

# SOURCES OF WATER IN RIVER FLOODPLAINS AND POSSIBILITIES OF THE COEXISTENCE OF WATER-WITHDRAWAL AREAS OF WATER SUPPLY SYSTEMS AND FLOODPLAIN FORESTS

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## Abstract

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Quaternary sediments in wide flat river floodplains are important accessible and often used resources of drinking water. On the other hand, increasing stress of the human society on water resources and their use cause local deterioration of growth or existence conditions for original forest or meadow ecosystems in affected areas of river floodplains. The paper deals with the evaluation of conditions enabling the coexistence of the “Water Supply Podluží” withdrawal area situated in the complex of floodplain forests and meadows in Forest District Tvrdonice. Effects of the water drawing are assessed on the establishment of the system of bored wells on the groundwater level based on data of long-term measurements on observation boreholes of the CHMI (Czech Hydrometeorological Institute). Response of a sudden or abrupt change in moisture conditions at the decreased groundwater level on the floodplain forest growth is demonstrated by the evaluation of a diameter increment of the group of trees of a mature stand, viz narrow-leaved ash (*Fraxinus angustifolia* V a h l.). On the area of the stand, one of the systems of drawing wells of the “Podluží water supply” is situated. The ash stand responded to the lowered groundwater level by the significant decrease in diameter increment. With respect to the fact that in the course of next years the level of groundwater table stabilized and a deeper decrease to the sandy gravel layer did not occur the forest stand managed to cope with changed conditions. After revitalization measures, increase in diameter increment to the previous level was noted. A cardinal condition for the optimization of the floodplain forest moisture regime is the capillary saturation of the surface soil layer (with the tree root system) of a depth of about 1.0 to 2.0 m from the groundwater level. Atmospheric precipitation of this climatically dry region can sometimes improve the soil moisture situation, however, in this case it is not decisive for the problem solution.

*Key words:* floodplain ecosystem, groundwater, ash, diameter increment, water supply system Podluží, water-withdrawal area

## Introduction

Problems of supplying the population by drinking water are and will be a topical subject everywhere man lives and develops his activities. The region of southern Moravia between Hodonín and Břeclav is a typical example. There, it was necessary to ensure a new water source after the severe disturbance of groundwater sources in the course of lignite mining in the vicinity of the village of Lužice. A group water supply system “Podluží” has been built as a substitute source of drinking water for affected villages. The water-withdrawal area of the water supply system occurs in the right-bank floodplain of the Morava river where a number of collecting wells is situated, viz in meadows and floodplain forests between Mikulčice and Moravská Nová Ves. The subject of the paper consists in the evaluation of changes in growth conditions for a floodplain forest ecosystem which occurred after putting the water supply system into continuous operation. Effects are evaluated of water pumping to the level of groundwater table and its dynamics and also subsequent influences of changes in the soil moisture regime on the diameter increment of *Fraxinus angustifolia* as one of the main commercial species of the floodplain forest.

## Material and methods

The area under study lies in the right-bank flat floodplain of the Morava river being situated from a road leading to the Mikulčice National Historic Landmark and ending in the region of the floodplain forest east of the village of Týnec. In the area, in total 40 collecting wells have been built. These wells are line-arranged in three separate sections of the “Podluží group water supply system”. The technical structure is in service since 1988 when a pilot operation was started. The collecting bored wells of a total depth of about 10 m make possible to collect water from the water-bearing bed of sandy gravel about 8.0 m thick (Kouřil, 1970). Water from the wells is taken through a sucking effect by means of siphons to three pumping stations transporting crude water to a water-treatment plant. A permanent water withdrawal from the spring area of an authorized immediate peak output of 120 l.s<sup>-1</sup> (actually observed peak is 86 l.s<sup>-1</sup>) requires creation of the depression curve of groundwater of about 3 m in axes of collecting wells which effects its level to a distance of about 450 m. The actual annual water withdrawal is, however, limited by the topical need of water which at present does not reach values supposed by the project. The withdrawal has not exceeded 2 170 000 m<sup>3</sup> year<sup>-1</sup> yet. Thus, the dynamics of groundwater level is subject to the topical situation in the need of water produced by the nearby water-treatment plant.

Hydrological and soil conditions are given and characterized by heterogeneous sediments of the Morava river the inner structure of which, dynamics of their development and finally also modelling the terrain surface are related to the number of factors. In the studied region, the actual river floodplain represents generally flat surface sloped along the river stream. In a historical period (before 1970), the floodplain was virtually yearly flooded. The originally meandering watercourse affected the formation of a markedly modelled micro-relief. Quaternary fluvial sediments are divided to Pleistocene roughly worked gravels and sands and to Holocene fine flood loams generally of heavy-textured particle-size distribution. The total thickness of Quaternary sediments under the present surface of the Morava river floodplain amounts to 5.5–12.0 m near Hodonín (Demek, 1997). The flood loam sedimentation occurred in the middle and upper Holocene roughly before 4000 years (Havlíček, 1994). In the withdrawal area of the Podluží water supply system, the thickness of the sediments ranged between 1.6 and 3.0 m. The underlying gravel sands reach a depth of about 10 m lying on Tertiary clays.

Information on the course of the groundwater table was obtained from measurements carried out in observation wells by the Czech Hydrometeorological Institute, branch office Brno. It refers to the borehole KBO476 on the hydrological profile HP 221 where observations were carried out in 1942 to 1997. To compare the course of the

groundwater table fluctuation in the Morava river floodplain not affected by the water main operation monitoring the KBO514 borehole is given. The borehole is situated on the hydrological profile HP 222 near Lanžhot where an uninterrupted series of measurements occurs since 1942 till the present time.

Changes caused by the uptake of water in the water-withdrawal area noted in the course of the groundwater table became evident in the diameter increment of narrow-leaved ash. The diameter increment was evaluated after the increment core sampling in the group of 20 trees situated within a distance of about 40 m in the vicinity of a collecting well No. HV 18. Stand 911B14 aged 135 years is of the following species composition: narrow-leaved ash 46%, pedunculate oak 39%, field maple 10% and lime 5%. Mean diameter at breast height (dbh) in ash is 58 cm, in oak 56 cm, ash height is 35 m, oak height 33 m. Field maple and lime are of subdominant position. Increment borers were carried out in the set of co-dominant narrow-leaved ash trees of dbh from 52 to 76 cm. The increment cores were obtained by means of a Pressler borer (at breast height), viz. always at a northern and southern side of each tree. The set of increment cores was statistically evaluated. Both increment cores were taken for the evaluation. In order to assess growth dynamics by means of annual ring analyses the locality with ash stand was selected. For statistical processing the confidence intervals were determined for  $P = 0.05$  during the period 1965–2004 and the differences were statistically tested. Developmental trend was fitted by regression lines.

## Results and discussion

Effects of the “Podluží water supply system” operation on natural conditions affecting the development and growth of floodplain forest ecosystems can be assessed based on the comparison of changes in hydrological conditions, i.e. from the course of changes in the groundwater table in relation to changes in the diameter increment of main commercial species narrow-leaved ash of which responds most sensitively (Vašíček et al., 1982). Fig. 1 demonstrates the annual dynamics in the course of the groundwater table in the observa-

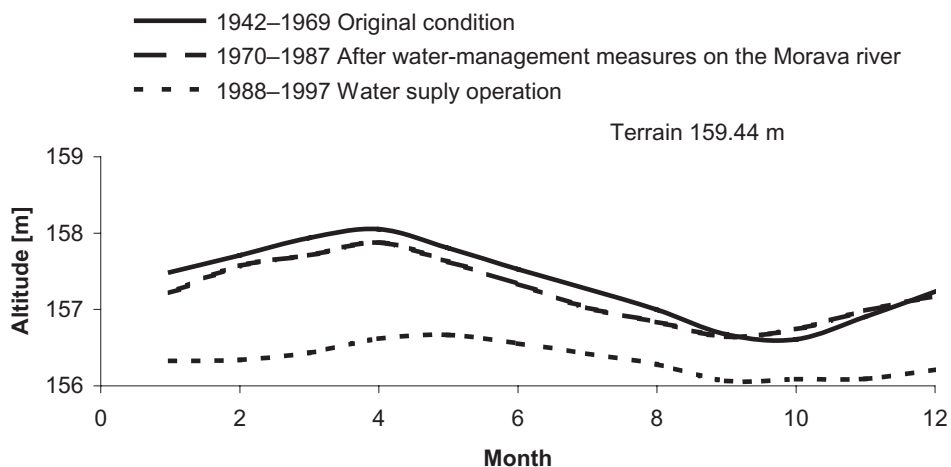


Fig. 1. Moravská Nová Ves HP 221 KBO476. Annual dynamics of the course of the groundwater table in periods under study.

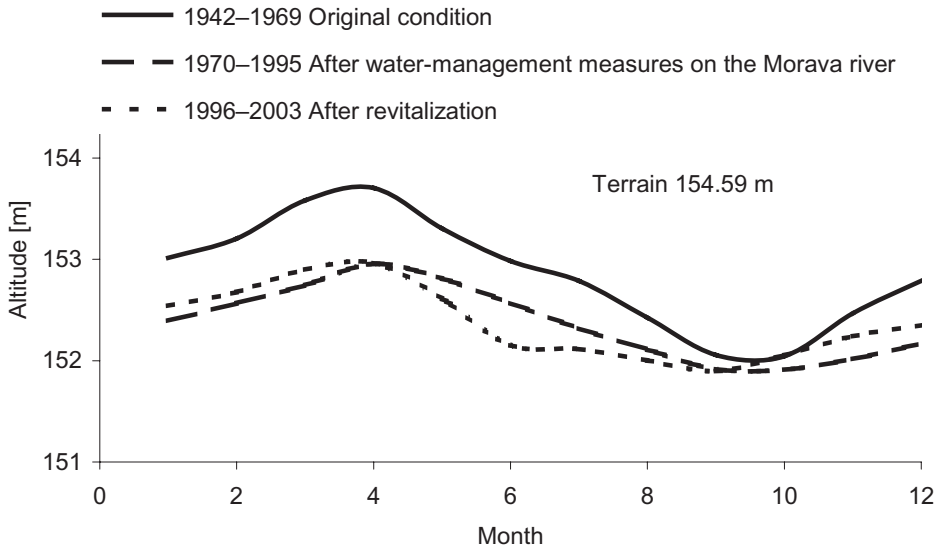


Fig. 2. Lanžhot HP 222 KBO514. Annual dynamics of the course of the groundwater table in periods under study.

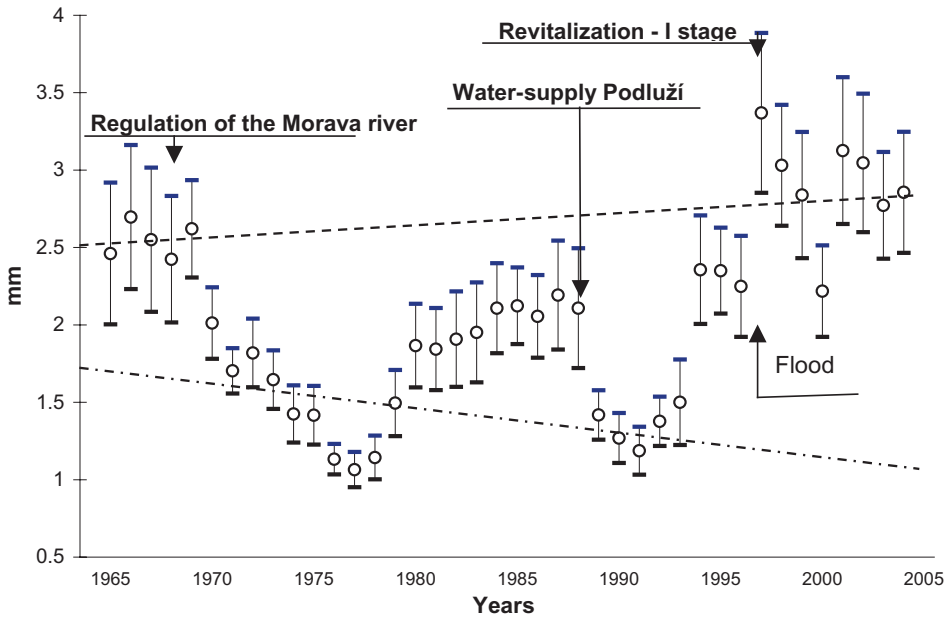


Fig. 3. Confidence intervals ( $P = 0.05$ ) of the annual radial increment of ash in 1965–2004.

tion borehole situated in the vicinity of the line of collecting wells of the Podluží water supply system (borehole KBO476). Based on the course it is evident that the original dynamics, i.e. spring maxima and autumn minima showed a height difference of 1.4 m and in the course of the year, they substantially changed after putting the Podluží water supply system into service. An abrupt decrease occurred of spring maximum values by about 1.3 m and of autumn minima by 0.5 m and the disturbance occurred of previous regular annual dynamics the floodplain ecosystem was adapted to which. Complexity of the hydrological and moisture regime of soils of the Morava river floodplain and of the effect of anthropic measures is shown in Fig. 2, i.e. observations in the KBO514 borehole which is situated out of the water supply withdrawal area being affected only by water-management measures of the Morava river in the 70s of the 20<sup>th</sup> century and revitalization measures at the end of the 90s of the 20<sup>th</sup> century. Both anthropic measures resulted in the decrease of the average groundwater table during spring maxima by about 1.0 m and autumn minima by about 0.2 m. It is important that the annual dynamics roughly copies the original condition which is, however, considerably suppressed as for its vertical extent.

Problems of the effect of changes in the hydrological and moisture regime of soils on production conditions of forest ecosystems were dealt with by a number of authors. Some of them studied the problems in relation to the preparation and implementation of water-management measures on the Dyje and Morava rivers (Horák, 1964; Mráz, 1979; Klimo, Kulhavý, 1999; Krontorád, 1974; Hadaš, 2000, 2003; Hadaš, Prax, 2001; Čermák, Prax, 2001; Penka et al., 1985, 1991; Palát, 1997; Prax, Hadaš, 1998; Vašíček, Prax, 1983 etc). Šmelko et al., (1992) give information on the effect of changes in the groundwater table on the diameter increment of trees. Actual data on the course of a diameter increment of narrow-leaved ash in a stand situated in the immediate vicinity of a collecting well of the water supply system are given by Fig. 3 which evaluates the course of the annual radial increment of a group of trees in the period of recent 40 years. In the figure, periods are depicted of anthropic measures when the groundwater table was affected and the measures responded in the course of the radial increment. The course showed negative after water-management measures on the Morava river (1969 to 1979) and after the start of the Podluží water supply system operation (1988 to 1994) and positively after the flood in 1997 and at present after the implementation of revitalization measures.

Based on the course of the annual radial increment depicted in Fig. 3 we can conclude that narrow-leaved ash responds sensitively to sudden changes in the moisture regime. Under given natural conditions, the species is able to cope with a possible moisture deficit (though with a loss) during a short time of six to eight years. Maděra (2004) mentions differences in the growing stock in mature stands of pedunculate oak amounting to as many as 120 m<sup>3</sup> per hectare (about CZK 300 000) between stands with a favourably moisture regime and stands which were affected by the significant decrease in the groundwater table. Also Mráz (1976), Vinš (1961), Hauck, Palát (2000), Mráz and Vinš (1973), Vyskot (1984), Ježík, Voško (2002) dealt with the study of the diameter increment of various species. These authors demonstrated effects of changed natural conditions on the diameter increment of trees. Bitvinskas (1974) mentions also other factors affecting values of the diameter increment of

trees, viz links to weather and also rhythms of solar activities. Alarming results are given by the work of the team of workers of the Institute of Forest Ecology, Mendel University of Agriculture and Forestry in Brno. In the 80s of the last century, the research workers dealt with the study of the problems in the complex of floodplain forests on the left bank of the Morava river south of Hodonín where the withdrawal area of the Holič water supply system occurred. At the locality virtually identical with the locality of the Podluží water supply system, decrease in the groundwater table even by several metres occurred in places due to the intense withdrawal of water. The capillary supply of water to the soil profile and thus to the root system of trees was eliminated. Forest stands affected by the measures gradually responded in such a way that first species of the “soft” floodplain forest died and the moisture stress manifested itself also in ash where the noticeable drying of leaves in tree crowns was found. Relatively lower losses due to the moisture stress were noticed in pedunculate oak (*Quercus robur* S I m k.) (Vašíček et al., 1982; Hadaš, 2000).

It follows that the dynamic groundwater table is essential for the successful growth of floodplain forests in the Morava river floodplain. The groundwater table has to remain (at its minimum level) in contact with overlying flood loams for a possibility of the capillary saturation of the root zone of trees.

## Conclusion

The floodplain ecosystem on the lower reach of the Morava river is heavily affected by anthropic measures to the moisture regime of soils as early as since the 70s of the last century. First, it referred to the extensive channel reconstruction of the Morava river and building a flood control dike. In 1988, the “Water Supply Podluží” was put into service. The withdrawal area of the water supply system affected above all the region of a floodplain forest in the vicinity of Moravská Nová Ves. At the end of the 90s of the last century, the project of revitalization measures was implemented to improve moisture conditions. The average level of groundwater table decreased due the withdrawal of drinking water by more than 1.0 m in the withdrawal area in spring. The annual dynamics of spring maxima and autumn minima in the given locality important for the floodplain forest also markedly decreased. Changes in the groundwater table after water-management measures and implemented revitalizations occurred also in the Lanžhot locality. In both cases, decrease in the groundwater table roughly by 1.0 m occurred during a spring maximum.

Thus, the floodplain forest responds sensitively to sudden moisture changes. A stand of ash situated in the locality of the “Water Supply Podluží” withdrawal area decreased its increment due to the Morava river channelization and owing to the water supply system operation from the value of a mean annual radial increment 2.0–3.0 mm to a value of 1.0–1.5 mm, i.e. roughly by a half. It is important that the ash stand managed to cope with the moisture stress in the course of 6–8 years. In 1997, extensive natural floods and in the following period also revitalization measures in the floodplain forest contributed to cope with the fact. If water pumping in the withdrawal area does not decrease the groundwater table to such a degree

that the capillary saturation of the relatively thin layer of flood loams would be interrupted the growth of the floodplain ecosystem is not substantially disturbed.

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