6 CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a brief summary of conclusions with respect to project implementation issues. Furthermore, the chapter contains recommendations on future applications of the modelling system and on water resources management in the project area.

6.1 Conclusions Regarding Project Implementation

The project has been completed in accordance with the Terms of References. In the following some key features in this respect are emphasized.

6.1.1 Equipment

Equipment for almost ECU 600,000 has been procured and installed during the project. Computer hardware and software constituted the main equipment items, but field and laboratory equipment as well as office equipment were also included. The backbone of the computer system is formed by two Hewlett Packard Apollo 9000/735 UNIX workstations.

The procured equipment has been extensively used during the project and it has fully accommodated the needs of the project. Although, the progress in developments of faster computers and more advanced software is tremendous in these years, the procured equipment will technologically be at the front end for years yet to come.

6.1.2 Establishment of a generalized integrated modelling system

An integrated mathematical modelling system suitable to address the water resources problems in the project area has been established. The modelling system is based on the following packages which can be used individually or brought together in an integrated manner:

* **MIKE SHE** which, on catchment scale, can simulate the major flow and transport processes of the hydrological cycle which are traditionally divided in separate components:
  - 1-D flow and transport in the unsaturated zone
  - 3-D flow and transport in the ground water zone
  - 2-D flow and transport on the ground surface
  - 1-D flow and transport in the river.

All the above processes are fully coupled allowing for feedbacks and interactions between components. In addition to the above mentioned components, MIKE SHE includes modules for multi-component chemical reactions in the ground water zone.

* **MIKE 11**, which is a one-dimensional river modelling system. MIKE 11 is used for hydraulics, sediment transport and morphology, and water quality. The modules for sediment transport and morphology are able to deal with cohesive and non-cohesive sediment transport, as well as the accompanying morphological changes of the river bed.

* **MIKE 21**, which is a two-dimensional hydrodynamic modelling system. MIKE 21 is used for reservoir modelling, including hydrodynamics, sediment transport and water quality.

* Both of the above mentioned models include **River/Reservoir Water Quality (WQ) and Eutrophication (EU)** modules to describe oxygen, ammonium, nitrate and phosphorus concentrations and oxygen demands as well as eutrophication issues.

* **DAISY** is a one-dimensional root zone model for simulation of crop production, soil water dynamics, and nitrogen dynamics in crop production for various agricultural management practices and strategies.

The above mentioned models are all generalized tools with comprehensive applicability ranges, they represent state-of-the-art technology, and they are well proven in a large number of international projects. In addition, some model modifications have been carried out during the project in order to accommodate the very special environment and problems observed in the area.

6.1.3 Establishment of Danubian Lowland Information System (DLIS)

An automated system has been developed to support the modelling activities. The integrated modelling system is interfaced to a central information system, called Danubian Lowland Information System (DLIS). DLIS can provide the different models with key input data and comprises post-processing facilities to elaborate further on the modelling results.

The two main components of the DLIS are a geographical information system (GIS), based on the ARC/INFO software package, and a relational data base management system (RDBMS), based on the INFORMIX software package.

6.1.4 Establishment of calibrated and validated models

On the basis of the generalized integrated modelling system and the DLIS a number of specific models has been established:

* 1-dimensional and 2-dimensional models of the Danube, the Hrusov reservoir and of the complex system of river branches on the Slovak flood plain. These models are able to address hydrodynamic-, water quality- and sediment transport aspects.

* Ground water flow on the Žitný Ostrov on regional and local scales.

* Transport and geochemical transformation of solutes.

* Crop growth, irrigation requirements and nitrate leaching.

These models are specifically calibrated and validated for the project area.

6.1.5 Model applications

The established models have been applied to selected number of practical problems, partly for demonstrating their applicability and partly for assisting the water resources decision makers by providing technical results to specific questions.

The model applications have been performed under a scenario framework comprising four different Water Management Regimes. The specific content of the Water Management Regimes and the associated scenarios have been defined through discussions in the project Steering Committee and through discussions with the Slovak Ministry of the Environment.

The four Water Management Regimes (WMR) are characterized as follows:

* WMRI is a reference situation reflecting the pre-dam situation.

* WMRII reflects a post-dam situation where in average about 400 m^3/s are diverted from the reservoir to the Old Danube.

* WMRIII reflects a post-dam situation where in average about 800 m^3/s are diverted from the reservoir to the Old Danube.

* WMRIV reflects a post-dam situation where in average about 200 m^3/s are diverted from the reservoir to the Old Danube.

6.1.6 Cooperation with Slovakian organisations

During the project the Consultant has cooperated closely with several Slovakian organisations. Most importantly, staff members from the following Slovak organisations have participated actively in, and have made comprehensive contributions to, the project:

- Comenius University (PRIF UK)
- Research Centre for Irrigation (VUZH)
- Water Research Institute (VUVH)
- Ground Water Consulting Ltd. (GWC)

PRIF UK is the recipient institution and the end user of the established models.

6.1.7 Transfer of technology and know-how

10 staff members from PRIF UK, VUZH and VUVH have in the beginning of the project received basic training in the applied modelling systems. Subsequently, they have in close cooperation with Consultant staff members established the various models from the first data collection and interpretation to the final model validation. During phase II of the project the Slovakian staff members have gradually taken over the major part of the work and most of the model application scenarios have been done almost independently by Slovakian staff members. These staff members are now fully trained and have obtained sufficient working experience with respect to the applied modelling systems. Hence, in this respect the transfer of know-how and technology has been very successful.

All project equipment, including the established modelling systems and DLIS as well as the specific model setups and data used during the project, have been successfully transferred to a new project office at PRIF UK.

However, as a result of various organisational changes during 1995 7 out of the 10 trained Slovakian staff members changed job from PRIF UK and VUVH respectively to a private firm, Ground Water Consulting Ltd., and one trained Slovakian staff member changed job from VUVH to the Slovak Ministry of the Environment. Thus, the full project know-how has not, as originally intended, been transferred to PRIF UK. Therefore, the Slovak Ministry of the Environment has initiated training of a new group of specialists established at PRIF UK. The training of this group will take place under a separate contract financed through additional funding by the EC. The training started in September 1995 and is to be completed by the end of March 1996.

6.1.8 International workshops

Two international workshops with participation of invited international specialists as well as Slovakian specialists have been conducted in June 1992 and in June 1995, respectively.

The first workshop, which took place during the Inception Phase, served as a review of the problem assessment, field works, modelling methodology and detailed project plans proposed by the Consultant.

At the second workshop, which took place in the middle of Phase II, the results of the model calibrations, model validations and the first model application results were reviewed.

Both workshops were held in a very positive atmosphere, and both the international and the Slovakian specialists provided constructive criticism and contributed significantly with many ideas and suggestions of considerable value for the project.

6.2 Recommendations on future Applications of Modelling System

The water resources problems in the project area are so complex, the amount of available data so large and the number of possible management options so high that it, in accordance with the Terms of References, has not been possible to fully process all technical data nor to provide optimal technical solutions to all the problems.

The established modelling system has, as a result of the comprehensive model validations and subsequent model applications, proven to be able to address the most important water resources problems in the area. The modelling tool thus established and now transferred to the Slovakian user has comprehensive fields of applications in connection with the future water resources management in the area.

Thus, it is strongly recommended, and in full accordance with the ultimate objectives of the Terms of References, that the modelling system and data bases established during the project be further applied in the coming years.

The following two subsections outline some obvious fields of future model applications and provide recommendations with respect to the new modelling group at PRIF UK.

6.2.1 Future model applications

On the basis of the model applications carried out during the project it is recommended to use the established modelling tool to carry out, amongst others, the following types of studies:

* Studies of the many possibilities for management in the Old Danube and the river branch system. The model scenarios carried out during this project have illustrated how the models can be used to predict the conditions in this area assuming different flow regimes and different management options such as underwater weirs in the Old Danube. The established models of the Old Danube and the river branch system provide reliable tools for defining management rules and operational practices, for instance in connection with flooding of the river branch system.

* Design studies of shape and type of underwater weirs, including the slope at the downstream side of the weir and including combinations with groynes.

* Studies of sediment flushing possibilities in the reservoir.

* Studies of sediment flushing possibility in the river branch system.

* Studies of alternative reservoir operation scenarios for how to manage situations where one or more of the structures at Gabcikovo or Cunovo are temporarily not fully functioning. This can form the basis for preparation of emergency plans.

* Studies of possible reestablishment of some connections between the river branches and the Old Danube. This would involve optimal location of connections and design and location of underwater weirs and/or establishment of gravel banks. The established models are ideally suited for such studies.

* Studies of possible effects on ground water pollution of point sources of nitrogen from e.g. manure.

* Studies of ground water pollution from point sources due to e.g. landfills and industrial waste dumps. Such studies have not been included in the present project, but the integrated modelling system is very suitable for such applications.

* Studies of possible effects on ground water dynamics of management of water levels in seepage canals.

* Studies of future development of ground water quality. This should be carried out in combination with the recommended future monitoring of ground water quality.

* Studies of ecological effects of different management options in the river branch system, including various flow regimes. This should be carried out in combination with the recommended future monitoring of ecology in the area.

6.2.2 Future modelling group at PRIF UK

At present, the modelling group trained during the project, now working with Ground Water Consulting Ltd, is fully capable of handling the modelling tools.

In order to upgrade the new group of specialists at PRIF UK to the same level, it will be required that the staff members of this group get the following training and working conditions:

* A basic training course, comprising theoretical and practical/operational introductions to the modelling systems as well as introductions to the established models.

* Full time working experience with the models.

6.3 Recommendations on Water Resources Management in the Danubian Lowland

Experiences from other countries suggest that the reservoir and river system may not come into a new equilibrium for the first couple of years. Hence it is strongly recommended to combine future model applications/predictions with a monitoring programme, which should continue for some years, e.g. on aspects related to floodplain ecology, sediment transport/morphology and geochemistry.

It is outside the Terms of References of the present project to define management objectives or to suggest a management decision framework for water resources. In line with strong recommendations from the international specialists at both international workshops it is recommended that the Slovakian authorities give emphasize to these issues.