tops and hill-slopes of some of the highest peaks of the mountain range. From the research of Šumava glacial lakes it implies that all of them have the same modelling – consisting of the lake wall, lake basin, and lake brook, and are enclosed by dumped moraines of various widths which in several bends close the lake areas. The lowest moraine is regularly several hundred metres distant from the central part of the lake basin. The central moraine belt of all the lakes lies between 1000–1100 m above sea-level and the lake surface is located in the high altitudes (900–1000 m above sea-level) under the highest peaks of the mountain range (1300–1456 m above sea-level). The orientation of the cirques which are not fixed to a structure of rocks is between north and south-east. It follows that the lakes are partially hollowed by glacier (cirque lakes) and partially dammed-up by the dumped moraine. With the exception of the lake Laka, all the others are very deep (Kunský 1933). Besides the undisputed landscape and aesthetic significance, they provide for the important refuge areas for the endangered types of water flora. There is one small glacial lake in Krkonoše Mts. – Mechové Lake, situated in morain near Dolní Mísečky.

4. Fluvial lakes

The lakes of fluvial origin occur in the floodplains of a lot of rivers in the world. Their existence gives evidence of the past development of the river beds especially in the middle and lower courses. After the flow-out from the headwater mountain regions where the river courses usually deepens their beds and carries off vast amount of alluviums, they become slower in the submountain regions, they deposit the carried-off materials and frequently relay their beds or spreads out to various river arms. In the further course in the flatlands and lowlands, they often create the meanders which may be detached (oxbowed) from the current river bed in the final stage (Fig. 2). The fluvial lakes originate in this way. These may also be formed at the one-time change of the course bed, e.g. in case of the floods or by a mere overflowing of the water course in case of the high water levels occurrence and their accumulations in the depression positions (periodical pools on the flooded meadows in the natural preserve Týnecké mokřiny). The special case occurs at the origination of a through-flow lake directly in the river bed, e.g. behind the undulation, at sudden change of the structure of geological bottom or in the places of radical change of the bed slope (natural preserve Skryjská jezírka). In several cases, the river meander has been detached artificially at the straightening of the course riverbed.

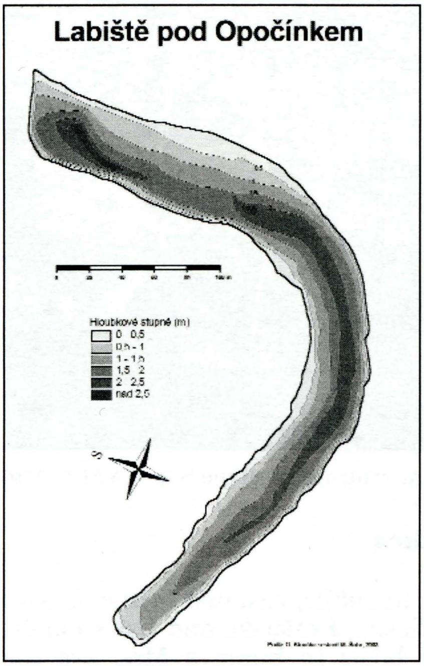

Fig. 2 – The Lake Labiště pod Opočínkem is typical fluvial lake, bathymetric map show layout depths in former river (in meters)

The fluvial lakes are the most frequent type of natural lakes in the Czech Republic and they are located especially along the courses of Labe (between Hradec Králové and Mělník – Fig. 3), Morava (between Zábřeh and Litovel and between Otrokovice and the junction with Dyje), Dyje (from Nové Mlýny to the junction with Morava), Lužnice (from Nová Ves to Nová řeka), Orlice (from Týniště to Hradec Králové) and Odra (from Košatka to Ostrava-Petřkovice). The riparian lakes often occur in the regions of special nature protection including the natural monuments as well as the national nature reserves. The most renowned are the National Nature Reserves Libický luh, Polanská niva, Křivé jezero, Ramena řeky Moravy, Vrapač, and others.

5. Karst lakes

The karst lakes originate by means of the accumulation of rainfall water or underground water in the recesses or depression positions of the karst minerals which include predominantly limestone and dolomite. Their origin

Fig. 3 – Fluvial lake Labiště pod Opočínkem (foto M. Šobr)

may be predetermined by the tectonic disturbances along which the underground water is rising and it is frequently directly fixed to the processes of karstic phenomena such as e.g. the formation of sinter terraces or travertine dams, the dissolution of carbonate rock by the aggressive rainfall or mineral waters, and others. The karst lakes may also be formed in the places where the cave profile constriction occurs or in front of the cave traps.

The karst lakes in the Czech Republic occur especially in the deepest abysses, cave areas and in exceptional cases in the beds of the water course under the spring of the karst waters. All the lakes are characterised by the specific thermic regime with a small amplitude of water temperature in the whole course and the considerable content of dissolved carbonates. With respect to the fact that the majority of them are located in the cave areas or deep terrain depressions, they serve rather for the aesthetic variation of caves and abysses than for the protection of the endangered species of animals.

The lake in Hranice Abyss has small surface size and its surface is situated 69.5 m under the edge of the rock wall. However, it is unique by its depth which amounts to 205 m according to the last measurements, due to which Hranice Abyss is the deepest abyss in the Central Europe. Unconfirmed measurement taken in the year 1960 has determined its depth even at 260 m. On the bottom of Macocha Abyss, there are two lakes of small sizes in the depth of 138.5 m. The upper lake is 11 m deep, the lower reaches the depth of up to 30 m.

6. Lakes dammed-up by landslides

The youngest natural lake in the Czech region is Mladotické (Odlezelské) jezero (Fig. 4) which is situated on the north of Plzeň, in the basin of the river

Fig. 4 – The Mladotické (Odlezelské) Lake, view from tributary part to dam – landslide (foto M. Šobr)

Střela. It originated by damming the valley of Mladotický potok by the landslide of overlaying feldspathic sandstone (arcoses) and pudding-stones on the western bottom of Potvorovský vrch. The landslide came about after the intensive rainfalls and subsequent catastrophic floods during the night from 27th to 28th May 1872. The brook valley was dammed in the length of ca 300 m. Since its origination, the intensive sedimentation of the lake proceeds. The maximum measured depth in the year 1972 was 7.7 m, the maximum depth at the last measurements taken in the year 1999 dropped to 6.7 m. Also the lake surface has diminished from 5.93 ha to 4.55 ha. Two small lakes dammed-up by landslide are probably located also in Moravia, in Vsetínské vrchy.

7. Organogenous lakes

The lakes of organogenous origin originate by the retention of the rainfall or underground water in the shallow depressions under the participation of peat bogs or moor lands formation. Therefore, we draw a distinction between the bog lakes and moor lakes which have specific origin, composition as well as water quality. The bog lakes originate most frequently inside the upland bogs where the soft rainfall water accumulates and is afterwards coloured by the products of peat bogs forming. The characteristic feature is the lack of the mineral substances and low pH which is most frequently within the range of 3–5 and thus disallows for the occurrence of a lot of species of animals. Minor trophy is also caused by rather limited utilisation of organic substances which occur to a great extent in the form of humus colloids which make the water rusty red or even red-brown colouring.

Fig. 5 – The Blatenská slať, example of organogenous lakes in the Šumava Mts. (foto T. Hrdinka)

The bog lakes are generally of small dimensions and they occur almost in all our border mountain ranges. The most of them are located in the resting area of Modravská slať in the central part of Šumava (Rokytecká slať, Roklanská slať, Blatenská slať – Fig. 5, Mlynářské slatě, Novohuťské močály, and others) and they number approximately two hundred. Also the largest organogenous lake is located in Šumava which is of valley bog type and which has been formed in Chalupská slať near Borové Lady (area of 1.3 ha).

Other distinguished areas of the occurrence of the bog lakes are Jizerské Mountains (Na Čihadle, Klečové louky, Černá jezírka, Rybí loučky, and others), Krušné Mountains (Velké and Malé Jeřábí jezero, Velký močál, Novodomské rašeliniště), Bohemian Forest (Lakes near Rozvadov), Krkonoše (Úpské rašeliniště, Pančavská louka), Orlické Mountains (Jelení lázeň, Pod Pětirozcestím), Jeseníky Mountains (Mechová jezírka near Rejvíz) and Slavkovský Forest (Sirňák, Smraďoch, Kladské rašeliniště). All the lakes are located in the protected nature areas, frequently in the category of national natural reserves (Velké Jeřábí jezero, Mechová jezírka near Rejvíz, Novodomské rašeliniště). At Červené blato near Suchdol nad Lužnicí and Borkovické Blato near the village of Zálší, the artificial organogenous lakes originated in connection with the peat diggings for the economic purposes.

By contrast, the moor lakes occur in the lower altitudes on the springs of the underground water or in the areas of occurrence of the deserted river arms in the advanced stage of land-filling. Water of the moor lakes is richer in mineral substances as well as in organic nutriments, and eutrophisation (organic enrichment) develops more often. The typical examples are minor, slowly disappearing detached meanders in the vicinity of Labe and Dyje and the lakes at the springs of mineral waters in the National Nature Reserve in

Soos near Františkovy Lázně. The special examples are the bog or moor pools on some brooks which probably developed out of the original ponds (Na Kačíně and the Rašelinné jezírko Rozsíčka). In those cases, it is rather difficult to determine whether it is an organogenous, anthropogenic (pond) or fluvial lake.

8. Anthropogenic Lakes

As the anthropogenic lakes we may regard all the water bodies which originated as a consequence of the human activity. These are the water works constructed for the purpose of specific utilisation or the lakes originated as a result of mining activities. These lakes are mostly wrongly omitted, and with respect to the high quality of some of mine waters and quarry waters, they could be effectively utilised in future, e.g. for the water-resources and recreation purposes. Also their environmental significance is not negligible, since they for the most part affect its surroundings positively and often form the areas of the concentration of natural values. Considering the high variability of the anthropogenic lakes, the further classification of them is necessary.

One large group is formed by ponds, the other one by the dam lakes and the last by the water bodies originated in connection with the mining activity. The former two groups have already been extensively dealt with in the specialised literature, therefore, we will focus on the lakes originated as a result of the mining of mineral resources which are one of the most numerous types of lakes in the Czech Republic.

Lakes originated in connection with the mineral resources mining are together with the fluvial lakes and ponds the most numerous types of water bodies in the Czech Republic. The lakes occur in the open pits and quarries of all kinds, at the associated waste dumps or in the subsidence basin-shaped valleys. The water bodies of various sizes originated either spontaneously or as a result of the specific, so called hydrologic reclamation. Their occurrence is naturally fixed to the presence and mining of the specific mineral resources which by their character affect, apart from the size and depth, also the parameters of the accumulated water of the surface as well as the underground origin. The parameters thus most often affected are colour and transparency of water, content of the specific minerals, pH and the resulting biological activity arising out of them. The important factor is also time which passed since the mining termination (even several hundreds of years) and the associated eutrophisation of accumulated water that is for the most part very slow and gradual and often is missing utterly. With respect to the above-mentioned, it is necessary to classify these lakes according to the type of mined mineral resources as follows: the lakes originated on the mining of sand and sand-gravel; kaolin; lignite and black coal; limestone, bluestone and greywacke; granite, diorite and whinstone; brick clay and loam and other mineral resources.

The lakes in the open sand and sand-gravel quarries belong to the most frequent type of the anthropogenic lakes in the Czech Republic. These are for the most part localised along the big as well as minor rivers in the area of Quaternary sand-gravel alluvial deposits. The lakes originated due to the mining of sand and sand-gravel are especially located along the watercourses of the river Labe (from Jaroměř to Lovosice), Morava (from Mohelnice to Hodonín), Lužnice (from Nová Ves to Veselí) and Odra (north of Ostrava). Sporadically, they occur in the basin of Jizera, Cidlina and Opava, and in other places of the Czech Republic.

The lakes originated after the mining of kaolin occur both in the traditional areas of mining and occasionally within the whole region of the Czech Republic. The highest concentration of the lakes the areas north of Cheb, west of Karlovy Vary and northern as well as southern surroundings of Horní Bříza. Sporadically, they occur in the minor quarries in the vicinity of Znojmo, Veverská Bitýška, Jedovnice in Moravský kras, Vidnava and Podbořany near Žatec. The lakes are mostly of smaller sizes than the water bodies in the coal mines and sand mines and they are not so deep.

The lakes originated after the mining of lignite and black coal, together with ponds and the lakes created due to the mining of sand-gravel, the most numerous type of the anthropogenic lakes in the Czech Republic. Their occurrence is especially fixed to the mining of lignite coal whose largest deposits are located in the lignite coal basin in the northern Bohemia. The largest number of the lakes is then localised in Sokolovská and Mostecká pánev and in the vicinity of the towns Teplice and Ústí nad Labem.

The next group of lakes may be found in the quarries in which the compact sediments of sea origin are mined, namely especially the limestone, bluestone and greywacke. Those minerals differ in their colour and the basic physical and chemical parameters, however, the quarry waters are equal as regards some of the parameters. The lakes are similar by their size, which is often of considerable dimensions, the depth, which may reach up to several tens of metres, and the colour and transparency of lake waters. The most well-known lakes fixed to the limestone mining are found in the quarries Velká and Malá Amerika near Mořina in the region of Karlštejn, and the similar lakes of smaller dimensions may be found in other places in Český kras. Another lakes occur only sporadically in the lenticles of crystalline limestones near Rabí and Hejnice and in the Neozoic limestones north of Valašské Meziříčí. The lakes in the bluestone mines are concentrated especially east of Bruntál, the singleton occurrence is also in the vicinity of Vrbno pod Pradědem and in Český kras. Another lakes are fixed to greywacke which occur only in Morava especially in the fringe areas of Oderské vrchy and Nízký Jeseník, sporadically, in Moravský kras or in the vicinity of Litovel. The water body in the compact sediments is also the lake in the quarry Rasová in claystone and sandstone near Komňa as well as the lake in the pudding stones of Cetraceous Period in the Natural Park Skalka near Žehušice.

The lakes originated in connection with the mining of granite are evenly spread in the region of the whole Středočeská pahorkatina and Českomoravská vrchovina on the places where the granite plutonic rock ascends towards the earth's surface. The highest concentration of the lakes may be found in the fringe area of Železné hory north of Hlinsko (quarry Srní, Fig. 6) in the vicinity of Skuteč, the other large concentration is the locality around Žulová in Žulovská pahorkatina in northern Moravia. The lakes fixed to diorite or granodiorite are located especially in Benešovská pahorkatina (Hříměždice and Kozárovice) and then only sporadically near Polička and Jablonné nad Orlicí. The lakes originated after the mining of whinstone sporadically occur in northern Bohemia at the well-known locality of Panská skála near Kamenický Šenov in the fringe area of České Středohoří and near Heřmanice in Frýdlantská pahorkatina. The solitary lake in whinstone may also be found in the quarry Hlavno near Sokolov. This group also includes the lake in the former teschenite (dark coarse-grained effusive rock) quarry near Žermanice in the vicinity of Havířov.

There are quite unique lakes in the Czech Republic. The lakes of this group originate after the mining of the mineral resources which affect the chemical composition of the lake water rather significantly. For example: Kamencové

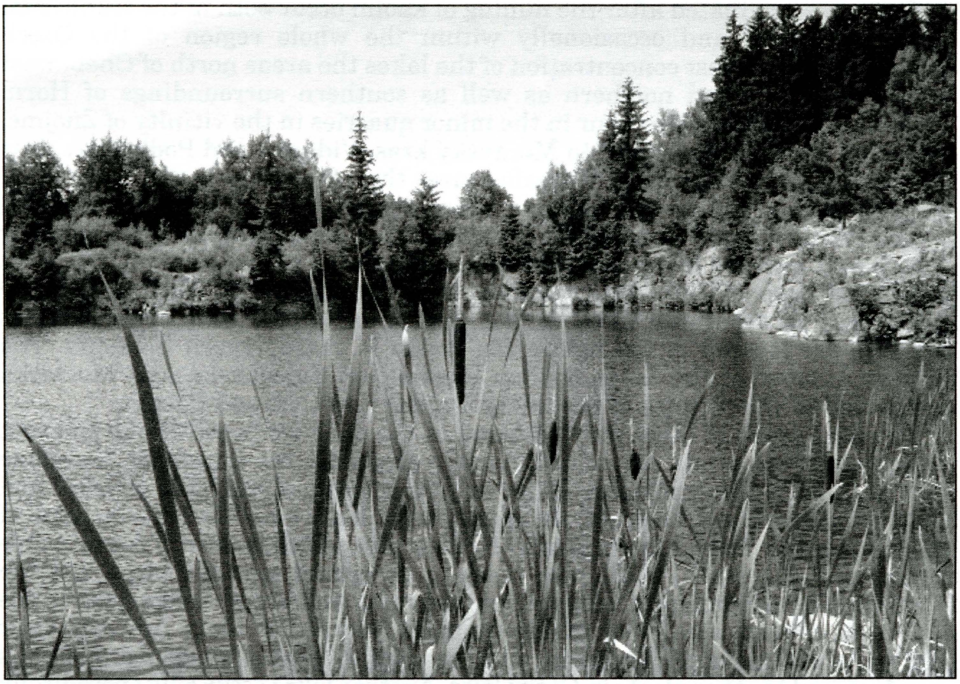

Fig. 6 – The Quarry Srní – lake originated in connection with the mining of granite (foto J. Česák)

jezírko (Alum lake) near town Chomutov, Červené jezírko (Red lake) near village Hromnice, Stříbrné jezírko (Silver lake) near Fulnek ect.

9. Conclusion

Besides the lakes of natural origin, in the Czech Republic there are also a lot of standing water accumulation originated in the locations after the completion of the mining of mineral resources. With respect to small number of natural lakes, those are of concern in our country and it is necessary to give attention to them within the scientific research. Information acquired within such research may be instrumental in the considerations of their future reasonable utilisation within the scope of the environmental protection and landscape preservation, water resources management purposes, and the recreation facilities. The water accumulations originated due to the mining activities are referred to as anthropogenic lakes. We use the term "lakes" in spite of the fact that they did not originate by means of natural processes.

The genetic classification is based on the classification of lakes according to the way of origination of the lake basin while the geomorphologic viewpoint prevails: glacial lakes, fluvial lakes, karst lakes, lakes dammed-up by landslides, organogenous lakes and anthropogenic lakes. As the anthropogenic lakes we may regard all the water bodies which originated as a consequence of the human activity – mining of mineral resources (sand, sand-gravel, kaolin, coal, limestone, bluestone, greywacke, granite, diorite, whinstone, brick clay, loam and other mineral resources).

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Shrnutí

GENETICKÁ KLASIFIKACE JEZER ČESKÉ REPUBLIKY

„Jako jezero je označována stojatá stagnující vodní hmota, která se nachází v prohlubni zemského povrchu, na všech stranách uzavřené a nemající spojení s mořem.“ Takto široce definuje jezero významný německý limnolog F. A. Forel (1901). Podle této definice lze za jezero považovat každou vodní plochu (louže, rybníky, močály), která nemá spojení s mořem bez ohledu na její velikost. Po rozboru další limnologické literatury (Hutchinson 1957, Wetzel 2001, Kalf 2002) jsme s přihlédnutím na specifické podmínky Česka formulovali vlast-

ní definici jezera: „Jezero je přírodní či antropogenní deprese na zemském povrchu nebo pod ním, trvale nebo dočasně vyplněná vodou. Oproti rybníkům a vodním nádržím se jezera nedají jednoduchým způsobem vypustit.“

Vedle jezer přírodního původu se v Česku vykytují rovněž četné stojaté vodní akumulace v prostorách po těžbě nerostných surovin. Vzhledem k malému počtu přírodních jezer mají pro naši zemi význam a je třeba jim věnovat pozornost v rámci badatelského výzkumu. Jeho poznatky mohou napomoci úvahám o jejich racionálním budoucím využití, ať už v rámci záměrů ochrany přírody a krajiny, k vodohospodářským účelům či rekreačnímu využití. Vodní akumulace vzniklé těžební činností člověka označujeme jako jezera antropogenní. Název "jezera" přitom užíváme i přes to, že nevznikla přírodními procesy. Mnohá z nich však přírodní jezera vlastnostmi svých vod připomínají. Zvláště ta antropogenní jezera, která vznikla po dávné těžební činnosti, vytvářejí často cenné přírodní ekosystémy, jež je třeba zachovat pro budoucí generace.

Jezera ledovcového původu nalezneme na Šumavě. Jedná se o pět jezer (Černé, Čertovo, Plešné, Prášilské a Laka), která leží v karech hrazených morénami Würmských ledovců. Kromě jezera Laka, jehož hráz byla uměle zvýšena, se vyznačují velkou hloubkou. V Krkonoších nalezneme malé ledovcové jezírko ležící v moréně pod Kotelními jamami, které se nazývá Mechové.

Fluviální jezera se nacházejí na dolním a středním toku našich řek. Jsou svědectvím dřívějšího vývoje říční sítě. Mnoho těchto „mrtvých ramen“ bylo odděleno uměle při rekultivacích vodních toků. Vyskytují se zejména podél toků Labe, Moravy, Dyje, Lužnice, Orlice a Odry.

Krasová jezera vznikají akumulací srážkové či podzemní vody v dutinách či depresích krasových hornin, jsou tedy vázána na vápencové případně dolomitové oblasti. Drobná krasová jezírka se vyskytují prakticky v každé české krasové oblasti. Většími krasovými vodními plochami jsou jezera na dnech propastí (Macocha, Hranická propast).

Nejmladším českým jezerem je Mladotické (Odlezelské) jezero, vzniklé zahrazením údolí Mladotického potoka v roce 1872. Menší sesuvem hrazená jezera se nacházejí také ve Vsetínských vrších.

Jezera organogenního původu vznikají nadržením srážkové či podzemní vody v mělkých depresích za spoluúčasti procesů rašelinní či tvorby slatin. Rašelinná jezera jsou obecně malých rozměrů a vyskytují se téměř ve všech našich pohraničních pohořích. Nejvíce se jich nachází v chráněném území Modravské slatě v centrální části Šumavy.

Antropogenní jezera lze rozdělit na tři základní skupiny. Rybníky, vodní nádrže a vodní plochy vzniklé v souvislosti s těžební činností člověka. Jak plyne z naší upravené definice pro česká jezera, zajímají nás antropogenní jezera vzniklá po těžbě nerostných surovin. Dělíme je podle druhu nerostné suroviny, po jejíž těžbě jsou pozůstatkem. Jsou to: 1. Písek a štěrkopísek, 2. kaolin, 3. hnědé a černé uhlí, 4. vápenec, břidlice a droby, 5. žula, diorit a čedič, 6. cihlářská hlína, jíl a 7. jiné nerostné suroviny.

Obr. 1 – Černé jezero – ledovcové jezero ležící v centrální části Šumavy (foto M. Šobr)
Obr. 2 – Jezero Labiště pod Opočínkem je typické fluviální jezero, bathymetrická mapa ukazuje rozložení hloubek v bývalé řece (v metrech)
Obr. 3 – Fluviální jezero Labiště pod Opočínkem (foto M. Šobr)
Obr. 4 – Mladotické (Odlezelské) jezero, pohled z oblasti přítoku ke hrázi – sesuvu (foto M. Šobr)
Obr. 5 – Blatenská slať, příklad organogenních jezer na Šumavě (foto T. Hrdinka)
Obr. 6 – Lom Srní – jezero vzniklé jako pozůstatek po těžbě žuly (foto J. Česák)

*(Authors are with Charles University in Prague, Faculty of Science, Department of Physical Geography and Geoecology, Albertov 6, 128 43 Praha 2, Czechia;
e-mail: sobr@natur.cuni.cz, jansky@natur.cuni.cz.)*

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ARVO JÄRVET

INFLUENCE OF HYDROLOGICAL CONDITIONS ON THE ECOLOGICAL STATE OF SHALLOW LAKE VŐRTSJÄRV

A. Järvet: *Influence of hydrological Conditions on the Ecological State of Shallow Lake Vőrtsjärv.* – Geografie – Sborník ČGS, 109, 2, pp. 129–144 (2004). – Lake Vőrtsjärv as a very shallow (mean depth 2.8 m) water-body and considerable water level fluctuations cause changes in both the surface area and volume of the lake. Due to the shallowness of the lake, low level periods are accompanied by several phenomena detrimental to its ecosystem, like cyanophyte blooms, overgrowing with macrophytes, resuspension of phosphorous compounds, restricted spawning places for pike and winter fish kills. In the years of low water level the perspectives to catch in established fishing sites using particular gear as well as access to harbours are hindered. Causal relations between the water regime and ecological state of the lake Vőrtsjärv have been discussed in this paper.
KEY WORDS: shallow lake – water regime – ice cover – ecological state – water management.

1. Introduction

L. Vőrtsjärv (Fig. 1) as a very shallow (mean depth 2.8 m) lake and considerable water level fluctuations cause changes in both the surface area and volume of the lake. During the highest (35.28 m) level, its surface area was estimated at 326 km^2, and the volume at 1.213 km^3. At the lowest water-stand (32.20 m), these values were 237 km2 and 0.383 km^3, respectively. Thus, the surface area of the lake may vary by the value of 89 km^2 and the volume by 830 km^3. The shallowness together with the large amplitude of water level fluctuations (annual mean 1.38 m, annual maximum 2.20 m, absolute range 2.92 m) cause fish kills in severe winter, intensive resuspension of sediments, intensive growth of macrophytes and cyanophyte blooms during low-level periods. In 1965 macrophytes covered only 15 % of the lake's area, since then their area has expanded remarkably (Haberman et al 1998). Due to the prevalence of westerly winds, the reed belt (mainly *Phragmites australis* and *Schoenoplectus lacustris*) is continuous and lush at the sheltered western shore and broken at the open eastern shore. The narrow southern tip of L. Vőrtsjärv is fully covered with macrophytes (*Nuphar lutea* and *Potamogeton lucens* are prevailing).

Hydrological observation data of shallow lakes are valuable indicators of long-term variation not only of water regime, also ecological conditions. Over the years the lake varied considerably with respect to depth and volume and as result to surface area. During the last ten-twenty years, the influence of hydrological factors on the ecological state on L. Vőrtsjärv has come into focus. A second reason for the increasing interest is that lake restoration (lake management) by connected measures of hydrological regulation and biological manipulation seems more effective than separated activity.

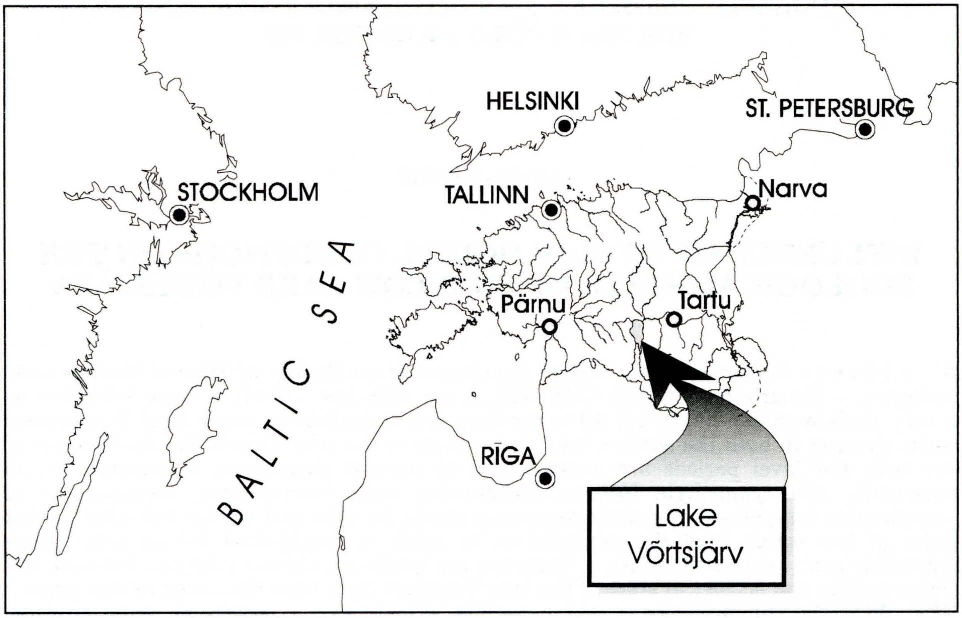

Fig. 1 – Location map of Lake Võrtsjärv

Changes of climatological conditions, which are reflected by cyclic fluctuation in the water regime and ice conditions over the long period, influence obviously to hydrophysical, and also hydrochemical and hydrobiological processes in the lake. The state variables of water quality are connected with hydrometeorological factors directly or indirectly. For example, an increase of the average depth of the lake results in a decrease of bottom irradiance and in the reduction of water column irradiance (Reinart 1999). The temporal variation of both quantity and type of ice influence the amount and type of light entering a lake, which in turn effects such processes as photosynthesis and oxygen production in the water masses under ice cover.

The main objectives of this study were:

1. Due to flat shores and small depth, fluctuations in the water level of L. Võrtsjärv are expressed with the changes large differences in morphometry and ecological conditions of lake.
2. According to shallowness, the ice cover has an important role in the formation of lake ecological conditions in a winter period. By hydrological characteristics it is possible to explain the winter condition of L. Võrtsjärv by active volume, and corresponding mean depth.
3. The annual cycle of weather conditions of water environment can be divided into seasons, which are described by qualitatively different climatological characteristics. The criteria for climatic seasons of lakes based on seasonal variability of water temperature and ice phenomena characteristics.
4. The ecological state of a Lake Võrtsjärv can be improved with the regulation of water level, because the strong dependence of ecological state on the water level is characteristic for relatively dry years and seasons.

It can be reported that water level has a very clear effect on the oxygen concentration during low water and long ice cover period. The increasing height of the water level was the single independent environmental factor demonstrating a clear fluctuations behaviour. Other environmental factors being rather constant, this smooth continuous trend offered a unique possibility to follow changes in the ecosystem (Nõges et al 1998). The characteristic features of the annual hydrological cycle of L. Võrtsjärv are a low water level in winter and a high water level in spring, which decreases gradually during summer and early autumn and is followed by a smaller peak in late autumn. The daily variation of the water level is within the range of centimetres, the monthly variation within the range of decimetres, but the annual amplitude exceeds 2 m.

The seasonal behaviour of nutrient compounds and their ratio (NO_3/N_{tot}, PO_4/P_{tot}) is different under changed hydrological conditions, because shallow lakes are more efficient in converting the available phosphorous and nitrogen into phytoplankton biomass (Nixdorf, Deneke 1997). For example, the proportion of mineral nitrogen in L. Võrtsjärv had its maximum (40–75 % of N_{tot}) in January and decreased gradually to about zero in the end of summer (Nõges et al 1997). The high winter water level of PO_4/P_{tot} dropped sharply in May, shortly after the ice break.

Optical properties of water as well as the mixing depth and resuspension rate of sediments, all determined by the water level, come to the forefront in the case of shallow and turbid L. Võrtsjärv where light limitation plays a major role in controlling phytoplankton growth (Nõges 1995). The influence of changes in the water level on different trophic levels is either direct or mediated by cascading effects in the food chain.

2. Long-term fluctuations of water level

The water level in the lake is fluctuating continuously in response to external factors. Variations in the level may be either relatively rapid, as in the case of seasonal variation, or long-term with a duration of several years. These differences vary in time, due to different precipitation, evaporation, in- and outflow patterns. Changes in the water level can be observed most clearly and most rapidly in shallow lakes whose catchment area exceeds the lakes surface at least 5–10 times. For L. Võrtsjärv with the catchment area of 3 104 km^2 this index is 11.5 at mean water level.

The harmful effect on the hydrological factors on the ecological and shoreline zone management becomes apparent under the following hydrological conditions:

- flood – monthly mean water level above 34.50 m;
- small depth of the lake – monthly mean water level below 33.00 m.

Both extremely high (over 35.00 m) and extremely low water level (below 32.50 m) have detrimental effects. In summer, during shallow water periods, small depth and lake volume and intensive primary production are a problem, and during floods the land use in the shoreline area and the traffic on small roads become complicated.

The aim of the analysis of long-term water regime was to detect statistically significant changes since 1871. The periodicity in long-term series of climate indicators of lakes is a very interesting and important issue for forecasting and economic purposes. Cyclic changes observed in nature have their sources in the global and regional variability of atmospheric circulation. Fluctuations in the water level in L. Võrtsjärv over the years are

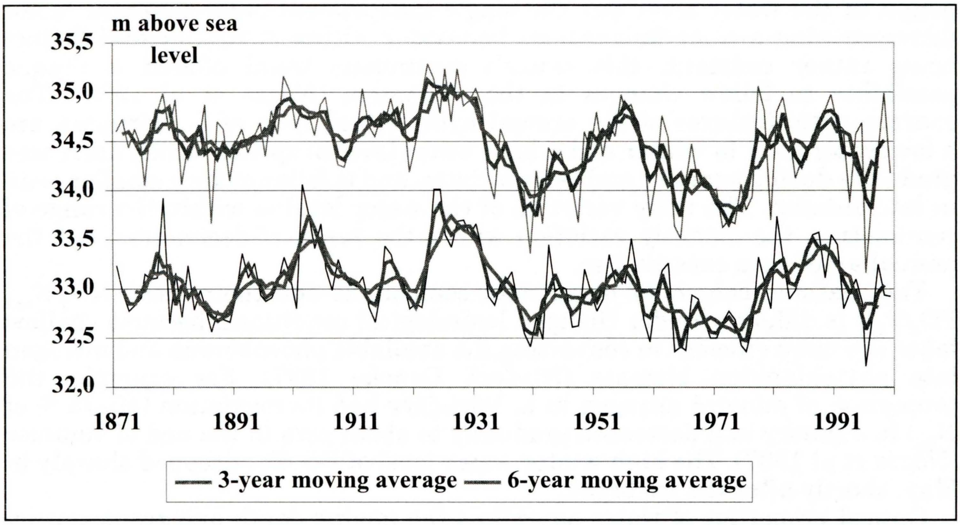

Fig. 2 – Long-period changes in annual maximum and minimum water level of Lake Võrtsjärv

considerable and seemingly quite random. Long-term water level measurements in L. Võrtsjärv show a sinusoidal alternation of low and high water states. Long-term changes in water regime can be seen most clearly in the dynamics of the minimum water level of a year (Fig. 2).

In order to demonstrate periodicities or cycles, spectral analysis is used. Using this method makes long-term periodicities visible and several periods can be identified. Figure 3 presents the results of the spectral analysis. Several peaks appear in the spectra. Altogether three groups of periodicity were detected:

1. short periods with a spectral peak at 3.6 years
2. medium periods at 6.4 years
3. long periods with a length between 24 and 32 years.

The spectral peak at 25.6 years seems to have an exceptional position. The identified very long periodicities – 64 and 128 years – are questionable in comparison with shorter spectral peaks, because the length of the time series was 128 years. Periodic fluctuations of water level with a 25–33-year period are characteristic of not only Estonia, but also of a much larger area in North Europe (North-West Russia, Latvia, Lithuania, southern part of Finland). Several authors (Libin, Jaani 1989; Behrendt, Stellmacher 1987; Hiltunen 1994) reported similar results for different large lakes in the northen part of Europe. Fluctuations with approximately the same time period were found for lakes Peipsi (Jaani 1996) and Ladoga and also in recent studies of river runoff change in Finland (Hiltunen 1994) and in the runoff coefficient in Estonia (Järvet 1995). Reap (1986) concluded on the basis of spectral analysis of L. Peipsi water level time series that the cycles of 6.1–6.4, 10–11 and 80–90 years are more evident, because the difference of main features of water regime between the two lakes is not significant.

The period since the beginning of the 1960s has been relatively dry compared with the earlier time, which is reflected by the long-term water level curve, with more frequent and longer low level (below 33.00 m) periods. Provided that the same periodicity continues, it is possible to forecast the

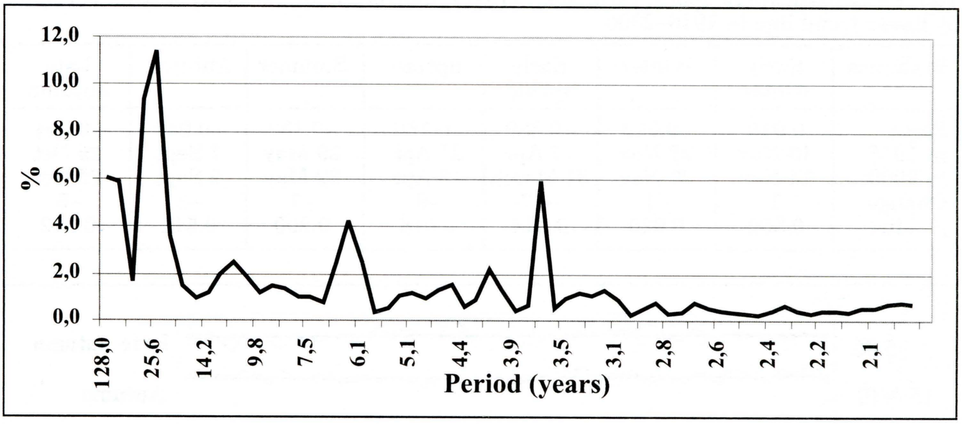

Fig. 3 – Spectrum of annual minimum water level in L. Võrtsjärv in 1871–2000

water regime in the near future. The negative phase (lower water level) if should last until the end of the 2010es, in the case of the 30-year fluctuation.

An analysis of the changes in the water level a six-year shift shows that periodic fluctuations have quite a stable character. It appears from a visual comparison (Fig. 2) that strong periodicity exists for periods of about 30 years. Level changes over the 20th century show a general tendency to a decrease, although periodic increases can be observed.

There is a strong connection between the periodic fluctuations of precipitation and changes in the hydrological regime in Estonia. Significant periodical changes in the water level of lakes are closely related to changes in precipitation and, to a lesser extent to the amount of evaporation. Data on the shifts of the spectral behaviour of water level can be obtained from the precipitation time series. The corrected time-series of spatial mean annual precipitation in Estonia indicates a clear periodicity (Jaagus 1998): cycles of 50–60, 25–33 and 5–7 years were detected. Temporal variability of evaporation is much lower than that of the runoff of rivers and water level of lakes. When annual precipitation in Estonia is less than 650 mm, then water level will depend on precipitation, and evaporation is stable (Järvet 1998). Based on the comparison of water balance elements, it can be concluded that the temporal variability of the water level of Lake Võrtsjärv is much higher than the variability of precipitation.

3. Long-term trends in thermal conditions

Typical variables of water climate, such as monthly mean water temperature, are not the best variables to describe ecological conditions associated with annual cycles in the organic activity in lakes. Therefore, climatic seasons, characterized by their start date and duration, are applied (Järvet 2000, 2001). Seven climatic seasons of water-bodies have been distinguished in Estonia. The climatic seasons of lakes are defined by water temperature and ice cover characteristics (date of the beginning and the end ice phenomena and ice cover). The seasons of colder half-year (late autumn, winter, early spring) determined only by ice data. A closed annual cycle consists of a sequence of regularity alternating ecological phases, which are

Tab. 1 – Statistics of temporal variability for start date of climatic seasons of Lake Vőrtsjärv by linear trend line in 1946–2000

Statistics	Early winter	Winter	Early spring	Spring	Summer	Autumn	Late autumn
Slope	0.016	–0.013	–0.339	–0.160	–0.132	–0.047	–0.094
in 1946	13 Nov	28 Nov	17 Apr	21 Apr	29 May	7 Sept	29 Oct
in 2000	14 Nov	27 Nov	31 March	13 Apr	22 May	5 Sept	25 Oct
Change	1	–1	–17	–8	–7	–2	–5
p value	0.882	0.920	0.014	0.018	0.200	0.511	0.312

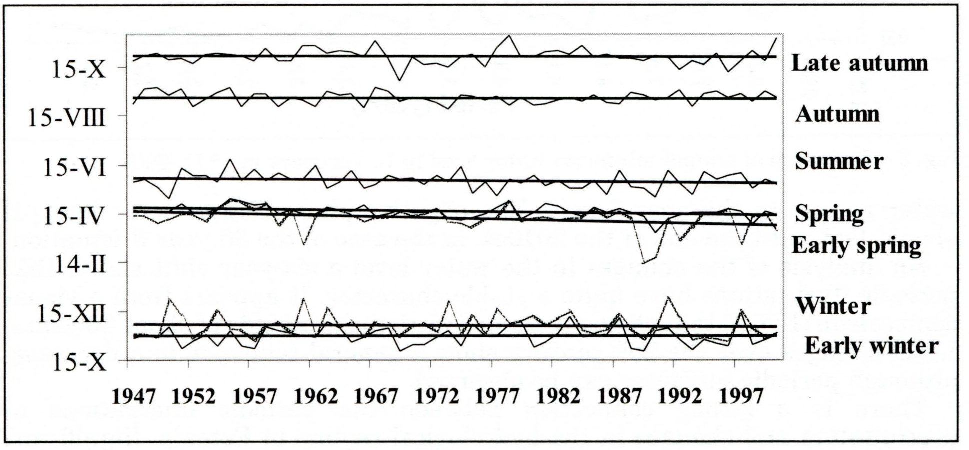

Fig. 4 – Long-term series and linear trends for start dates of climatic seasons L. Vőrtsjärv

expressed using beginning dates, duration and intervals. The thermal characteristics of lakes are particularly responsive to changes in the weather and frequently amplify the effects of regional-scale variations in the circulation of the atmosphere.

Results of linear regression analysis of long-term series indicate the presence of some long-term changes. Changes in trend in Table 1 are differences between trend-line values calculated for years 2000 and 1947. Positive changes show a tendency for climatic seasons to start later and vice versa (Tab. 1).

Climatic seasons of Lake Vőrtsjärv for the whole year tend to begin earlier, except early winter and winter, which start at same time. A statistically significant trend was determined only for the start date of early spring (beginning of break-up of ice-cover), also for the beginning of spring (daily mean water temperature increase above 4 °C). Start dates of early spring have shifted on L. Vőrtsjärv from 17 April to 31 March.

The summer period (from spring to late autumn) has lengthened by 1 week during the 55year period. Most significant trend was obtained for winter (ice cover period). The shortening of the winter season by 17 days is calculated. A statistically significant trend was determined only for the beginning date of early spring – significance at $p<0.05$ level. Other clearly trends were obtained for early winter and autumn, but statistically not significant due to the high temporal variability of the time series (Fig. 4).

The summer half year (period from the beginning of spring to the end of late autumn) has lengthened during 55 years on L. Vőrtsjärv 9 days. The periods of rapid warming tended to occur earlier in the year and there was an associated extension in the length of the biological summer. The shortening of the winter season by 18 and 16 days is statistically significant. All the long-term tendencies observed in Estonian large lakes are in a good accordance with the trend of increasing mean air temperature during winter and spring seasons, and with the trend of decreasing spatial mean snow cover duration (Jaagus, Ahas 2000).

4. Influence of summertime hydrological conditions on the ecological state

Quantitative responses of the biota to increased nutrient loading are adequate in a nutrient-limited environment but can differ in a wide range in the case of other limitations. Optical properties of water as well as the mixing depth and resuspension rate of sediments, all determined by the water level, come to the forefront in the case of shallow and turbid L. Vörtsjärv where light limitation plays a major role in controlling phytoplankton growth (Nöges 1995). Despite the rather stable nutrient content the biological indices of the trophic state fluctuate strongly depending on water richness. The influence of changes in the water level on different trophic levels is either direct or mediated by cascading effects in the food chain.

Wind-exposed northern and eastern coasts of the lake are bordered with a mostly continuous belt of *Phragmites australis* (Cav.) Trin. ex Steud., followed by submerged *Potamogeton perfoliatus* L. at a depth of about 2 m. Only in places exposed to the strongest wave action, the reed-beds become narrow or fragmentary, often separated from the shore by a shallow open water area. The western coast is richer in vegetation. The zone of floating-leaved plants – *Nuphar luteum* (L.) Smith – is distinct in places, while the zone of submerged vegetation is everywhere well formed. The southern corner of the lake is fully overgrown with macrophytes. Depending on fluctuations in the water level the abundance and distribution boundaries of different species vary greatly. Besides eutrophication, also lasting low-level periods in dry years contribute to the broadening of reed-bed areas.

Water level controls phytoplankton biomass in L. Võrtsjärv both through light conditions and nutrient availability. During periods of high water level, large amounts of phosphorus are accumulated in the sediments while phytoplankton is mainly light-limited. In the periods of low water level, light conditions improve and sediment disturbance enriches the water more with phosphorus than with nitrogen. As a result, nitrogen limitation is switched on, and nitrogen-fixing species get an advantage in competition (Nõges et al, 1998).

Water level is one of the main factors determining to a great extent the success of spawning and hence the abundance and catches of many fish species. In L. Võrtsjärv water level has a particular significant effect on the abundance of pike, which lays its eggs in overflooded shallow places (as a rule, up to 0.5 m), mostly on dead vegetation. In the case of high water level, the spawning areas of pike are rather extensive, which lays a firm foundation for the formation of a strong pike generation. There is an evident positive correlation ($r = 0.45$; $n = 30$; $p < 0.01$) between mean water level in spring and pike catch in the lake (Järvalt, Pihu 2002). As a rule, abundant pike catches

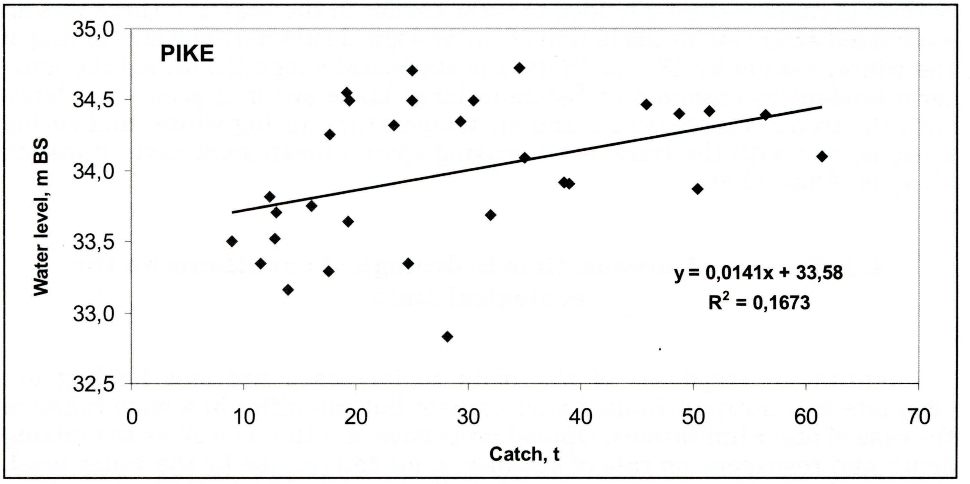

Fig. 5 – A correlation between annual pike catch and mean water level

follow, with a 4–5year delay, periods of high water level, and small catches occur, with a similar delay, after periods of low water level. This is in accordance with the age composition of pike catches in L. Võrtsjärv, where usually 4–5year-old specimens are dominating. On the ground of an experimental trawl catch a still stronger positive correlation ($r = 0.61$; $n = 23$; $p < 0.01$) was found between the abundance of a particular pike generation and water level in the spawning period (April–May) in the lake (Fig. 5; Järvalt, Pihu 2002).

5. Influence of wintertime hydrological conditions on the ecological state

Investigation about long-term changes of water and ice regime on L. Võrtsjärv gives some information not only about the hydrological conditions, but also about the trends and changes of ecological conditions caused by ice cover and water retention time. Winter conditions of a lake, especially the oxygen amount and concentration in water depend upon the duration of ice cover, thickness of ice and snow.

Ice cover has an essential part in the formation of lake ecological conditions, especially in a winter period (Fig. 6). Several winter fish kills (in 1939, 1948, 1967, 1969, 1978, 1987) have been documented on the L. Võrtsjärv during this century. Most of them (1939, 1948, 1967, 1969) coincided with low-level periods and, hence, with a higher primary production in the preceding summer and oxygen depletion during winter. Important indices of water-body climate factors are the duration and thickness of ice cover and from a lake volume point the ice volume.

To calculate a changes in lake morphometry, the lake volume, surface area, and average depth were determined at maximum ice thickness, which corresponds with wintertime minimum water level. By hydrological characteristics it is possible to explain the wintertime ecological conditions of lake by active volume, and corresponding mean depth. In calculating active

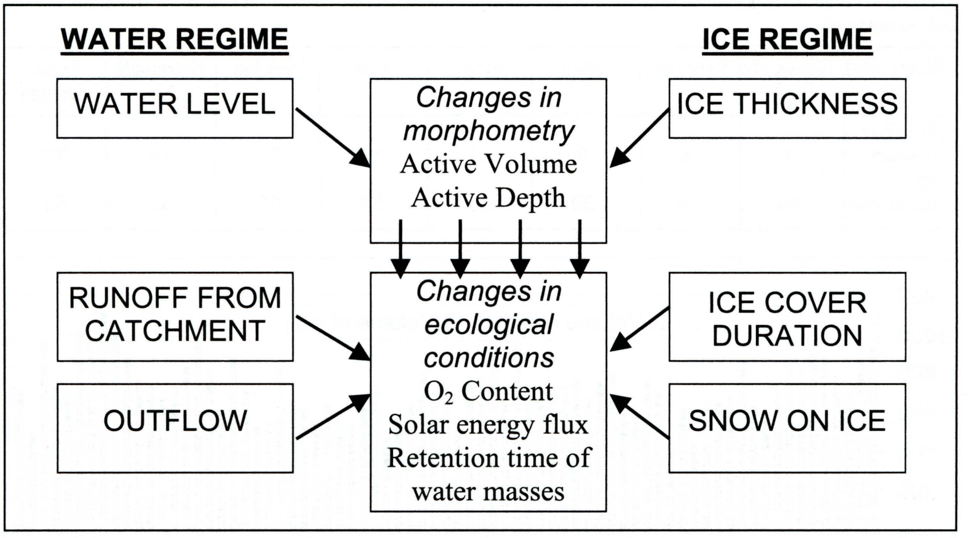

Fig. 6 – A principal scheme of wintertime hydrological factors influence on the morphometry and ecological conditions of shallow lake

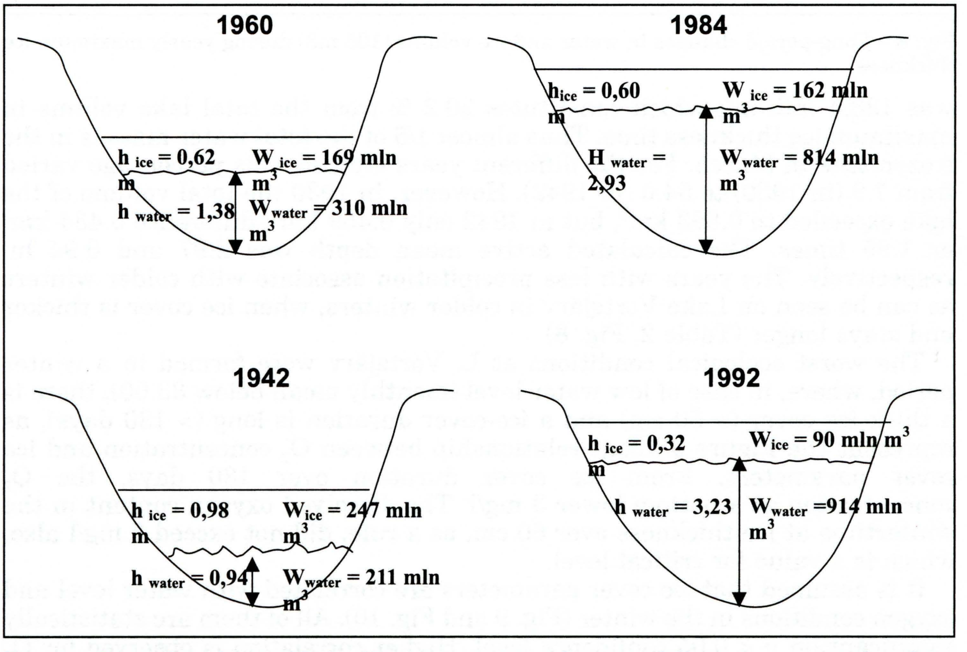

Fig. 7 – Examples about of Lake Võrtsjärv active volume in different water level and ice thickness conditions

volume the ice volume (or dead volume) is subtracted from the total volume, as the volume of ice is actually temporary unused water for the lake ecosystems (Fig. 7).

The annual maximum ice volume ranges from 69.7 mil m^3 (in 1961) to 247.5 mil. m^3 (in 1942). The mean ice volume (in 1925–1997) on L. Võrtsjärv

Tab. 2 – The duration of years by minimum wintertime water level and maximum ice thickness (cm)

Water level	Extremely high	Very high	High	Middle	Low	Very low	Extremely low	Total, average
Number of years	1	4	9	11	16	17	15	73
Ice thickness	40	38	59	53	52	53	62	54

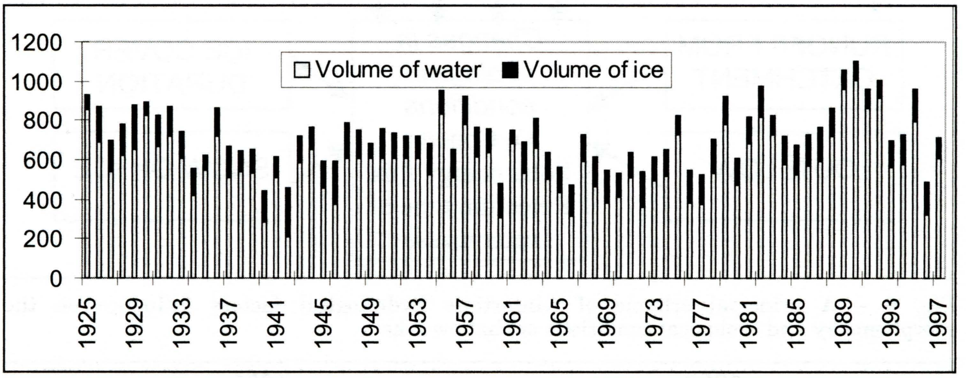

Fig. 8 – Long-period changes in water and ice volume (106 m3) during yearly maximum ice thickness

was 138.4 mil. m^3, which constitutes 20.2 % from the total lake volume in maximum ice thickness time. Thus almost 1/5 of the total water mass is in the frozen sate in March. For the different years studied, this percentage varied from 7.9 (in 1930) to 54.0 (in 1942). However, in 1930 the total volume of the lake exceeded to 0.893 km^3, but in 1942 only 0.459 km^3; difference 0.434 km^3 or 1.95 times. The calculated active mean depth was 2.97 and 0.94 m, respectively. The years with less precipitation associate with colder winters as can be seen on Lake Võrtsjärv in colder winters, when ice cover is thicker and stays longer (Table 2, Fig. 8).

The worst ecological conditions at L. Võrtsjärv were formed in a winter period, where, in case of low water level (monthly mean below 33.00), there is a thick ice cover (> 50 cm) and a ice-cover duration is long (> 130 days), as represent the Figure 9 about relationship between O_2 concentration and ice cover parameters. From ice cover duration over 130 days, the O_2 concentration at a bottom lower 3 mg/l. The dissolved oxygen content in the wintertime at ice thickness over 60 cm, as a rule, did not exceed 3 mg/l also, which is a value for critical level.

It is assumed that ice cover parameters are correlated with water level and oxygen conditions in the winter (Fig. 9 and Fig. 10). All of them are statistically significant on $p < 0.05$ confidence level. Higher correlation is observed for O_2 content in bottom layer (Table 3) than in surface part. At a bottom the concentrations of O_2 were always lower measured in the upper layers. It can be explained by the fact that there are often observed the depletion of O_2 for bottom sediment oxidation and surface layer is characterised sometimes in March by photosynthetical aeration – the algal activity just under the ice.

The winter of 1995/1996 has been another example of the disastrous consequences of the low water level. After the highly productive summer of

Tab. 3 – Regression equations relating ice cover duration (days) and maximum ice thickness (cm) to O_2 minimum concentration (mg/l) in water (n = 28)

x-variable	Equation	r	p
	Surface layer		
Ice cover duration	y = –0.06 x + 17.67	0.366	0.055
Ice thickness	y = –0.15 x + 16.91	0.417	0.027
	Bottom layer		
Ice cover duration	y = –0.10 x +16.76	0.486	0.009
Ice thickness	y = –0.21 x + 15.22	0.533	0.003

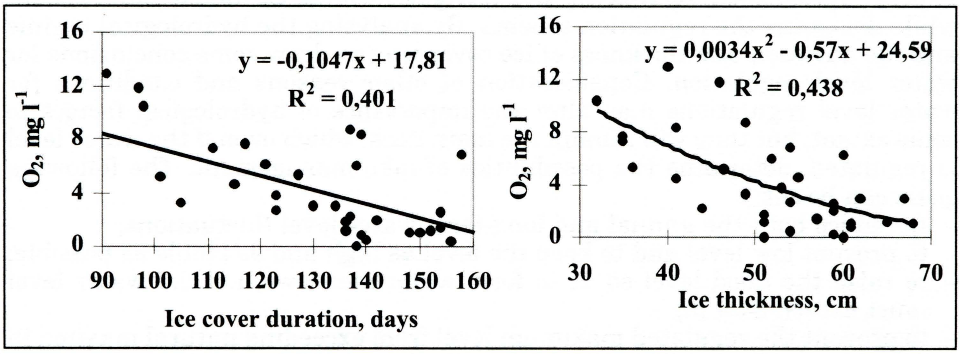

Fig. 9 – The correlation between ice cover characteristics and wintertime minimum dissolved O_2 content (mg/l) in water: left – duration (days), right – thickness (cm) in 1968–2000

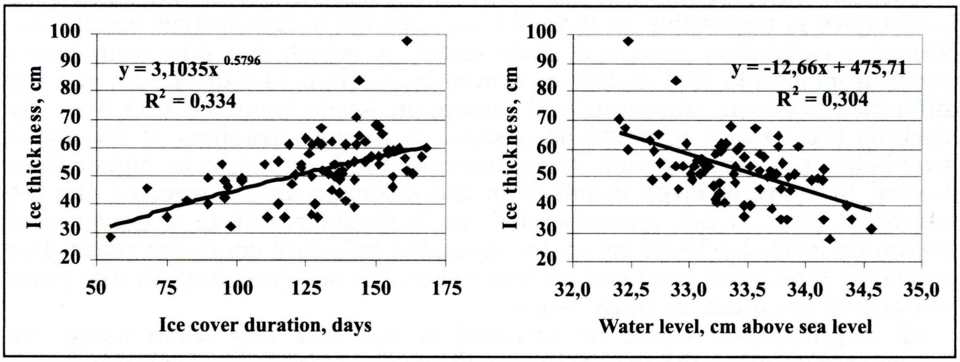

Fig. 10 – Correlation between ice cover characteristics and a minimum water level in winter

1995 the lake was frozen at an extremely low level. The winter has been cold and the lake has been covered by thick ice (~0.6 m) and snow (~0.3 m). There have been no thaws from mid-December till the beginning of March. The lowest oxygen concentrations during the studied 30 years (2.3 mg.l^{-1} just below the ice, 0.4 mg.l^{-1} in the bottom layer) were registered on 1st March.

Very low oxygen concentration in L. Võrtsjärv in the winter of 1996 can precisely be explained by low water level and a large amount of ice (31.5 % from total water mass of the lake). The lowest oxygen concentrations during the last 35 years (2.3 mg.l^{-1} just below the ice, 0.4 mg.l^{-1} in the bottom layer) were registered on 1 March 1996 (Nõges et al 1998). The winter of 1986/1987 has been an example of the disastrous consequences of a long winter, thick ice and snow cover. After the highly productive summer of 1986 the lake was frozen in November. The winter has been cold and the lake has been covered by thick ice (0.64 m) and the thickness of snow cover was recorded in the beginning of March 0.41 m.

6. Improving the ecological state by water level regulation

Lake Võrtsjärv with its large drainage area, bad outflow conditions and flat shores is a complicated object for water level regulation. The requirements of fishery, agriculture, recreation and navigation must be taken into account while designing the regulation scheme. By analysing the hydrological regime and the duration and thickness of ice cover we can draw some conclusions for water level regulation. Consideration of other reasons and conditions for water level regulations may alter the importance of hydrological factors to some extent, but they will remain the main ones, which even if the water level is regulated, determine the possibilities of lake management. The following goals can be set:

- to reduce both the annual and long-term water level fluctuations;
- to prevent low level and to keep the level as high and as stable as possible;
- to raise the flood level so as to form water-meadows, i.e. the water level must exceed 34.4 m;
- to prevent the regulated maximum level from exceeding natural maxima in order to avoid flooding of buildings and roads;
- to guarantee the sanitary minimum flow in the River Emajõgi (outflow L. Võrtsjärv).

Outflow calculations showed that a constraint level regulation of L.Võrtsjärv is impossible as it would requires far better outflow conditions. Nineteen regulation scenarios were tested in which the minimum levels varied from 33.0 to 33.7 m, the maximum levels from 34.0 to 34.8 m, and the difference between minimum and maximum levels from 0.6 to 1.8 m. By blocking the outflow it would be possible to prevent dropping of the water level below the set minimum value, however the level might be higher than desired in years of large runoff from the drainage area. Lowering the set minimum level is not recommended, as it would result in a decrease of maximum levels by 30–50 cm in dry years, but only by 5 cm in wet years. The regulated maximum level can be lower than the set maximum in dry years and exceed the latter in rainy years.

All requirements would be satisfied in the best way when using the following regulation scheme: filling of the lake proceeds in April-May when the regulator is closed. Lowering of the water level starts in the second half of May at the maximum flow rate determined by the outflow conditions, until it reaches the set minimum (usually in September). The water level would increase slightly in November and December. In years when the lake cannot be regulated due to the high level in the outflow, or due to excessive inflow, the regulator would be opened and the natural regime established. It would be reasonable to keep the minimum level at 33.7 m which is the long-term average and to which the level can be lowered in most cases (75 % of years). The regulated maximum water level is to be 34.8 m in which case forced maxima would reach 35.6 m.

As a result of regulation measures water level dynamics does not change much. It will generally follow the natural pattern but will proceed at a higher level and will have a smaller amplitude. The level will be about 1 m higher during low-water periods. Extraordinary high levels do not exceed much natural maxima, as the natural level equals at 1 % probability 35.50 m and the regulated level 35.6 m. The annual mean amplitude of level fluctuations will decrease by 0.3 m (from 1.4 to 1.1 m), the annual maximum amplitude by more than 1 m.

7. Conclusions

The most important problem of L. Võrtsjärv is the fluctuation of its level. The lower level is the result of climate change causing both decreased river inflow and increased effective evaporation. Low water periods, making up 10 % of the total number of days according to the observation data, are harmful to the ecological conditions of the lake. The active volume of the lake is the smallest with shallow water level (mean below 33.00 m in March) and thick ice cover in winters, which may cause a decrease in the oxygen content below the critical level, i.e. <2-3 mg/l.

Lasting low-water periods in L. Võrtsjärv are accompanied by a number of adverse biological phenomena consisting generally in destabilizing of the ecosystem. An increase in phytoplankton and bacterioplankton biomass deteriorates the transparency and gas regime of the lake. Low-level periods accelerate the overgrowing of shallow coastal areas with macrophytes and deteriorates the spawning conditions for pike by restriction of spawning places and for pike-perch by the spawn being buried under sediments. Greatest success would be achieved by reducing sediment resuspension and by strengthening light limitation on phytoplankton, which would control primary production and the amount of particulate matter in the water.

The analysis of the factors that influence the ecological state of Lake Võrtsjärv in winter, confirm that the main cause of variability are the water level and ice thickness. The results indicate that water level has a very clear effect on the O_2 content during low water-stand and long ice cover period. The active volume of the lake is the smallest with shallow water level (mean below 33.00 in March) and thick ice cover (> 50–60 cm) in winters, which may cause the decrease of oxygen content below critical level – <2–3 mg/l. But even a small change in ice cover and water level characteristics during mild winters has a significant positive influence on a ecological state.

With high water level, the overflooding of large areas causes problems mainly for agriculture and forestry. By means of the regulation of the water regime, by raising the minimum and maintaining the optimum level, conditions in the lake can be improved. Regulation of water level, especially by raising the minimum level, would have the positive effects on the ecological state of the lake. To decreasing the ice cover influence on L. Võrtsjärv ecosystems it is necessary to keep regulated winter water level on 33.50–33.70, as recommended. Water level regulation (i.e. low water elevation) can favourably affect L. Võrtsjärv, but the construction of regulating facilities mostly depends on economic factors. Taking into consideration the very small slope of the outflow Emajõgi R., the water level regulation of the lake by an early-planned scheme is aggravated at least by 50 % of years. It is not possible to avoid inundations by regulation facilities. Their danger and duration may even increase with regulated higher water level.

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S h r n u t í

VLIV HYDROLOGICKÝCH PODMÍNEK NA EKOLOGICKÝ STAV MĚLKÉHO JEZERA VÖRTS

Jezero Vörts v Estonsku je velmi mělké (průměrná hloubka vody 2,8 m) a značné kolísání jeho úrovně vyvolává změny jak pokud jde o jeho rozlohu, tak pokud jde o jeho objem vody. Při nejvyšším stavu vody (35,28 m) je jeho plocha odhadovaná na 326 km^2 a objem na 1.213 km^3. Při nejnižším stavu vody (32,20 m) činí tyto hodnoty 237 km^2 a 383 km^3. Tedy rozloha plochy se liší o 89 km^2 a objem o 830 km^3.

Změny klimatických podmínek, které se promítají v cyklickém kolísání vodního systému a ledových podmínek po dlouhé období, ovlivňují zřetelně hydrofyzikální a také hydrochemické a hydrobiologické procesy v jezeře. Proměnlivý stav kvality vody je spojen s hydrometeorologickými faktory přímo nebo nepřímo. Například zvýšení průměrného stavu vody v jezeře vede ke snížení ozáření dna a ke snížení ozáření vodního sloupce. Přechodná změna jak množství, tak druhu ledu, ovlivňuje množství a druh světla pronikajícího do jezera, což působí na takové procesy jako je fotosyntéza a produkce kyslíku ve vodních masách pod ledovou pokrývkou. Optické vlastnosti vody stejně jako měnící se hloubka a měnící se podíl usazenin, což je určováno stavem vody, vystupuje do popředí v případě mělčin a zakalení jezera Vörts, kde nedostatek světla má velkou roli při regulaci růstu fytoplanktonu.

Vliv změn stavu vody na různých trofických úrovních má přímé nebo zprostředkované stupňovité účinky na potravní řetězec.

Škodlivý účinek hydrologických faktorů na ekologickou a mělčinovou oblast nastává zřetelně v důsledku následujících hydrologických podmínek: záplavy – měsíční úroveň vody nad 34,50 m, malá hloubka jezera – měsíční úroveň vody pod 33,00 m.

Jak extrémně vysoký (nad 35,00 m), tak i extrémně nízký stav vody (pod 32,50 m) mají škodlivé účinky. V létě během období nízkého stavu vody, se malá hloubka a objem jezera a intenzivní primární produkce stává problémem a během záplav také.

Ke znázornění periodicity cyklů byla využita spektrální analýza. Použití této metody zviditelnilo dlouhodobou periodicitu a některá období mohla být identifikována. Tabulka 3 uvádí výsledky spektrálních analýz. Ve spektru se objevují některé vrcholy. Současně byly zjištěny tři skupiny periodicity: krátká období se spektrálním vrcholem za 3,6 roku, střední období za 6,4 roků, dlouhá období o délce mezi 24 a 32 roky.

Zdá se, že spektrální vrchol za 25,8 let má výjimečné postavení. Byla zjištěna velmi dlouhá periodicita – 64 a 128 let –, což je problematické ve srovnání s kratšími spektrálními vrcholy, protože délka časových řad byla 128 let.

Ledová pokrývka je základní součástí při tvorbě ekologických podmínek jezera, zejména v zimním období. Několik zimních úhynů ryb (v letech 1939, 1948, 1967, 1969, 1978, 1987) bylo v jezeře Vörts dokumentováno během minulého století. K většině z nich (1939, 1948, 1967, 1969) došlo v obdobích s nízkým stavem vody a z důvodu vyšší základní produkce v předcházejícím létě a vyčerpání kyslíku během zimy. Důležitými ukazateli klimatických faktorů stavu vody je délka a síla ledové pokrývky a poměr objemu vody jezera k objemu ledu.

Odhady změn v morfometrii jezera, objemu vody v jezeře, rozsahu plochy a průměrné hloubky vycházely z maximální síly ledu, což odpovídá zimnímu minimu úrovně vody. Hydrologickými charakteristikami lze vysvětlit zimní ekologické podmínky jezera pokud jde o pohyblivý objem vody a odpovídající hloubku. Při výpočtu pohyblivého objemu je objem ledu (čili pevný objem) odečten od celkového objemu, protože objem ledu je dočasně nevyužitá voda pro udržování ekosystémů.

Roční maximum objemu ledu se pohybuje od 69,7 mil m^3 (v roce 1961) do 247,5 mil. m^3 (v roce 1942). Průměrný stav objemu ledu (v letech 1925 – 1997) na jezeře Vörts činil 138,4 mil m^3, což činí 20,2 % z celkového objemu jezera v době maximální ledové pokrývky. Téměř 1/5 celkové masy vody je zmrzlá v březnu. Bylo vypočteno, že toto procento v různých letech kolísalo od 7,9 (v roce 1930) do 54,0 (v roce 1942). Avšak v roce 1930 celkový objem jezera převyšoval 893 km^3, zatím co v roce 1942 činil pouze 459 km^3, rozdíl tedy představoval 434 km^3 čili 1,95násobek. Vypočtená hloubka pohyblivé vody činila v příslušných letech 2,97 a 0,94 m. Byly to roky s nižšími srážkami ve spojení s chladnějšími zimami, jak to bývá na jezeře Vörts v chladnějších zimách, kdy ledová pokrývka je silnější a vydrží déle.

Horší ekologické podmínky na jezeře Vörts vznikaly v zimním období, kdy v případě nízkého stavu vody (měsíční průměr nižší než 33,00), je zde ledová pokrývka o síle > 50 cm) a vydrží déle (> 130 dní) jak uvádí tabulka 9 o vzájemných vztazích mezi koncentrací kyslíku a parametry ledové pokrývky. Při ledové pokrývce trvající déle než 30 dní je koncentrace u dna nižší než 3 mg/l. Obsah kyslíku v zimním období při síle ledu vyšší než 60 cm, jak je pravidlem, nepřesahuje také 3 mg/l, což je hodnota na kritické úrovni.

Odhaduje se, že parametry ledové pokrývky odpovídají úrovni vody a kyslíkovým podmínkám v zimě. To lze statisticky vyjádřit vzorcem $P < 0,05$ počtu pravděpodobnosti. U dna byla koncentrace kyslíku vždy nižší než v horních vrstvách. To může být vysvětleno jako skutečnost, že je zde často pozorováno vyčerpání kyslíku pro okysličení usazenin u dna a vrchní vrstva je někdy v zimě charakterizována fotosyntetickým provzdušněním – rozmnožováním řas přímo pod ledem.

Při rozboru hydrologického režimu a trvání a síly ledové pokrývky můžeme dospět k některým závěrům o regulaci úrovně vody. Požadavky rybářství, zemědělství, rekreace a plavby musí vzít v úvahu stanovení regulace systému. Jezero Vörts s širokou odtokovou oblastí a nevhodnými odtokovými podmínkami a mělkými břehy je komplikovaným objektem regulace úrovně vody. Zvážení těchto důvodů a podmínek regulace stavu vody může usměrnit význam hydrologických faktorů do určité míry, ale ty zůstávají hlavní,a ty, dokonce i když je úroveň vody regulována, určují možnosti správy jezera.

Následující cíle mohou být dosaženy: snížení jak ročního, tak dlouhodobého kolísání stavu vody, předcházení snížení stavu vody a udržení stavu vody tak vysoko jak je to možné, zvýšení míry zaplavování tak, aby byly zaplavovány louky, tj. stav vody musí převýšit 34,4 m, regulací maximálního stavu vody předcházet odhadovanému přirozenému maximu, aby se předešlo zaplavování budov a silnic.

Výpočet odtoku potvrdil, že nucená regulace úrovně jezera Vörts není možná, protože by to vyžadovalo mnohem lepší odtokové podmínky. Bylo testováno devatenáct scénářů regulace, ve kterých se minimální stav vody pohyboval od 33,0 do 33,7 m, maximální stav od 34,0 do 34,8 m a rozdíl mezi minimálním a maximálním stavem od 0,6 do 1,8 m.

Blokování odtoku by bylo možné, aby se předešlo snížení stavu vody pod míru minimální hodnoty, avšak stav vody by mohl být vyšší než žádoucí v letech s velkými srážkovými odtoky z přítokové oblasti jezera. Snížení míry minimální úrovně se nedoporučuje, protože by vedlo nejen ke snížení maximální úrovně o 30–50 cm v suchých letech, ale dokonce o 5 cm v deštivých letech. Regulovaná maximální úroveň může být nižší než maximum v suchých letech a později může být překročena v deštivých letech.

Všechny požadavky by byly nejlépe uspokojeny uplatněním následujícího schématu regulace: naplnění jezera v dubnu–květnu, kdy je regulační zařízení částečně uzavřeno. Snižování stavu vody zahájit v druhé polovině května na míru maximálního odtoku určovanou odtokovými podmínkami až dosáhne minimální míry (zpravidla v září). Stav vody by se mohl mírně zvýšit v listopadu a prosinci. V letech, kdy jezero nelze regulovat kvůli systému průtoku nebo kvůli nadměrnému přítoku, regulační zařízení by mělo být uzavřeno a zaveden přirozený režim. Bylo by rozumné zachovat minimální stav 33,7 m, který je dlouhodobým průměrem a na který může být snížen. V největším počtu případů (75 % let). Regulovaný maximální stav vody by mohl být 34,8 m, při čemž by se maximálně mohl zvýšit na 35,6 m.

V důsledku regulačních opatření by se dynamika stavu vody příliš nezměnila. Následovala by přirozený vzor, ale postupovala by na vyšší úrovni a měla by menší amplitudu. Mimořádně vysoký stav by překračoval přirozené maximum pouze o 1 %, protože přirozený stav by činil 35,5 m a regulovaný stav 35,6 m. Roční amplituda kolísání stavu vody by se snížila o 0,3 m (z 1,4 m na 1,1 m) roční amplituda maxima o více než 1 m.

Obr. 1 – Mapa polohy jezera Vörts
Obr. 2 – Dlouhodobé změny ročního maximálního a minimálního stavu vody v jezeře Vörts
Obr. 3 – Spektrum ročního minimálního stavu vody
Obr. 4 – Dlouhodobé řady a lineární trendy trvání klimatických sezón jezera Vörts
Obr. 5 – Vzájemné vztahy mezi ročními srážkami v povodí a stavem vody v jezeře
Obr. 6.– Základní schéma vlivu zimních hydrologických faktorů na morfometrii a ekologické podmínky mělkého jezera
Obr. 7 – Příklady pohyblivého objemu vody jezera Vörts při různém stavu vody a různé síle ledu
Obr. 8 – Dlouhodobé změny objemu vody a ledu (106 m^3) během ročního maxima síly ledu
Obr. 9 – Vzájemný vztah mezi charakteristikami ledové pokrývky a zimní minimální úrovní rozpuštěného obsahu kyslíku (mg/l) ve vodě: vlevo – trvání (dny), vpravo – síla ledu (cm) v letech 1968–2000
Obr. 10 –Vzájemný vztah mezi charakteristikou ledové pokrývky a mezi stavem vody v zimě.

(Author is with University of Tartu, Department of Geography, Vanemuise 46, 51014 Tartu, Estonia, e-mail: ajarvet@ut.ee.)

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GOOD PRACTICES FOR SUSTAINABLE WATER AND TERRITORIAL MANAGEMENT: EXPERIENCES FROM ALPS AND TRANSFERABILITY

M. De Marchi: *Good practices for sustainable water and territorial management: experiences from Alps and transferability.* – Geografie – Sborník ČGS, 109, 2, pp. 145–155 (2004). – The article deals with the application in Alpine area of Italy, Germany and Austria of one of the models to diffuse sustainable choices known as "good practice". A pioneer survey about the application of good practices in water and territorial management is presented with the analysis of main results. Then the successful factors and the transferability of good practice are discussed. The article intends to represent an opportunity of exchanging experiences to implement sustainable decision making about water and territorial management.
KEY WORDS: water management – territorial management – Alps experience.

Introduction

Alps are considered an island of ecological diversity in the middle Europe. The importance of natural dimension and the sensitivity of Alpine area, give to Alpine communities the responsibility for the development of socio-economically and ecologically integrated spatial organisation. So, in the last ten years, into the paradigm of sustainability, Alpine communities have been able to test and implement local strategies with outputs also outside the strict Alpine space.

A survey to collect the sustainability practices of Alpine communities was implemented during the year 2000 through a project financed by the Alpine Space Program within the context of financing from structural funds of the European Commission. Partners of the projects were:
- National Environmental Protection Agency, Provincial Environmental Protection Agency of Trento, Region Friuli Venezia Giulia (Italy)
- Federal ministry for agriculture, forestry, environmental and water management (Austria)
- Bayerisches StaatsMinisterium fur LandesEntwicklung un UnmweltFragen, CIPRA Deutscland (Germany).

All the experiences have been collected in the "Handbook of good practices for sustainable development of the Alpine Space" printed in German, Italian, English (Boso et al. 2001) and published in a Internet Site in 2001.

This paper tries to present some interesting experiences developed in Alpine regions of Italy, Austria and Germany, looking for elements granting the success and transferability of good practices.

The Alpine Space

In Alpine area of France, Switzerland, Germany, Liechtenstein, Austria, Italy, Slovenia 13 million of people live and work and more than 100 million of people decide to make tourism (Cipra 1998, 2000). A heavy transport network made up by roads, highways, railways cross the Alps joining southern with northern side of Europe.

These are the driving forces of relationships ecosystems and society in the Alps influencing the big change in land use and land cover. (EEA 1995; Diamantini 1996; Cipra 1998; Diamantini, Zanon 1999; Dalla Libera 1999b; De Marchi 1999b, 1999c; EEA 1999; Cipra 2000; Zanon 2000). Despite these critical dynamics Alpine ecosystems show a good quality of biodiversity, an important forested area, and a good extension of cultural landscape produced by the long activity of agriculture and pastoral practices (Scheiring 1996; De Marchi 2000).

Water and river ecosystem quality shows some critical situation near settlements, winter sport areas, intensive farming areas. Lakes in many cases suffer eutrofication even if the scarce population density and the presence of areas far from transportation network offer situation of integrity of water ecosystems. Water quantity and quality is important for the supply of fresh water for human consumption in the densely populated plain areas (Cipra 1998; Callegari, De Marchi 1999; Cipra 2000).

Air quality remain the critical point of Alpine environment specially for the areas near the communication networks and the Alpine cities (Cipra 1998; Dalla Libera 1999a, 1999b; Dalla Libera, L, Dalla Libera, P. 1999; Cipra 2000).

Alps supply communities outside the mountain landscape with fresh water and energy, so the choices of Alpine communities have to deal constantly with the dialectic local-regional: regional decisions about transportation system, energy, water supply, can conflict with local decision on spatial organisation, land use, territorial development (Provincia Autonoma di Trento, Centro di Ecologia Alpina 1997; De Marchi, Diamantini, Mattolin 2000).

Problems and methods: a cooperative work

To understand how Alpine communities are facing the sustainability challenge a survey of implementation of good practices for sustainable development has been realised. The survey was limited to the area financed by the European project, the Alpine regions of Italy, Austria and Germany.

The preparation of survey asked for a strong exchange among the project partners to define "what a good practice is". In the panorama of sustainability after Rio events three main models of implementing sustainability have been consolidated (UN 1997).

The first, the bottom up approach to sustainability, Local Agenda 21 (LA21), deals with mobilisation of local community (mainly at municipal level) to build in a participatory way a local sustainable development plan (ICLEI 1996, 1998a, 1998b).

The second, a top down approach to sustainability, typical of national sustainability plans or regional sustainability plans, is a commitment of national or regional governments to implement sustainability policies defining a "higher level plan" with the task of orienting the whole national or regional planning system (Australian Government, Department of Environment and Heritage 1992; UK Government 2002).

Good practices represent the third model for sustainability implementation (Habitat 2001). Good practices, like Local Agenda 21, are grass-root way to sustainability, but they are not general and inclusive as LA21, the objective of a good practice is limited and sometime modest, the result is not a plan, but a defined action. Good practices spread up in developing countries and were definitively recognised as important tool for sustainability during the conference Habitat II held in Istanbul in 1996.

Good practice need less preparation and organization of a LA21, it allows local community to learn sustainability trough the commitment in setting and solving a defined problem. This way of dealing with the problems of local community results easier than to deal with a global and multi-sector plan like LA21. A successful good practice give the community the security to face a new sustainability task.

The project partners started meeting in October 1998 to implement the survey and to define the way of result diffusion. It was immediately clear that diffusion of results was the main task of the project. It was decided to produce a handbook in two languages (Italian and German) with English abstracts, the handbook will be printed and also diffused with a Internet Site.

The targets of paper handbook were local administration of Alps, business community, NGOs, local interest groups. The Internet site was devoted to young people, schools and citizens.

During the first half of 1999 it was prepared the document "Criteria for sustainable spatial and regional development, concerning the selection, evaluation and representation of good practice", in which the partners defined and established the basic content for implementation of the project. It also contains common positions concerning the possibility of classifying plans and projects for spatial and regional sustainable development.

In the meeting on 21 March 2000 in Salzburg, it was defined a proposal for the criteria for the selection, analysis and presentation of examples of good practice. The draft, prepared by Austria, was completed in collaboration with the representatives of Italy and Germany and was then approved.

The fundamental points were summarised in 12 basic criteria and in a procedure for the presentation of the good practice (see tab. 1). This allowed the comparison with the preliminary requirements identified and with the projects implemented in completely different contexts.

The key point were that attention must be paid not so much to the technical-quantitative characteristics of the practice, such as for example to the money necessary for realisation or results in terms of the number of activities, as rather to the qualitative peculiarities and the innovative processes which make them exemplary.

What is important is not so much the possibility of adapting pre-packaged experiences to other contexts, as the supplying of valid examples of sustainable planning on the basis of which to communicate and exchange intentions, ideas, comments and further proposals.

Consequently, the objective was to leave sufficient space for the highlighting of specific national aspects, rather than aiming to harmonise orientation for the determination of issues and operating methods.

Starting from April 2000 the surveys was implemented through visits, interviews, phone contacts, collection of documents (Tab. 2).

Tab. 1 – Criteria for the selection of good practices

I - Limitation of use or depreciation of natural resources, reduction of existing burdens·

- Reduction of use pressure on land resources caused by settlement and expansion of infrastructure
- Reduction of the pressure on energy resources partially caused by settlement and infrastructure expansion, and switching from fossil to renewable energy sources, preferably available in the Alpine region
- Avoidance of over-use of near nature regions·
- Avoidance of endangerment of variety through under-use

II - Social aspects

- Avoidance of poorly adapted measures by focusing on participation, local initiative and durable process orientation·
- Use of societal variety as an advantage, e.g. through timely instigation of initiatives and through inner-Alpine or trans-Alpine co-operation

III - Economic aspects

- Quantitative orientation of economic activities along the lines of limitedness of natural resources as well as of existing infrastructure available
- Qualitative orientation of economic activities along the lines of the availability of regional resources in regional and immaterial respect

IV - Value orientation

- Determination of normative components of sustainability in spatial planning and development in the Alpine space

V - Decision system

- Adaptation of the structures at the base of decision systems and processes (politics, legal system, administration) to Alpine specific resource oriented objectives

VI - Integration

- Integrated consideration of social, economic and ecological aspects, with the latter compound having priority on account of the limiting character characteristic of Alpine space
- Fitting into superior considerations by way of explicit reference to all-Alpine or trans-Alpine conceptions with sustainability aspects

Analysis of Alpine good practices

Good practices were selected following the criteria above that can be summarised in four aspects fundamental for sustainable spatial development: enhancement of the quality of life, participation of actors, reinforcement of regional economies, maintenance of the ecological heritage.

Many experiences were analysed, but only 37 were considered good practices and appeared in the handbook (tab. 3). The distribution of good practices among the three countries shows as the German side of Alps produced more experiences: 17 in Austria, 14 in Germany and only 6 in Italy. However in Italy good practices are concentrated in the Autonomous Province of Trento (4 cases), the other two cases one is in the Autonomous Province of Bozen the other in the Autonomous Region Friuli Venezia Giulia (BOSO et al. 2001).

It is important to stress as the work was really a pioneer attempt, considering the difficulties to individuate and evaluate experiences in a wide area in which local communities have as last objective the "publicity" of their successful experiences.

The 37 good practices has been analysed considering:

Tab. 2 – Two examples of good practices in water and territory management

EGAR - Catchment areas in Alpine Regions The EGAR Project allowed various local, provincial and federal authorities as well as technical bodies in Germany, Italy and Austria to co-operate on an interdisciplinary basis in order to deal with physical planning issues in the Alps in a more transparent and efficient way. Potential dangers from torrents and avalanches are observed to define high risk areas and to plan land use in a sustainable and precautionary way. Pilot actions were developed in two alpine areas, the Zillertal and the torrent areas between Garmisch-Partenkirchen an Oberammergau, to collect and compare data about land use and natural dangers. These areas revealed existing and potential conflicts among river geomorphology and social use of territory and conflicts among different actors. The know-how acquired through this project leads to smarter tools for spatial sustainable planning, conflict management and may serve as a model for other regions.
Clean Drinking Water for Munich In Mangfalltal region, about 40 kilometers south of the city of Munich, more than 2250 hectares of agricultural land are being worked under the guidelines of biological farming, to prevent any pesticides or fertilizers from polluting the most important resource of fresh water of Bavarian capital.The Stadtwerke München GmbH (the Munich water facilities) have started a special program to promote organic farming, paying the farmers for their participation at the programme, this represent a pioneer innovation in programme of water management. Also, the Stadtwerke München GmbH cooperates with the organic farming organisations, trying to establish ways to sell the products in the region.All these activities have not only led to a natural, environmentally sound way of agriculture, a beautiful idyllic landscape and an effective conservation of the cultural landscape and traditional farming, but also saves the city of Munich a lot of money: during most of the year, no chemical treatment whatsoever of the drinking water is necessary.

- the issues linked with the Alpine Convention[1] and relative protocols of reference (tab. 4)
- the three dimensions of sustainability (environmental conservation, economic development and social improvement and participation; tab. 5)
- the benefits of good practice implementation (tab. 6)

Each good practice normally touches many dimensions of sustainability, many protocols of Alpine Convention, and offers many benefits.

The benefits of good practices are grouped in six categories, which covers a large numbers of punctual benefits, as table 7 shows. Each project can provide more than one punctual benefits.

Good practices: successful factors and transferability

The best way to extend know how as regards the operational context of complex and strongly interrelated issues is to produce practical examples. In territorial development the propagation of so-called “valid examples” is a particularly effective method for the spreading of knowledge. The documentation of examples of “Good Practice” indeed has a double effect: on the one hand it allows the authors to make known the solutions adopted by them, while on the other it supplies users with an outline of effective solutions.

[1] The aim of Alpine Convention is the maintenance of local populations and traditional settlements, through the planning of infrastructures responding to development needs and environmental protection, in order to avoid mountain depopulation (Alpine Convention 1991); http://www.cipra.org.

Tab. 3 – List of selected good practices

Country	Good Practices
A	The Noric region
A	Biosphere reserve Grosse Walsertal
A	Regional cooperation Villach – the city and its surrounding
A	The environmental program of upper Austria
A	The region Kirchdorf – a region for nature, work and leisure
A	The way of Steinbach – an example of local regeneration
A	Traditional farm housing in Salzburg
A	Program for a sustainable regional development in Lungau
A	"Vital land" – Allgäu/Tirol
A	Egar – catchment area in alpine regions
A	Alpine park Karwendel
A	Nature and living Bregenzer Wald
A	Sustainable mobility – car-free tourism
A	Potential settlement areas in the alpine region
A	E5 – program for an efficient energy policy within the communities
A	Alliance in the alps – network of communities
A	Climate alliance Austria – climate protection in small communities
I	Environmental plan for the sustainable development of the province of Trento
I	Forestry development plan for the pine' plateau
I	Participatory urban development plan in an alpine commune – Sutrio
I	1998 state of the environment report of autonomous province of Trento
I	The Naturno model: participatory ecological planning at local government level
I	The socio-economic development plan for Roncegno
D	Biomass heating facilities Reit im Winkl
D	Restoration and management of alpine meadows at Mittenwald
D	"Ecologically sound ski-touring" of Germany's alpine club
D	Eu-life-projects "wetland restoration in the southern Chiemgau area"
D	Ecological restoration of the Gschwender horn skiing area
D	Landscape preservation and sustainable tourism in Hindelang
D	Interest group for car-free tourism towns in Bavaria
D	Regional rural development Auerbergland
D	Clean drinking water for Munich
D	Nature and culture between Oberammergau und Reutte
D	Sustainable development Achental
D	Sustainable land use in Stephanskirchen
D	Electronic travel logistics in the Berchtesgaden national park region
D	"Cars on holiday" – Public transport concept southern Allgäu

Tab. 4 – Good practices and the protocols of Alpine Convention

Protocol	N° of good practices
Energy	13
Transports	13
Tourism	18
Soil protection	13
Mountain forests	6
Sustainable development and territorial planning	15
Mountain farming	14
Nature and landscape protection	21

However, it not forget that the effective extension of "Good Practice" is not based on imitation of the solutions illustrated, but rather on the intelligent application of these to specific local context.

What is important to understand is first of all why the practice worked and why not. After the analysis of typology of practice and benefits it becomes useful to highlight the successful factors of implemented good practices. Table 8 shows in details the 8 categories of successful

Tab. 5 – Good practices and dimensions of sustainability

	Environmental conservation	Economic development	Social improvement and participation
Austria	16	11	9
Italy	5	1	3
Germany	14	4	2
Total	35	16	14

Tab. 6 – Benefits of good practices

	Air and Mobility	Landscape	Planning	Values and Culture	Political and Social Issues	Local Economy and Tourism
Austria	9	4	4	8	2	10
Italy	1	1	3	2	2	3
Germany	6	7	1	8	2	5
Total	16	12	8	18	6	18

Tab. 7 – Detailed benefits of good practices

Category of benefits	Detailed benefits	n° of good practices
Air and mobility	Development of alternative energy	9
	Energy saving	4
	Improvement of sustainable mobility	6
	Municipal energy balance	3
	Reduction of air pollutants	8
	Reduction of noise	6
Landscape	Conservation of biodiversity	7
	Ecological architecture	1
	Ecological restoration	1
	Growth of organic farming	4
	Reduction of water pollutants	1
	Waste reduction	1
Planning	Environmental risk monitoring	2
	Prevention of soil erosion	1
	Rural building projects	1
	Scientific supporting to political sustainable planning	3
	Sustainable territorial planning	1
	Urban restoration	1
Values and Culture	Change of values and behaviours	10
	Improvement of Environmental education and consciousness	7
	Reinforcement of traditional culture	3
Political and Social Issues	Welfare	1
	Empowerment	5
Local Economy and Tourism	Growth of local typical productions and marketing	10
	Sustainable tourism management	9
	Economic growth	5

factors resulted from the survey. Is it possible to group in a more "condensed" way the successful factors in two main "macro" categories: the technical dimension and the cooperative dimension.

Tab. 8 – Successful factors of good practices

	Austria	Italy	Germany	Total
Methodology and expertise	3	3	4	10
Information	4	2	1	7
Funds	2	3	1	6
Wide cooperation among citizens, private and public organization, NGO	10	4	11	25
Cooperation Among Local Authorities.	7		4	11
Cooperation among Local and Central Authorities	6	1	1	8
Transboundary cooperation	4			4
Commitment of Local Authorities	1	1	2	4

The first deals with expertise of facilitators, methodologies used to implement the practice, the availability of financial resources and the diffusion of information. The second deals with different typology of cooperation: among different actors (NGO, citizens, administrations, business), among different scale (local, central, trans-boundary).

The main successful factor seems to be the wide cooperation among different actors (25 good practices stress this issue). This main "factor" is followed by two others: the cooperation among local authorities (11 cases), methodology and expertise (10 cases).

Even if technical factors represent only 23 cases than "cooperative" factors weight for 52 cases, it is important to stress as good cooperation is also "matter" of good expertise and good ability of facilitate participatory processes.

To understand better successful factors it is possible to look for problems faced by the good practice implementation. The survey shows as problems resulted connected with cooperation: difficulties of involvement of firms, citizens, other local authorities, or instability of local administration.

However in the 37 reported practices problems were not able to "kill" the experience and normally they were solved through the adoption of organizational solutions facilitating exchange and participation.

The transferability of a good practice has more to do with cooperation participation and the ability of defining an appropriate organisation than with technical innovation per se.

After one decade of spotted experiences of sustainability the need now is to consolidate sustainability practice and to embody sustainability approach into current individual, public, private, actions.

Communities of the Alps, as many innovative communities in the world, have produced in this ten years a wide spectrum of sustainability experiences in research, business, public administration, civil society, and in different sectors from tourism to farming, from transport to landscape water and territorial management.

It is time now for a second generation of sustainability actions based not much in pilot experiences but more on consolidation and diffusion of winning practices. So, exchange among partners, monitoring of successful experiences, and a strategic integration among knowledge communication and practices, are the kernels of definitive transition to sustainability horizon.

Sustainability culture should become diffused orientation of decision making practices not remaining the heritage of enlightened minorities or the theoretical benchmark far from reality.

Daily decision making of individuals, firms, public administrations, have to face condition of complexity and uncertainity and needs sustainability vision to take strategic and adaptative decisions.

In this changing context sustainability are not optional decision, but are becoming decided option. This new decision making paradigm can be easily supported by a wise diffusion, exchange, confrontation and integration of existing experiences to build new futures, as Winograd and Flores (1986) wrote: "The important is not to choice but to create".

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Shrnutí

ZKUŠENOSTI Z ALP S VHODNÝMI POSTUPY PRO ŘÍZENÍ ÚZEMÍ A UDRŽITELNÉ HOSPODAŘENÍ S VODOU A JEJICH APLIKOVATELNOST

Alpy jsou považovány za ostrůvek ekologické rozmanitosti ve střední Evropě. Významná přírodní poloha a citlivost alpské oblasti přináší alpským obcím odpovědnost za rozvoj sociálně ekonomické a ekologicky integrované organizace prostoru. Proto byly alpské obce v posledních deseti letech jako vzor udržitelnosti schopné vyzkoušet a realizovat místní strategie, jejichž výsledky přesahují rámec alpského prostoru.

Pro pochopení toho, jak alpské obce přispěly k tomuto cíli, byl v průběhu roku 2000 vypracován přehled o vhodných postupech pro udržitelný rozvoj. Přehled se omezil na akce alpských oblastí Itálie, Rakouska a Německa, financované v rámci evropského projektu. Vhodné postupy byly vybrány podle čtyř základních kritérií pro udržitelný rozvoj prostředí: zvýšení kvality života, zapojení účastníků, posílení ekonomiky oblasti, zachování ekologického odkazu.

Mnoho zkušeností bylo analyzováno, ale pouze 37 bylo shledáno za postupy vhodné a bylo publikováno v „Příručce vhodných postupů pro udržitelný rozvoj alpského prostoru", vydané v němčině, italštině a angličtině (Boso a kol. 2001) a na Internetu v roce 2001.

Je třeba zdůraznit, že při práci byl uplatněn opravdu průkopnický přístup, zvažující obtíže při odlišení a vyhodnocení zkušeností v rozsáhlé oblasti, v níž se místní obce staly předmětem zveřejnění svých úspěšných zkušeností.

37 vhodných postupů, které byly analyzovány, se týká: otázek vyplývajících z Alpské konvence a navazujících doporučení; tří ukazatelů udržitelnosti (zachování životního prostředí, ekonomického rozvoje, zlepšení sociální úrovně a účasti); výhod realizace vhodného postupu.

Každý vhodný postup se týká mnoha ukazatelů udržitelnosti, mnoha pravidel Alpské konvence a nabízí řadu výhod. Dokumentace příkladů „vhodného postupu“ má dvojí účinek: na jedné straně umožňuje autorům zveřejnit řešení, která přijali, na druhé straně nabízí uživatelům přehled účinných řešení.

Nelze však zapomenout na to, že účinné uplatnění „vhodného postupu“ nespočívá v napodobení uvedených řešení, ale spíše v jejich inteligentním přizpůsobení specifickým místním podmínkám. Uplatnění vhodného postupu je možné v rámci spolupráce a účasti a schopnosti definovat odpovídající organizaci spíše než formou samotné technické inovace.

Seznam vybraných vhodných postupů (země – vhodný postup): Rakousko – Oblast Noric, R – Zachování biosféry v Grosse Walsertalu, R – Oblastní spolupráce města Villach a okolí, R – Program ochrany životního prostředí v Horních Rakousích, R – Oblast Kirchdorf – místo pro přírodu, práci a odpočinek, R – Cesta Steinbachu – příklad místní regenerace, R – Tradiční vesnické bydlení v Salzburgu, R – Program udržitelného oblastního rozvoje v Lungau, R – „Živá země“ – Allgäu/Tyrolsko, R – Egar – sběrné území v alpské oblasti, R – Alpský park Karwendel, R – Přírodní a životní podmínky v Bregenzer Wald, R – Udržitelná mobilita – turistika bez automobilů, R – Vhodná místa pro osídlení v alpské oblasti, R – E5 – program účinné energetické politiky v rámci obcí, R – Spojenectví v Alpách – síť obcí, R – Klimatické propojení Rakouska – ochrana ovzduší v malých obcích, R – Plánování udržitelného rozvoje životního prostředí v provincii Trento, Itálie – Plánování rozvoje zalesnění náhorních plošin, I – Plánování městského rozvoje v alpské komuně Sutrio, I – 1998 Model Naturno: ekologické plánování na místní správní úrovni, I – Plán sociálně ekonomického rozvoje pro Roncegno, Německo – Možnosti vytápění biomasou v Reit im Winkl, N – Obnova a udržování alpských luk v Mittenwaldu, N – Živé projekty EU „obnova mokřin v jižní části Chiemgau“, N – Obnova ekologických podmínek v lyžařské oblasti Gschwenderu, N – Ochrana krajiny a udržitelný turistický ruch v Hindelangu, A -Zájmová skupina pro turistiku bez automobilů v bavorských městech, A – Oblastní rozvoj venkova Auerberglandu, N – Čistá pitná voda pro Mnichov, N – Příroda a kultura mezi Oberammergau a Reutte, N – Udržitelný rozvoj Achentalu, N – Udržitelné využívání půdy v Stephanskirchen, N – Elektronická organizace cestovního ruchu na území Berchtestgadenského národního parku, N – „Automobily na dovolené“ Koncepce veřejné dopravy v jižní části Allgäu.

*(Author is at University of Padova, Department of Geography;
e-mail: massimo.de-marchi@unipd.it)*

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PILAR PANEQUE SALGADO, SERAFÍN CORRAL QUINTANA, ÂNGELA GUIMARÃES PEREIRA, LEANDRO DEL MORAL ITUARTE, BELÉN PEDREGAL MATEOS

THE NEW EU WATER FRAMEWORK DIRECTIVE AND PARTICIPATIVE EVALUATION PROCESSES: USE OF MULTICRITERIA TOOLS IN THE EVALUATION OF WATER MANAGEMENT OPTIONS IN THE COSTA DEL SOL (SOUTH SPAIN)

P. Paneque, S. Corral, A Pereira, L. del Moral, B. Pedregal: *The new EU water framework directive and participative evaluation processes: use of multicriteria tools in the evaluation of water management options in the Costa Del Sol (south Spain).* – Geografie – Sborník ČGS, 109, 2, pp. 156–169 (2004). – The European Union Water Framework Directive has become an engine of change in water policy, particularly in so far as it prioritises the rational use of water, restoration of the good ecological status of water ecosystems and public participation – diversity of perspectives and values – in decision-making, as a vital instrument to achieve these aims. This paper presents the results of the implementation of a participatory evaluation process to assess water management alternatives for the water supply in the Costa del Sol Occidental area in the province of Malaga. The techniques used in the process were multi-criteria evaluation and social research, with the involvement of the social actors identified in the analysis as a central tenet. It is maintained that by implementing participatory processes, it is possible to arrive at unconventional diagnoses, which can be developed into innovative water management alternatives, and that by taking into account all the values and interests at stake, it is possible to find solutions that overcome inertia, look beyond short-term considerations and rationalize social conflicts and resistance.
KEY WORDS: water management – integrated evaluation – participation – stakeholders.

Introduction

The European Union Water Framework Directive has become an engine of change in water policy, particularly in so far as it prioritises the rational use of water in both economic and social terms, restoration of the good ecological status of water ecosystems and public participation in decision-making, as a vital instrument to achieve these aims. Based on this three-pronged reference framework, the Directive requires the evaluation of all water resource management projects to ensure that they meet established objectives. The ultimate aim of promoting public participation is to map the diversity of perspectives and values that may be brought to bear on water resource management problems and, in this way, improve the quality of the solutions devised and avert conflict after the final decision has been taken.

With a view to proposing a methodology for water management authorities to implement the participatory evaluation of water plans and projects, a project entitled *Integrated Evaluation for Sustainable River Basin*

Governance[1] (ADVISOR) is being carried out over the period 2001–2004, as part of the European Commission Fifth Framework Programme for Research. Project participants include the New University of Lisbon (Portugal), the European Commission Joint Research Centre in Ispra (Italy), the University of the Aegean (Greece), the Free University of Amsterdam (Netherlands), the Macaulay Institute in Aberdeen (United Kingdom) and the University of La Laguna, the University of Seville and the University of Pablo de Olavide in Spain. The National Water Institute of Portugal, the Regional Development Agency for the Cyclades Islands in Greece and the Water Department of the Regional Government of Andalusia (Junta de Andalucía) are also taking part in the project as end users[2].

The ADVISOR project seeks to design such a methodology based on the concept of *integrated evaluation*, construed as an approach capable of addressing the uncertainty and complexity intrinsic in issues such as the sustainable use of water resources and as a reflective and iterative evaluation process, which takes into account the social environment in which the scientific and political activities are being carried out and which involves laypeople as well as experts and interest groups. In order to accommodate the complexity inherent in social and environmental systems, integrated evaluation seeks to bring together different disciplines and sources and to map the problem under review on an appropriate spatial and political scale, taking into account the numerous connections existing between the two. Another key feature of this approach is that it seeks to ensure that the evaluation activities are not divorced from developments in the political, social and institutional context in which they are carried out. This permits the systematic combination of conventional scientific knowledge and the information generated by other social actors to be used as the basis for environmental action.

On the basis of this theoretical definition, the first ADVISOR work package (2001) focused on the analysis of past evaluations of completed water projects, with a view to drawing conclusions on the methodologies employed and on potential opportunities and obstacles revealed in each case study in order to develop an integrated approach for future evaluation processes. The case studies reviewed included the following: i) construction of a dam on the River Evinos to increase the drinking water supply to the city of Athens (Greece); ii) designation of the River Ythan and estuary as a nitrate vulnerable zone, with a view to reducing high nitrate concentration levels in waters draining off agricultural land, and so improve water quality in areas of great ecological value (Scotland, United Kingdom); iii) project for the extensive rehabilitation of Grensmaas, involving improving flood defence systems, creating natural areas and the extraction of gravel, by restoring the Meuse River flood channel and plain (Netherlands); iv) construction of the Alqueva dam on the River Guadiana to improve irrigation and the overall development of the Alentejo region (Portugal); v) construction of the Ebro transfer to redistribute water resources in Spain by redirecting water from the River Ebro to the Mediterranean coast.

The objective of the project's second work package (2002) was to contribute to the development of an integrated theory for the evaluation of river basin

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1 ADVISOR Contract EVK1-CT-2000-00074, EC-Energy, Environment and Sustainable Development RTD Programme. http://gasa.dcea.fct.unl.pt/ecoman/projects/advisor.

2 A key figure given that it is an applied research project.

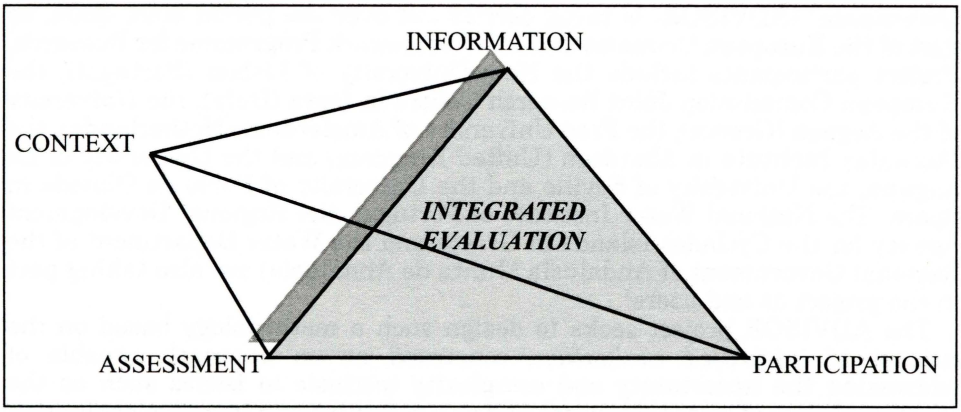

Fig. 1 – Evaluation tetrahedron. Source: Videira et all (2002, p. 163)

projects in the European Union. To this end, the five case studies mentioned above were compared using an approach termed the *evaluation tetrahedron* (figure 1). This methodological diagram includes the four dimensions of analysis that all evaluation processes should address in order to fulfil the requirements established in the Water Framework Directive: information, assessment, participation and context.

The two work packages carried out to date allow general conclusions to be drawn on current evaluation practice in real-life situations. First, all the projects examined have been approved by the relevant authorities in each case and are currently being implemented, although this does not signify an absence of uncertainty as regards their feasibility or likelihood of completion. Second, assumptions about the unquestionable value of the projects are based on an indisputable diagnosis of the problem and possible solutions, implying that the necessity and technical viability of the projects are self-evident. Furthermore, the projects are clearly formulated on the premise of the indisputable value of the project, based on the assumption that the benefits are always greater than the costs. This should be regarded as a reflection of widely accepted and hegemonic values and long-held traditions in the water policy arena of each country, which are not, however, immune to tensions and conflicts that express the dynamics of change in the social perception of water resources. Lastly, the evaluation processes carried out in the case studies analysed tended to simplify the ecological and social processes at the initial diagnosis stage, failing to examine the causes of the problems identified and the likely consequences of these problems on natural and social systems. Furthermore, uncertainty about how these systems function is not reflected in the situation diagnosis or in the strategic solutions adopted.

These general considerations reveal that the evaluation of the hydrological projects was not regarded as a process required prior to project design and approval, but rather as a matter that could be resolved *a posteriori*. It is therefore evident that in making a situation diagnosis or considering solutions to the identified problems, the overriding considerations were the values and beliefs that contribute to “myths” about water issues, making difficult, if not impossible, any discussion of solutions other than those established by the “implicit” strategy, that is, those strongly assumed at the start of the process. It can therefore be concluded that the role of evaluation processes to date has been to justify and defend a decision already taken and

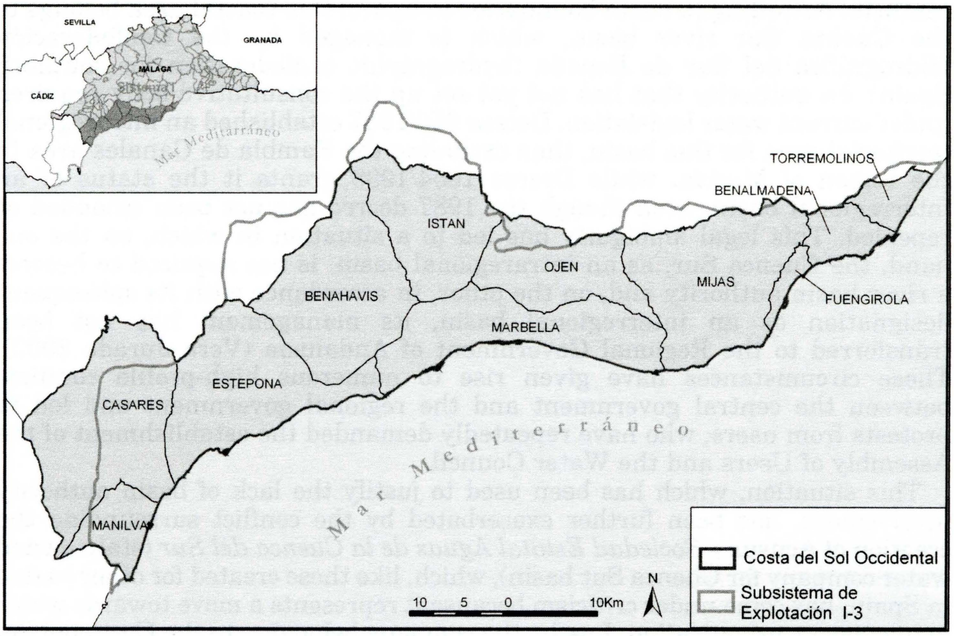

Fig. 2 – Location and boundaries of the area under study. Source: 1:100,000scale digital map of Andalusia. Own elaboration.

not to provide an extensive, integrated evaluation of the issue prior to water policy decisions being taken. This seriously limits the effectiveness and usefulness of information and participation processes, generally leading to more frustration than satisfaction among social stakeholders.

Costa del Sol Occidental (province of Malaga)

In the third part of the project, methodologies were developed in accordance with the initial concept of integrated water project evaluation, which are useful to the authorities responsible for decision-making in this area. To this end, each participating team proposed a case study to serve as a laboratory to test the proposed methodologies. For this third work package, the Spanish team selected Costa del Sol Occidental in the province of Malaga (figure 2), an area where alternatives for improving the water supply to the coastal strip are currently under debate.

It is an area that has experienced rapid growth in tourism in recent decades, which has led to a transformation of the area's socio-demographic and economic structures, mounting pressure on resources and land use restructuring. This area is particularly relevant as a case study for our purposes because it has suffered bouts of drought, which have highlighted competition and conflict between different water uses, the uncontrolled increase of certain water uses and the lack of forward planning by the competent authorities, whose response has been to instigate reactive emergency measures (Paneque 2003).

Furthermore, the organisational structure of water management in Costa del Sol Occidental is particularly complex, further exacerbating existing conflicts. According to basin boundaries in Spain, this coastal area belongs to the Cuenca Sur river basin, which is managed by the Confederación Hidrográfica del Sur de España (hydrographic confederation for southern Spain), an authority that has not yet set up the consultative body required under current water legislation. Decree 650/1987 established an intraregional territorial area for this basin, thus excluding the Rambla de Canales area in the region of Murcia, while Decree 1664/1998 grants it the status of an interregional basin, even though the 1987 decree has not been amended or repealed. This legal ambiguity has led to a situation in which, on the one hand, the Cuenca Sur, as an intraregional basin, is not required to become a river basin authority and, on the other, in accordance with its subsequent designation as an interregional basin, its management has not been transferred to the Regional Government of Andalusia (Vera Jurado 2003). These circumstances have given rise to numerous high-profile conflicts between the central government and the regional government and led to protests from users, who have repeatedly demanded the establishment of the Assembly of Users and the Water Council.

This situation, which has been used to justify the lack of basin authority involvement, has been further exacerbated by the conflict surrounding the creation of Acusur – *Sociedad Estatal Aguas de la Cuenca del Sur* (state-owned water company for Cuenca Sur basin), which, like those created for other basins in Spain, has come under criticism because it represents a move towards water management privatisation. Lastly, the company belonging to the Costa del Sol Occidental Joint Municipal Corporation, Acosol – *Aguas y Saneamiento de la Costa del Sol* (Costa del Sol water and sewerage), which is responsible for managing water supply and sewerage services in the eleven municipalities that it covers, has also been caught up in controversy. In addition to opposing the attempts of certain town councils to privatise these services – in some cases the matter has been taken to the Andalusian Supreme Court of Justice – it has been involved in a legal battle for the control of the desalination plant in Marbella, the Corporation's main alternative water resource asset.

Proposed methodology

The methodology proposed to evaluate water management alternatives in such a problematic context is *social multi-criteria evaluation*, using the NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) model, designed by Munda (1994) and developed by the Joint Research Centre in Ispra (Italy) in 1995. Multi-criteria evaluation can be defined as a set of techniques used to support decision-making processes with the analysis of a number of alternatives, taking into account conflicting interests and multiple criteria, usually including economic, social and environmental factors. By including social considerations, it is ensured that the intervention of scientists in political processes implies a responsibility to society as a whole and not just to decision makers (Munda 2002). As a conflict management tool, multi-criteria evaluation has demonstrated its usefulness in solving many environmental management problems and improves the quality and effectiveness of the decision-making process itself.

The main properties of NAIADE as an evaluation tool are as follows:

It allows the use of information affected by different types and degrees of uncertainty, such as qualitative information (linguistic variables), quantitative information, precise information (crisp numbers) and fuzzy information (well defined unlimited numbers), which is of great importance when processing information with a high degree of uncertainty, that is, information that is not wholly accurate, reliable, exhaustive and unequivocal.

NAIADE differs from other multi-criteria methods in that there is no differential weighting of the different criteria used to evaluate the alternatives. All the criteria are given the same weight and are therefore not prioritised according to whether they are economic, environmental or socio-institutional in nature.

Conflicting values have traditionally been integrated in multi-criteria decision aids either by weighting the criteria used or by taking certain "ethical" evaluation criteria into account. NAIADE proposes a third option based on the application of conflict analysis procedures integrated with multi-criteria evaluation to enable decision-makers to take "defensible" or "maintainable" policy decisions that reduce the degree of discrepancy and achieve a compromise solution (Corral 2000).

Therefore, the purpose of the NAIADE model is not to produce an undisputable or "optimum" ranking of alternatives, but to rationalize the problem and provide a horizontal and vertical framework for communication among the social actors involved. This evaluation model is a useful tool in conflict resolution experiences because it implements a participatory and deliberative approach from the moment the problem is defined, identifies the possible alternatives and proposes criteria for pairwise comparison.

NAIADE allows for two types of mutually enriching evaluations. The first is a *multi-criteria analysis* based on the score values assigned to the criteria of each alternative and performed using a matrix (known as the *impact matrix*). The second is an equity evaluation, which analyses the value judgements of the stakeholders involved in the evaluation process for each alternative using another matrix (known as the *equity matrix*) and the possible formation of *coalitions* (stakeholder groups who defend one of the proposed alternatives). In order to fulfil integrated evaluation objectives, multi-criteria analysis, specifically the NAIADE model, is therefore used in combination with *institutional analysis* and *social research* methods.[3]

This methodological framework (figure 3) is used to define the problem to be appraised, determine the scope of study, identify the stakeholders and interests involved and establish the alternatives and criteria proposed by the stakeholders to be discussed in the debate. Once the alternatives have been evaluated, the results of the analysis are presented to all the stakeholders involved in the previous research phases, following the *focus group* methodology (Dürrenberg et al. 1997, Kasemir et al. 1997, Morgan 1998, McLaughlin 1992) – the analysts facilitate the process and act as observers – with a view to obtaining feedback, sharing and honing the information collected and discussing the results achieved up to that point.

The proposed methodology responds perfectly to the need to open the social debate on water resource allocation to map all the implications, interests and issues surrounding water management and, in this way, find solutions that

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[3] The combination of participatory and institutional approaches with multi-criteria evaluation was proposed and tested in the VALSE project, specifically in the case study on the evaluation of water management alternatives in the region of Troina in Sicily, which did not seek to provide solutions to existing conflicts, but to progress towards compromise solutions capable of achieving a high degree of consensus among the different stakeholder groups – see De Marchi et al. (2000).

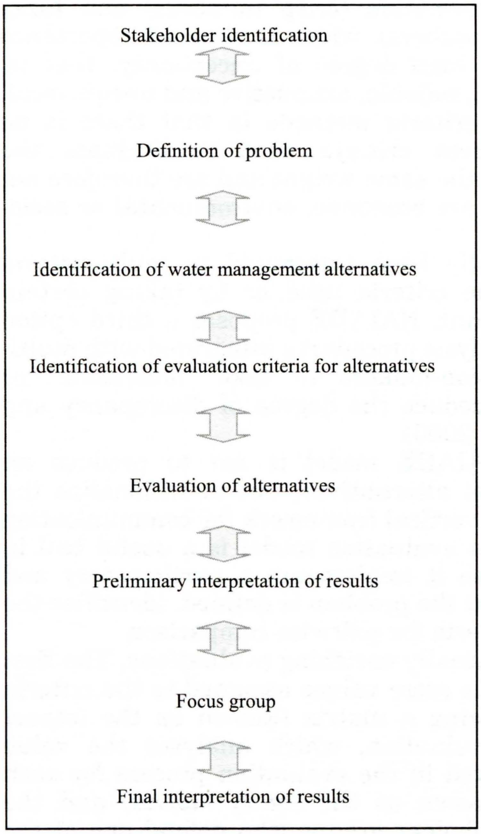


Fig. 3 – Evaluation process methodology diagram

overcome inertia and look beyond short-term transitory considerations, while at the same time averting or rationalising social conflicts and resistance.

Evaluation of the water supply system

The stakeholder identification process is inextricably linked to the decision context study and runs parallel to the problem definition stage, as it is the stakeholders who define the problem, and this, in turn, influences the selection of stakeholders and, above all, their capacity or power to act. It is important to remember that different stakeholders will make different contributions and introduce new perspectives into the process. Consequently, selection of the participating actors is one of the key factors in the process and strongly influences the extent to which the results of the evaluation are relevant to the real-world problem at hand and, as a result, the operational ability of the stakeholders to contribute to successful conflict resolution. It is therefore essential that the social actors be identified and selected on the basis of a careful analysis of the social and institutional framework in which they operate.

Guidance on Public Participation in relation to the Water Framework Directive produced by the European Commission, with a view to establishing a common implementation strategy (CIS-WG 2.9, 2002), recommends that the identification and analysis of stakeholders – referred to as “interested parties” – should be carried out by conducting *interviews* among a selection of all potential stakeholders. In the case under review, the prior selection of stakeholders to be interviewed was made on the basis of an analysis of the context and the legislative framework, supported by an *analysis of the national and local press*, which helped to identify the individuals and public and private bodies and organizations that play an active part in the water management debate in the area under study. This preliminary list of stakeholders was added to on the basis of suggestions made by those interviewed during the first round of interviews as to who they believed should be included (figure 4). The information provided by the stakeholders in the course of the interviews was then recorded in a *written questionnaire* completed by the stakeholders after the interviews.

The final selection of stakeholders is not always accepted by all the sectors

DECISION MAKERS

1. Confederación Hidrográfica del Sur de España
2. Water Department, Regional Ministry of Public Works and Transport, Junta de Andalucía
3. Directorate General for Tourism Planning, Regional Ministry of Tourism and Sport, Junta de Andalucía
4. Malaga Provincial Office for Public Works and Transport, Junta de Andalucía
5. Environment Section, Malaga Provincial Council

BUSINESS ORGANISATIONS

6. Aguas y Saneamiento de la Costa del Sol, S.A. (Joint Corporation of Costa del Sol Occidental Municipalities
7. Empresa Municipal de Aguas de Benalmádena, S.A.
8. Aquagest Sur, S.A. (concessionaire for Marbella City Council)
9. Costa del Sol Hoteliers' Association
10. Union of Small Crop and Livestock Farmers

CITIZENS' ORGANIZATIONS

11. Ecologistas en Acción
12. Valle del Genal Working Group
13. Comisiones Obreras (trade union)
14. Consumers' and Users' Association

EXPERTS

15. Technical Office for Strategic Action in the Province of Malaga
16. University of Malaga

Fig. 4 – Stakeholders identified in the Costa del Sol Occidental area

consulted. In this case, limitations on the number of participants meant leaving out some important players, such as the municipal authorities – a total of 11 in the area under study – which were only indirectly involved in the evaluation exercise through two municipal water companies. Some very influential stakeholders in this coastal area, such as the association of urban developers and construction companies, were not included because they were not willing to participate.

The purpose of the *problem definition* stage is not simply to describe the situation, but to map the perceptions of the population regarding the issue under review. Therefore, the viewpoints and judgement values expressed by the actors, mainly in the social media and in interviews, are of utmost interest. It is the job of the analysts to consider the different problem definitions put forward by the stakeholders and draw on their own experience to determine what, in their opinion, the core issue is, as public participation does not in any way exempt experts from responsibility.

In the various contacts with the identified stakeholders, two different perceptions of the water problem in the Costa del Sol Occidental area came to light. One was the definition of the problem from the viewpoint of the authority responsible for water resource management in the area, Confederación Hidrográfica del Sur, as reflected in the Cuenca Sur River Basin Hydrological Plan, based on the concept of a *structural water deficit*, affecting the whole of the river basin and resource use systems located in the area under study. This diagnosis serves as an argument for investment in new hydraulic infrastructures to improve the water supply in the area, in spite of the fact that the authority goes to great lengths to downplay the problem in the media, presenting a balanced, problem-free situation.

In the interviews and questionnaires, the other stakeholders highlighted the fact that the Costa del Sol Occidental water supply situation is subject to tensions, conflicts and deficiencies and put forward the view that the underlying problem is not a *shortage* of water but *resource mismanagement*. The majority of the stakeholders regarded the Costa del Sol Occidental as an area with abundant water resources, but beleaguered by incompetent administration, and criticised the lack of forward planning and land use management in a geographic area suffering the effects of unbounded growth, a lack of coordination among the authorities responsible for water management and those responsible for territorial and economic planning and management and weak, ineffective water management information and participation mechanisms.

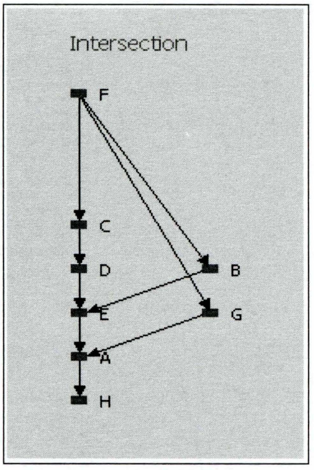
Stakeholder involvement was also ensured in the *identification of water management alternatives* and *evaluation criteria*, as it was in the stakeholder identification and problem definition stages. The fact that the problem was perceived in different ways and the diversity of judgement values and interests at stake enhanced the process implemented to identify alternatives and evaluation criteria, since the criteria matched the different positions of the stakeholders consulted exactly. The proposed alternatives that were accepted by the majority of the actors involved both action aimed at increasing available resources by means of new hydraulic infrastructures and measures to improve demand management and control urban growth. Most of the stakeholders had more trouble identifying criteria to evaluate these alternatives, beyond the usual categorisation into economic, environmental and social criteria.

Alternatives: Heightening of the La Concepción dam; Use of desalinated water; Reuse of waste water; Modernisation of irrigation systems; Rationalised use of ground water; Improved efficiency and water savings in the urban water supply; Territorial policies to control urban development; Non-intervention: maintenance of status quo.

Criteria: Implementation costs; Operating costs; Effect on employment; Effect on economic activity; Impact on the ecological status of water systems; Impact on other ecosystems; Visual impact on the landscape; Degree of institutional difficulty; Degree of social acceptance; Equitable distribution of costs and benefits; Time required to fulfil the established objective.

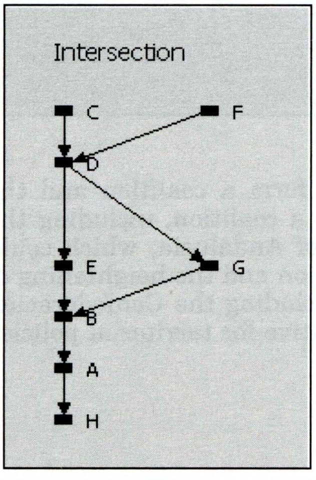
On the basis of the alternatives and criteria identified by the stakeholders, a matrix was constructed with value scores for each of the proposed water management alternatives, according to the eleven evaluation criteria. The matrix was based on data from specialized literature and technical reports, including quantitative, qualitative, crisp and fuzzy values. The results allow a comparison of the alternatives and the generation of a ranking according to the selected criteria. In order to evaluate the proposed alternatives according to the respective positions of the stakeholders, generating a new ranking, the NAIADE model was then used to perform an analysis based on another matrix, reflecting the qualitative assessment of the alternatives made by the participating stakeholders in the written questionnaires (figure 5).

The *equity analysis* also provides information about the position of the stakeholders on each of the alternatives and the possible formation of coalitions among them to defend or veto a given alternative. This provides an insight into which alternatives are more likely to be accepted, although the highest-ranking alternatives are not necessarily the most feasible. To



RANKING OF ALTERNATIVES ACCORDING TO EVALUATION CRITERIA

1. Improved efficiency and water savings in the urban water supply
2. Reuse of waste water
3. Modernisation of irrigation systems/use of desalinated water
4. Rationalised use of ground water/territorial policies to control urban development
5. Heightening of the La Concepción dam
6 Non-intervention



RANKING OF ALTERNATIVES ACCORDING TO STAKEHOLDERS

1 Reuse of waste water/improved efficiency and water savings in the urban water supply
2 Modernisation of irrigation systems
3 Rationalised use of ground water/territorial policies to control urban development
4 Use of desalinated water
5 Heightening of the La Concepción dam
6 Non-intervention

Fig. 5 – Ranking of alternatives according to evaluation criteria and stakeholders

determine the feasibility of an alternative it is necessary to consider the real power of each stakeholder or coalition of stakeholders.[4] Based on these positions, a *dendrogram of coalitions* is produced. This is a graphic representation of the formation of possible "alliances" among stakeholders in the form of a tree diagram, which provides an insight into the degree of divergence.

Figure 6 shows the distances separating the stakeholders, which determines a greater or lesser degree of *support* for the alternatives evaluated. These coalitions will have what NAIADE terms *power of veto*, that is, the power to obstruct the implementation of any of the alternatives,

[4] It is important to note that in multi-criteria evaluation using NAIADE, it is assumed that all the stakeholders are equally powerful and they are not weighted according to their real decision-making capacity. This may be a limiting factor in finding the best solution, but not in producing a ranking of alternatives according to their acceptability to stakeholders.

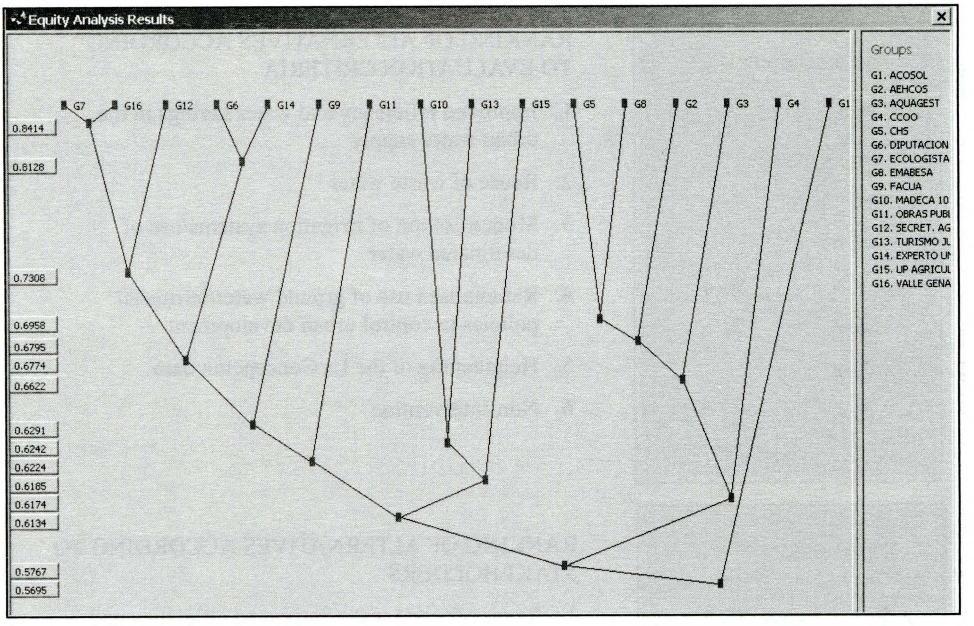


Fig. 6 – Dendrogram of coalitions

determined by the number of stakeholders who form a coalition and the degree of internal cohesion. In this case, there is a coalition, including the Water Department of the Regional Government of Andalusia, which could veto (or obstruct) the alternatives of non-intervention and the heightening of the La Concepción dam, and another coalition, including the Confederación Hidrográfica del Sur, which could veto the alternative for territorial policies to control urban development.

Main results

The evaluation process carried out with the aid of NAIADE revealed that in an *open discussion framework* social actors in the Costa del Sol area consider that the main issue is poor water resource management rather than a shortage of water. This demonstrates that in an open participatory discussion process, unconventional judgements of the situation may come to light, changing the identification of solutions and prioritisation of a given alternative by the stakeholders. In this case study, the primary focus was on the reuse of waste water, the modernization of irrigation systems and improved efficiency and water-saving measures in the urban water supply system. Measures to generate new conventional resources were also considered important, although not a top priority.

In the analyses carried out, there was no change in the two bottom-ranking alternatives, namely non-intervention and the heightening of the La Concepción dam, the main elements of the policy to increase conventional resources in the area, in spite of significant support from what has been termed the *institutional* framework. This leads to the conclusion that the most plausible alternatives for solving the water supply problem in the Costa del Sol Occidental area, that is, alternatives backed by the water management authorities, are not the best-performing alternatives in terms of economic, environmental and institutional criteria on a ten-year timeline or in terms of acceptance by stakeholders with legitimate interests in decision-making. This explains the heated debate on water resource management in the area and the objections raised with regard to certain alternatives. The preference of the competent public authorities for the construction of new hydraulic infrastructures in the province of Malaga to increase water regulation in coming years and for putting the Marbella desalination plant in operation in emergency situations is the result of institutional framework pressures, dictated by short-term considerations, and the failure to provide hydrological planning formulated as part of territorial reference planning. This is a concrete expression of the gap between *reflection* and *real-life dynamics*, and the failure to bridge this gap affects territorial policies and constitutes a major obstacle in the transition towards sustainable social organisation models.

Furthermore, when the preliminary results were presented to the stakeholders simultaneously in a focus group meeting, two considerations key to the analysis of this evaluation exercise were detected. First, when the stakeholders were presented with the final list of alternatives that had been worked on, they suggested the inclusion of other alternatives initially proposed by a small number of stakeholders, but not included in the final evaluation exercise precisely because they did not enjoy extensive support. Following an open debate, some of these alternatives (reforestation of catchment basins) figured among those receiving most support from the participating stakeholders. This shows that the latter phase in which all the stakeholders meet is crucial, because it can significantly change the final result, as issues overlooked during individual contacts are raised and debated. Second, in this phase of the participatory process the absence of certain sectors and, indirectly, the conflicts existing among them were noted. These stakeholders, who were reticent to attend the initial meetings, were mainly from the tourist sector and, more significantly, the authority responsible for water management in the area, Confederación Hidrográfica del Sur de España.

In summary, in the case study analysed, the proposed methodological approach proved to be a useful tool in dealing with water management conflicts, as it improved the quality and effectiveness of the decision-making process and contributed to determining which policy decisions could be best defended before all the stakeholders, thus reducing the degree of discrepancy and achieving a certain degree of consensus. By opening the social debate on water resource allocation to map all the implications, issues and interests involved, it is possible to find solutions that overcome inertia and look beyond short-term considerations, while averting and rationalising social conflict and resistance. However, it also highlighted the barriers that prevent the effective implementation of this type of evaluations, including the stakeholder conflict factor, in other words, the diverse and sometimes opposing values and interests at stake in water management issues.

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Shrnutí

NOVÁ RÁMCOVÁ SMĚRNICE EU O VODNÍM HOSPODÁŘSTVÍ A ÚČASTI V HODNOTÍCÍCH PROCESECH: VYUŽITÍ MULTIKRITERIÁLNÍCH NÁSTROJŮ PRO HODNOCENÍ MOŽNOSTÍ ŘÍZENÍ VODNÍHO HOSPODÁŘSTVÍ V COSTA DEL SOL (JIŽNÍ ŠPANĚLSKO)

Rámcová směrnice Evropské Unie o vodním hospodářství se má stát nástrojem politiky hospodaření s vodou zejména pokud jde o priority v racionálním využití vody, obnovení správného ekologického charakteru vodních ekosystémů a veřejného zastoupení – rozmanitých perspektiv a hodnot – při rozhodování jako životně důležitého nástroje pro dosažení těchto cílů. Tento dokument uvádí výsledky realizace procesu hodnocení za veřejné účasti při stanovení alternativ řízení vodního hospodářství pro zásobování vodou oblasti Costa del Sol Occidental v provincii Malaga. V procesu byly použity techniky multikriteriálního hodnocení a výzkumu se zapojením účastníků uvedených v analýzách jako ústřední princip.

Multikriteria sociálního vývoje byly aplikovány při použití modelu NAIADE (Nový přístup k účinnému hodnocení a rozhodování o životním prostředí) navrženém v práci Munda (1994) a rozpracovaném Společným výzkumným střediskem v Ispra (Itálie) v roce 1995.

Proces hodnocení uskutečněný s pomoci NAIADE v této případové studii ukázal, že účastníci z oblasti Costa del Sol v rámcové otevřené diskusi dospěli k závěru, že hlavním problémem je špatné řízení využití vodních zdrojů spíše než nedostatek vody podle oficiálních zpráv. Navíc se ukazuje, že otevřená diskuse účastníků a nekonvenční posouzení stavu může snadno vést ke změně identifikace řešení a preferenci alternativy doporučené účastníky. V této případové studii bylo základním středem pozornosti opětovné použití od-

padní vody, modernizace zavlažovacích systémů a zlepšení účinnosti úsporných opatření v městském systému zásobování vodou. Opatření vedoucí k vytváření nových konvenčních zdrojů byla také považována za důležitou, nikoliv však za prvořadou.

Dále, když předběžné výsledky byly předloženy účastníkům současně na skupinovém zasedání, byly zjištěny dva klíčové názory. Za prvé, když byli účastníci seznámeni s konečným seznamem alternativ, které byly vypracovány, navrhli zahrnutí dalších alternativ, navržených původně malým počtem účastníků, ale nezahrnutých do konečného hodnocení vzhledem k tomu, že nezískaly širokou podporu. Po otevřené debatě, některé z těchto alternativ (nové zalesnění vodních sběrných oblastí) figurovaly mezi těmi, které získaly největší podporu účastníků. To ukazuje, že pozdější etapa, v níž se všichni účastníci setkali, byla rozhodující, protože mohla podstatně změnit konečný výsledek, protože problémy během osobních setkání byly důkladně projednány. Za druhé v této etapě účastnického procesu nebyly zastoupeny některé úseky a tím nepřímo i některé konflikty existující mezi nimi. Ti účastníci, kteří byli na předchozích zasedáních zdrženliví, pocházeli hlavně z odvětví turistického ruchu a ještě významněji z orgánů odpovědných za hospodaření vodou v této oblasti Confederación del Sur de España.

Metodický postup navržený ve shrnutí analyzované případové studie prokázal, že je užitečným nástrojem při řešení konfliktů vodního hospodářství, jako je zlepšení kvality a účinnosti rozhodovacího procesu a přispěl ke zjištění, že politická rozhodnutí by mohla nejlépe obstát před všemi účastníky, snížit stupeň rozporů a vést k určitému stupni shody.

Otevřením společné diskuse o umístění vodních zdrojů po zmapování všech aspektů, problémů a zájmů je možné nalézt řešení k překonání setrvačnosti v myšlení a krátkodobých úvah a tím odvrátit a předcházet sociálním konfliktům a odporu. Avšak lze také překonat překážky, které brání účinnému uskutečňování tohoto typu hodnocení, včetně konfliktních faktorů účastníků, jinými slovy, rozdílným a někdy protichůdným hodnotám a zájmům při řešení otázek vodního hospodářství.

Obr. 1 – Schéma hodnocení (tetrahedron). Pramen: Videira a kol. (2002, s. 163)
Obr. 2 – Lokalizace a hranice oblasti, která byla předmětem studie. Pramen: digitální mapa Andalusie v měřítku: 1:100 000. Vlastní zpracování.
Obr. 3 – Diagram metodiky hodnotícího procesu (určení účastníků, vymezení problému, stanovení alternativ řízení vodního hospodářství, určení kritérii hodnocení alternativ, vyhodnocení alternativ, předběžné shrnutí výsledků, skupina otázek ve středu pozornosti, konečné vyhodnocení výsledků).
Obr. 4 – Účastníci zapojení v oblasti Costa del Sol Occidental (rozhodovací orgány, obchodní organizace, občanské organizace, experti)
Obr. 5 – Klasifikace alternativ podle kritérií hodnocení a účastníků. Klasifikace alternativ podle kritérií hodnocení: 1. zlepšení účinnosti a úspory vody v zásobování měst vodou, 2. opětovné použití odpadních vod, 3. modernizace zavlažovacích systémů/využití odsolené vody, 4. racionalizace využití podzemních vod/územní plánování kontroly rozvoje měst, 5. posílení koncepce přehrady, 6. nevměšování. Klasifikace alternativ podle účastníků: 1. opětovné použití odpadních vod/zlepšení účinnosti a úspory vody v zásobování měst vodou, 2. modernizace zavlažovacích systémů, 3. racionalizace využití podzemních vod/územní plánování kontroly rozvoje měst, 4. využití odsolené vody, 5. posílení koncepce přehrady, 6. nevměšování.
Obr. 6 – Dendrogram srážek

*(**P. Paneque** is with University of Pablo de Olavide,Department of Humanities, Carretera de Utrera km 1, 41013 Seville. Fax: +34 954349817; e-mail:. **S. Corral** is with University of La Laguna, Department of Institutional Economics, Economic Statistics and Econometrics, Campus de Guajara s/n, 38071 La Laguna, S/C de Tenerife. **Â. Pereira** is with Institute for the Protection and Security of the Citizen, Joint Research Centre, European Commission. Via E. Fermi, 1, 21020 (VA) Ispra, Italy. **L. del Moral** and **B. Pedregal** are with University of Seville,Department of Human Geography, C/ María de Padilla s/n, 41004 Seville.)*

Arrived to the editorial board on March 3, 2004

RAFAEL BAENA ESCUDERO, BELÉN GARCÍA MARTÍNEZ, INMACULADA GUERRERO AMADOR, FILIP HARTVICH, BRIGITTE LEICHT, LARA MARCHIOL ET AL[1]

FLOODS 2002 IN PRAGUE - REFLECTIONS, LESSONS AND IDEAS

R. Baena, B. García, I. Guerrero, F. Hartvich, B. Leicht, L. Marchiol et al.: *Floods 2002 in Prague – reflections, lessons and ideas.* – Geografie – Sborník ČGS, 109, 2, pp. 170–180 (2004). – This contribution deals with the consequences of floods, which affected the capital of CR, Prague, in august 2002. The members of working group have seen the situation one year after the event. The article is divided into three parts, each dealing with specific area of problems. First part concerns the measures that should be taken before the flood event occurs, including long-term flood protection strategy. In the second part we discuss the succession of steps to be performed in order to minimize the endangerment of public and the damages during the flood period. Last section suggests solutions and lessons that might be taken from the 2002 flood event's course and its consequences in Prague.
KEY WORDS: 2002 floods – Prague – Vltava – flood consequences – Erasmus programme.

1. Introduction

Under the Intensive Programme (29716-IC-1-2001-1-ERASMUS IP-5) Water management in transition countries, on the subject "Water resources-their management and protection", the Work Group "Flood and flood protection" analysed the floods in August 2002, in the Vltava River, on the stretch through the city of Prague.

The workshop activities and the scientific learning process can be divided into three stages:

1. Preparation phase: To prepare themselves for the stationary seminar, all the working group participants received an introductory essay which contained the necessary basics on the issue of "Flood and Flood Protection" in the Czech Republic. The emphasis was laid on the August 2002 flood catastrophe.
2. On-site-learning phase: During the stationary seminar in Prague the following activities were arranged to improve the group-knowledge about the causes and effects of the August 2002 flood:
   a) introductory expert lectures
   b) excursions to different sites in Prague which were heavily afflicted by the flood (the suburbs of Karlín and Troja with the Zoo, the Metro system) and to the main flood forecasting office (Czech Hydrometeorological Institute)
   c) expert interviews with geographers, hydrologists and meteorologists

[1] Laura Giacomini, Andrea Guaran, Alexandra Králová, Andreas Licht, Hannah Neu, Luca Pezzullo, Veronika Weingerová

3. Post-processing phase: Discussion of facts within the group, processing of information and presentation of results and compilation of the results in a working-group report.

During the post-processing phase it became clear to the group that the issues dealt with and discussed should be related to three levels of subject:

I. Before flood: studies of history, geomorphology, land ordination, etc. What do we know about river and its surroundings?

II. During flood: work plans, evacuation and coordination. During August 2002's catastrophe – what was the situation and what were the actions taken? Was everything possible done?

III. After flood: restoration and cleaning of the city and damage evaluation, embedding the gained knowledge in city planning. What lessons should be learned from the flood?

We decided to follow the same structure when composing this article.

2. The 2002 flood in Prague

2. 1 Before flood

There are two key assumptions for the ordination of land located on river banks: firstly, the fact that floods are not disasters but rather natural phenomena responding to extreme although frequent processes in the function of rivers, hence the existence of flood plains and their associated morphology (Ward 1978; Mateu 1990; Díaz, Baena 1999). It is, therefore, the human intervention involved in locating towns or cities on river banks, with their high population and concentration of activities, which prompts and increases the risk (Parker et al. 1982; Baena, García 1995). Secondly, the fact that a prompted risk such as this should be dealt with as a problem of interaction between society and the environment (Burton et al. 1978; Guerrero, Baena 1996).

The obvious solution is to study the geometry of the potentially floodable areas from a *historical* and *hydrogeomorphological* viewpoint. This is grounded on the conceptual bases and methods used in fluvial geomorphology (Pardé 1955; Tricart 1961, Thorner 1980) applied both to ordination and to the restoration of rivers (Guerrero, Baena 2002).

First task is to notice the historical floods and their parameters and then we will define the morphohydrological units (Baena, Guerrero 2002; Guerrero, Baena 2002), which allows greater understanding and explanation of the distribution and extent attained by the floods in the stretch of the Vltava River running through the city of Prague.

2. 1. 1 Vltava and its flood history

The historic series of exceptional river flows in Prague, since 1827, shows the general trend noted in European rivers towards a reduction in exceptional flows over the last two centuries (Petts et al. 1989), this only being interrupted by several isolated events during the second half of the 19th century (4,500 $m^3.s^{-1}$ in 1845, and 4,000 $m^3.s^{-1}$ in 1862 and 1890) and one (!) in the mid 20^{th} century (3,300 $m^3.s^{-1}$ in 1940).

The extent of rainfalls recorded in the Czech Republic for August 2002 represents an exceptional phenomenon due to the regional coverage of the area affected (tens of thousands km^2) and the persistence (from 6th to 15th August 2002) and the intensity of the same throughout Central Europe. The following discharge amounted to 5,160 m^3.s^{-1}.

2. 1. 2 Morphohydrological units

Geomorphologically, the stretch of river flowing through Prague itself responds to the meandriform model, winding gently with a wide, medium gradient flow and a mixed load (gravels and sands), running through a reduced flood plain as this is hemmed in by hillsides. These characteristics limit the possibilities of lamination of the peak-flows, generating alternation in the convergence and divergence of the flood flows, depending on if straight stretches are followed by bends or if natural or artificial obstacles interfere with current circulation. Between Vyšehrad and Sedlec are concerned, three morphohydrological units have been differentiated between, from South to North (see Fig. 1):

Vyšehrad–Letenské sady unit: Here the flow is limited by high embankment walls, with the exception of areas of ancient mills and laterally positioned isles (Kampa, Žofín, etc.) This led to an imbalance in the action of the river, which is more active on the lower left bank (Kampa, Vojanovy sady), unprotected by mobile barriers (due to historic city protectionists), while on Old Town side the barriers proved highly efficient. In this unit, many people would have to be evacuated in the case of barriers overflow. This zone

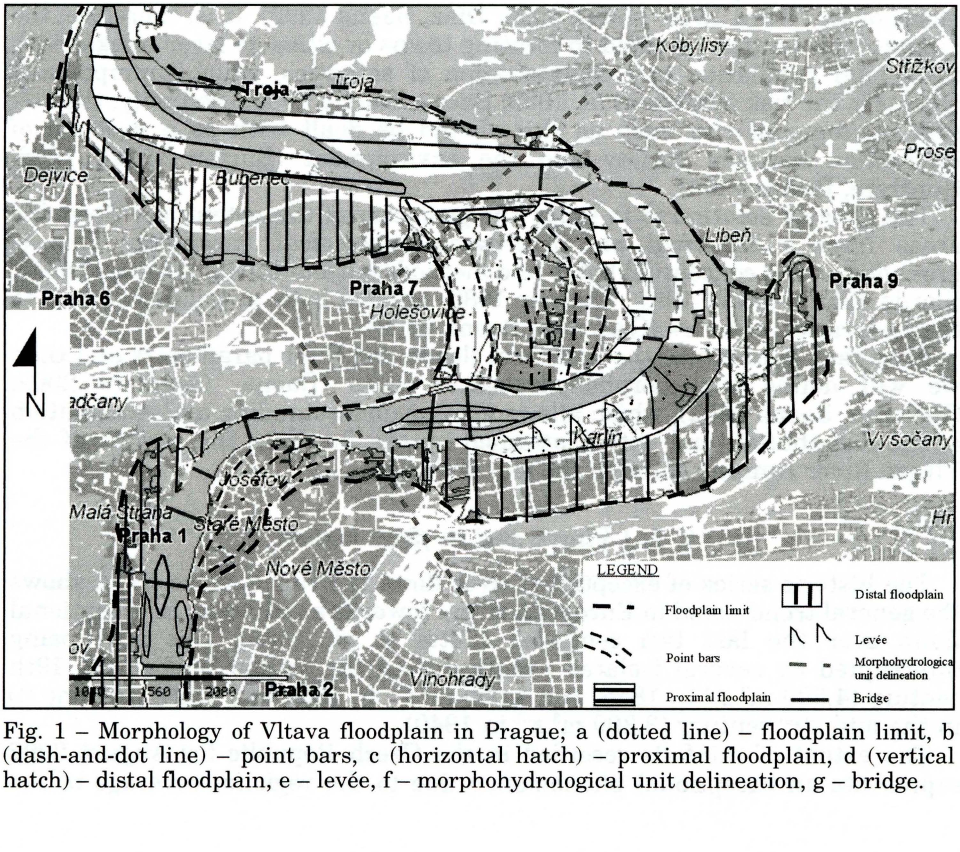

Fig. 1 – Morphology of Vltava floodplain in Prague; a (dotted line) – floodplain limit, b (dash-and-dot line) – point bars, c (horizontal hatch) – proximal floodplain, d (vertical hatch) – distal floodplain, e – levée, f – morphohydrological unit delineation, g – bridge.

corresponds to the historic sector of the city, of high historical value and includes famous Charles Bridge, an important axis around which tourism is articulated.

Karlín-Holešovice unit: Including the great Holešovice meander, geomorphologically it represented the essential sector for lamination of peak-flows of the Vltava River in this area after the narrowing stretch found in the previous unit. Within this unit, the divergence of flows occurs, with important depositional effects of point bars in Holešovice, and vertical in the concave bench of Karlín, either in the form of sands and limes (overbank deposits) in the levee that nowadays represents the old isle of Rohansky, or in the form of clays (channel-fill deposits) in the abandoned meander area of Karlín. This unit has undergone a greater number of changes during the Holocene, both of a natural character (lateral movements of meander with moments of expansion and the formation of point bars on the right bank, such as neck cut off of the same with the abandonment of the river course), and of an anthropic origin linked to the development of Liben, Holešovice and Karlín.

Troja-Bubeneč unit: Integrating the old sedimentary decantation stretch *par excellence*, due to the pool of overflows before concentrating once again after Bubeneč. Nowadays, because of the contemporary change that occurred in the previous unit, this represents the only area available for flood inundation. Hence, its function as a proximal flood plain and, therefore, subject to a progressive increase in the effects of flooding. The Pelc-Tyrolka area, on the Troja bank towards which the most intense flows from the Liben and Maniny areas run, is noted for its vulnerability.

2. 2 During the flood

2. 2. 1 Initial conditions

The August 2002 flood in the Czech Republic was caused by two waves of intensive precipitation. The first wave hit the Czech Republic from August 6th to 8th. The rain belt connected to the frontal system stayed stable over the southern part of Bohemia for more than one day and released extensive rainfalls leading to a complete saturation of the Vltava river basin. Only two and half days later, on August 11th, the next depression, accompanied by heavy rainfalls, reached the Czech Republic and moved only slowly through southwest Bohemia to Moravia. At this point, the river basins were still saturated. Though Vltava Cascade was able to absorb the discharge of the first precipitation wave, its retention capacity was overburdened with the second wave. A few kilometres upstream from Prague, the Vltava meets with the Berounka river, whose recurrence period of maximum discharges at that time exceeded 500 years. Additionally, the peaks of the two rivers‘ flood waves met at the same time. It was the combination of all those coincidences, which was at the end able to cause one of the biggest catastrophes the city of Prague has experienced.

2. 2. 2. Forecast and warning system

In case of a flood, there are flood commissions of municipalities, of river basins and the Central Flood Commission of the Czech Republic who are responsible for the organisation and management of flood control and flood protection (Šolc 2002).

The flood forecast and warning service is one task of the Czech Hydrometeorological Institute (PVS CHMI). The central forecasting office (CFO/CPP) is located in Prague Komořany, furthermore there are regional forecasting offices (RFO/RPP) located in the former regional capitals. The forecast and warning system is based on complex input data like radar data from the national and Central European radar network, satellite data from Meteosat and the US polar satellites and from ALADIN, the regional weather modelling system.

The CHMI cooperates closely with the state-run river basin authorities (Povodí). In case of a flood, the warnings and informative reports of the CHMI concerning the current situation are distributed through the operation centre (OPIS) of the Fire Rescue Service to the adequate addressees, i.e. to flood control commissions, bodies of public administration like the Ministries of Environment, Agriculture and Interior, all Povodí companies' control centres and to the Czech Television that informs the citizens. Information can also be found on the institute's website.

During August 2002 flood, the CHMI operated day and night and continuously sent alerts, warnings and informative reports about flood development and forecasts to the above mentioned institutions which were responsible for crisis management and public information. Unfortunately, there were also considerable problems that had to be faced: the unexpected extremity of the flood, the variety of influencing parameters (exact dispersion of the forecasted precipitation, information about the runoff-rates from reservoirs, etc.) and uncertainties (missing data due to flooded or destroyed gauging stations), as well as time stress and the lack of scientific experience with such extreme situations, finally defined the limits of such a well organised forecasting system.

2. 2. 3 The situation in Prague during the flood of August 2002

In the following text some examples are given to present a picture of what was the situation like in Prague during the flood.

Karlín: Karlín is Prague's first suburb, which was erected according to a development plan in the year 1816. It is located immediately outside the original city walls built. It consists mainly of blocks of flats with inner courtyards. In the 1890s Karlín changed to a typical quarter of the working class when textile manufactures and later on factory floors of heavy industry were settled (Schneibergová 2003). The whole quarter was evacuated in August 2002. The damage of the flood can still be seen by means of collapsed houses (Fig. 2). Only in September 2003 the tram lines started operating again. Some houses are still uninhabited and the missing plaster of the walls shows the water level of the Vltava River during the flood. It has to be highlighted that during flood, the Karlín area did not receive the same protection as for example the old city district even though it is more densely populated.

"River City Prague": The "River City Prague" site is located on 6 hectares at the tip of a 66 hectare disused railway yard, parallel to the Vltava River along Rohanské embankment and opposite of Štvanice Island. It forms an extension of Karlín, at a distance of only a few minutes walk from the city centre. The "River-City-Prague"-project was designed as a high standard business district, which should serve to revitalise the area. The aim is to strengthen the integration of Karlín into the existing city structure (Rivercity

Fig. 2 – Collapsed building in Karlín (summer 2002)

Prague 2003) and to build up an additional. In August 2002 the construction work was at a more or less initial state. As the complete area was seriously affected by the flood (see fig. 2), it was feared that investments could be withdrawn.

The Metro: The damage in the whole ČR during August 2002's flood amounted to 73 billion CZK (> 2,5 billion), 10 % of which was caused in the Metro system (damages or loss of technical equipment, electricity system). On average, the Metro transports more than 1 million people per day. Serious actions (i. e. closing of the stations) were not taken until August 13th – at the very peak of the flood. At that point many people still had to be evacuated from the metro stations.

This can be considered as a key problem of decision-making:

- Who should take the responsibility for the decision to close the Metro system (administration, municipal transport services)?
- What if at the end it would not have been necessary – who would have to justify the financial losses and costs, which are connected with a closure, and evacuation measures?

An early closing of the Metro would have saved a lot of money!

Troja and the Prague Zoo: Troja is one of the northern outskirts of Prague and Prague ZOO is located here. The situation in the ZOO was especially dramatic: They were prepared for a 20 to 50 year flood and it was not before the night of August 12th that the fact that it is going to be worse was displayed. If they would have been correctly informed a day earlier, more animals could have been saved. In total 1.000 animals were evacuated (750 birds, 100 mammals and 150 critters) within only three days. However, 80 birds and nine mammals died during the flood; and some died as a consequence of the stress. The lower level of the ZOO was heavily damaged and partially destroyed. Up to now, the reconstruction costs have amounted to 2 million (Lothar 2002, oral interviews).

2. 3 After the flood

The August 2002 floods reached on some rivers recurrence period of 500–1 000 years. The catastrophe claimed 17 lives, tens of thousands citizens had to be evacuated and the financial losses amounted to over 73 billion CZK (over 2,5 billion Euro). During the event, the system of dams (Vltava cascade) was of little use for the mitigation of over 500 years flood category. It has been calculated that, even if the reservoirs had more storage empty at the arrival of the flood, these would not have been able to lower the peakflow discharge of more than the 8 %.

The extremity of the flood 2002 suggests some remarks and ideas about the losses, their evaluation and protection against their repeating. The complex interaction among economical, insurancial, social and geographical aspects of such catastrophical events brings forth the need for a multicomponential model of losses assessment and after-action review of implemented processes.

2. 3. 1 Structural assesment (Losses Evaluation)

Urban planning: As a consequence of the 2002 Flood, the Urban Planning of all the high-risk zone has been corrected: it is expected that building concessions in the high-risk areas are not to be given at all. The 2002 Flood could represent the right occasion to start a project based on the rigorous control of the widespread building along the Vltava river.

Economical: industrial/structural: The Restructure Planning of the afflicted area has to be taken into consideration: not only architectural aspects, but also social and economic geography plays an important role in this project. To summarize the best solution for the situation in Karlín would be an agreement between Czech authorities and international investors: while local administrators allow finishing of the River City Prague along the Vltava river – in a high-risk zone – the foreign investors should realize adequate flood protection measures, thus protecting the old part of Karlín as well. Gradually some of the industrial activities buildings could be removed from Karlín to a low-risk zone.

Economical: financial/insurancial: As a result of the significant losses by the 2002 flood the insurance companies have redefined the risk zones. On one hand the insurance ban on areas up of Q20 agreement could help, but on the other hand it is not clear if there is a real collaboration between private insurance companies and public local institutions. In this case new studies could only help companies to plan their insurance policy in a better way, reducing their payments.

2. 3. 2 Non-structural assessments (Processes evaluation)

Emergency planning troubles: The emergency planning was more efficient and accurate than in the case of the 1997 flood: then the emergency decision-makers´ inexperience, people's confusion and the incorrect (panic-provoking) media information caused many mismanagements and troubles. After the

Fig. 3 – Working group „Floods“ at work

2002 flood experience many municipalities developed a Flood Management Plan; the emergency planning process is therefore greatly enhanced, but there is always space for improvement.

Interaction among authorities: In future, it will be necessary to enhance the real-time operational coordination among Municipalities, River Basin Authorities and Scientific Agencies, although the cooperation seems to be much better than in the 1997, when even basic communication appeared to cause problems.

Community involvement: The Community Resilience factor – a very important vulnerability measure – was improved by 1997 flood. While in the 1997 hardly anybody knew the simplest disaster behaviour rules, in the 2002 the general level of information and knowledge was much higher.

An involvement of people in the risk management can improve the CR factor. The following conditions help to reach the target:

- clear risk prevention campaign
- involvement of communities in the land-use policy
- improving the communication among communities, important companies and private insurance firms in the high-risk zones
- defining of the emergency priorities and their announcing to the citizens.

3. Conclusion

The Prague city area flooded during the summer of 2002 once again underlines just how the presence of man and his activities on the floodable banks of a river turns a natural phenomenon into disaster perceived as exceptional. The solution involves admitting that river level situations of this nature (5 160 m³/s.) may be recurrent, particularly if we consider the principle of instability, changes in the river system and even change of its main control factor – climate.

For this reason, the preventive solution, includes an adequate organization of river environment. This involves assuming that the preservation of a given river sector (in this case the stretch between Vyšehrad and Letenské sady) for its historical and patrimonial value, means to allow the water to overflow out of the channel downstream, i.e. under Letná and Josefov.

Therefore, this is either provided by a planning of exceptional water flows over the Holešovice point bars by restricting building and clearing part of the floodplain, or the overflowing waters will continue to return to the old abandoned course on the floodplain of Karlín. The other areas identified in this article as a close flood plain should exclusively contain uses compatible with their high frequency floodable character, which will doubtless avoid these problems occurring in other areas of the river's course.

Structural prevention can be carried out also through the improving of works already realized, like banks' raising and reinforcement. Furthermore, where the geomorphological situation allows, polders and dry ponds should be built along the course of the river.

It is clear that most of these structures can not be carried out in Prague: it is unavoidable that either flood-resistant buildings should only be allowed in endangered zones, or a total change of land use should be introduced, particularly in a high-crowded build up areas like Karlín. Mobile barriers represent the best additional solution on high embankments, having limited environmental and visual impact.

From the non-structural activities, it is always necessary to improve and renovate flood warnings and evacuation plans; this is possible using the sound network among institutions, as suggested above. Creating clear and strict laws in the urban planning is one of the most important things to do to prevent the worst consequences of natural catastrophes. Using the GIS – Geographic Information System – may help to determine the areas in danger and consequently classify the high-, middle- and low-risk zone.

3. 1 Was everything possible done correctly?

From a distant perspective, it is difficult to judge whether the actions taken during the flood were sufficient and if decisions were made the right way or not.

First of all, it seemed as if the work of the CHMI and the organisation of the flood forecasting system are excellent, but also limited when it comes to the point where science and technology face situations of such a particularity and extremity as during August 2002's flood.

As far as the flood protection system is concerned, in a first step, the incomplete system of the mobile barriers and secondly the question of prioritising could be discussed. Was it a good decision to give the old city-district top priority instead of protecting first area, which are more densely populated (like Karlín)?

Regarding at the situation in the Metro system, it is hard to understand why actions were taken so late. One could assume that this was (economically) calculated risk without any sense of responsibility. Let's highlight the paradox of the final results: It was the late closing of the Metro system that was responsible for the main share of the material losses in Prague.

It has to be awaited what lessons have been learned from the experience of August 2002 flood concerning the civil protection. Is there an evaluation system, which reveals deficiencies, and will those be smoothed out?

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Shrnutí

POVODNĚ 2002 V PRAZE – NÁPADY, REFLEXE A POUČENÍ

V rámci náplně Intenzivního Programu Erasmus, konaného pod názvem „Management vodních zdrojů v zemích bývalého východního bloku" na půdě Univerzity Karlovy v Praze ve dnech 22.–31.8. 2003, řešily jednotlivé pracovní skupiny zadaná témata, přičemž na kon-

ci semináře každá skupina prezentovala své výsledky jednak formou přednášky s diskusí, jednak shrnujícím článkem. Tento článek je jedním z výsledných výstupů pracovní skupiny „Povodně a protipovodňová ochrana".

Náplní článku je popis, analýza a závěrem i několik postřehů a doporučení, týkajících se průběhu povodní v srpnu 2002 v Praze. Pracovní skupina měla možnost se seznámit s následky přibližně rok po povodních. Článek je rozčleněn do tří částí, které odpovídají třem logickým krokům protipovodňové ochrany:

Před povodní – vypracování dlouhodobé strategie protipovodňové ochrany, morfohydrologické zhodnocení městského areálů, vymezení zátopových oblastí, plánování evakuace, to vše na základě studia historických podkladů a zkušeností, geomorfologického mapování.

Během povodně – hlavním cílem je zajistit bezpečnost obyvatel a snížit na minimum majetkové škody, a zajištění fungující komunikace pro koordinaci činnosti povodňových orgánů, zajištění včasné a přesné informovanosti obyvatelstva.

Po povodni – odstranění následků povodní, poučení z povodní, analýza účinnosti stávajících protipovodňových opatření, případně jejich úprava, aktualizace povodňových plánů a označení problematických míst a postupů.

Obr. 1 – Morfologie nivy Vltavy v Praze; a (přerušovaná čára) – rozsah nivy, b (čerchovaná čára) – jesepový val, c (vodorovná šrafa) – blízká niva, d (svislá šrafa) – vzdálená niva, e – ochranná hráz, f – vymezemí morfohydrologické jednotky, g – most.
Obr. 2 – Zřícený dům v Karlíně (léto 2002)
Obr. 3 – Členové pracovní skupiny „Povodně" při práci.

Members of Working Group I: ***Rafael Baena Escudero*** *is with University of Sevilla, e-mail: baena@us.es.* ***Belén García Martínez*** *is with University of Sevilla, e-mail: mbelen@us.es.* ***Laura Giacomini*** *is with University of Padua, e-mail: laura.giacomini@unipd.it.* ***Inmaculada Guerrero Amador*** *is with University of Sevilla, e-mail: Inmaguer@us.es.* ***Andrea Guaran*** *is with University of Udine, e-mail: andrea.guaran@dest.uniud.it.* ***Filip Hartvich*** *is with Charles Univesity in Prague, e-mail: hartvich@irsm.cas.cz.* ***Alexandra Králová*** *is with Charles Univesity in Prague, e-mail: AKralova@cpoj.cz.* ***Brigitte Leicht*** *(University of Mainz), e-mail: B.Leicht@geo.uni-mainz.de.* ***Andreas Licht*** *is with University of Mainz, e-mail: Kuehlimainz@gmx.de.* ***Lara Marchiol*** *is with University of Udine, e-mail: blade77@despammed.com.* ***Hannah Neu*** *is with University of Mainz, e-mail: Hannah.neu@web.de.* ***Luca Pezzullo*** *is with University of Padua, e-mail: luca.pezzullo@unipd.it.* ***Veronika Weingerová*** *is with Charles Univesity in Prague.*

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KATRIN ALAMETS, MAGDALENA BICANOVÁ, PETRA JUDOVÁ, HENN PÄRNAMETS, LEVENTE RONCZYK, SYLVA RÖDLOVÁ

WATER QUALITY CHANGES AND ITS TRENDS IN THE CZECH REPUBLIC

K. Alamets, M. Bicanová, P. Judová, H. Pärnamets, L. Ronczyk, S. Rödlová: *Water Quality Changes and Its Trends in the Czech Republic.* – Geografie – Sborník ČGS, 109, 2, pp. 181–188 (2004). – The state of environment in 1989 was a result of political and economic development of Czechoslovakia during preceding 40 years. Political and economical changes were the reason why the water quality in the Czech Republic has been significantly changing since 90´s. In this text we want to describe not only these changes, but also their causes, includingthe legislation changes due to preparation for the membership in the EU and their consequences in the field of water management, water quality, water ecosystems restoration and others.
KEY WORDS: water quality – water pollution – restoration – water law – EU enlargement (admittance to the EU) – IP Erasmus.

1. Introduction

This work attempts to introduce the contemporary state and development of the surface water quality in the Czech Republic. First, the information about the water quality before 1989 is briefly outlined. The essential part of the study presents a historical overview of the water quality changes.

Surface water quality is defined by several very complex parameters; therefore it is difficult to say something about the water quality trends, as the indicators of water quality can change independently on each other. It means that some features can improve, but others can deteriorate at the same time, and in this situation any evaluation is a difficult task.

2. Study Area, Methods, and Problems

Under the Intensive Programme (29716-IC-1-2001-1-ERASMUS IP-5) Water management in transition countries, on the subject "Water resources – their management and protection of water resources in central Europe", working group "Water Quality" studied the problems linked with given themes in following phases:

1. Preparation phase: All members of the working group received an essay with basic information about water quality and connected problems before the beginning of the Intensive Programme.
2. On-site-learning phase:
   a) Expert lectures at the Charles University, Prague
   b) Excursions with lectures in specialized organizations, facilities and

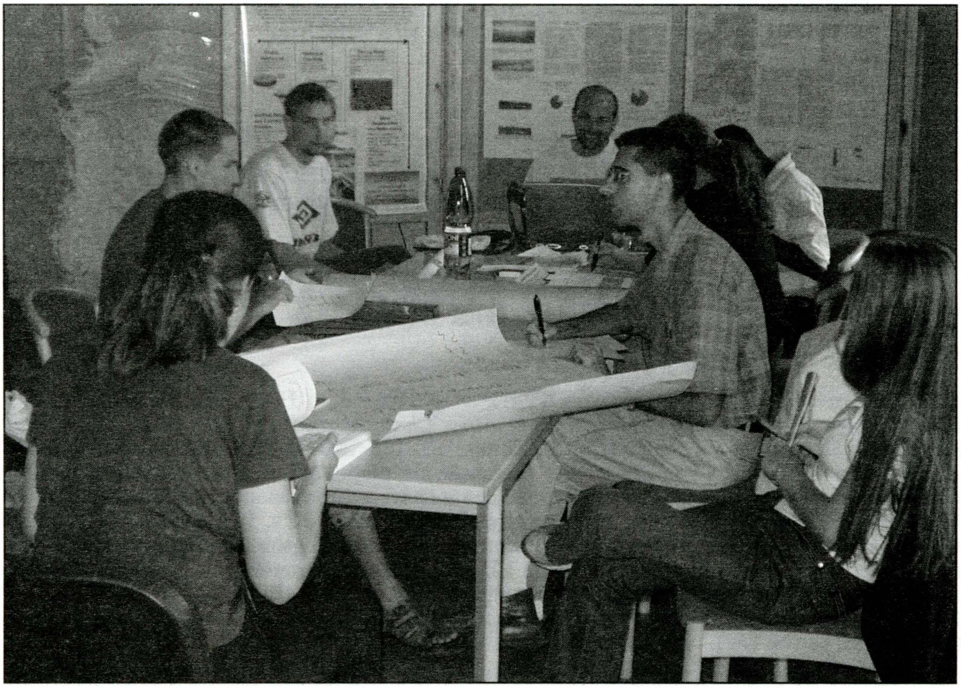

Fig. 1 – Water quality working group discussing its presentation

areas: Povodí Vltavy a.s. (Vltava catchment organization), Prague Municipal sewage treatment plant, Velké Popovice Brewery water treatment plant, small treatment plant in Pyšely village, polluted Pyšely stream, half restored pond in Velké Popovice and restored part of Stropnice river catchment

c) Measuring of basic water quality parameters in Pyšely stream

3. Post-processing phase: Discussion, processing and presentation of results (Fig. 1).

3. Water Quality in Czechoslovakia before 1989

The unsatisfactory ecological state of water ecosystems in 1989 corresponded to the whole state of environment and was a result of political and economic development of Czechoslovakia.

Considering that majority of rivers spring within the territory of the Czech Republic and only few flow in from abroad, the water pollution is practically only domestic product, which is in addition flowing into neighbouring countries.

The water quality is being monitored since 1950's in some profiles and since 1963 regularly in fixed network of checking profiles. There are 284 profiles, which are observed once in every month (www.chmi.cz). The monitoring is based on physical and chemical parameters, heavy metals, specific organic compounds and biological and microbiological samples. Water quality is described by a scale of 5 classes.

The main sources of water pollution are towns and communities, industrial factories and agriculture (Pitter 1999). Detecting of sources helped to establish many precautions, including production restrictions and limits of pollution, but it was mostly ineffective because of insufficient realization and many “exceptional” allowances. The main problems were (www.env.cz):
- Organic biodegradable pollution
- Surface erosion and diffuse runoff of fertilizers
- Frequent oil accidents (500 annually) accidental water pollution
- Contamination with specific compounds that were not included in limits and were not regularly monitored.

Another problem was in insufficient technical equipment of wastewater treatment plants, so the water was not treated enough. Treatment plants in many cities of regional importance (over 100 000 inhabitants) were overloaded and in some of them there were even no treatment plants.

4. Water Quality Changes after 1989

In development of the water quality the most significant change occurs at the beginning of the 90s. The political system change in the 1989 had an impact on water quality throughout the period of economic crisis. The environmentalists call it “gift-effect”, because the economic crisis resulted in a significant reduction on pollution. After the change of regime the mining, the chemical and textile industry as well as the farming decreased their production, and at the same time the gradually rising prices of drinking and irrigation water led to a decrease in the water consumption.

So the economical transformation brought the significant change in the pollution sources structure and the components of water quality. A characteristic feature of the pollution sources change is the fast decline of impact of the point sources of pollution as a result of decreasing industrial production, restructuring and international pressure (Langhammer 1999). EU and Germany financially supported construction and modernisation of sewage treatment plants in the beginning of the 90s.

The main significant improvement was reduction of heavy metals, radioactive pollutants, BOD_5, COD and $N\text{-}NH_4$. In spite of decreasing agricultural activities and lower usage of the $N\text{-}NO_3$ fertilizers, the contamination has not shown any significant changes (Janský 2002). Phosphorus load is still high because of missing third step of treatment in many treatment plants, which causes wide spread eutrophication problem (Fig. 2).

Discharged pollution decreased remarkably compared to the 1990 level. The recent situation in communal facilities in the Czech Republic is (www.env.cz):
- 89,8 % of population is connected to public water supply systems
- 77,4 % of population living in houses is connected to public sewerage systems
- all municipalities with population equal or above 10 000 have waste water treatment plant.

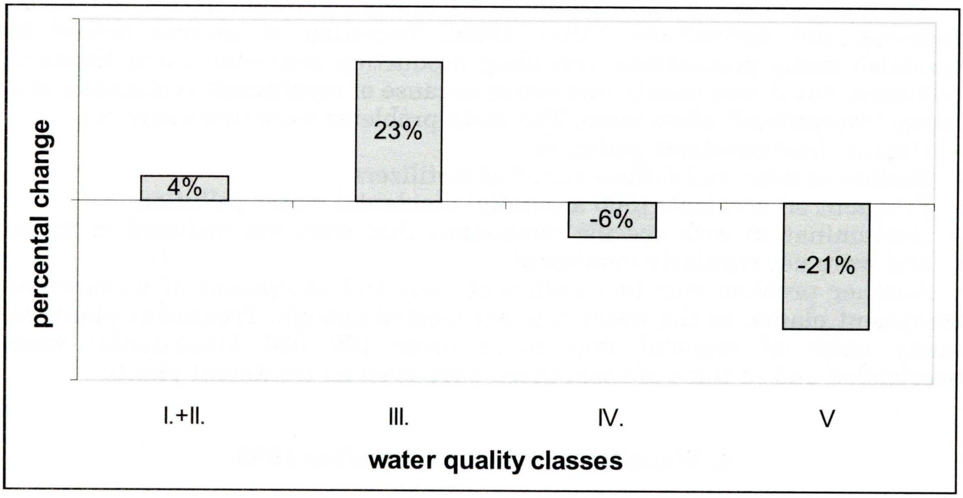

Fig. 2 – Relative change of water quality classes in the Czech Republic in the years 1991–1992 and 1999–2000. Source: Ministry of Environment, www.env.cz.

5. Water Quality in Small Watersheds

Water quality monitoring of small watersheds and small water reservoirs is being run under the auspices of agriculture water authorities. There are six monitoring programs in the Czech Republic. Four of them are specialized on the streams and two on water reservoirs.

Indicators of the volume of nutrients (N-NH_4, N-NO_3 and PT), toxic PCBs and PAH decreased. Also heavy metals (Cu, Cr, Zn, Pb) and faecal contamination (enterococcus) have debased during 2002. Very complex task for the future is to solve 'non-point' pollutants entering watercourses from wide area of the catchment. The contamination is generated by agricultural and small municipal sources. The greatest task of coming years will be the construction of missing wastewater networks and treatment plants. Without such an investment the EU Water Directive is unachievable. This environmental situation has historical roots, due to the fact that environmental aspects were neglected during the socialism and now it requires billions Euro and a new practice in agriculture.

6. Changes in Management and Protection of Water Sources

The geographical position of the Czech Republic brings the responsibility for quality of water flowing to the neighbouring countries. International treaties can constitute necessary pressure in the matter and especially Germany – as a downstream country of Elbe River and also EU member – tries to force the Czech water authorities to protect and improve surface water quality.

Main changes that the European Union brings into water sector, relates to EU Water Framework Directive 2000/60/EC. According to this Directive, the Czech water law 254/2001 was created in the year 2001. In the Czech Republic it is the Ministry of the Environment and the Ministry of Agriculture that are responsible for implementation.

The Czech water law includes a significant range of rules and recommendations and their implementation requires participation of technical institutions and other experts. In the Czech Republic, several supporting organisations are involved (T.G.M. Water Research Institute, the Czech Hydrometeorological Institute, 5 River Basin Companies, etc.).

The most important fields that are influenced by the transposition of new legislation are urban wastewater treatments, nitrates pollution from agriculture, dangerous substances, bathing water quality, drinking water, groundwater protection and quality of fresh water as an environment for the water life.

In the Czech Republic there were designated areas according to the EU directives – in terms of the Urban waste water treatment directive (91/271/EEC), the whole Czech Republic is a sensitive area, the Nitrate directive (91/67/EEC) identifies vulnerable zones on 36 % of the Czech Republic.

There is a need to ensure construction and reconstruction of sewerage networks and wastewater treatment plants particularly in settlements between 2000 and 10 000 inhabitants and reconstruction and intensification of waste water treatment plants in towns and cities of over 10 000 inhabitants. The Czech Republic requests for these steps the transitional period ongoing until December 31st, 2010.

7. Restoration of Water Ecosystems

The water quality is relatively closely connected with ecological state of landscape. To ensure international obligations, the International Commissions for Protection of Elbe, Danube and Odra Rivers were established. It was not the first step to improve water ecosystems. The Czech government proclaimed the Program for restoration of water systems in 1992 (Novotná, Kender 1997).

The goals of this program are (Láger, www.priroda.cz):

- To undo negative results of previous unsuitable land arrangements and unsuitable land management and to adapt drainages of large areas.
- To support and increase water retention capacity of landscape by slowing down surface and subsurface runoff.
- To increase infiltration and retentive abilities of soil profile and retaining of water in reservoirs, lakes or wetlands.
- To restore natural function of water streams by correcting their unsuitable modifications.
- To create protective bank areas and new bank vegetation.
- To make relatively stabile river basin.
- To support natural cleansing capacity of water by various arrangements of stream components.
- To increase stability of water regime by decreasing differences between minimal and maximal flow, etc.

This program is financed from the state budget from governmental grant. A working group from Ministry of Environment and some other organizations supervise the programme and are responsible for it (Fig. 3, 4).

8. Future Trends of Water Quality

The co-operation is the key because water provides the basis for a whole range of activities from agriculture and fishing to power generation, industry,

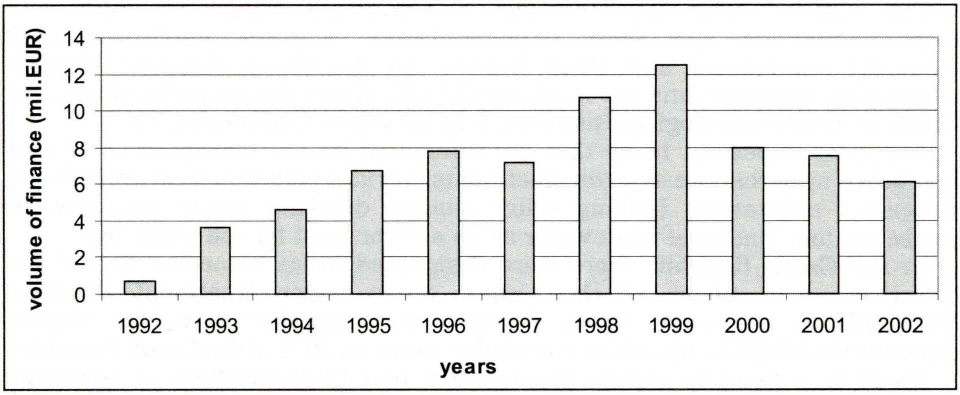

Fig. 3 – Amount of money given to restoration programmes in the Czech Republic. Source: Ministry of Environment, www.env.cz. During the years 1992–2002 nearly 2000 projects were realized. About 2,4 milliard CZK (75,5 millions) were invested. In the first period (1992–1995) relatively small projects (0,5–1,5 millions CZK) were financed. In the second period (1995–2002) bigger projects (1–3 millions CZK) overtook (www.env.cz).

Fig. 4 – Visiting of restored part of Stropnice River

transport and tourism. Also citizens, NGOs and authorities at all levels of government should be more involved, which will help to ensure that the demanding timetable of the EU legislation requirements will be met. The Framework Directive aims to prevent pollution at source and sets out control mechanisms to guarantee that all pollution sources are managed in a sustainable way.

Although today much of Europe's ground waters and surface waters are polluted, they should all reach "good status" by the year 2015.

Hopefully the same situation will be reached in the Czech Republic. It is important that the new approaches of EU have to be transposed according to the local conditions in the country considering the existing institutional framework, traditions, possibilities, needs and availability of resources.

Taking into account the real and substantial needs of the country, the changes brought by EU are not overambitious and impossible anymore.

9. Conclusion

Our working group was aimed at water quality changes and their prediction in the future. Members of our group estimated from accessible materials, lectures and excursions, that surface water quality in the Czech Republic have been improving since the beginning of 90s. The main reason is agriculture management changes and construction and reconstruction of sewage treatment plants, which still continues.

Thanks to another frame of reference on nature, higher pressure on improving of whole ecosystems emerged. Because of it water ecosystems restoration programmes were established and they try and deal with this problem.

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Nitrate Directive (91/67/EEC)

Shrnutí

TRENDY VE ZMĚNĚ KVALITY VODY V ČESKÉ REPUBLICE

V rámci mezinárodního semináře „Intenzivní program – (29716-IC-1-2001-1-ERASMUS IP-5) Management vodního hospodářství přistupujících zemí“ na téma „Vodní zdroje –management a ochrana vodních zdrojů ve střední Evropě“ se mezinárodní pracovní skupina „Kvalita vody“, složená ze studentů a pedagogů několika evropských universit, soustředila na problémy spojené se změnou a vývojem kvality povrchových vod v České republice. Během semináře vyslechla tato skupina několik odborných přednášek, navštívila specializované instituce a pracovala v terénu. Cílem práce bylo mimo jiné i seznámit členy skupiny s vývojem kvality vody v České republice a jeho příčinami.

V minulém období byla díky nešetrnému vztahu k přírodě zdevastována značná část životního prostředí včetně jeho vodní složky. Na znečištění se nejvíce podílely organické látky z bodových zdrojů znečištění a splach průmyslových hnojiv ze zemědělských ploch. K dalšímu znečišťování – především ropnými látkami – docházelo při poměrně častých haváriích (až 500 za rok) a při únicích jinak specifických látek, které nebyly ani monitorovány. Vedle intenzivního zemědělství a rozvíjejícího se průmyslu byla značným zdrojem znečištění sídla bez čistíren odpadních vod nebo s čistírnami pouze částečně funkčními.

Nejvýznamnější změna jakosti vody nastala v 90. letech minulého století. Politické změny a ekonomická deprese provázená recesí průmyslu i zemědělství se výrazně projevila na snížení koncentrací znečišťujících látek ve vodách. V následném období se snížil počet především bodových zdrojů znečištění a to jednak vlivem již zmiňované recese průmyslové výroby a jednak výstavbou a rekonstrukcí čistíren odpadních vod, iniciovanou mezinárodním tlakem a značnou především finanční podporou. Díky těmto krokům se výrazně snížily koncentrace zejména amoniakálního dusíku a organických látek.

Kvalita vody se tedy v národním měřítku zlepšila a tento trend díky dalším opatřením stále pokračuje. Do popředí se také dostal další rozměr vodního prostředí – jeho ekologická hodnota a to zejména díky změně pohledu na přírodní bohatství. Díky tomuto procesu byl pro vodní prostředí ustanoven program Revitalizace říčních systémů, z něhož plynou zdroje na uvedení částí vodního prostředí do přírodě blízkého stavu.

Obr. 1 – Pracovní skupina „kvalita vody“ připravuje prezentaci.
Obr. 2 – Relativní změna tříd jakosti vody v České republice v letech 1991–1992 a 1999–2000. Osa x – třídy jakosti vody, osa y – procentuální změna. Zdroj: Ministerstvo životního prostředí, www.env.cz.
Obr. 3 – Finanční prostředky poskytnuté programu Revitalizace říčních systémů v České Republice. Osa x – roky, osa y – objem financí (mil. EUR). Zdroj: Ministerstvo životního prostředí, www.env.cz. V letech 1992–2002 bylo realizováno téměř 2000 projektů a investováno 2,4 miliard Kč (75,5 milionů EUR). V prvním období (1992–1995) byly financovány menší projekty (0,5–1,5 milionů Kč). Ve druhém období (1996–2002) převažovaly větší projekty (1–3 miliony Kč).
Obr. 4 – Návštěva revitalizované části povodí Stropnice.

*(**K. Alamets** is a student of University of Tartu, Estonia, e-mail: kevelyn@ut.ee. **M. Bicanová** is a student of Charles University, Faculty of Science, Czechia, e-mail: madlabi@hotmail.com. **P. Judová** is PGS student of Charles University, Faculty of Science, Czechia, e-mail: petra.judova@email.cz. **H. Pärnamets** is a student of University of Tartu, Estonia, e-mail: Henn.Parnamets@ekm.envir.ee. **L. Ronczyk** is a student University of Pecs, Hungary, e-mail: ronczykl@freemail.hu. **S. Rödlová** is PGS student of Charles University, Faculty of Science, Czechia, e-mail: sylva.rodlova@seznam.cz.)*

Members of Working Group II: Water quality and restoration of water ecosystems: Belen Pedregal, Daria Quatrida, Chiara Zanini, Christian Hauzar, István Fodor, Karolína Macháčková, Lara Marchiol, Martin Hais, Massimo De Marchi, Milada Matoušková.

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MIROSLAV ŠOBR, TIBOR PÉCS, FILIP HARTVICH

LAKES AND WATER RESERVOIRS IN THE CZECH REPUBLIC

M. Šobr, T. Pécs, F. Hartvich et al.: *Lakes and water reservoirs in the Czech Republic.* – Geografie – Sborník ČGS, 109, 2, pp. 189–196 (2004). – The paper provides information about the activities, work and results of the working group "Lakes and water reservoirs in the Czech Republic" during the Intensive Programme ERASMUS in August 2003 in Prague. First part of the article provides information about water reservoirs in the Czech Republic, the second describes the excursion to the Třeboň basin, and finally we present basic information about the youngest lake in the Czech Republic, Mladotické Lake, which we also visited during our field programme.
KEY WORDS: lakes – water reservoirs – ponds – Czech Republic.

1. Introduction

Under the Intensive Programme (29716-IC-1-2001-1-ERASMUS IP-5) Water management in transition countries, on the subject „Water resources in central Europe“, the working group "Lakes and water reservoirs in the Czech Republic" analysed resources of slack water. The workshop activities can be divided into three areas of interest: large water reservoirs, south-bohemian ponds in Třeboň basin and an example of a natural, landslide dammed lake – Mladotické (Odlezelské) lake.

In the course of the seminary, many interesting lectures were given by the most prominent experts from scientific instituions as well as from Vltava River authority company. These lectures covered most of areas of current hydrological issues, concerning this working group's interests, including the occurrence and purposes of the valley water reservoirs, management of the fishponds, or the genetic typology of the lakes. Our field excursions were aimed at covering all three areas of interest, i.e. dams and large water reservoirs, of which we visited Štěchovice and Slapy reservoirs, fishponds in the Třeboň basin (excursion to the largest Czech pond Rožmberk) and Mladotické lake, where we took part in the field measurements.

2. Water reservoirs in the Czech Republic

There are in total 24 340 water reservoirs and fishponds within the territory of the Czech Republic, holding a total volume of 4,159 million m^3. Out of this number, there are 115 large reservoirs (in the year 2000), with a total volume of 3,521 million m^3.

The construction of the dams in the Czech Republic has been particularly intensive in the second half of 20th century, when the largest dammed lakes were built. In the year 1945, there were only 41 dam reservoirs in Czechoslovakia, in the year 1975 their number increased to 100 only in the Czech Republic. Nowadays, the number of large water reservoirs is approximately 115.

The dam reservoirs have wide spectrum of uses and for the most part they are multifunctional. The most important uses are:

- water supply for the local population (for example w. r. Švihov on Želivka River, main source of drink water for Prague)
- water supply for the industry and energetics (w. r. Hněvkovice, providing cooling water for Temelín nuclear power plant)
- water power production (w. r. Orlík, with biggest peak water power plant)
- flood protection (w. r. Šance, w. r. Morávka in Beskydy)
- discharge regulation and retention of the water in the landscape (Vltava cascade)
- irrigation (w. r. Rozkoš in NE Bohemia)
- other uses (including fish-breeding, ship transportation and sports and leisure activities).

For illustration see Tables 1 and 2, showing the basic parameters of the most important water works. The largest dam reservoir in the Czech Republic by the water surface is Lipno I, with the area of 4 870 ha, followed by the dam reservoir Orlík, which holds the biggest volume of water (716.5 million m^3). The highest dam is the water reservoir of Dalešice, reaching the height of 99.5 m.

Apart from the large dam reservoirs, there are also water reservoirs of minor size, built for specific purposes, for example at present non-fuctional reservoirs for the floating of timber in Moravskoslezské Beskydy and in

Tab. 1 – Reservoirs with storage capacity superior to 100 million m^3 (after The Dams in Czech Republic, 2001)

Name	River	Year of completion	Capacity	Purpose
Orlík	Vltava	1963	716,5	H, C, I, R
Lipno	Vltava	1960	306	H, C, R
Nechranice	Ohře	1968	272,4	S, H, C, I, R
Slapy	Vltava	1957	269,3	H, C, I, R
Želivka (Švihov)	Želivka	1975	266	S
Slezská Harta	Moravice	1997	219	S, H, C, R
Nové Mlýny I, II, III	Dyje	1988	133,9	C, I, R, H
Dalešice	Jihlava	1978	127,3	H, R
Vranov	Dyje	1934	122,7	H, C, S, R

Tab. 2 – The most important water power plants in Czech Republic (after The Dams in Czech Republic, 2001)

Name	River	Year of completion	Capacity (MW)	
Dlouhé Stráně	Desná	1996	650	pumped storage
Dalešice	Jihlava	1978	450	pumped storage
Orlík	Vltava	1963	364	peak
Slapy	Vltava	1957	144	peak
Lipno	Vltava	1960	120	peak
Štěchovice II	Vltava	1949 (rehab. 1995)	45	pumped storage
Kamýk	Vltava	1963	40	peak
Štěchovice I	Vltava	1944	22,5	peak
Střekov	Labe	1936	19,5	run-of-river
Vranov	Vranov	1933	16,32	peak

Šumava or numerous multi-purpose reservoirs used mostly for the fire protection and recreation in towns and villages.

Our programme included a visit of two dams on the Vltava River. First, we visited the information centre of the Vltava cascade in Štěchovice, where we learned about the history of the building of the Cascade as well as about the course of the catastrophic 2002 floods on the dams. Then we absolved a guided tour in the peak water power plant with pumped storage in Štěchovice, which was still under repairs after the floods. Other goal of the trip was the dam Slapy, situated in the Vltava cascade above Štěchovice. This is one of the biggest dams in the Czech Republic, exceeding the height of 65 m and holding over 270 mil. m^3. The warden of the lake guided us inside the body of the dam and explained us, among other, the function of its stability measuring devices.

3. Ponds in the Třeboň basin

Small water reservoirs and ponds play very important role in the water circulation by improving the water infiltration and its retention in the landscape. Particularly the fishponds are being built since 12^{th} century and therefore they strongly influence the appearance of the country as well. As mentioned above, the participants of the IP Erasmus visited the Třeboň basin, one of the most famous and typical pond basins.

The Třeboň basin is located in South Bohemia, not far from the Austria border. Its surface is formed by a flat or only slightly undulated plain, reaching the altitudes between 403–550 m a.s.l. The basin is rich in both surface and groundwaters due to its geological structure, mostly consisting of layers of sedimentary rocks and crystalline rocks in higher elevations.

This region has been influenced by human activity for more than eight centuries. A particularly important phenomenon is the building of an extensive system of fishponds, shallow water basins of various size, artificial lakes with area ranging from 0,1 to several hundreds hectares. The ponds can be classified according to their water source:

- the sky ponds
- headwater ponds
- river and brook ponds.

The first group ponds are supplied only by the rainwater, which is rather soft and contains only small amount of mineral substances. The ponds, belonging to the second group, are fed by the spring water, localized either on the shores or on the bottom. The spring water may be significantly mineralised. The third category is the most common type, these ponds have the inflow of cool and well-oxygenated water from the water flows, which is suitable for the biota.

As a rule, people nowadays automatically connect the characteristic Czech landscape with ponds, scattered patches of forest and meadows, mixed with fields. This image can actually be found typically in Třeboň basin. Some of the ponds lie in the open countryside, while hills and forests embrace others, but they all have one thing in common: they are of antropogenic origin.

The Třeboň basin has a unique network of artificial canals, which fill and drain the fishponds used for local traditional fish breeding (particularly carps). There are nowadays 465 fishponds in the basin, covering total area of 7 484 hectares. The tradition of fish breeding that made the Třeboň region famous dates back for many centuries (Kuklík, Hrbáček 1984).

The oldest fishponds were built almost 900 years ago. The first pond in Bohemia was constructed as early as in the year 1115 a.d. The oldest pond in southern Bohemia is Dvořiště – founded in 1363 a.d. The building started with coming of the Christian monks, who founded several monasteries in the region. The development of the pond-building craft may be described on the example of the Třeboň basin. The first significant development of the pond building took place during the era of kings Jan Lucembursky and Karel IV., in the 14th century. Then the ponds mainly served as a drinking water source and also already for the fish breeding, securing thus the source of additional food.

During the Hussite wars, the development was temporarily suppressed. However, in the first half of the 15th century, under the reign of the Rožmberks (one of the mightiest noblemen family in Czech kingdom), it took a new direction. By 1450 a.d., there were only about 20 fishponds, with an area of 700 hectares. The turn of the 15th and 16th century and the 16th century was the busiest period of fishpond construction. By that time, in the regions with fertile soils the pond farming was abandoned (for example in the Elbe valley).

Famous names of important fishpond builders of this era include Štěpánek Netolický, Jakub Krčín, Mikuláš Ruthard (Janský, Šobr et al. 2003). The ponds Velký Tisý, Opatovický and Horusický were constructed by Josef Štěpánek Netolický under the reign of Duke Petr Vok of Rožmberk. However, Netolický´s paramount work was the Golden Canal (Zlatá stoka), which supplies water into the largest pond in southern Bohemia from the Lužnice River.

In the second half of the 16th century, Jakub Krčín of Jelčany became renowned for the construction of large-sized ponds and he also contributed to extension and modernisation of others (Dvořiště, Opatovický etc.). Among other works, he constructed the pond Rožmberk (1590 a.d.), then the largest pond in Europe and currently the biggest pond in Czech Republic – with water area of 489 hectares (originally even 1 060 hectares).

The third famous developer and builder was Mikuláš Ruthard, who played an important role in the construction of the pond system near Chlumec. He supervised the construction of the ponds and became renowned for the building of the Staňkovský pond (1544 a.d.), which is the longest and deepest of the Czech ponds, and holds the biggest amount of water.

In the 17th century, especially after the Thirty Years War, pond fishing declined. At the end of the 18th century, during the reforms by Austrian emperor Joseph the second, the ponds had to give way to more profitable wheat growing. The beginning of the 19th century was a period of rapid pond drying in southern Bohemia and in the course of the years 1825–52 five large and twelve smaller ponds in the Třeboň basin were abandoned. However, some of them were renewed in the second half of the 19th century.

Aside from the Třeboň basin, many ponds are located in the České Budějovice basin, in Blatensko (southeast from Plzeň), in Polabí, and in the basins along the lower courses of the rivers Dyje and Odra. In total, there are approximately 21 000 ponds with an area of 49 000 hectares in the Czech Republic, out of which 40 000 hectares in Bohemia. Ten ponds with surface of more than 200 hectares are located in southern Bohemia. The ponds of similar size occur in other places in the Czech Republic only sporadically – lake Máchovo (north Bohemia), Nesyt (southern Moravia), Velké Dářko (north of Českomoravská highland) (Janský, Šobr et al. 2003).

Nowadays the main function of the ponds is the fish-production for profit, both for the Czech market and for the export. In Třeboň basin, the most of the fishponds are owned and operated by the joint-stock company Třeboň Fisheries. Some of the ponds have other uses as well, like flood-control and recreation (for example Máchovo lake).

Apart from these functions, the ponds play an important role in the protection of natural environment as well, some of the bogs and ponds are even protected as wetlands of international significance. There are many particularly protected areas, including two Ramsar Sites (Třeboň Fishponds and Třeboň Peatlands), five national natural reserves, 27 other small-scale protected areas and an European Ecological Network core area (Ševčík, Nedbalová 1995). The Třeboň Biosphere Reserve is a unique birdlife territory. In the core area as well as in the natural reserves and monuments within the buffer zone, many unique and endangered species occur.

Current problems of ponds include eutrophization, caused by intensive agriculture and fish-farming management (fertilizing, liming, large fish stocks), and siltation, which has been a problem since the 15th century due to heavy load of clayey material in the watercourses. During our excursion to the dam of Rožmberk pond, we discussed the situation on the pond in the course of 2002 catastrophic flood and the current ecological problems of the Třeboň basin ponds with the warden of the pond.

4. Mladotické (Odlezelské) Lake

Among the tasks of our working group were the field research and measurements, which we performed on our field trip to Mladotické lake.

The Mladotické (called also Odlezelské) lake is the youngest natural lake in the Czech Republic. It originated in the year 1872 after intensive rainfall,

Fig. 1 – Practical work on Mladotice Lake

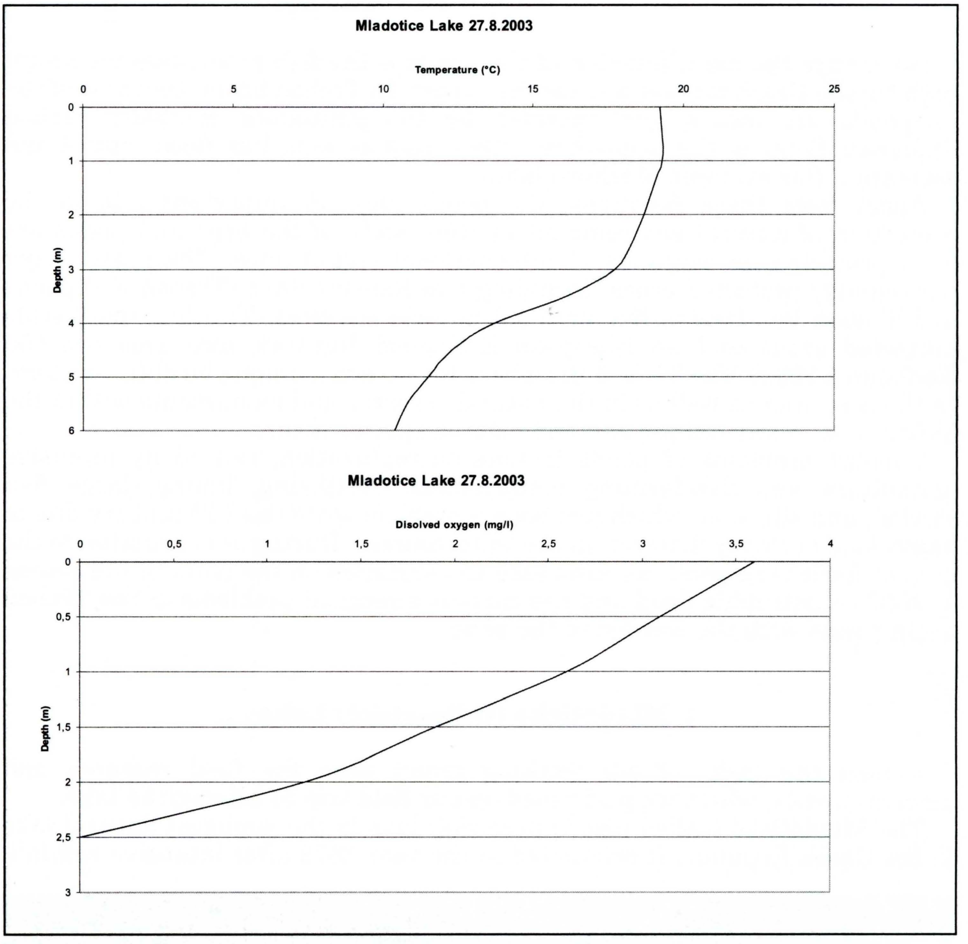

Fig. 2 – Vertical profiles of water temperature (typical summer vertical stratification) and dissolved oxygen (oxygen amount is measurable only to depth of 2,5 m)

when the valley of the Mladotický brook was blocked by a landslide. The brook-valley was dammed in the lenght of about 300 meters. Some basic parameters of the lake:

- surface area: 4,55 hectares
- maximum depth: 6,7 m
- maximum width: 80 m
- 12 villages in catchment area.

All results of research activities (Janský, Urbanová 1994; Janský 2003; Janský, Šobr et al. 2003) were presented during the field work The members of the Working Group took part in measuring of physical and biological characteristics of water quality (conductivity, temperature, transparency, water colour, dissolved oxygen, zooplankton – see fig. 1, 2). We discussed results of our observation and also current ecological problems (nutrification, siltation, and negative impact of agriculture) on the water ecosystem of the Mladotické Lake.

5. Conclusion

Under the Intensive Programme Water management in transition countries (on the subject „Water resources in central Europe“) the Work Group Lakes and water reservoirs in the Czech Republic give informations about genetic types of slack waters. Our lectures and excursions was divided into three parts. Under the excursion to the central Bohemia participants saw Slapy and Štěchovice water reservoirs. There is a long tradition of geographic research of Mladotické (Odlezelské) Lake, which is phenomenal of origin. Participants of group Lakes and water reservoirs could see under the one-day excursion to catchement of lake all problems (nutrification, siltation etc.). Under the excursion to the South Bohemia participants gave lecture about fishponds in Třeboň basin direct to history and present problems.

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Shrnutí

JEZERA A PŘEHRADNÍ NÁDRŽE V ČESKÉ REPUBLICE

Článek podává informace o činnosti a výsledcích pracovní skupiny „Jezera a přehradní nádrže v České republice“ v průběhu intensivního programu ERASMUS v srpnu 2003 v Praze. V první části se zabýváme problematikou přehradních nádrží, druhá část je věnována rybníkům v Třeboňské pánvi, v poslední části uvádíme základní informace o Mladotickém (Odlezelském) jezeru.

V průběhu IP Erasmus posluchači vyslechli několik přednášek, kde dostali informace o všech genetických typech jezer na území Česka. Zorganizovali jsme rovněž několik terénních exkurzí – přehrady Slapy a Štěchovice, Mladotické (Odlezelské) jezero a rybník Rožmberk v Třeboňské pánvi.

Na území Česka se nachází celkem 24 340 vodních nádrží a rybníků, které zadržují celkem 4,159 mld. m^3. Velkých nádrží je k roku 2000 evidováno 115, ty zadržují celkem 3,521 mld. m^3 vody. Nejvíce přehrad bylo postaveno po roce 1945. Přehrady mají různé funkce, většinou jsou víceúčelové. Slouží jako zásobárny pitné vody (Švihov), zásobárny vody pro průmysl (Hněvkovice), jsou na nich instalovány vodní elektrárny, plní protipovodňovou funkci, jsou regulátory průtoku vody v řekách, jejich voda je využívána na zavlažování a rovněž slouží k rekreačním účelům (sport, rybaření, koupání). Základní parametry některých našich vodních nádrží jsou v tabulkách 1 a 2 (Dams in Czech Republic 2000).

Intenzivní program zahrnoval návštěvu vodních děl Slapy a Štěchovice, které jsou součástí Vltavské kaskády. Účastníci programu se seznámili s funkcí Vltavské kaskády v době katastrofálních povodní v srpnu 2002.

Nejvýznamnější rybniční soustava v Česku se nachází v Třeboňské pánvi. První rybníky byly založeny ve 12. století, velký rozvoj rybníkářství nastal ve 14. století za vlády Karla IV. a v 15.–16. století. Nejznámějšími staviteli jsou Štěpánek Netolický a Jakub Krčín z Jelčan, kteří se proslavili stavbami Zlaté stoky resp. rybníka Rožmberk (Kuklík, Hrbáček 1984; Ševčík, Nedbalová 1995). V rámci exkurze do Jižních Čech jsme navštívili náš největší rybník Rožmberk (489 ha). Byli jsme seznámeni se současným ekologickým stavem a funkcemi jihočeských rybníků. Vyzdvižen byl též vliv celé rybniční soustavy na průběh povodně na Lužnici v srpnu 2003.

Mladotické (Odlezelské) jezero je nejmladším přírodním jezerem v Česku. Vzniklo přehrazením údolí Mladotického potoka mohutným sesuvem v důsledku intenzivních přívalových srážek v roce 1872. V době terénní exkurze s účastníky programu jsme prezentovali dosavadní výsledky výzkumu (Janský, Urbanová 1994; Janský 2003; Janský, Šobr et al. 2003). Rovněž jsme prováděli měření základních fyzikálních vlastností vody (průhlednost, teplota, vodivost, rozpuštěný kyslík) a odběry zooplanktonu (obr. 1 a 2). Rovněž jsme diskutovali současné ekologické problémy celého povodí.

Obr. 1 – Praktické práce na Mladotickém jezeře

Obr. 2 – Vertikální teplotní profil (typické letní zvrstvení) a rozpuštěný kyslík (rozpuštěný kyslík se vyskytoval pouze do hloubky 2,5 m); a – osa x – teplota (°C), osa y – hloubka (m); b – osa x – rozpuštěný kyslík (mg/l), osa y – hloubka (m).

*(**Miroslav Šobr** is with Charles University in Prague, Faculty of Science, Department of Physical Geography and Geoecology, Albertov 6, 128 43 Praha 2, Czechia; e-mail: sobr@natur.cuni.cz. **Tibor Pécs** is PhD student, Institut of Geography, Faculty of Science, Univerzity of Pécz, Hungary. **Filip Hartvich** is with Charles University in Prague, Faculty of Science, Department of Physical Geography and Geoecology, Albertov 6, 128 43 Praha 2, Czechia; e-mail: f.hartvich@volny.cz.)*

Members of Working Group III: Lakes and water reservoirs: Adnan Daas, Antonella Rondinone, Arvo Järvet, Bohumír Janský, Franca Battigelli, Giovanni Sistu, Julek Česák, Paola Porcu, Ricardo Biddau, Volker Heidt, Yameogo Lassane.

Arrived to the editorial board on March 2, 2004

IP Erasmus cooperation of geographical institutions

UNIVERSITY OF CAGLIARI, FACULTY OF POLITICAL SCIENCES,
Department of Earth Sciences, Department of Economic and Social Researches
Viale Sant'Ignazio da Laconi 78, I-09123 Cagliari, Italy
Contact person in the IP Erasmus: Dr. Giovanni Sistu
e-mail: sistug@unica.it, website: http://www@unica.it

The Studium Generalis Kalaritanum was founded in 1607 along the lines of the old Spanish Universities of Salamanca, Valladolid and Llerida. Originally, it offered degrees in Law, Latin, Greek and Hebrew Literature, Liberal Arts, Medicine, Surgery, Philosophy and Science. During the 19th and the 20th centuries, increasing emphasis was placed on research activities, and internationally recognized research findings, especially in the fields of Medicine, Physics, Chemistry, Biology and Archeology, were obtained. Today, the great dream, to expand the body of the University of Cagliari, has almost come true, thanks to the new University area in the outskirts of the town. The new campus is located in Monserrato, on an area of 73 hectares. It will host the science departments and their respective institutes.

Main hydrological research projects since 2000:

Geochemical processes of natural waters. Impact of dismantled mines on water resources (Prof. Luca Fanfani, Department of Earth Sciences)

The water environment and its improvement. (Prof. Felice Di Gregorio, Department of Earth Sciences)

Water policy in Sardinia. Administration of the water resources and related economic conflicts (Dr. Giovanni Sistu, Department of Economic and Social Researches).

Key publications:

CIDU, R., BIAGINI, C., FANFANI, L., LA RUFFA, G., MARRAS, I. (2001): Mine closure at Monteponi (Italy): effect of the cessation of dewatering on the quality of shallow groundwater, Applied Geochemistry, 16, No. 5, pp. 489-502.

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SISTU, G. (2002), El recurso invisible: la gestión del agua en Cerdeña", in "Actes del I Congrés Balears 2015. L'aigua. Perspectives de futur", Questions de Balears 2015, No. 1, Sa Noxtra, Palma (Illes Balears), pp. 193-213.

JOHANNES GUTENBERG UNIVERSITY OF MAINZ,
Department of Geography, RegioComun – Institute for Strategic Regional Planning

Becherweg 21, D 55 099 Mainz, Germany
Contact persons in the IP ERASMUS: Prof. Dr. Volker Heidt, Dr. Jamill Sabbagh, Brigitte Leicht, MSc.
e-mails: V.Heidt@geo.uni-mainz.de, B.Leicht@geo.uni-mainz.de, website: http://www.uni-mainz.de

For many years, the research work of the founders of RegioComun – Institute for Strategic Regional Planning at the Department of Geography, University of Mainz has been dedicated to the diversity of theoretical and methodological problems in the field of future-oriented land-use management and planning. The importance of sustainable land use patterns becomes especially apparent in areas highly sensitive to natural disasters such as floods. During the last years, the research group of RegioComun has conducted several projects treating the issue of sustainable land use management in flooding areas.

Main hydrological research projects since 2000:

Integrated Concept of Land use in the Flooding Area of the Hördter Rheinaue, commissioned by: Ministry of the Environment, State of Rhineland-Palatinate; in cooperation with: WWF-Institute for Floodplain Ecology and BCE – Björnsen Consulting Engineers, Koblenz; duration: 1998–2000

IRMA-ID: Multifunctional Development of Flood-prone Areas – Premises and Perspectives for Agricultural Uses in Flood-prone Areas of the Upper Rhine River, commissioned by: State Office for Water Supply and Distribution, State of Rhineland-Palatinate (2001)

Regio-Economical Incentive Programme for the Hördter Rheinaue, commissioned by: Ministry of the Environment, State of Rhineland-Palatinate; duration: since 2001

UNIVERSITY OF PADUA, Department of Geography "G.Morandini"
Via del Santo, 26, I 35123, Padua, Italy
Contact persons in the IP ERASMUS: Prof. Dr. Pierpaolo Faggi, Dr. Massimo De Marchi
E-mails: ; , website:http://www.geogr.unipd.it

Department of Geography "G. Morandini" at University of Padova, is the oldest Italian department of Geography, it was instituted in 1873. The department deals with all the issues of geography from physical to human geography, and it is connected with 3 faculties: Arts, Natural Sciences, Education. There are more than 1600 students taking the courses of different geographical issues offered by the department: physical geography, environmental geology, geomorphology, GIS, human geography, social geography, regional geography, geography of development, geography of population, history of geographical thought, historical geography, cartography, didactic of geography, geography of tourism, applied geography. Actually the department is responsible for the 3 years "laurea" (BA) in "Geografia dei processi territoriali" (Geography of territorial processes), with about 50 student per year and the 3 years "laurea" (BA) in "Cooperazione allo sviluppo" (Development cooperation), with about 60 student per year. At post graduate level the department offer the 3 years PhD in Human and environment with 4 places every year. The department is strongly involved in teaching innovation based on cooperative learning, group work, field works, stages and contacts with local governments, private or governmental organizations, NGO. There are agreement and international cooperation among the department and African Universities (Sudan, Camerun, Burkina Faso).

Water related research:

Dynamic and evolutionary geomorphology – the research dels with the recent evolution of Po Plain and with the karst environments.

Glaciology – the research dels with glaciers' fluctuations, glaciers' regime, reconstruction of mass balance of glaciers. The department participate also in Antarctic research.

Human and environment – in this area research deals with interface land-sea, mountain environments, agriculture.

Historical geography – the research deals with the study of Po river delta.

Environment and territory in developing countries – in this area research deals with water management, environmental conflicts, hydraulic territorialisation. Many African hydrological basins are studied: Nile, Senegal, Niger, Volta, Chad-Logone.

Key publications:

BERTONCIN, M., PASE, A. (2003): Debiti d'acqua e crediti di sviluppo. I conti aperti del Ciad. 25, Universita di Padova, Dipartimento di geografia, pp. 1-29.

BERTONCIN, M., SISTU, G., CURA, A. (2001): Acqua, Attori, Territorio/ Water, Stakeholders, Territory. Cagliari: C.U.E.C. (Italy), pp. 1-256).

BONDESAN, A., CANIATO, G., GASPARINI, D., VALLERANI, F., ZANETTI, M. (2003): Il Brenta, Cierre Edizioni, Verona (Italy).

CASTIGLIONI, G. B., PELLEGRINI, G. B. (2001): Note illustrative della Carta Geomorfologica della Pianura Padana / Illustrative Notes of the Geomorphological Map

of Po Plain. Supplementi di Geografia fisica e Dinamica Quaternaria, 4, 208 p., supl.
DE MARCHI, M. (2002): Environmental security and regional sustainability: focusing on development coalitions and resource flows. In: Diamantini, C.: The region: approaches for sustainable development, Temi publisher, Trento, pp. 265-283.
FAGGI, P.; BETHEMONT, J.; ZOUNGRANA, T. P. (2003): La Vallée du Sourou (Burkina Faso). Gencse d'un territoire hydraulique dans l'Afrique sahélo-soudanienne, L'Harmattan, Paris, pp. 1-230.

UNIVERSITY OF PÉCS, FACULTY OF SCIENCES,
Institute of geography, Department of Environmental Geography and Meteorology

Contact persons in the IP ERASMUS: Prof. Dr. István Fodor
Address: H-7624, Pécs, Ifjusag ut. 6.
e-mail: fodor@rkk.dti.hu http://www.isc.pte.hu

The Institute of Geography, University of Pécs belongs to the Faculty of Sciences. It is divided into nine departments, and has 40 employees including the administrative staff. Institute of Geography awards Bachelor's Degree, Teacher's Diploma, and also offers Ph.D program, named "Earth Scincies". One of these nine departments is the Department of Environmental Geography and Meteorology, focussing on environmental issues and the regional development. Among other research project the department also conducts research on water resources and water management, co-operating with local authorities, governmental institutes and neighbouring countries, at local, regional and international scale.

Main hydrological research projects since 2000:

Ministry for Environment: Historical survey of floodplain transformation in the Danube-Drava National Park 2000–2003

Ministry of Environment: The Danube-Drava National Park, a Region Organised on the Basis of Natural Values, 1999–2001

Hungarian Scientific Research Fund. Heavy-metall content of suspended sediments of Hungarian part of Tisza River. 2002–2003

Key publications since 2000:

HALASI-KUN, G. J., FODOR, I., LO PINTO, R., SKALA, CH., eds (2001): Drava valley – A Sciene for International Cooperation, Pollution and Water Resources Columbia University Seminar Proceedings.
HALASI-KUN, G. J., FODOR, I., LO PINTO, R., eds (2003): Studies of Environmental Protection in the Carpathian Basin, Pollution and Water Resources Columbia University Seminar Proceedings.
LÓCZY, D. (2004): Danube. In: Gupta, A. (ed.): Large Rivers. John Wiley and Sons, Chichester (in print).
SZEDERKÉNYI, T. (2004): Heavy-metall content of suspended sediments of Hungarian part of Tisza River. Acta Geologica Hungarica, Special Vol. for Szédeczky-Kondor Centennial (in print).
FÁBIÁN, SZ. (2004): Geomorphological Hazards of Lower Reaches of Danube in Hungary, Geomorphologia Slovaka 3, No. 2, pp 77-80.

CHARLES UNIVERSITY IN PRAGUE, FACULTY OF SCIENCE,
Department of Physical Geography and Geoecology

Albertov 6, CZ 128 43 Prague 2, Czechia
Contact person in IP ERASMUS: Dr. Milada Matoušková
e-mail: matouskova@natur.cuni.cz, website: http://www.natur.cuni.cz

The Department of Physical Geography and Geoecology is linked to the former Department of Cartography and Physical Geography founded in 1953. Its present form dates from 1991 and its activities traditionally include the whole spectrum of the scientific branch of Physical Geography – geomorphology, meteorology and climatology, hydrology, pedogeography and biogeography and recently also the problems of Geoecology. The scientific activity of the Department is characterized at present by a synthetic approach to solved scientific problems. The main directions of the Department's scientific activity cover nearly the whole spectrum of taught problems: regional geomorphological field analysis and classification; geomorphological mapping, research of water erosion; relief development in high mountain regions, engineering geomorphology; anthropogenous transformation of the natural sphere; surface waters hydrological regime, floods and flood protection, pollution of waters and sediments; dynamics of suspended and dissolved sediment load, climatic regionalization and regional climatological research. In all these fields, the scientific activity of the Department covers not only basic, but also applied research. This second group includes for instance: studies connected to the floods and flood protection, pollution of surface water and sediments within the Elbe project; studies on risks in the localities of nuclear power plants and nuclear waste deposits; research on air pollution in Prague and some other projects going on in co-operation with, or by order or request of, different institutions.

The pedagogical activity of the Department includes bachelor degree courses in all geographical branches, including a double-discipline course of Geography. It also provides a master's degree course in Physical Geography and organizes a post-graduate course of that orientation.

Main hydrological research projects since 2000:

Charles University Foundation, Nr. 178/2000/B-GEO, Dynamics of suspended and dissolved sediment load in various geographical conditions of the Czech Republic (2000–2002), Z. Kliment, J. Langhammer

Charles University Foundation, Nr. 211/2001/B/GEO, Specific pollution of water bodies in the Berounka river basin (2001–2003), J. Langhammer, M. Matoušková

COST Action 623: Soil Erosion and Global Change, Evaluation of nonpoint pollution sources, (2002–2003), J. Langhammer, Z. Kliment, J. Stehlík

Czech Science Foundation, Nr. 205/03/Z046, Environmental changes impact on flood efects. (2003–2004), J. Langhammer et al.

Czech Science Foundation, Nr. 205/03/1264, Lakes of the Czech Republic (2003–2005), B. Janský et al.

Key publications since 2000:

JANSKÝ, B. (2001): Nuevo levantamiento geodésico – hidrográfico de los orígenes del Amazonas. Revista Geográfica, Número 128, Julio – Diciembre, 200, pp. 151-154.

JANSKÝ, B., ŠOBR, M. et al. (2003): Lakes of the Czech Republic. Faculty of Science, Charles University in Prague, Department of Physical Geography, Prague, 216 p.

KLIMENT, Z. (2000): Balance, regime and geochemistry of suspended sediment of the Blšanka River. Geography–Journal of Czech Geographic Society, 105, No. 3, Czech Geographic Society, Praha, p. 255-265.

LANGHAMMER, J. (2002): Evaluation of Non-point sources of Pollution of Surface Water Using GIS, Acta Universitatis Carolinae, Environmentalica 16, Karolinum, Praha, pp. 81-88.

MATOUŠKOVÁ, M. (2002): Methods of Ecomorphological Evaluation of Stream Habitat Quality, Acta Universitatis Carolinae, Environmentalica 16, Karolinum, Praha, pp. 63-70.

UNIVERSITY OF SEVILLA, FACULTY OF GEOGRAPHY AND HISTORY,
Department of Human Geography

Address: María de Padilla s/n 41004 Sevilla, SPAIN
Contact persons in the IP ERASMUS: Dr. Belén Pedregal Mateos
e-mail: bpedregal@us.es, website: http://www.us.es

The Department of Human Geography of Seville is part of the Faculty of History and Geography, and it has about 16 employees including administrative staff. This Department together with the Department of Physical and Regional Geography, offers a Bachelor's Degree in Geography, and also offers independently a Ph.D. program, which has about 30 students. The Department has been working for the on hydrological risks management closely connected with regional and spatial planning. Its work has had not only an academic orientation, but it has also participated, as independent and external advisor, in various phases of preparation and evaluation of projects related with water management and spatial planning, both at a governmental and a non-governmental level, at regional, national and European scale.

The Department of Physical Geography also offers a Ph.D program named "Climate Change and Natural Hazards" with courses on fluvial system and restoration. The research group "Applied Physical Geography and Patrimony" has been working for the last years on fluvial geomorphology, river restoration and fluvial system management, at local and regional scale.

Main hydrological research projects since 2000:

Programme CNRS/SHS Eau, environnement et société Centre Nacional de la Recherche Scientifique, Laboratoire Dynamiques Sociales et Recomposition des Espaces (LADYSS) – UMR 7533 – (CNRS): Crises hydrauliques et perception du risque environnemental en Méditerranée occidentale. 2003–2006.

EC Science Research Development: Environment and Climate Fifth Framework Programme. European Commission, D.G. XI. Contract EVK1-CT-2000-00074: "Integrated Evaluation for Sustainable River Basin Governance" (ADVISOR). 2001–2003.

EC Science Research Development: Environment and Climate Fourth (EC) Framework Programme. European Commission, D.G. XI Contract Number: ENV4 CT97 0447. "Societal and Institutional Responses to Climate Change and Climatic Hazards: Managing Changing Floods and Drought Risk" (SIRCH). 1998–2000.

Ministerio de Fomento: Evaluation of the deterioration and analysis by damages for river erosion-sedimentation in bridges of the national network of highways and railroads in western Andalusia: causes, prediction and proposals for conservation of the infrastructure. 2003–2006.

Convenio de colaboración entre la Consejería de Obras Públicas y Transportes de la Junta de Andalucía y la Universidad de Sevilla: El Canal del Bajo Guadalquivir en el contexto de l desarrollo, configuración actual y perspectivas futuras del sistema hidráulico regional. 2002–2004.

Key publications:

MORAL, L. (2001): Planification hydrologique et politique territoriale en Espagne, Hérodote. Revue de Géographie et de géopolitique, Paris, No. 102, pp. 87-112.

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BAENA, E., R., GUERRERO A., I. (2002): Integrated assessment and management of the ecosystems affected by the Aznalcollar mining spill (SW, Spain)" IOC/ICAM/UNESCO Technical report. Paris, pp.115-120.

UNIVERSITY OF TARTU, INSTITUT OF GEOGRAPHY,

Department of Physical Geography and Landscape Ecology

Address: Vanemuise Str. 46, 51014 TARTU, Estonia
Contact persons in the IP ERASMUS: Prof. Dr. Arvo Järvet
e-mail: ajarvet@ut.ee, website: http://www.geo.ut.ee

The Department of Geography in Tartu University is established in 1919. The Chair of Physical Geography and Landscape Ecology (Head prof. Ülo Mander) is teaching both traditional disciplines of physical geography and fast developing aspects of landscape analysis and environmental sciences. Scientific research is carried out in several aspects of the same fields as nutrient fluxes in landscape, landscape changes, changes in climate and related reactions in hydrology and water management. Wide cooperation with other research institutions, local authorities and state departments both in Estonia and worldwide is an essential part of everyday activities. The main water related studies are connected with researches of the use of natural and seminatural wetlands for waste-water purification, nutrient fluxes in landscapes and water management planning using integrated river basin principle.

Main hydrological research projects since 2000:

INCO-COPERNICUS A2 grant No ERBIC-CT96-0100 on "Research and Information on Water Purification by Means of Constructed Wetlands (BIOPLATOS) in the Ukraine, Supported by Studies in Estonia, Finland, the Netherlands and Sweden", 1996–2000, Contractor Prof. Ü. Mander.

EU 5FP RTD project PRIMROSE Process based Integrated Management of constructed and Riverine wetlands for Optimal control of wastewater at catchment ScalE (EVK1-2000-00728), 2000–2003, Contractor Prof. Ü. Mander.

INCO-COPERNICUS grant ICA2-1999-10052 Kola Water Quality, 2000–2004, Associate Contractor Prof. Ü. Mander.

Research project of UNEP "Country Case Study on Climate Change Impacts and Adaptation Assessment of Water Resources in the Republic of Estonia. UNEP/GEF project GF/2200-96-45" , associate project leader Arvo Järvet.

Research Project of Estonian Ministry of Environment "Human Impact on the Waterbodies and Water Management Planning on the Lake Võrtsjärv Catchment Area", 2001–2004, project leader Arvo Järvet.

Key publications:

MANDER, Ü., KUUSEMETS, V., LÕHMUS, K. and MAURING, T. (1997): Efficiency and dimensioning of riparian buffer zones in agricultural catchments. Ecological Engineering, 8, pp. 299-324.

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UNIVERSITY OF UDINE, Dipartimento Economia Societa Territorio

Via delle Scienze 208, I 33100 Udine, ITALY
Contact person in the Erasmus IP: Prof. Dr. Franca Battigelli
e-mail: franca.battigelli@uniud.it, website: http://web.uniud.it

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At the University of Udine, geographical studies are developed in two different departments: Human Geography is part of the multidisciplinary Department of Economics, Society, Territory, while Physical Geography belongs to the Department of Geo-resources and Territory. With regard to didactics, both Human and Physical Geography are offered as compulsory or optional teaching courses in a number of degree courses in several faculties: Human Geography in the Faculty of Arts, of Modern Languages, of Teachers' Training; Physical Geography in Engineering and Agricultural Sciences. Besides, the following curricula in Human Geography are offered: a 3-years Socio-Anthropo-Geographical curriculum within the first-level Degree course in Arts; a second-level Degree course in Geography (2 years). The section of Human Geography has been working for a number of years in water-related research and teaching, with different approaches and orientations that can be summarized as follows.

Water related research:

1. Regional studies: Tourism and (un)sustainable water demand in Jordan.

Accessibility to water in the West Bank and Gaza Strip: international and inter-uses conflicts, water quality and quantity, unequal access.

Flood hazard in the Tagliamento river basin (Friuli, Italy): the perception of risk from different stakeholders, the debate about solutions and their sustainability.

Increasing water demand for tourism in Lignano Sabbiadoro seaside resort (Friuli, Italy).

2. Water and education. Towards a "culture of water".

Water in the landscape: studying, conserving, managing waterscapes.

Water-related names of places: documents of territory-forming processes, signs of identity, cultural heritage.

Didactics of water at the School for Teachers' Training. Research about case studies; elaboration of multimedia teaching units on water.

Presented Posters on the IP ERASMUS Prague 2003

ALAMETS, K. (2003): Comparison of rivers ecosystems in Estonia by chemical and biological monitoring data. University of Tartu

BATTIGELLI, F. (2003): Hydric Problems in West Bank and Gaza. University of Udine

COMBE, C. (2003): The "Lyons's Y": for a historical and spatial approach to flood hazard in urban and periurban areas. University of St. Etienne

GUARAN, A., MARCHIOL, L. (2003): Tagliamento river, between floods and flood protection. University of Udine

HAIS, M. (2003): Changes in Land Cover Temperature and Humidity Parameters Resulting from Spruce Forests Decay in the Centre of the Šumava National Park. Charles University in Prague

HAUZAR, CH. (2003): Waterconflicts in the Middle East. University of Mainz

JÄRVET, A. (2003): Spatial planning in water management (Lake Võrtsjärv basin case study in Estonia). University of Tartu

JUDOVÁ, P. (2003): The Quality of Surface Waters of the Šlapanka River Catchment. Charles University in Prague

LEVENTE, R. (2003): Possibilities of sustaintable water usage of Pécs. University of Pécs.

LICHT, A., NEU, H. (2003): Ecocity Shanghai. University of Mainz

MATOUŠKOVÁ, M. (2003): Ecohydrological monitoring of streams habitat. Charles University in Prague

PÄRMETS, H. (2003): Nature conservation and management of polders in Estonia. University of Tartu

ŠOBR, M. (2003): Lakes in the Czech Republic. Charles University in Prague

TANCA, A. (2003). New technologies and information flows for sustaintable water management. University of Cagliari

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Ročník 109, číslo 2, vyšlo v červenci 2004

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