Integrated watershed approach in controlling point and non-point source pollution within Zelivka drinking water reservoir

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Abstract An agricultural watershed involves manipulation of soil, water and other natural resources and it has profound impacts on ecosystems. To manage these complex issues, we must understand causes and consequences and interactions-related transport of pollutants, quality of the environment, mitigation measures and policy measures. A ten year period of economic changes has been analysed with respect to sustainable development concerning Zelivka drinking water reservoir and its watershed, where agriculture and forestry are the main human activities. It is recommended that all land users within a catchment area should receive payments for their contribution to water cycle management. Setting up the prevention principles and best management practices financially subsidized by a local water company has been found very effective in both point and non-point source pollution abatement, and the newly prepared Clean Water Programme actively involves local municipal authorities as well. The first step based on systems analysis was to propose effective strategies and select alternative measures and ways for their financing. Long term monitoring of nutrient loads entering the reservoir and hazardous events statistics resulted in maps characterising the territory including vulnerable zones and risk factors. Financing involves providing annual payments to farmers, who undertake to manage specified areas of their land in a particular way and one-off payments to realise proposed issues ensuring soil conservation and watershed ecosystem benefits.

Keywords Clean Water Programme; diffuse pollution abatement; integrated agricultural and water management; sustainable development; water quality monitoring; watershed ecosystem

Introduction

Motto: "The degradation of the natural environment by now had to become of increasing concern not only to ecologists and environmentalists but also to politicians and the general public".

EU Water Directive Protection

The draft Water Framework Directive of the European Union calls for the integrated, sustainable management of water bodies. This approach is intended to achieve good ecological status throughout the entire catchment area of a river. In a broad sense, the environmental objectives can be integrated with economic, social and cultural goals.

In the Czech Republic for the past forty years there has been a lack of any understanding and methodology for integrated planning and management, as well as a lack of a regulatory framework for "Integrated Thinking". The first steps to change this were made by Eiseltova (1995). The location of the Zelivka watershed is shown in Figure 1.

Drivers of changes in actual water management patterns

- Better understanding of common perceptions and expectations with respect to water, both as an environmental resource and an economic good.
- Local communities are demonstrating an increasing desire to become involved in the planning and management of their immediate aquatic environment.

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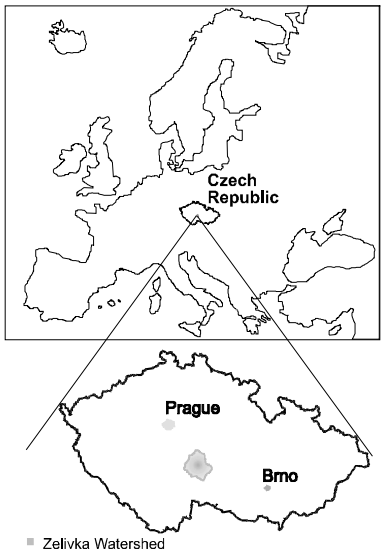

Figure 1 Location of Zelivka watershed

- Regulatory authorities have identified the river catchment as the most appropriate geographical basis for planning and managing water resources.
- An increased emphasis on integrated water management approaches as a tool to develop long term strategic plans.

Reform of Common Agricultural Policy (CAP)

Planned reform of the CAP of the European Community is set out and a newly formulated agricultural effort is reasonably linked to environmental improvements. According to Doucha (2000) farmers are now seen as not only producers of food and fibre, but it is evident that they can produce various positive externalities for the rural socio-economy. In this framework the Czech Government, with respect to previous ideas, assigned the Ministry of Agriculture to introduce a new complex program for set-aside areas support with the aim to encourage farmers into "non-food" agricultural production activities. Diffuse pollution from agriculture can be controlled when land use changes, particularly when no-plough arable farming is practised in areas where erosion into watercourses is a problem.

Reform of public administration

In accordance with EU directives related to regional development to be adopted by the Czech Republic, a real decentralisation of the state executive runs to changes in local and regional authorities' competencies. The first part of the new Regions has been set up and local authorities have declared regional priorities, tasks and strategies. As a result of the new conception, Zelivka watershed territory is now divided into three independent administrative regions, which still emphases needs for integration and co-operation in creation of sustainable development strategies in order to keep the country habitable and cultivable. The restoration of watercourses is one of the main objectives of the Czech environmental legislation supported by donation policy, as well.

Objectives

Integrated Watershed Approach (IWA)

At first decision analyses using an integrated approach are instruments needed for effective

description and understanding of watershed ecosystems. Consequently IWA must be assigned to authorities or organisations that are responsible for co-ordinating and implementing any actions needed to improve the quality status of Zelivka reservoir. To resolve the problem we need to put together modelling tools, decision support systems, basic knowledge on the functioning of the ecosystem and so on. An integrated watershed approach and management strategy within a hydrologically defined catchment area provides a co-ordinating framework for water supply protection, pollution prevention and ecosystem preservation. The sustainable water development of a given region is not a spontaneous process, but needs a strategy based on profound understanding of hydrology, biotic mechanisms and the economics of the catchment (Zalewski *et al*.,1996).

Clean Water Programme

Due to significant interactions between agriculture and the ecosystem within the watershed a comprehensive programme is required to assess the environmental impacts of agriculture. The Clean Water Programme identifies waters actually or potentially affected by pollution from nutrient loads. Consequently the interests and liabilities of the local municipality, regional authorities and the Prague Waterworks Company were involved. Thus the process of priority action consultation revealed the need both for more vigorous implementation and for a broader and deeper approach within the watershed of Zelivka drinking water reservoir. By that time the priority measures to tackle the main sources of pollution are discussed in multi-year projections and the financial framework is estimated. This should result in negotiations with the management of VIVENDI WATER, which has been newly established to operate water supply.

Data collection and methods

The goal of the integrated watershed approach is to stipulate a project that brings economic and environmental gains, providing a model for similar cases in the whole Czech Republic, as well. The framework of the methodological approach adopted can be divided into the following issues:

- analysis of the actual situation of the watershed ecosystem and water body
- definition of targets for sustainable water development
- quantitative assessment of deficits
- determination of proposed measures
- analysis of scenarios and cost-benefits assigned
- implementation of the short, middle and long measures
- results, monitoring and evaluation

The area studied is a small agricultural watershed (85 km^2) comprising mixed arable fields and temporary grass fields in a high erosion risk area. Although located very close to the reservoir dam (Figure 2), it is still undergoing production-oriented agriculture with environmental impacts because of the intensive use of fertilisers and pesticides (Chour *et al*., 1993). A stream, Sedlicky brook, drains the sub-catchment area, of which profile P-01 is included in a long-monitoring program of water quality concerning the Zelivka reservoir. Long-term trends in the concentrations of nitrate and total-P have been assessed from data gathered between 1976 and 2000 and expressed in the annual mean concentrations (see below).

To assess shifts of actual Czech environmental policy in favour of the direction entirely away from production-based payments to farmers, a set of state executive programmes of funding were analysed. Further pollution reduction is achieved in close consultation between the authorities and target groups.

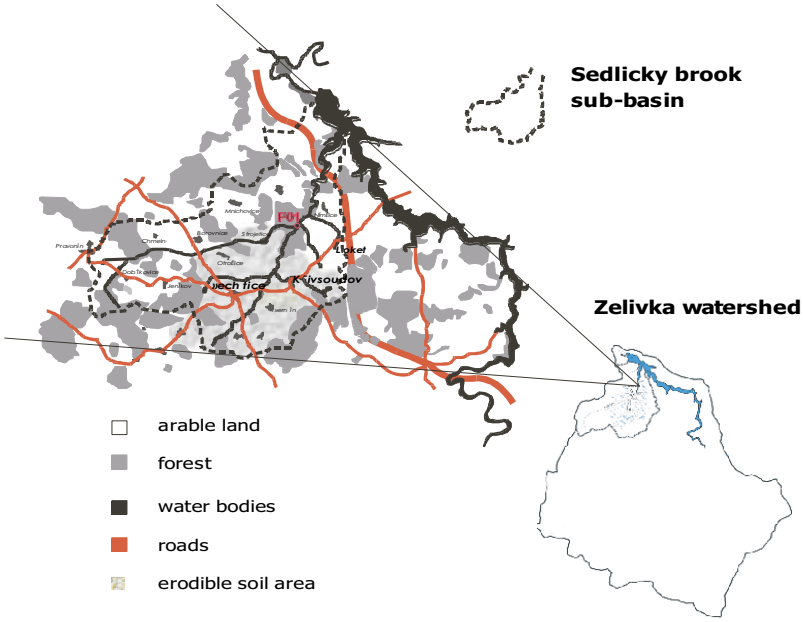

Figure 2 Location of case study concerning agricultural impacts on environment

Results and discussion

The water quality of Sedlicky brook feeding the Zelivka reservoir is chiefly characterised by diffuse pollution from nutrients as a result of intensive agricultural land use and soil erosion. Under the soil conservation programme to control the pollution of water by nutrient transport from agricultural fields, the country is preparing codes of best agricultural practice in order to reduce the level of nitrate loss to surface waters and groundwater from agriculture (Holas *et al.*, 1999). Agricultural pollution is assessed in accordance with actual land cover (Table 1) and land use (Table 2) of the Sedlicky brook sub-catchment.

Until the year 2000, the main changes of crop rotation on arable land have been influenced by agricultural market products only. Large-scale cultivation practices lead directly

Table 1 Land cover

	area km^2	% ratio
Arable land	45.02	53.0
Grassland	11.68	13.7
Forests	24.23	28.5
Water area	0.43	0.5
Other land (infrastructure)	3.66	4.3
Total area	**85.02**	**100.0**

Table 2 Land use in accordance with average crop rotation

Crop	%	Crop rotation in the Agrocoop Cechtice in 1996–1999			
		1996	1997	1998	1999
Cereals	51	49.3	51.0	47.9	41.5
Corn for silage	16	14.6	15.9	16.5	20.5
Rape seed for oil	11	8.7	10.0	9.6	11.3
Potatoes	9	8.0	7.1	7.4	7.5
Fodder plants	13	14.7	14.0	11.5	ca 11.9

to increased soil erosion and storm run-off has continued with the silting of watercourses and pre-reservoir sedimentary pool. Impacts of that agricultural production system on environmental issues seen in the long-term monitoring data are presented in Figures 3 and 4. The environmental trend of nutrient loads is estimated from long-term monitoring data collected on the profile P-01 closing the Sedlicky brook sub-catchment. In the year 2000 non-point source pollutants such as nitrate and phosphorus reached limits set out for drinking water quality.

Phosphorus (P) transfer from agricultural land to surface waters contributed significantly to eutrophication, excess algal growth and associated water quality problems in the Zelivka drinking water reservoir. Arable farming practices within the erodible soil area had a high potential of diffuse P pollution to surface waters. In 1992 a case study on erosion and silting processes in the Sedlicky brook sub-basin estimated the annual average soil loss as 1.8–4.1 tonnes per hectare. The annual average transport of N from arable land is 2.5 $g.m^2$ and of P is 0.01 $g.m^2$. A positive relation was found between grassland soil surface and the annual average N and P emissions. In this case N loss reaches 1.5 $g.m^2$ and P transport was reduced to 0.003 $g.m^2$. Total P load into the reservoir due to surface run-off is approximately 10–60%.

The Zelivka Waterworks provides the most advanced and the largest water supply for Prague. In addition, it provides drinking water for the Central Bohemian and Jihlava Regions. The volume of the water supply reservoir is 266.56 mil m^3 and water retention is 400–700 days. Water quality in the reservoir is regularly monitored. In 2000 average values of selected parameters at outlets from the Zelivka Waterworks were as shown in Table 3.

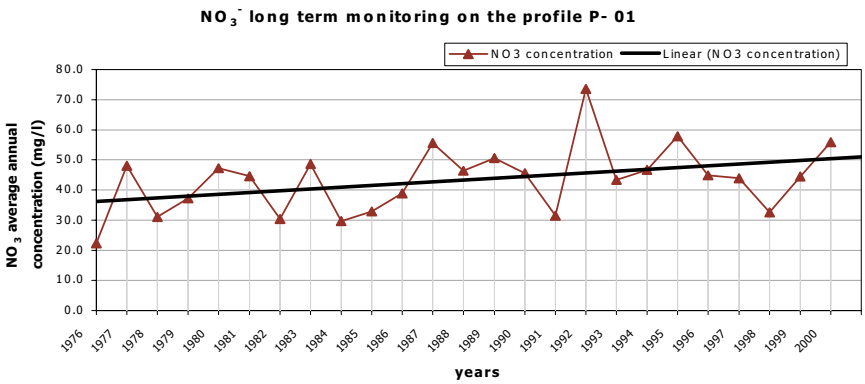

Figure 3 Results of long-term monitoring of nitrate

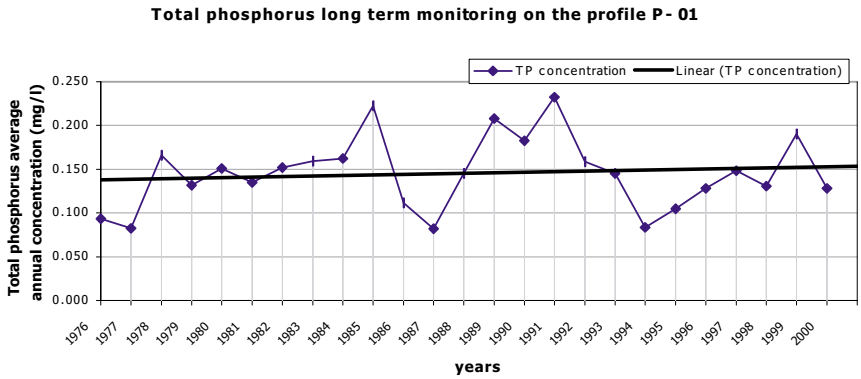

Figure 4 Results of long-term monitoring of phosphorus

Table 3 Water quality in the reservoir

Parameter	Average value	Water quality Czech standard
pH	8.3*	6–8
COD	1.5 mg/l	Max. 3 mg/l
Nitrates	32 mg/l	Max. 50 mg/l
Hardness	1.2 mmol/l	0.9–5.0 mmol/l
German scale degree	6.772°N	5.04–28.0°N
Iron	0.02 mg/l	Max. 0.3 mg/l
TOC (organic carbon)	2.74 mg/l	Max. 5.0 mg/l

* Exclusion from the Czech standard allowed by hygienic authority

The Czech Ministry of Agriculture is willing to change polluting agricultural practices and has prepared a system of subsidies and payments to farmers. It may well become a useful model for setting out criteria and schemes for both water protective and land use management to promote environmentally bound benefits. The consistent strategy of active support, starting with soil conservation for vulnerable zone mitigation, is getting under way. This kind of area-specific approach ensures coherence within water management and physical planning in large-scale agricultural and rural development.

It has become clear that water management could achieve sustainability more effectively and efficiently if the polices of those directly involved were not only closely interrelated with each other but also carefully co-ordinated with other relevant areas of policy. The development and maintenance of a healthy and resilient water ecosystem requires financial and economic co-operation supported by the state executive (see Figure 5). This philosophy was accepted in the environmentally oriented programme documents presented by the Social Democratic Government which was elected in 1998.

Clean Water Programme

The first steps were taken when privatisation of the Zelivka Waterworks was launched in 1998 and local municipalities within the watershed have been declared as co-owners of the water supply infrastructure. Nevertheless, while the first evaluation study focused on controlling point and nonpoint source pollution, the focus shifted to other regional problems, such as business opportunities and growing unemployment which led to a very useful public communication concerning the water management project. The Clean Water Programme within the watershed of Zelivka drinking water reservoir is designed to identify watershed ecosystem quality improvement and maintenance towards guaranteed sustainable water supply and water use. Step by step creation of a complex and integrated water management plan for the overall watershed has a framework including the following parts:

- involve stakeholders in local decision making and regional strategies co-ordination
- protect water quality and ecosystem health by looking at sub-watersheds
- support changes in agricultural practices resulting in more environmentally-sustainable agriculture
- set up controlling criteria for expected cost-effective protection of water resource
- make information available to save considerable time and money

As can be seen in Figure 6 the Clean Water Programme assigns functions to the various water systems through the overall watershed strategy. Proposed measures included in the financial incentive program have been assessed to cost from 700 to 900 million Czech crowns.

Conclusions

This paper reviews a watershed-wide approach to restoring and protecting a small

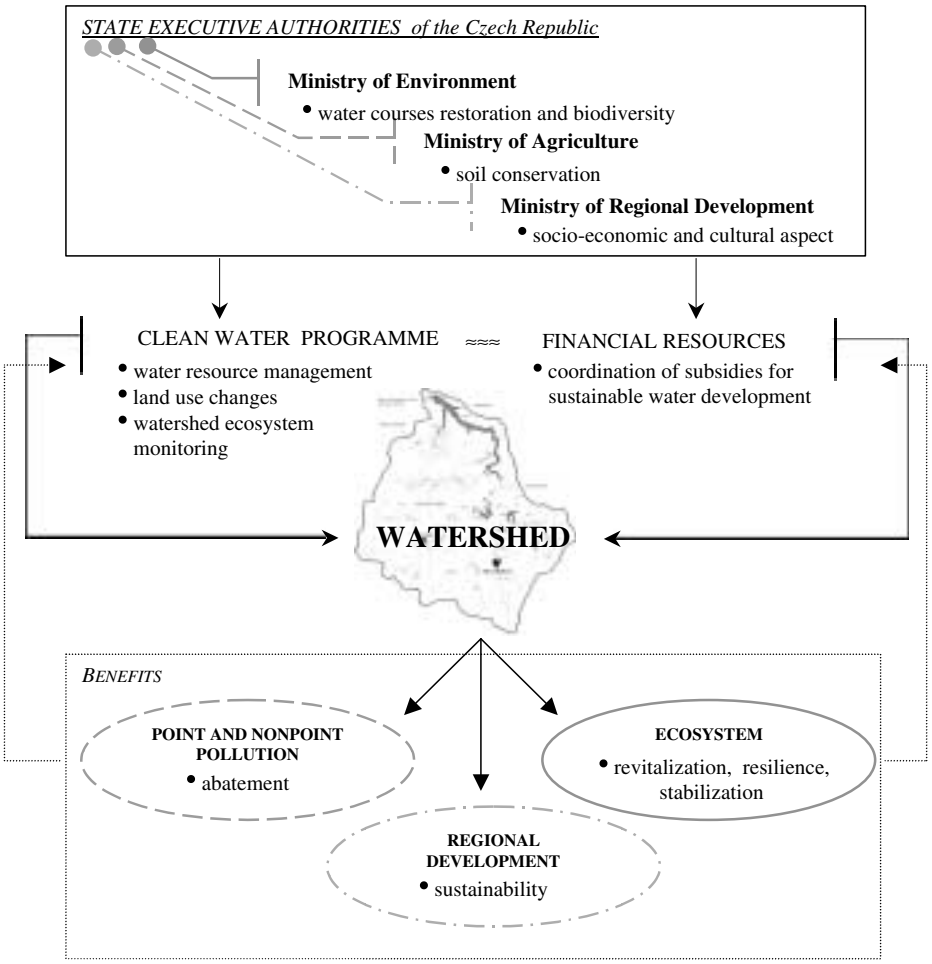

Figure 5 Integrated Watershed Approach

sub-catchment area where diffuse loading is currently the major source of nitrates and phosphorus input into the drinking water reservoir. Long-term monitoring of nutrient loads reveals an upward trend close to the Czech water quality limits due to intensive agriculture. Consequently integrated assessment requires simultaneous examination of the whole agricultural system and its environmental impacts.

Related to the EC document "Water Framework Directive" new and more stringent measures have recently been imposed on Czech agricultural production when set aside farming and non-food land use should be applied. The end objective is payments to farmers in favour of environmental improvement. Managing agricultural nutrients to protect water quality remains a major challenge in the Clean Water Programme established within the overall watershed of Zelivka reservoir.

Regional planning and policy are required where there are physical and political constraints in managing the water supply. All stakeholders should support the implementation of watershed plans through all related activities. A working demonstration of the integrated watershed approach evaluates state executive programmes that fund environmentally oriented catchment planning and management.

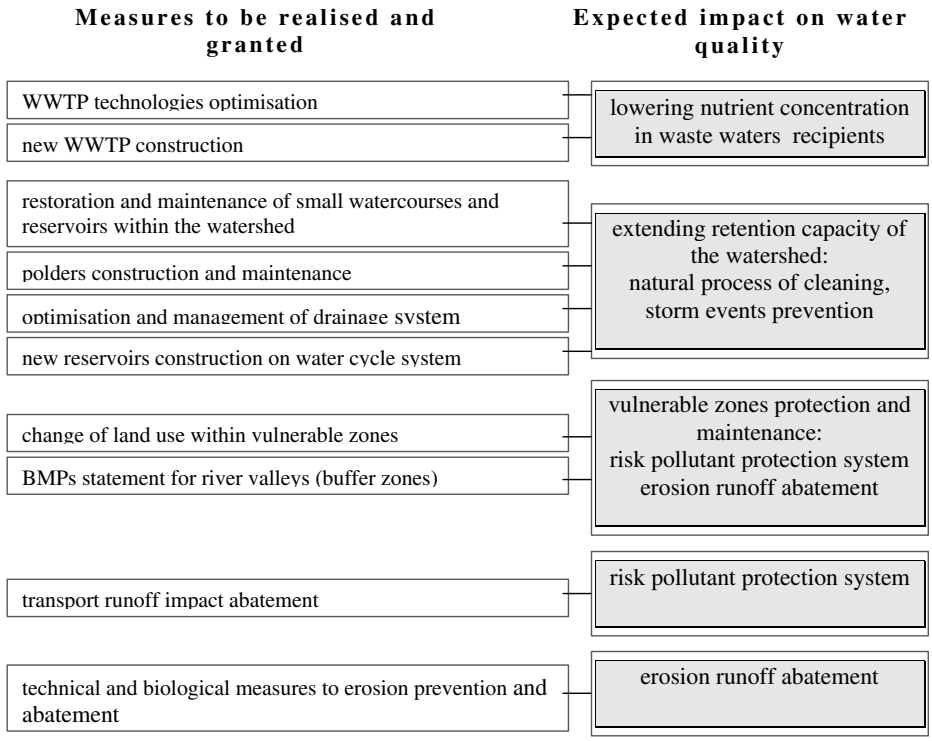

Figure 6 Clean Water Programme proposed by Zelivka Waterworks

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