A Case Study of the Flood Control by the Water Management System on the River Ohře

Jiří Sovina
Czech University of Life Sciences Prague
Faculty of Environmental Sciences
Department of Applied Geoinformatics and Spatial Planning,
Kamýcká 129, 165 21 Praha 6 – Suchdol, CZ

Email adress : sovina@fzp.czu.cz

Abstract

At the Department of Applied Geoinformatics and Spatial Planning, Faculty of Environmental Sciences of the Czech University of Life Sciences in Prague and at the Department of Hydraulic Structures, Faculty of Civil Engineering, Czech Technical University in Prague, the problem of an operative control of the water management systems is studied, funded by the grant project. On occasion of the Dispatchers' Games held in November 2008 at premise of the Ohře River Basin Authority, state enterprise, in Chomutov, the model of a water management system on the river Ohře was tested. The model of the system covers entire basin upstream to the dam site of Nechranice reservoir, using the HEC-ResSim 3.0 program.
The model of was created at the Czech University of Life Sciences in Prague, based on the data provided by the Ohře River Basin Authority, state enterprise. For sake of presentation, the passage of a historical flood was selected. The discharge was somewhat increased to amplify risks to the flood prone regions. An advice of the optimum flow control of the reservoir system Skalka, Jesenice, Horka, Březová, Stanovice and Nechranice was given the highest priority. The output of the model was used at the Dispatchers' Games to confront the computer-supported operation control with that as suggested by the players' team of the Vltava River Basin Authority, state enterprise. The model has proven its full functionality and usability in the field of research and also in practical application.

KEYWORDS: water management system, flood control, simulation, the Dispatchers' Games, HEC-ResSim 3.0

Introduction

At the Department of Applied Geoinformatics and Spatial Planning, Faculty of Environmental Science, Czech University of Life Sciences in Prague, the problems of operative control of the water management systems is solved, in connection with the work on the grant projects oriented at the monitoring problems and control in the sphere of the water management. This assignment is worked on in cooperation with the Department of Hydraulic Structures, Faculty of Civil Engineering, Czech Technical University in Prague. It concerns, among others, the testing of the possibilities of utilization of the program media developed by the US Army Corps of Engineers, Hydrologic Engineering Center, USACE. These programs were released to the public, they are used worldwide and known under the abbreviation „HEC“. In this group of program media, the simulation program HEC- ResSim 3.0 (Reservoir System Simulation Program) is at disposal for the control of the water management systems. In this study it was used as a support for the dispatchers' control work at the Dispatchers' Games held in November 2008 at the Ohře River Basin Authority, state enterprise. A welcome opportunity to field the WMS model created in HEC-ResSim 3.0 were the Dispatchers' Games, organized after several years interval by the Ohře River Basin Authority, state enterprise, on the 10th and 11th Oct. 2008, thus continuing the earlier begun tradition.

This paper was subsidized by the Grant Agency Czech Republic, project reg. No. 03/07/1620 „Prediction and simulation models in the operative management theory“.

The author express his thanks namely to the specialists of the Ohře River Basin Authority, state enterprise, Ing. Václav Klečka and Ing. Pavel Eger for their support and creation of conditions for the realization of this case study.

Methods

In April 2007 an actual version of the HEC-ResSim 3.0 program was issued, representing a more robust modelling instrument in comparison with the previous version 2.0. It offers new possibilities as regards the function modelling of water-pumping stations and water power plants, the possibility of using the logic constructions of the „If – Then – Else“ type, of the users' scripts and of the management based on the user-defined time series. It brings further substantial improvement of many functions known with the previous version of the HEC-ResSim 3.0 and so it represents a suitable instrument for the control simulation of all substantial functions performed on reservoirs and water management systems (WMS) under normal and extreme situations.

In this computer environment it is possible to define a model of any regular WMS in a satisfactory detail and to run simulations based on time series defined either by real events in the river basin, based on forecasts or any other tested alternatives. For the inputs and outputs of the time series the connection to the HEC Data Storage System is used which represents the general standard for the data storage in the USA, utilized e.g by the federal institutions (USACE HEC, USNWS, EPA, USGS,USSCS) and by further subjects operating in the sphere of water management. This way the HEC-ResSim 3.0 together with other program media „HEC“, especially HEC-RAS, HEC-HMS, HEC-FIA is used as a part of the integrated system CWMS (Corps Water Management System) exploited by the working places USACE for the needs of the WMS and water works management in the United States.

The water management system of the Ohře river basin and affluents

For the study of the appropriate dispatchers' control procedure at the „Games“, the most significant part of the Ohře river basin was chosen, from its spring and upper flow in Bavaria up to the dam profile of the waterwork Nechranice, with all its affluents and above all with the significant waterworks where the flood flow can be influenced by manipulation. Progressing along the river downstream, they are the waterworks Skalka and Jesenice (on the river Odrava) in the Cheb region, both of which together represent one waterwork in the sense of the approved manipulation regulations. Further, included into the „Games“ was the water reservoir Horka on the Liboc brook with its not negligible retention content (available storage capacity) of 2,12 mil.m^3, even though in reality it is a typical water power plant reservoir and its protective storage is classified as non-manageable by the manipulation regulation.The couple of waterworks in the Teplá river basin – the waterwork Březová and the waterwork Stanovice (on the Lomnice brook) – was another significant element, again defined by the manipulation regulation as one system. The largest waterwork concluding the entire river basin studied at the „Games“ was the waterwork Nechranice with the total protective storage of 51,77 mil. m, of which 36,56 mil.m3 represent a manageable content and with the harmless flow rate under the dam of 200m3/s, as stipulated by the manipulation regulation. The water power plant reservoir Podhora on the upper flow of the river Teplá was not included into the dispatching simulation.

Topography and map bases

The assignment of the study of the area and waterworks defined as stated above was to create a model capable to simulate the flood control, using the HEC-ResSim 3.0 program. By the formulation of mutual connectivity of the waterworks and river segments, the program forms the topology of the system according to the map bases and stores it in the data base of the project. The maps in the ESRI shape-file format proved to be the optimal base, even though other formats such as for instance dap, img, jpg and others, e.g. ASCH NetTIN can be used. The program media from the development USACE HEC generally support the use of the geographical information systems and data formats ESRI.

The construction of the model

The processing of the map bases and the defining of individual fundamental managed and non-managed elements of the WMS model itself, is performed in the first of the three program moduls named „Watershed Setup“. It serves for the creation of the basic net of the river segments, reservoirs and their junctions, of the computational points and further components of the system, generally labelled as „projects“. The careful assembly and verification of the topology is a condition for the successful functioning of the model. In the second modul „Reservoir Network“ the program enables to create variants of the earlier created basic element systems of the WMS, the defining of their component parts in a high detail and the defining of their behavioral rules. In this modul not only parameters of reservoirs and their functional objects are defined, but the characteristics of the river segments as well. The ResSim system enables the choice of various algorithms for the solving of the continual flow in the river net. For the waterworks the reservoir storage is determined and their requested water level behaviour can be defined (the so called regulated variables), for instance on the base of the dispatcher graphs set by the manipulation regulation.

For every reservoir storage capacity, the management rules were defined, valid for the water reservoir as a whole and for its part objects , such as for instance spillways, closures, power plants, outlets etc. Various ways were used for doing so. Fundamentally, one way was the defining of the external procedures performed by the service personell – the direct manipulations, the typical example of which is for instance the preventive reservoir drainage before the arrival of the predicted flood wave. Or the manipulation in the feedback regime, defined as the function of the state of other components of WMS, depending for instance on the condition that the maximal flow rate should not be exceeded at the given profiles lower on the river flow. Such places were especially the junction of Ohře and Odrava or the Thermal profile in Karlovy Vary on the river Teplá. Understandably, the program enables to define the management rules for keeping the required minimal flow rate in given profiles.

The management rules that are at disposal for the waterworks can be principally divided into:

- The rules for the release function that can be defined for the resrvoirs as a whole, for the dam objels en masse, with the selection of priorities in their usage (e.g. the precedence of the water power plants) and understandably for the individual manageable spillways, outlets and take-offs (eventually their user-defined groups).
- The management rules dependent on the flow rate in the given profile under the waterwork (the downstream control function), defined for the waterwork as a whole.
- The tandem operations ensuring optimalization in the capacity usage on the waterworks cascade.
- The rules for the extreme flood situations(Induced Surcharge).

- The rules dependent on the velocity of the changes in other data, e.g. inlet, outlet, movement of the level (Flow Rate of Change Limit, Elevation Rate of Change Limit)
- The management rules for pumping stations and water power plants with the possibility of entering several levels of time harmonograms and other specific rules.
- The script-defined management rules. These are designed above all for special procedures of the outlet control. ResSim 3.0 has been recently equipped with the script editor using the syntax of the Jython language (the implementation of the Python language into the Java platform), from which the usable system objects are lucidly available.

Version 3.0 offers also the possibility of using logic constructions of the „If – Then – Else“ type, directly in the editor of the reservoir characteristics and functions (Reservoir Editor). In figure 2, the example of the usage of this construction is presented, for the definition of management rules on the reservoir Skalka during a flood so that it practically complies with the relatively complicated conditions set by the „handling regulations“, depending on the inflow into the reservoir and the position of the water level. Under these conditions, by continuous manipulation, a very effective usage of a not very large storage capacity is reached

Simulation of the management process

For the management simulation the modul „**Simulation**“ was used, because it enables testing and storing many management variants. After the end of the simulation run, defined by the time of start and end (date and time) and by the marginal conditions for the beginning of the run, the flow rates and states can be read, practically for all components of the system in an optional phase of the simulation. Well-arranged graphic and corresponding tabular output is at disposal and it is possible to print them or to process them e.g. by the MS Excel.

Results

By the kind consent of the organizer of the „Dispatchers Games“, the representatives of the Czech University of Life Sciences Prague also took part, with their model interpretation in the HEC-ResSim 3.0 program and were associated with the Vltava river basin team. Their intention was to see if the use of this model can contribute to the dispatchers' decision making. In individual steps of the „Game“, the simulations were run on the model, the direct manipulations on the waterworks were set, e.g. the preventive drainage of the available storage capacity based on the forecasts generated by the AquaLog system and individual results of the measures taken were tested. Other components of the system were put into the autoregulation regime, making them dependent on the elevation of the water level in the reservoirs or on the flow rate in the profiles of the river net under observation. The first result of the model operation was the justification of a relatively massive preventive drainage on some waterworks, mainly on Březová, with the view of saving Karlovy Vary and on Jesenice and on Horka. The results of the manipulations were evaluated by the HYDROG model which is routinely used by the dispatchers of the Ohře river basin.

At the closing of the „Games“, the results of an unsatisfactory model calibration appeared, above all as regards the transformation of the flood wave in a relatively long flow section from Karlovy Vary up to the Nechranice dam and as regards the definition of the affluent from the part of basin from the entry of the rivulet Bystřice near Ostrov up to Nechranice where there is no representative measurement on small streams. Consequently, the model foretold a somewhat lower water level in the Nechranice bief than that calculated by the dispatchers from the Ohře river basin, at the end. This difference could be eliminated by

calibration of the model in confrontation with several other real events or by other calibration methods.

Discussion

The system is relatively complicated and sofisticated, offering priority to individual rules and it represents a practically universal means for the description of objects and their functions especially in waterworks, including for instance the quantification and the time distribution of evaporation and dam seepage.
In comparison with the carefully worked-out waterworks problems, the river segment models are more schematic, but they are fully satisfactory for the needs of expressing the usual hydraulic processes.
The mastering of the rules represents the most difficult task. In addition to the basic variants of the model assembly which can be stored under unique names, the „alternatives“ are defined, comprising above all the definition of the time sequences and marginal conditions.
The freely accessible program version does not allow for the stepping in the simulation and does nor enable any interruption and entry into the running simulation. It is not oriented on the on-line use, though possibly the modifications routinely used by USACE-HEC are able to do so. Nevertheless, it allows for the testing of a great many alternatives in a short time and so to analyze the function of the MWS in high detail.

Conclusions

At the conclusion we can state that the mathematical model of the WMS of the Ohře river basin performed by the HEC-ResSim 3.0 program fully proved its functionality and practical usability. HEC-ResSim proved to be a very productive modelling instrument with the perspective of a wide use, and freely accessible at that. It was found suitable for the development and research purposes and for the school instruction on hydroinformatics. Its use in the routine operations requires the formation and maintaining of the operative input/output data base, preferably in HEC-DSS. In this study, the management model has been adapted and tested for this purpose, though, nevertheless the quasi on-line connection to the measured places in the scope of the waterworks ought to be procured, too. This way the program is standardly used in the United States. In future, we intend to include the ResSim program into the scope of the forecast and management system of a chosen WMS where the inputs into the system would be generated in the probability regime so that the management process could be taken into account in the conditions of uncertainty.

References

HEC-ResSim 3.0, Reservoir System Simulation program, US Army Corps of Engineers, Hydrologic Engineering Center
AquaLog, Modelling/Real-time forecasting system in Water Resources, AquaLogic Consulting, Ltd.
Hydrog, Precipitation-Runoff distributive model, HySoft, Brno, Prof. Ing. Miloš Starý, CSc.

Tables and Figures

List of figures:
Fig.1 The total river basin situation
Fig. 2 The definition of the rules for the flood control on the waterwork Skalka
Fig. 3 The hydrograph of inflow and outflow (below) and the graph of the water level on the waterwork Skalka, the simulation result.
Fig. 4 The simulation result for the Ohře and Odrava junction.