5 SUMMARY OF MODEL APPLICATION

This chapter provides a brief summary of the model applications described in Volume III of the Final Report.

5.1 Introduction

In order to illustrate the applicability of the established integrated modelling system a number of application scenarios have been carried out. The results of these scenarios can support technical decisions and management policies in the project area.

The contents of the scenarios have been discussed and approved at meetings of the Steering Committee. It should be emphasized that the selected application scenarios do not imply any preference with regard to water management regime, but have been made with an aim to demonstrate the applicability of the modelling tool. Hence, the presented model calculations should not be considered the final use of the model, but may serve as references of comparison when Slovakian specialists carry out further model calculations in the future.

5.2 Selected Water Management Regimes

In order to serve as a framework for the application scenarios four different Water Management Regimes were identified. The following terminology was used in the scenario simulations:

- A *Water Management Regime* is defined by the operation rules for the major structures at Cunovo, Dobrohost and Gabçikovo for the post-dam conditions and no regulation for the pre-dam conditions. Thus, given a hydrological time series of Danube inflow at Bratislava, the overall discharge regime can be explicitly calculated. Hence, the selected Water Management Regime defines the water management as far as the overall discharges are concerned.

- *Management Options* are here defined as options for management of the system under a given Water Management Regime, e.g. all management possibilities except for changes in the prespecified discharges at the three major structures that define the Water Management Regime.

- A *Scenario* is defined as calculations of conditions for ground water, agriculture or ecology under a given Water Management Regime and one management option.

The following general conditions have been assumed for the management scenarios:

- Scenarios will be limited to areas on Slovak territory.
- The presence of the Gabçikovo-Cunovo structures and the Hrusov reservoir (Variant C) forms the framework for all post-dam scenarios.
- Scenarios should be directed at key areas from an ecological or management perspective.
- The different scenarios should differ significantly from each other in order to show impacts of importance for the decision making.

The following four water management regimes have been chosen in agreement between the Slovak Ministry of the Environment and the Consultant.

I. Pre-dam 1990.
The water management regime in 1990 serves as a reference for the pre-dam situation for ground water conditions, agriculture and ecology. This regime is characterized by no regulation at Cunovo, Dobrohost and Gabçikovo and by the river topography from around 1990.

II. Post-dam (400 m^3/s).
This regime is represented by the water management which has taken place since the filling of the side branches, i.e. since summer 1993. The discharge regime is characterised by an average annual discharge at Cunovo to the Old Danube of about 400 m^3/s and an average intake to the river branches at Dobrohost of about 40 m^3/s.

III. Post-dam (800 m^3/s).
An allocation of 800 m^3/s and 40 m^3/s as average annual discharge to the Old Danube and intake to the river branches, respectively.

IV. Post-dam (200 m^3/s, and more dynamic inlet to the river branch system)
An allocation of 200 m^3/s to the Old Danube as average annual discharge and 40 m^3/s. The inlet into the river branch system is, in average, approximately the same as in Water Management Regimes II and III, but with larger discharge variations.

5.3 Ground Water Flow Regime

The ground water flow was modelled using the MIKE SHE hydrological modelling system coupled with the MIKE 11 hydrodynamic modelling system.

5.3.1 Objectives

The objectives of application scenarios in relation to ground water flow were:

- to study the regional ground water flow regime on Žitný Ostrov for WMRI, WMRII and WMRIII, mainly in terms of ground water levels and dynamics of the ground water table.

- to study the flow regime around the Hrusov reservoir for WMRI, WMRII and WMRIII, mainly in terms of ground water flow and infiltration from the reservoir.

- to provide ground water flow velocities for simulation of transport and geochemical transformation of solutes on regional scale and on local reservoir scale.

5.3.2 Main conclusions

Regional Ground Water Flow Regime

Comparison of model results of for WMRI (pre-dam) and the two post-dam scenarios WMRII and WMRIII lead to the following conclusions:

The damming of the Danube has lead to an increase in ground water levels in the upstream part of the Žitný Ostrov. In a narrow zone around the reservoir the ground water table has increased with about 4-5 meters, but in general the increase is in the order of 0.5-1 meter. In the central part of the Žitný Ostrov the ground water levels initially decreased with about 0.5-1 meter due to the decreased water levels in the Old Danube. However, when filling the river branch system the ground water levels was brought back to the pre-dam level. Fig. 5.1 shows the calculated differences between WMRI (pre-dam) and WMRII (post-dam, 400 m^3/s).

A comparison of two post-dam regimes, WMRII (400 m^3/s) and WMRIII (800 m^3/s), revealed only minor changes. In the upstream part of the Žitný Ostrov ground water levels were slightly lower for WMRIII than for WMRII. The largest difference is about 0.5 meter close to Samorin, but in general the differences is only in the order of 0.10 to 0.20 m. In a narrow zone along the Old Danube ground water levels will be higher in WMRIII than in WMRII due to higher water levels in the Old Danube for WMRIII.

The most significant difference between WMRI and WMRII/WMRIII is in the ground water table fluctuations. The sum of the annual ground water fluctuations (Pegelweg) in WMRII and WMRIII was reduced to about 1/3 of WMRI in most of the upstream part of Žitný Ostrov. However, a management scenario with temporal variations of water levels in the seepage canals indicate that for areas less than about 1.5 km away from the canals it will be possible to establish groundwater dynamics with the same Pegelweg as in WMRI (pre-dam).

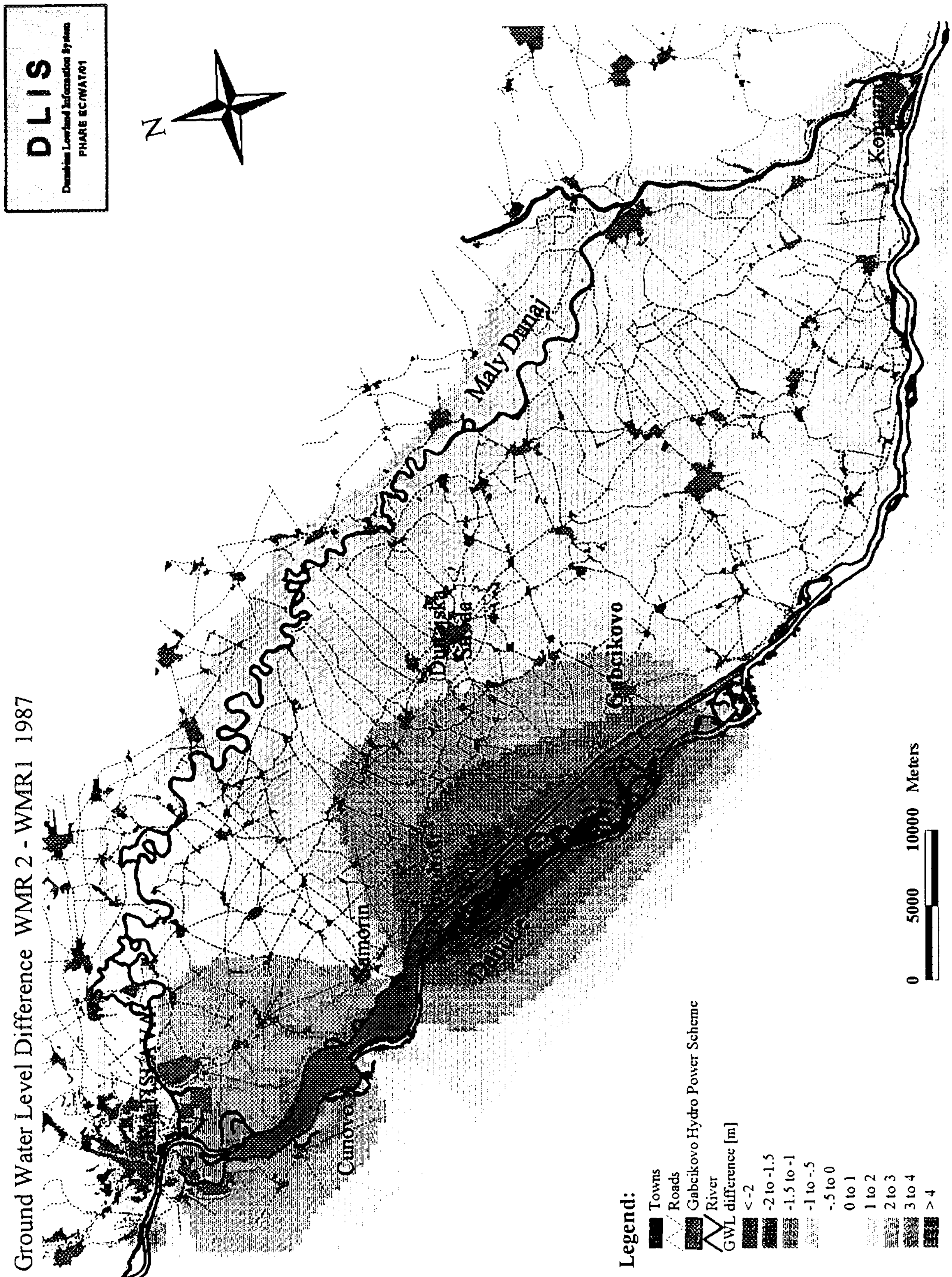

Fig. 5.1 *Difference between WMRI (pre-dam) and WMRII (post-dam, 400 m^3/s) in average ground water levels calculated corresponding to 1987 discharge conditions at Bratislava. (+:increase in WMRII, -:decrease in WMRII).*

Ground Water Recharge

Before the damming of the Danube the major part of the ground water recharge took place in the reach of Danube where the Hrusov reservoir is now located. If siltation of the reservoir bottom takes place this might lead to significant changes in the infiltration pattern and hence also to the entire ground water flow regime on Žitný Ostrov. For WMRII and WMRIII only limited sedimentation takes place in the old river bed, from where most of the ground water recharge takes place. From Bratislava to Dobrohost a ground water recharge of just below 30 m^3/s was simulated in average for WMRI in 1987. For WMRII and WMRIII a ground water recharge of about twice this amount was simulated. Practically, no difference in infiltration pattern was observed between WMRII and WMRIII. Ground water recharge will only change significantly if sedimentation takes place in the old river bed. Sediment transport simulations does not indicate that such a situation is likely, and hence problems with regard to a reduction of ground water recharge is not to be expected.

5.3.3 Assessment of uncertainties of model predictions

The uncertainties related to model prediction of ground water levels can generally be considered to be within the range 0.5 - 1 meter. The uncertainties on predictions of differences between ground water levels of two alternative scenarios can be considered to be less than the uncertainty on the absolute level.

The uncertainties related to prediction of ground water flow velocities of importance for transport and geochemical reactions may be large when considering small scales (< 100 m) due to the very significant spatial variability of hydraulic conductivities. However, if considering an area comprising for example 100 model grids the difference between average flow velocities in nature and in the model can be expected to be rather small. Hence, when making solute transport simulations the overall transport patterns and transport times can be expected to be simulated rather precisely.

5.4 Agriculture

The agricultural modelling was carried out using the DAISY modelling system.

5.4.1 Objectives

The main objectives of the agricultural scenario simulations was to assess the influence of the damming of the Danube on:

- crop growth potential on Žitný Ostrov

- irrigation requirements, and

- nitrate leaching risk

In order to address these issues model simulations were carried out for WMRI and WMRII and the results were compared.

5.4.2 Main conclusions

The changes in agricultural production on Žitný Ostrov due to the damming of the Danube are marginal. The difference in crop yield indexes between pre-dam (WM-RI) and post-dam (WMRII) scenarios was simulated to be less than 1% for irrigated as well as non-irrigated areas.

About 70-80% of the agricultural areas on Žitný Ostrov require irrigation. The damming of the Danube has not lead to significant changes in irrigation requirements. In areas where the ground water table has increased due to the damming of the Danube the ground water table is located a few metres into the gravel aquifer. The gravel layer forms an efficient capillary barrier and only if the ground water table enters the fine textured top soil irrigation requirements will be different. This has only happened at very few locations within the Žitný Ostrov.

The simulated average nitrate leaching is generally low compared to estimates from some Western European countries (eg Denmark) and appeared to be almost the same before and after damming of the Danube. The area weighted average leaching was 12.0 kg N/ha for WMRI and 12.3 kg N/ha for WMRII. The highest leaching (up to 30-35 kg N/ha) was simulated in areas where the top soil is thin. Fig. 5.2 illustrates the areal distribution of nitrogen leaching on Žitný Ostrov.

5.4.3 Assessment of uncertainties of model predictions

There are considerable uncertainties related to model predictions of the absolute values of crop growth and nitrogen leaching. These uncertainties can be reduced by further investigations, but this would require new field observations combined with modelling studies. In comparison, the uncertainties on estimates of irrigation requirements are less.

The uncertainties on differences between conditions corresponding to two alternative scenarios are, however, significantly smaller. Hence the above conclusions regarding possible changes in agricultural production, irrigation requirement and nitrate leaching can be considered to be reasonably accurate.

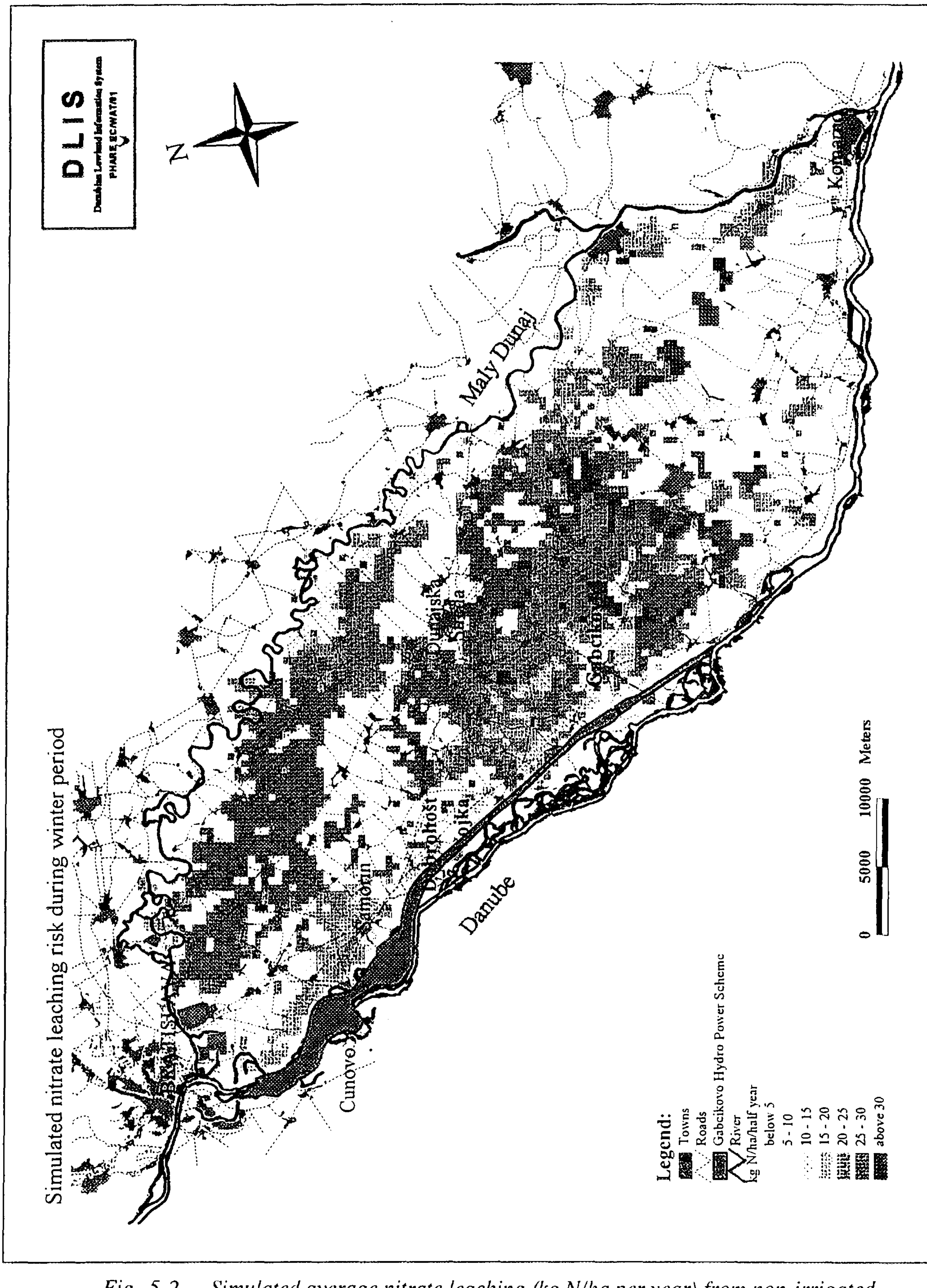

Fig. 5.2 Simulated average nitrate leaching (kg N/ha per year) from non-irrigated soil columns during the winter season in the period 1987-1991 for Water Management Regime II.

5.5 Ground Water Quality

The modelling system applied was the Advection Dispersion and Geochemical modules of the MIKE SHE modelling system.

5.5.1 Objectives

The main objectives of the ground water quality modelling were:

- to study if the presence of the reservoir together with the changes in infiltration of river water and ground water dynamics may induce changes in ground water quality. Fine organic matter may accumulate on the reservoir bottom, thereby creating a reactive sediment layer. The river water recharging the aquifer has to pass through this layer, which may induce a change in the chemical/biological composition of the infiltrating water. An increased infiltration of river water could also affect the quality of the ground water from being oxic or suboxic towards being anoxic, which is undesirable for the drinking water supply plants in the vicinity of the reservoir. Particular attention should therefore be on the likely redox status of the ground water.

- to characterize the fate of NO_3 leached from the agricultural fields in the inland area of Žitný Ostrov. High NO_3 concentrations are observed in some inland wells, resulting from extensive leaching from the surface.

In order to describe the changes in ground water quality due to the damming of the Danube model scenarios were carried out for WMRI and WMRII.

The geochemical modelling is based on a ground water flow field calculated with the regional ground water models and with the local model of the reservoir area.

In order to simulate the fate of nitrate on regional scale time-series of nitrate on Žitný Ostrov was derived from DAISY scenario simulations.

Water quality parameters of the water that recharges the aquifer was estimated based on modelling results with the MIKE 11 Water Quality model of the Danube and the MIKE 21 Eutrophication model of the reservoir.

5.5.2 Main conclusions

The results of the regional model show that denitrification is slow when compared to other areas. This means that the shallow subsurface is susceptible to NO_3 contamination from the surface. Minimizing NO_3 leaching is therefore desirable for protection of the shallow ground water resources.

The results for the reservoir model indicate that the change in geohydrological conditions for the reservoir causes a high flux of river recharge to the subsurface together with an increase in the infiltration area. This means that the water works would be more vulnerable to water quality degradation in the Danube river, since both the flow rates are higher and the distance to the infiltration area is shorter. Monitoring of ground water quality in the vicinity of the reservoir and the water works is thus of prime importance. Fig. 5.3 shows NO_3 concentrations around the reservoir where some of the major water supply installations are located. The figure also illustrates the importance of including the denitrification process.

5.5.3 Assessment of uncertainties of model predictions

The uncertainties on predictions of ground water quality are significantly larger than uncertainties related to ground water levels and flow velocities due to uncertainties on geochemical processes and parameters. In this context the very large spatial variations of hydraulic and geochemical parameters at small scales (< 1 m) puts limitations to the accuracy which can be expected in the model predictions.

The complex geochemical model is believed to give a good overall description of the ground water quality regime for the Kalinkovo profile where local field data have been used for its calibration. The model can be considered to have predictive capability in this area.

For predictions on localities outside the Kalinkovo area the complex model can not be considered very accurate. However, the developed model code is so general and contains the key processes, that it, after calibration against local data, can be expected to be able to provide accurate predictions. It is therefore strongly recommended to combine future geochemical modelling studies with local field monitoring programmes.

Used on a regional scale to simulate the fate of nitrate the model can provide orders of magnitude of concentrations and can serve as a good tool for assessing e.g. mass balance of nitrate taking influx from the river, leaching from the root zone and denitrification into account.

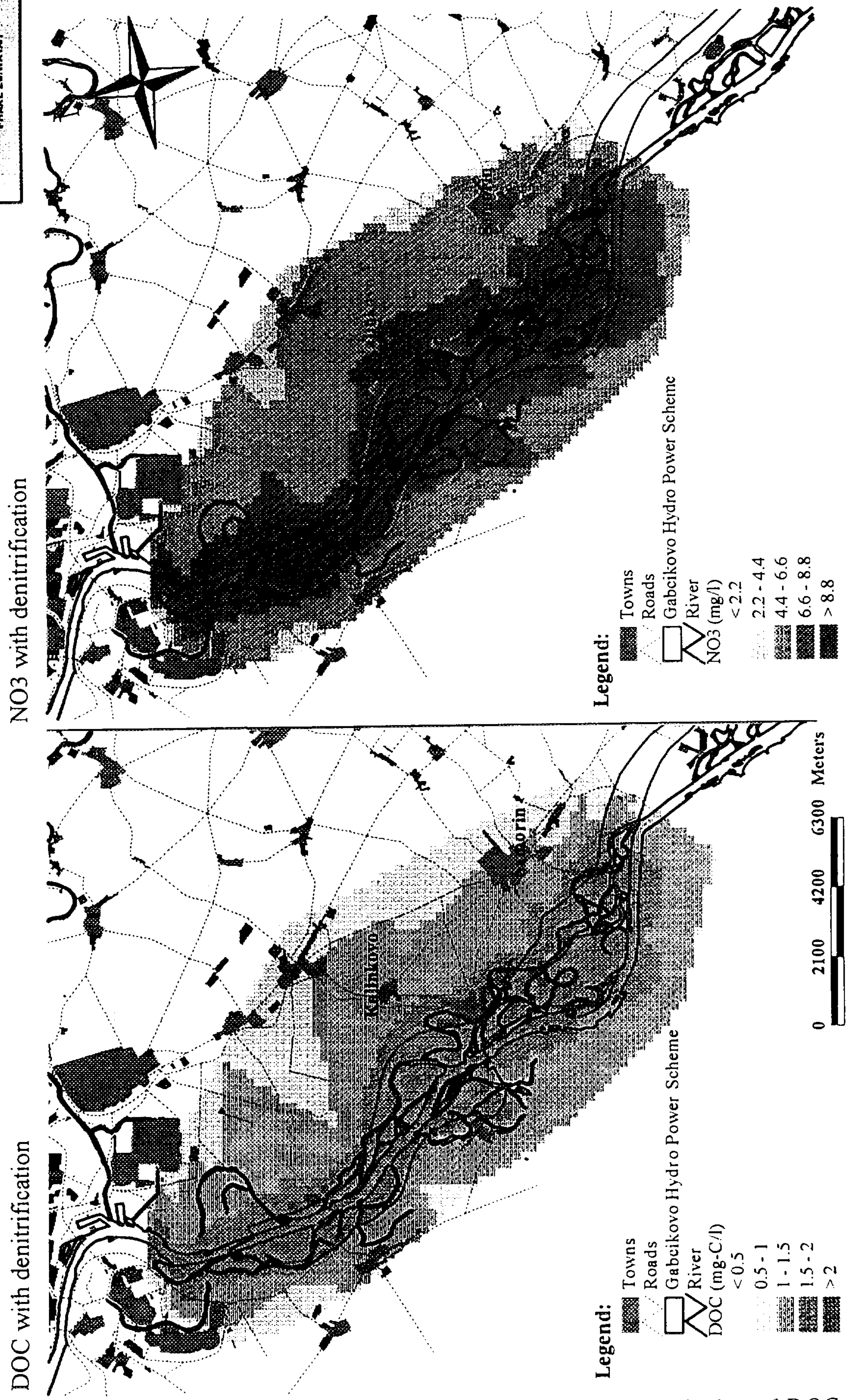

Fig. 5.3a Simulations with the reservoir model for WMRII. Distribution of DOC (dissolved organic carbon) and NO_3 taking the denitrification process into account.

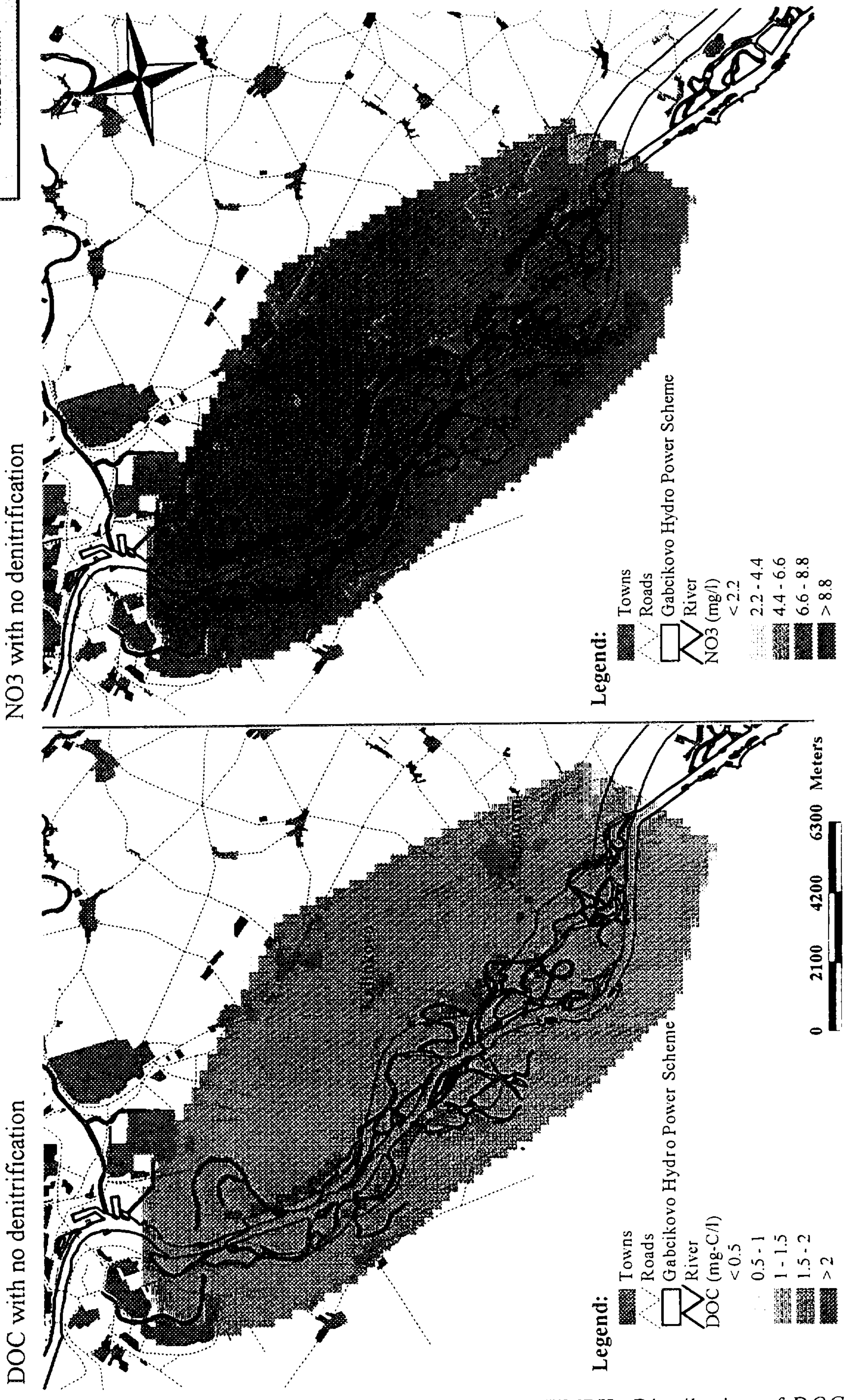

Fig. 5.3b Simulations with the reservoir model for WMRII. Distribution of DOC (dissolved organic carbon) and NO_3 without taking the denitrification process into account.

5.6 Hydrodynamics, Sediment Transport and Water Quality in the Danube

The modelling systems applied are the hydrodynamic, sediment transport and water quality modules of MIKE 11.

5.6.1 Objectives

When the hydro power production at Gabçikovo was initiated the Danube water was diverted to the Gabçikovo hydropower plant leaving only a fraction of the water for the Old Danube. Obviously such a change will affect the hydrodynamics of the old river significantly. Reduced flow velocities and water depth in the Old Danube may induce water quality problems. The construction of the upstream reservoir in combination with the altered flow regime in the Old Danube may also change the sediment deposition/erosion pattern undesirably.

The main objective of the hydrodynamic, water quality and sediment transport simulation for the Danube is to predict (quantify) such changes.

Hydrodynamic, water quality and sediment transport simulations were carried out for all four Water Management Regimes.

Management options including construction of underwater weirs in the Old Danube or upheaveling of the river bed by supplying gravel were investigated. The aim of such management options should be to bring the water levels in the Old Danube back to the level before damming of the Danube.

5.6.2 Main conclusions

Hydrodynamics

By introducing eight underwater weirs with heights of about four meters in the Old Danube the water level can be increased in the order of 1 - 3 metres, which for low flow conditions (1000 m^3/s) brings the water level close to the pre-dam (WMRI) conditions. For average flow conditions (2000 m^3/s) the water levels for WMRI is about 1 - 1½ m higher than in WMRII. Water levels in WMR III (800 m^3/s) is about 2 metres higher than WMR IV (200 m^3/s).

The studied underwater weir solution will make the Old Danube look rather unnatural with a series of cascades, in particular during low flow conditions. The flow velocities between the weirs will be lower (0.5 - 1 m^3/s for average flow), while the velocities on the weirs will be higher (2 - 3 m^3/s for average flow). Therefore, it would be required to derive and study a more optimal shape of the weir as well as to accompany it with other measures.

Sediment Transport

The overall morphological changes in the Old Danube have been assessed by using a one-dimensional model in which redistribution of sediment within a cross-section is disregarded. Due to the low flow velocities in the Old Danube for WMR II, WMR III and WMRIV almost no bed erosion will take place. Moreover, the river bed is not supplied with coarse material due to the trapping effects of the reservoir. Hence, large scale morphological changes in the Old Danube river bed are very modest according to the model. However, significant local changes (which cannot be resolved in the one-dimensional model) in channel forms may take place. If underwater weirs are constructed in the Old Danube transport of bed load and the coarser fractions of suspended load will be stopped at the weirs. Only the finer sediment fractions may be transported over weirs.

Close to the confluence between the outlet canal and the Old Danube bed erosion will take place due to a sudden increase in river discharge.

Water Quality

In general, water quality simulations do not indicate major problems in the Old Danube. For all post-dam scenarios the lowest oxygen concentrations are simulated in the backwater zone close to the confluence between the outlet canal and the Danube. Model results for a worst case situation are presented in Fig. 5.4. This situation corresponds to discharges of approximately 1000 m^3/s at Bratislava of which all (WMR I), 400 m^3/s (WMR II), 800 m^3/s (WMR III) and 200 m^3/s (WMR-IV), respectively, flows in the Danube channel between Cunovo and the downstream confluence with the power canal. Furthermore, respiration rates corresponding to the highest ones observed during the field campaign, i.e. summer periods with high biological activities, have been assumed. The oxygen concentrations have diurnal variations which generally increase with decrease in discharge. The concentrations shown in Fig. 5.4 are the minimum ones occurring early morning between 3 and 6 am. The maximum concentrations occurring late afternoon are typically 2-3 mg O_2/l higher. It is seen from the figure that this worst case minimum concentration is 5-6 mg O_2/l with the exception of WMR IV with underwater weirs, where it is around 2.5 mg O_2/l. Whereas 2.5 mg O_2/l in general is a very low concentration critical to fish species, but generally not to benthic faunal, it must be emphasized that this worst case situation will occur very rarely and over only a few km river length. Furthermore, this critical situation will have a duration of a few hours, so that the fish may move away and return afterwards. Hence, such rarely occurring worst case situations are not expected to have significant long lasting ecological effects.

5.6.3 Assessment of uncertainties of model predictions

The hydrodynamic models are considered very reliable. The uncertainty of water level predictions are assessed to be in the order of ± 20 cm. By far the most important uncertainty is the fact that the river cross-sections are subject to continuous changes mainly due to gravel excavation. The consequence of this is that model uncertainties are a function of time. Hence, if the model can predict water levels with an accuracy of ± 20 cm this uncertainty may be ± 50 cm in the year 2000. Thus, in order to maintain the predictive power of the model, river cross-sections in the model must be updated as changes occur and as new field surveys provide new cross-sectional data.

Model predictions of sediment transport, bed load as well as suspended load, are much more uncertain than prediction of water levels and velocities. Sensitivity analyses have indicated that the sediment transport predictions are accurate within a factor of 2.

The uncertainties of the oxygen predictions can within the calibration range of the model, i.e. WMR I and WMR III, be estimated to ± 1 mg O_2/l. It should be noticed, however, that the very low oxygen concentrations predicted in WMR IV, represent values far outside the regime for which the model was calibrated. Hence, the simulated low oxygen concentrations are subject to larger uncertainties than the oxygen concentrations predicted for WMR I and WMR III. Similarly, it should be emphasized that the model has not been calibrated to conditions with underwater weirs. The higher reaeration due higher velocities over the weirs are incorporated explicitly in the model, but it has not been possible to calibrate this. These uncertainties can be reduced significantly by establishing a proper monitoring programme.

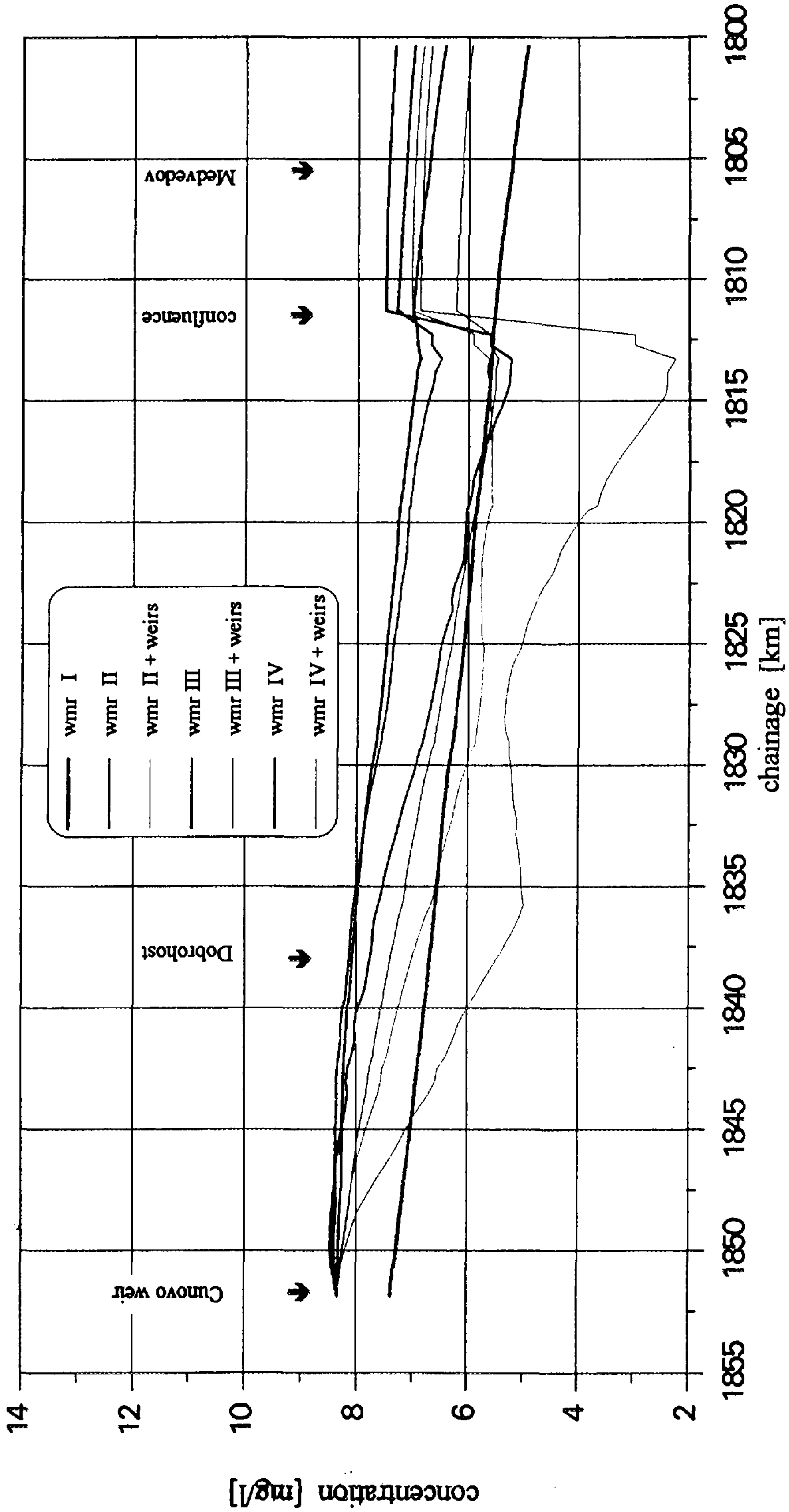

Fig. 5.4 Longitudinal profile of a worst case minimum oxygen concentrations (6 a.m.) in the Old Danube for the different Water Management Regimes and Management Options.

5.7 Hydrodynamics, Sediment Transport and Water Quality in the River Branch System

The applied modelling system was the hydrodynamic-, sediment transport- and eutrophication modules of the MIKE 11 modelling system.

5.7.1 Objectives

Before the damming of the Danube, the river branch system was filled with water and for high flow events the system was flooded and there was connectivity between the river branches and the main channel of the Danube. These connections were only functioning in high flow conditions a few weeks per year. After the damming the water level in the Old Danube decreased significantly and connections between the main river and the river branch system were blocked. In order to prevent the river branches from drying out a hydraulic structure was built at Dobrohost supplying the river branches with water from the hydropower canal. Hence, the flow regime in the flood plain system changed to an artificial regime, mainly controlled by the flow through the inlet structure at Dobrohost. This system provides many management options, namely the structure at Dobrohost, weirs and culverts within the river branch system and finally the water level (flow regime) in the Old Danube.

The main objectives of this chapter are to characterize the flow regime, the water quality regime and the sedimentation regime in the river branch system for the four different water management regimes.

5.7.2 Main conclusions

Hydrodynamics

For all post-dam scenarios (WMRII-WMRIV), the water levels in most of the river branch system are higher than in the pre-dam (WMRI) conditions. The simulations, however, also clearly demonstrate that the hydraulic regime has been totally altered after the damming of the Danube. In brief, the post-dam simulations are characterized by branches which are continuously filled with water but in general with very low flow velocities and almost stagnant water in the most downstream compartments. Before the damming many river branches were dry or with stagnant water in the upstream compartments. In the more downstream compartments, the regime was much more dynamic than the post-dam regime, with dry periods and periods with high water levels and flow velocities during floods followed by periods with stagnant water.

Although the simulated scenarios do not represent optimized situations, the model application has demonstrated that the flow regime in the river branches can be controlled to a large extent by operation of the Dobrohost weir in combination with operation of the culverts in the system. A more natural flood plain flow regime can only be obtained if the connections to the Old Danube are reestablished and if the water level in the Old Danube is increased. A longitudinal profile of flow velocities at different discharges is shown in Fig. 5.5. Furthermore, the figure illustrates the effects of establishing one connection to the Old Danube river and effects of decreasing invert elevations on the culverts in the river branch system.

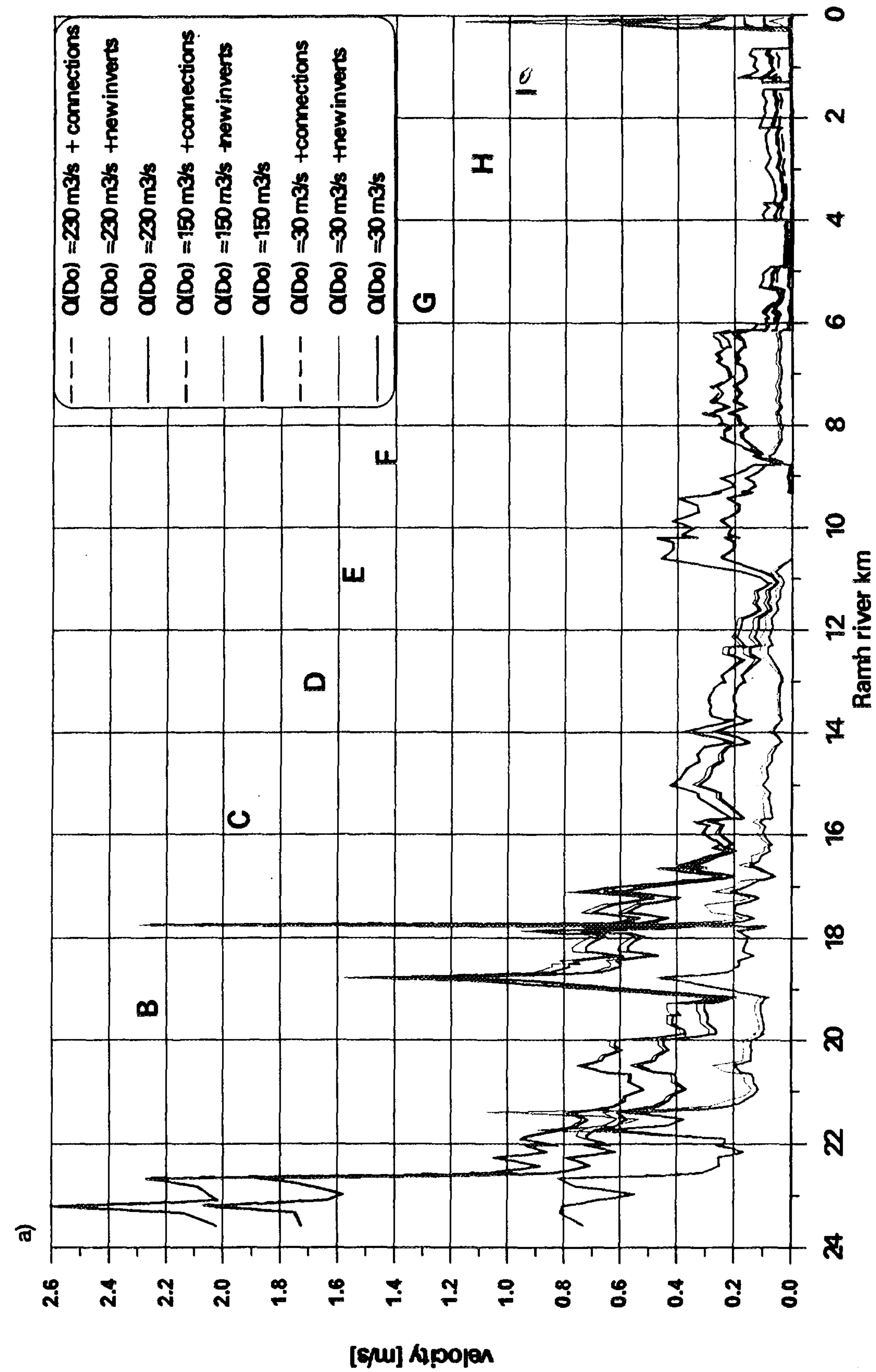

Fig. 5.5 *Longitudinal flow velocity profile in the main branch of the river branch system (+connections : reopening of one connection to the Old Danube, +new inverts: reduction of invert elevations on culverts in the river branch system).*

Sediment Transport

Siltation of suspended sediment in the river branches only takes place in the blind river branches with almost stagnant water. The main river branches in the upstream compartment are not subject to siltation due to high flow velocities. The main river branches in the downstream parts, where the flow velocities are lower, are not subject to siltation either, as practically no sediment reaches the downstream compartments.

Attempts to flush the system may, however, lead to situations where erosion takes place in the main branches in the upstream compartments, but settles again in the downstream compartments where flow velocities fall below the critical velocity for deposition. Thus, flushing of the system should be carefully studied using the model in order to avoid undesirable effects. The flushing simulations also indicate that it is not possible to flush blind river arms, hence, these will be subject to continuous sedimentation. Many blind river arms have been created due to blocking of the connections to the Old Danube. Hence, re-opening of some connections may enable flushing of such branches.

Water Quality

Simulations with the calibrated eutrophication (water quality) model do not indicate any significant eutrophication problems in the river branch system.

5.7.3 Assessment of uncertainties of model predictions

The uncertainty of the water level predictions are expected to be about 10-20 cm. With regard to flow velocities and discharges the uncertainties are relatively larger due to highly non-uniformity of the river branch channels and due to the significant water loss by infiltration.

The sediment transport model can be used for prediction of trends in sediment transport and of the potential sedimentation and potential erosion areas. Thus the model is suitable for qualitative evaluations of the effects of various operation strategies with respect to sedimentation in the flood plain system. For quantitative assessments the uncertainty of the model results is at least of the same order of magnitude as the sedimentation rates predicted by the model.

The water quality model gives most reliable results for the main branches, while there are larger uncertainties related to predictions in the small channels and in particularly in the blind ends of the river branch system, where either macrophytes in shallow areas or stratification of the water column at deep water locations may occur.

5.8 Hydrodynamics, Sediment Transport and Water Quality in the Hrusov Reservoir

The applied modelling system includes the hydrodynamic-, sediment transport and eutrophication modules of the MIKE 21 modelling system.

5.8.1 Objectives

The objectives of the hydrodynamic simulations of the reservoir are to describe the surface water flow regime in terms of the flow depth and velocity distribution in the reservoir for the two post-dam water management regimes WMR II and WMR III. These regimes are crucial for the reservoir ecology and they create the basis for further sediment transport and eutrophication simulations.

The objective of sediment transport modelling activities is to study the effects of different discharge regimes (WMR II and WMR III) on the sedimentation patterns in the reservoir and thus to the leakage characteristics of the bed layer which may influence the infiltration to the ground water.

The objective of the water quality modelling of the reservoir is to assess whether eutrophication problems in the Hrusov reservoir can be expected or not.

5.8.2 Main conclusions

Hydrodynamics

There are no significant differences between WMR II and WMR III in terms of flow patterns and velocities in the reservoir for medium and high discharges.

Sediment Transport

The small differences in the flow pattern also result in only small differences in deposition patterns between WMRII and WMRIII. From the total suspended sediment inflow of 2.3 million t during a one year period, about 56% for WMR III and 60% for WMR II will deposit in the reservoir. During high flow periods, approximately 30% of the transported material will deposit in the reservoir, mainly in the downstream part. During low flow periods, almost all material settles down, the major portion in the upstream area. Based on the model results a relation between discharge and sediment load for WMR II and WMR III was established. This relation can be used to give a rough estimate of deposition in the reservoir for different discharges assuming reservoir operation rules similar to WMR II and WMR III. Fig. 5.6 shows the deposition patterns after one year of simulation for WMRII and WMRIII, respectively.

Water Quality

Due to the short retention time in the reservoir no eutrophication problems in the reservoir will occur.

5.8.3 Assessment of uncertainties of model predictions

Although the available data to evaluate the accuracy of the hydrodynamic model are scarce, it is believed that the calculations of flow velocities in general are rather accurate. The largest uncertainties are related to situations with extremely high wind speeds.

The uncertainty of the model predictions for the overall reservoir sedimentation is estimated to be less than 50%. Local differences of a higher order of magnitude may occur due to bed forms which cannot be resolved in the 100x50 m^2 computational grid. Continuous monitoring of reservoir sedimentation is required in order to improve the accuracy of the reservoir sediment transport model.

The uncertainties on the eutrophication model predictions cannot be directly estimated on the basis of the existing data. However, sensitivity analyses indicate that the uncertainties on the chlorophyll concentrations are about 20%, which will not affect the above main conclusion.

5.9 Ecology

Predictions of aquatic ecotopes in the Danube, the reservoir and in the river branch system are made on the basis of the results of the application scenarios described above.

Terrestrial ecotopes in the river branch system is predicted based on results of an integrated flood plain model. This model uses the coupled version of the MIKE 11 and MIKE SHE modelling systems.

5.9.1 Objectives

The objectives of the ecological predictions associated to the four Water Management Regimes are to demonstrate a methodology of combining the quantitative model predictions of hydrological conditions with qualitative ecological inferences.

As no clear ecological objectives have been decided for the area, and as it is outside the Terms of References of the present project to define such objectives, it is not possible to identify species which can be characterized as the most suitable indicators in describing the various ecotopes. Hence the description given below might as well have been based on other indicators.

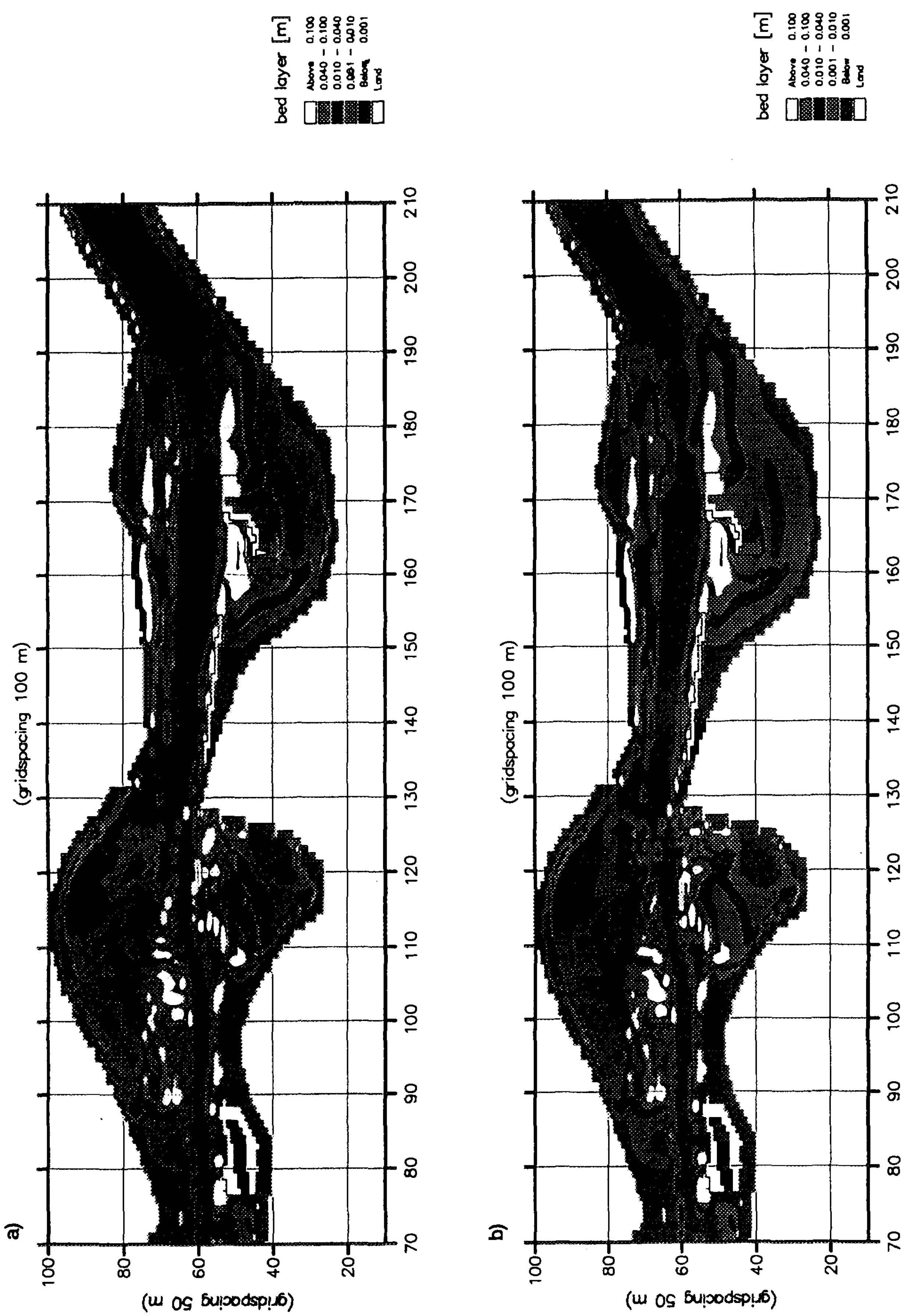

Fig. 5.6 Deposition of sediments in the Hrusov reservoir after one year of simulation in WMRII (a) and WMRIII (b).

5.9.2 Main conclusions

Aquatic Ecotopes in the Danube River System

The conditions in terms of aquatic ecotopes in the river branch system and the Hrusov reservoir are very similar for all the studied post-dam regimes.

In *the river branches* conditions are characterized by generally low flow velocities. Due to the absence of flushing, muddy bottom sediments will develop in secondary branches and water vegetation is expected in all shallow reaches, eventually leading to the terrestrialization of narrow and shallow branches. However, for many species that can be considered typical for river branches, being mainly less critical rheophile species, a large variety in living conditions is maintained. Furthermore, it should be noted that detrimentally low oxygen conditions are not expected and that eutrophication as far as it may occur in the dead-end branches will be within the range of natural variation. However, conditions for typical species could be improved further if the weirs could be made passable to these less swift swimmers. Water vegetation typical for the periodical desiccation in former high water branches will disappear, since all branches and all the previously temporary pools have become permanent waters. Overall an increase in primary and secondary aquatic production is expected.

In *the Hrusov reservoir* less critical rheophile fish species will find suitable living conditions along the path of the former river channel. In addition, species typical for river branches may be expected in adjacent more shallow areas with moderate to slow flowing conditions. Upstream of the Cunovo weir large shallow areas are present where water vegetation will settle.

Because of the presence of weirs at Cunovo and Dobrohost and also those in the river branch system, most species will only be able to migrate upstream from Sap to Bratislava through the ship locks at Gabcikovo. The conditions for *migrating species* can be greatly improved by making these weirs passable.

Without underwater weirs and with an upheaveled river bed conditions for typical rheophile fish species in the Old Danube are slightly worse in WMR II than in WMR I while WMRIII has slightly better conditions than WMRI. WMR IV renders the Old Danube largely unsuitable for critical species, mainly because of too low flow velocities in the downstream parts. The reduction in flow velocities will, on the other hand, improve conditions for other species as compared to the pre-dam situation with the uniform river channels with very high flow velocities. The limited water level variation may induce the settlement of softwood species and a largely natural succession of softwood forests along shores and upon gravel banks.

With underwater weirs conditions for rheophile fish species in the Old Danube deteriorate in all water management regimes with WMR III being best. WMR IV makes the Old Danube largely unsuitable to most rheophile fish species, for which only suitable conditions may remain downstream of the Cunovo weir and some other weirs in the upstream part. However, reduction in flow velocities, will result in improved conditions for other species, and without knowing the ecological objectives it cannot be stated which condition is the most optimal.

Reestablishment of some connections between the river branch system and the Old Danube would be valuable in general.

Terrestric Ecotopes in the River Branch System without Underwater Weirs in the Old Danube

For WMR II (post-dam), flooding is less extensive, less intensive and varies only slightly between different years. Also variations in Pegelweg on a weekly, seasonal and inter-annual basis are less than for pre-dam conditions (WMR I). The Pegelweg variations can most likely be restored by maintaining suitable water level fluctuations in the seepage canal through operation of the hydraulic structures in the seepage canal. Average ground water levels have decreased in a narrow zone close to the Old Danube. In general, there is no significant change in ground water levels in the flood plain area due to the damming of the Danube, leading to very limited effect upon the flood plain forests and especially upon the less sensitive Canadian poplars. In terms of soil moisture regimes, limited effects could be observed for the rainwater dependent regimes (i.e. regimes where vegetation depends on rain rather than on capillary rise from ground water) that dominated already the northern and eastern parts of the modelled flood plain area.

Especially where flooding is less intense, conditions for the herb-layer will have changed substantially. An exception is areas in a limited zone along the river branches in the upper compartments were ground water levels have increased slightly.

Terrestric Ecotopes in the River Branch System with Underwater Weirs and Upheaveled River Bed in the Old Danube

Model results show that when using underwater weirs, average ground water may be restored in large parts of the area, especially in WMR III. For WMR II and even more for WMR IV, drained pockets with lower ground water levels adjusted to the water levels downstream of the underwater weirs can be expected.

Also soil moisture regimes are largely restored, although non-typical flood-rainwater dependent soil moisture regimes remain present in WMR II, and most probably especially in WMR IV. In WMR III also, previously shallow ground water levels (<0.7 m) may be largely restored and, as a consequence, also ground water dependent moisture regimes.

The conclusions regarding terrestrial ecotopes are made on the basis of model results with the integrated flood plain model. Important information has been provided by mapping ground water classes and soil moisture classes based on combinations of different model results. An example of a map of different ground water classes is shown in Fig. 5.7

5.9.3 Assessment of uncertainties of model predictions

In general, predictions of ecological changes are more uncertain than model predictions of changes in water levels, flow velocities, sedimentation and surface water quality. In the present case this is reenforced by the lack of suitable data for calibration of the 'ecological model'. Use of data presently being collected as part of a comprehensive ecological monitoring programme can improve the reliability of the ecological predictions.

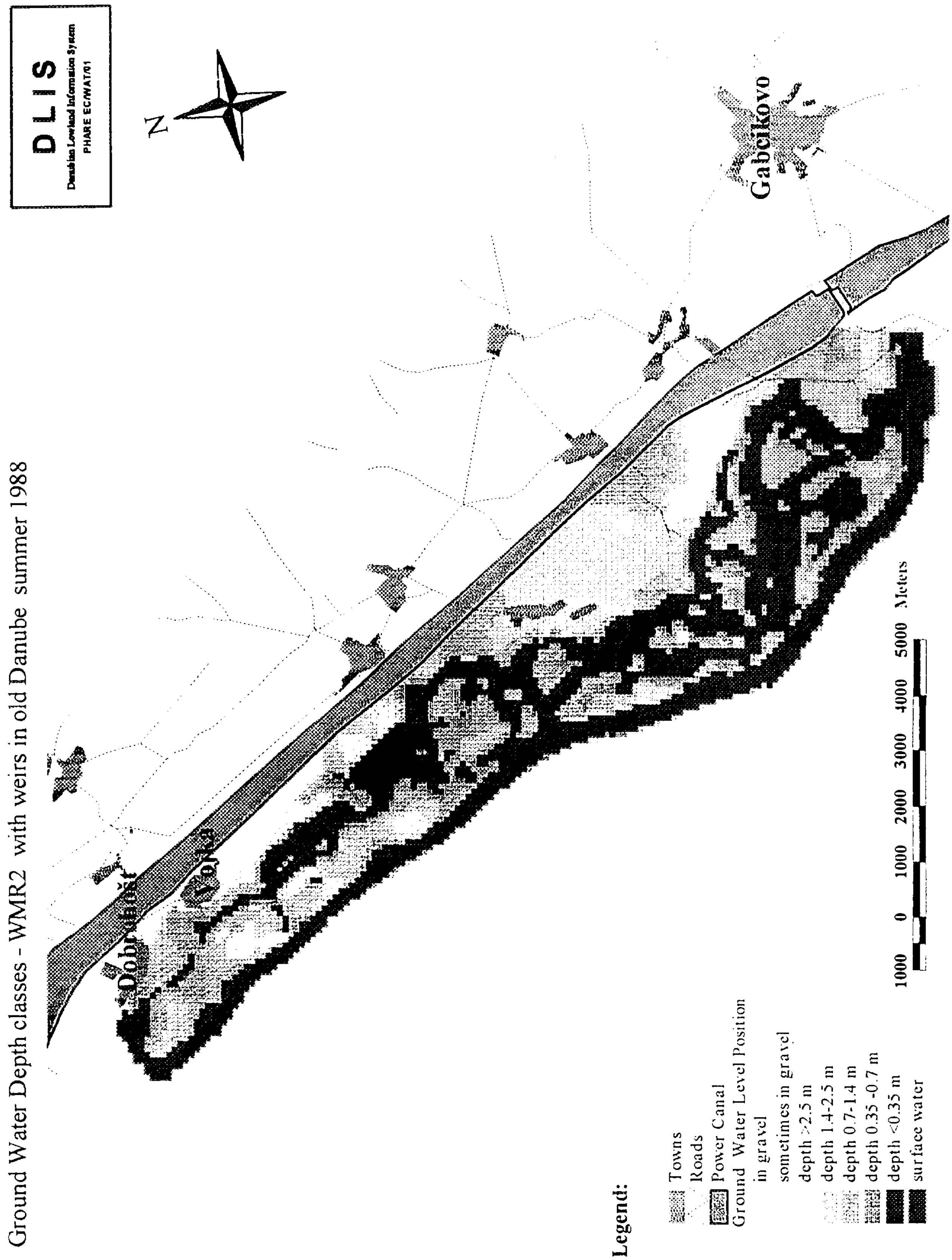

Fig 5.7 *Average Ground Water Classes for the growing season of 1989 (WMRII, with under water weirs in the Old Danube).*