DHI ref. 69/99

MIKE 11 as Flood Management and Flood Forecasting Tool for the Odra River, Poland.

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1 ABSTRACT

As a result of extreme rainfall events during July 1997, a devastating flood affected much of southern Poland, the worst ever registered. The flood was particularly severe within the Odra river basin and extensive flooding outside the main channel was observed.

The present paper describes the staged implementation of a flood forecasting system based on the MIKE 11 river modelling tool and the Flood Watch forecasting system for the upper and middle Odra basin. The Odra River is characterised by a complex river network, a large number of hydrotechnical structures (more than 95 on the main river and around 430 when all tributaries are included) as well as 14 flood storage reservoirs (polders). The development of timely and reliable forecasting for this complicated river system therefore requires a careful balance between accurate representation of the flood wave movement and extent and the need for a rapid forecasts. In this paper the staged development of such a model is highlighted. One of the major advantages of the physically-based modelling tools like MIKE 11 is that the same system can be used to evaluate flood protection measures, such as the proposed Raciborz reservoir or improved operation of the control structures.

2 BACKGROUND

The objective of the DEPA Flood Management project is to provide an operational flood forecasting and management tools for the Upper Vistula and the Upper and Middle Odra rivers. The extensive flooding experienced during 1997 has highlighted the value of adopting modern flood management tools in Poland. Based on a request from the Ministry of Environmental Protection, Natural Resources and Forestry in Warsaw, the Danish Environmental Protection Agency (DEPA) early 1998 decided to finance the transfer of Danish flood management technology to Poland.

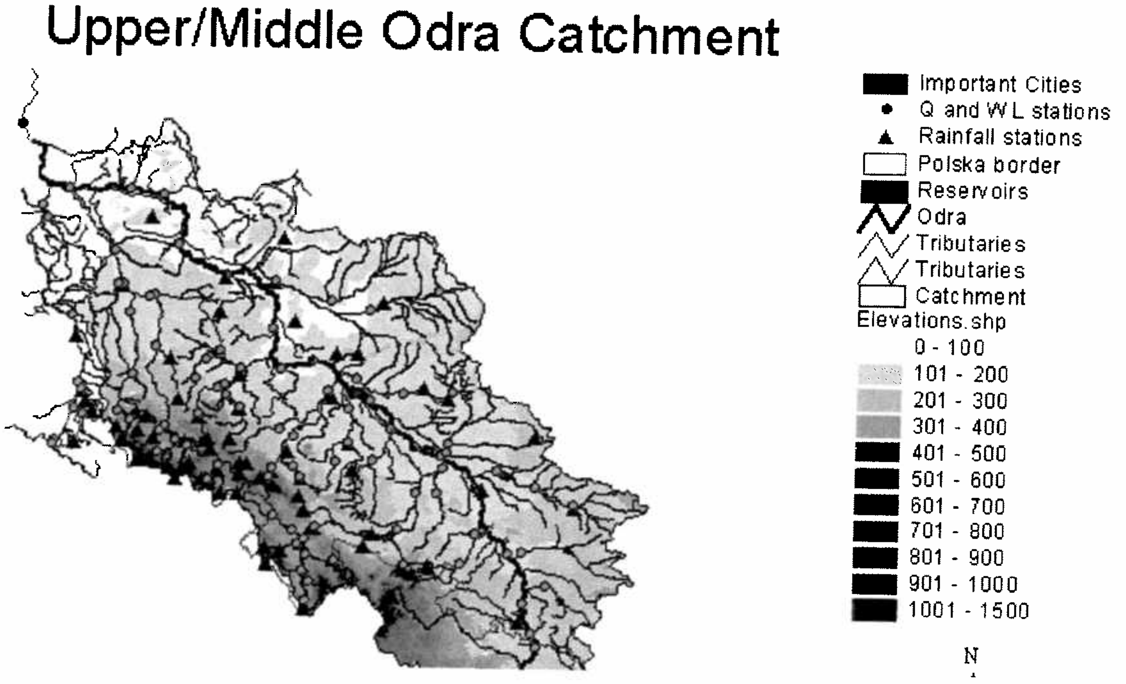
The project comprises the transfer of flood management technology (software, hardware, comprehensive training and know-how) for a total of 6.4 million Danish Crown (approx. 1 mill. US$) to Poland. In addition, DEPA is also supporting a similar flood management project in the Czech Republic. The aim is not only to provide state of the art flood management technology to the two countries but also to encourage co-ordination of flood prevention activities, which will provide substantial benefits for the population and property in the Odra and Vistula river basins

The project focuses on strengthening the capabilities of the Polish authorities in the use of modern flood management technology. The participating institutes in Poland are the Institute of Meteorology and Water Management (IMGW) with their branch offices in Wroclaw, Krakow and Warsaw and the Regional Water Board (RZGW) with their branch offices in Wroclaw and Krakow. The consulting company GEOMOR is acting as local consultants throughout the project. The Danish Hydraulic Institute (DHI) will provide a flood management system and consulting services including training. The project has supplied flood forecast management systems that are now installed in the branch offices of all participating institutions.

Following the devastating flood in 1997 the World Bank has launched a 200 mill. US$ Emergency Flood Recovery project in 1998 with a duration of 3 years. Component B of this project supports a strengthening of the meteorological and hydrological data collection, which also includes survey of new topographical data. The installed flood forecasting management system is ready to be updated and further developed with data from the World Bank Project. At that time a very comprehensive flood management tool will be ready using the new data and the telemetry system provided by the World Bank project and used in the Flood Management System. A close co-ordination will therefore be maintained between these projects.

The DEPA Flood Management project began in May 1998 and is scheduled for completion in October 2000.

3 UPPER AND MIDDLE ODRA RIVER BASIN



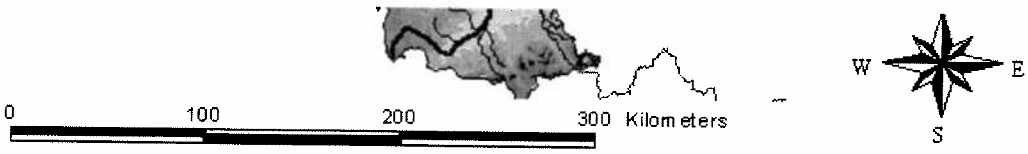


Figure 1. Upper/Middle Odra catchment (49,000 km2) showing the extent of the main rivemodel, rivemodel, location of hydro-meteorological stations etc.

The upper and middle Odra basin covers an area of more tham 49,000 km2, and includes more than 500 km of the main river Odra with its out spring in the Czech Republic. The area in Czech Republic accounts for 6250 km2 of the total catchment area.

For the Upper and Middle Odra Catchment, the Institute of Meteorology and Water Management (IMGW-Wroclaw) is responsible for the collection and storage of hydro-meteorological data for water planning and management and is also responsible for flood forecasting. Rainfall, evaporation and temperature data has been collected from are available from 77 rainfall and 11 climate stations. Water level and discharge are available at 92 stations. In addition, for hydrodynamic modelling cross-section data at more than 500 locations along the main river and more than 100 cross-sections on the tributaries are available. Already at the data collection stage GIS is used to provide a convenient and highly visual overview of the available data. Indeed the project database consists of a combination of Arcview GIS database and Mike Zero time series databases.

4 DEVELOPMENT OF THE MODELLING SYSTEM ON ODRA

General

The Flood Forecasting System is being implemented based on the MIKE 11 river modelling system, (DHI, 1999). The system is designed to perform the calculations required to predict the variations in discharge and water level in a river system as a result of catchment rainfall and inflow/outflow through boundaries in the river system. One of the advantages of the physically based models like MIKE 11, is that this system can be used, not only, for forecasting but also for flood control studies and strategic planning for flood protection.

The Odra river has been extensively developed over the years, and navigation forms an important element of river operational policy. As a result, a number of river bends and meanders have been eliminated by constructing short-cut channels. This has resulted in a reduction of the total modelled river length of around 15km. River chainages however are based on the "un-cut" river and have not been altered. Every structure, river junction, bridge, lock etc. is referenced by the old chainage system, including every river cross section. Hence it was not feasible to introduce a new chainage system for the model, desirable as this may have been. Instead, the model itself was "cut" at over 10 locations, with separate branches delineating reaches upstream and downstream of known bend cuts locations. This has complicated the model setup slightly but has the advantage that the modelled river chainages coincide with those used by the partner organisations.

Set-up of the hydrological model

The Odra catchment has been subdivided into a number of sub-catchments. The rainfall runoff processed within these subcatchments are modelled using the NAM hydrological model, (DHI, 1998).

The catchment inflow to Odra takes place from 6 catchments along the Odra river as shown on Figure 2 (yellow catchments). These 6 catchments are so-called uncontrolled catchments without any gauging stations to be used for calibration of the runoff. Instead 10 catchments on tributaries to Odra, shown on Figure 2 as the green catchments, were selected for calibration purpose.

Finally parameters from the calibrated catchments have been transferred to the uncontrolled catchments on Odra. In general the mountain catchments have higher specific runoff than the lower regions due to higher rainfall in the mountains. In addition the storage capacity of the surface zone and the root zone is less in the mountains. Typical values for the surface storage, root zone storage and the time constant for overland flow are shown in the table below:

Parameter	**Mountains catchments**	**Lower tributaries**	**Odra catchments**
Surface storage	10-15 mm	15-20 mm	20 mm
Root zone storage	100-125 mm	150-225 mm	175-225 mm
Overlandflow, ck1	20 hours	30-100 hours	40-72 hours

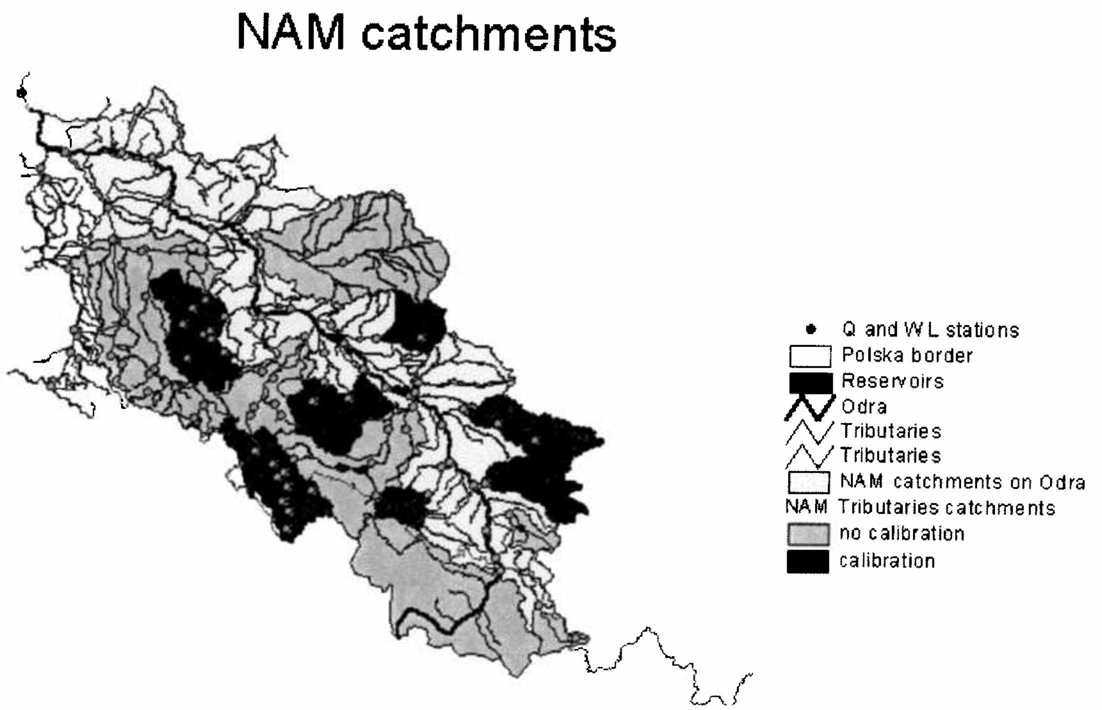


Figure 2. NAM catchments: Yellow: Inflow to HD, Green: Calibrated cartchments, Light green: no calibration.

Figure 3 and Figure 4 show a comparison between observed and simulated discharge from two catchment on lower tributaries close to the Odra River.

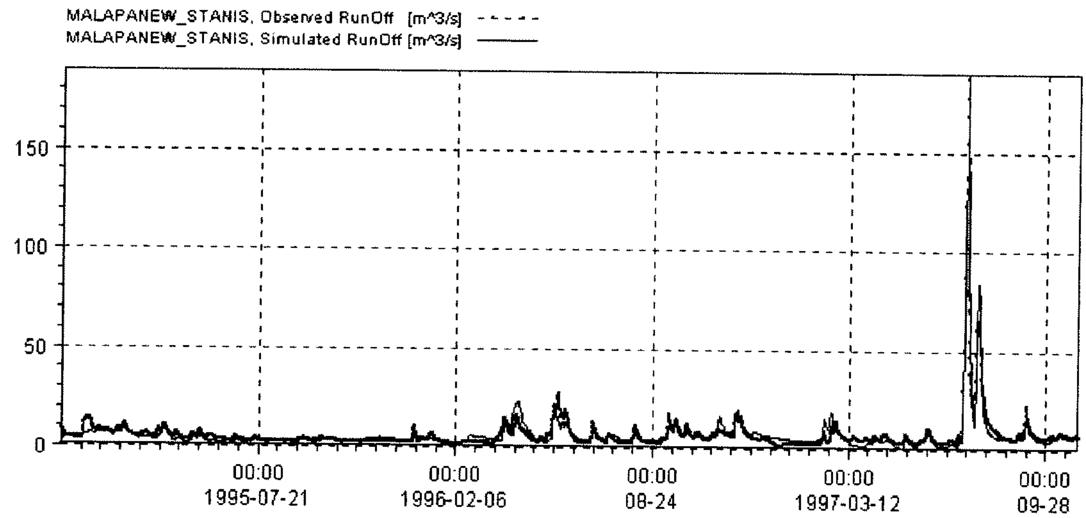


Figure 3. Simulated discharge compared with observed discharge in Mala Panew river catchment.

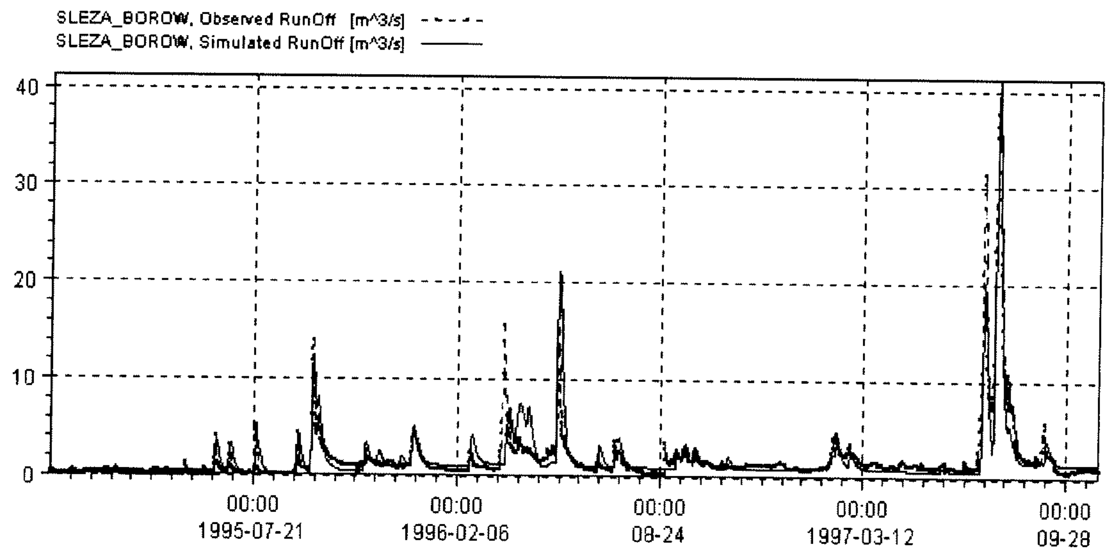


Figure 4. Simulated discharge compared with observed discharge in Sleza Borow river catchment.

The Hydrodynamic model

A hydrodynamic set-up has been prepared for approximately 500 km of the Odra river. In addition the lower part of 11 tributaries has been included in the model, while timeseries for inflow from the upper part of these 11 tributaries are included as boundary inflow to the model. As described in the section above runoff from 6 catchments along Odra forms the lateral inflow to the river. Figure 5 shows the model schematisation.

The river is described by measured cross-sections for each 1000 meter of the river. In addition information on flood extent observed during the 1997 flood has been used to develop a quasi 2-D model on the flood plains, which is joined to the main river by a series of link channels. Finally the model includes the most important structures and polders along the Odra river. The model has a total number of 250 river branches including the flood plain schematisation.

The data used for model calibration include time series from more than 10 important stations along Odra for Water Level and Discharge. The model has been calibrated on data for the period from 1995-1997.

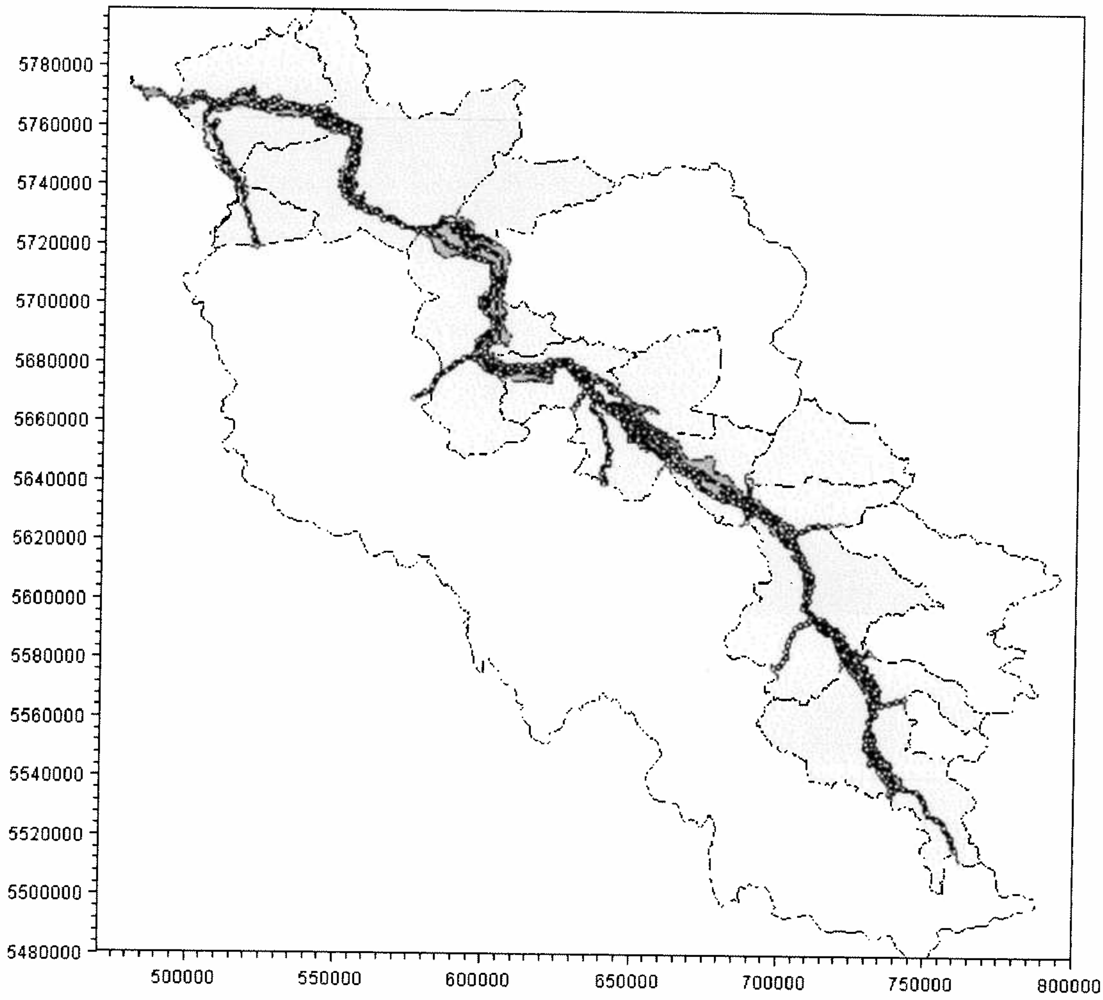


Figure 5. Schematisation of the MIKE 11 branch route system (blue) including computational points. Yellow: NAM catchment with lateral inflow. Light blue: Flood extent observed during the the 1997 flood.

Model setup around Wroclaw

The Odra River around Wroclaw has been highly developed for many centuries, and there is evidence that the river was dammed and used for power generation (water mills) more than 500 years ago.

Today the complex network of channels around the old and new towns of Wroclaw serve a range of purposes, namely:

- Navigation
- Flood alleviation
- Hydopower generation

The model setup around the city if formed by two main groups, the hydropower complex within the old city, which is nested within the larger navigation and flood control system surrounding the city and its suburbs.

The model set-up around Wroclaw water system is shown on Figure 6.

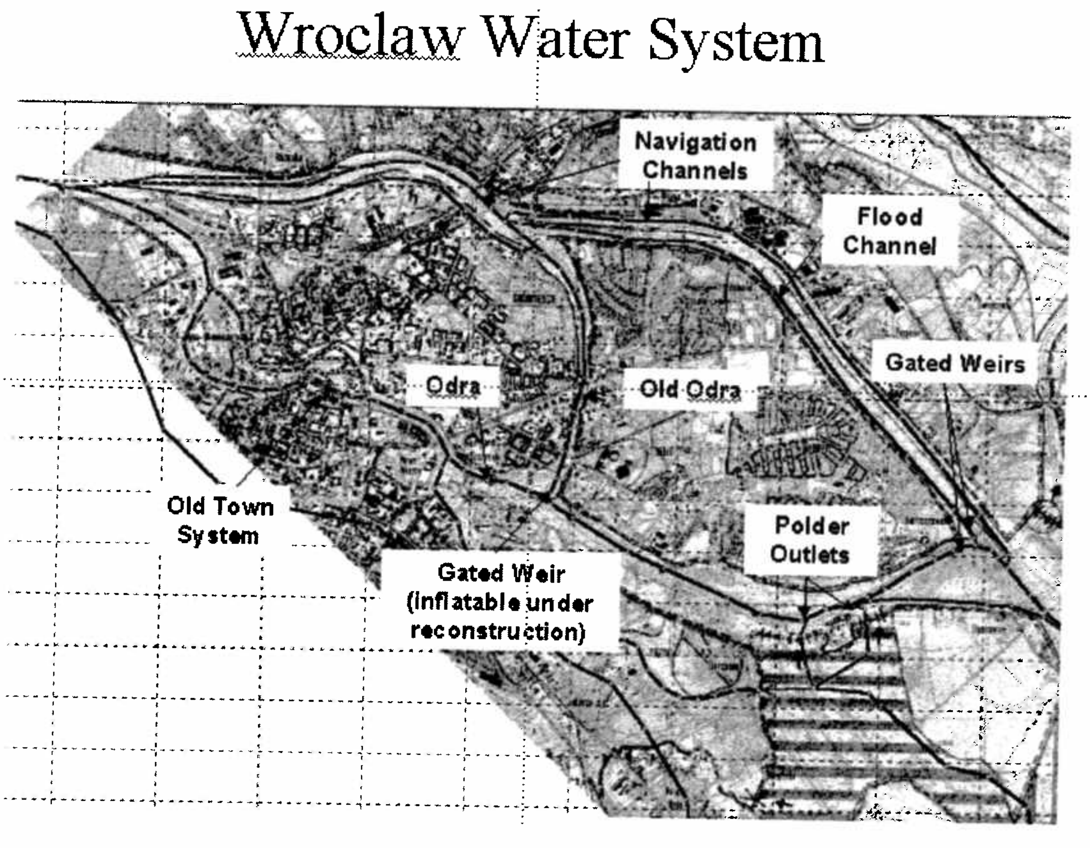


Figure 6. Model set-up on the Wroclaw Water system.

The old city system is built upon very old works, originally designed for flour production via a number of water mills. In the early 1960's, run-of-river hydropower plants were installed on two separate arms of the river, taking advantage of an approximate 6 metre drop in water level formerly provided by old dams. Upstream of the hydropower plants, the old mill race and wooden weirs used to control the water levels previously are now drowned out at all but the minimum flows.

The greater Wroclaw system is by contrast mainly designed for navigation with flood alleviation as a secondary criteria. A number of navigation channels with lock controls have been constructed upstream of the city and to its north, on an old arm of the Odra river. A flood alleviation channel has also been constructed to divert water around the old city system. Flow control is achieved by a range of vertical sluice and radial sector gates, and fixed weirs.

During the 1997 flood, many of these structures were damaged and are now under reconstruction. The flow control weir which regulated flow into the Old Odra is being replaced by an inflatable weir.

Flood mitigation for Wroclaw itself relies mainly on the presence of three large polders

- Olawa-Lipki; Volume=30m.m^3
- Trestno; Volume = 3.8 m.m^3
- Olawka; Volume = 12m.m^3

Flow into and out of the polders is regulated according to a set of standing orders. Inlet structures typically comprise long uncontrolled weirs (1000 m crest length) whilst outlet structures are often high capacity gated sluices. The polders are very effective in providing flood protection through temporary flood storage, although in 1997 all the polder defences were completely overwhelmed due to the large volume of floodwater.

Polders are mainly included as separate flood channels rather than flood cells as they extend along the river 5-10 km and the longitudinal slope is considerable.

5 APPLICATION SCENARIOS

After having developed and calibrated the model, it is possible to study various options for flood alleviation. At least 5 different flood alleviation scenarios has been or will be analysed and optimised with the model for selection of the most promising flood protection measures.

Three of the most promising flood alleviation scenarios are:

- Flood Bypass channel of the city of Wroclaw
- Additional polder storage upstream of Wroclaw
- Polder storage for the town of Raciborz, located on the upper reaches of the modelled river.

Figure 7 shows the proposed flood alleviation near Wroclaw.

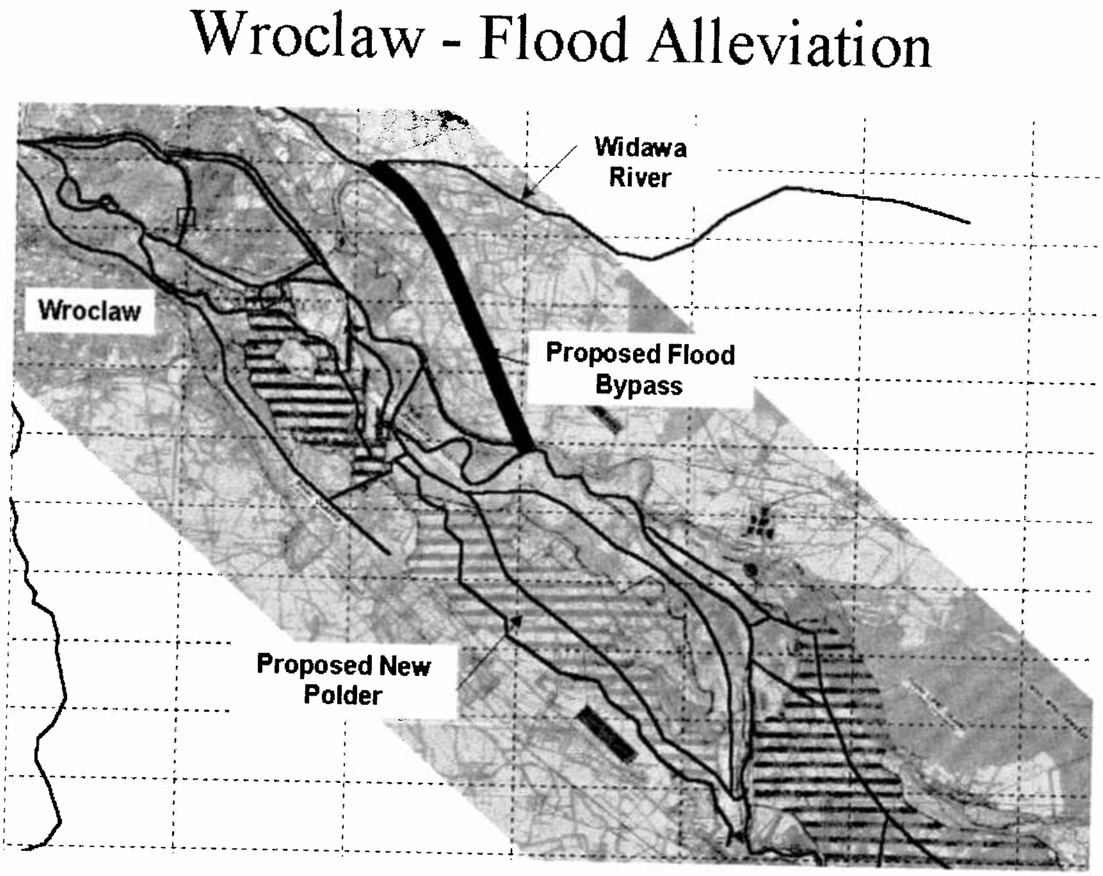
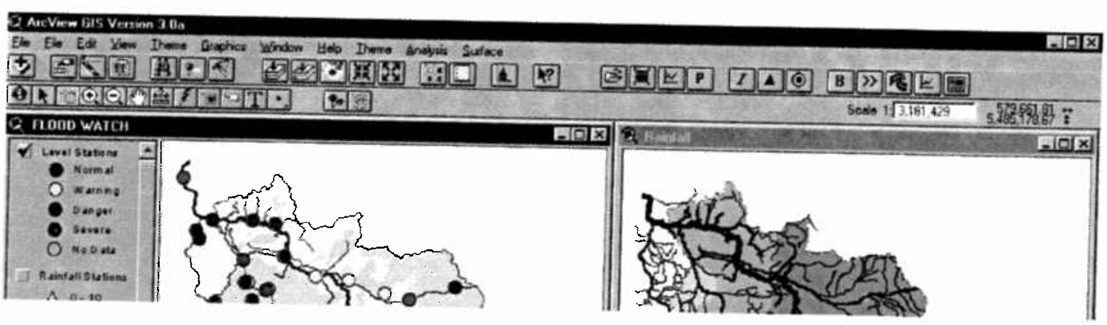


Figure 7. Proposed flood alleviation for Wroclaw.

6 FLOODWATCH

The operational flood forecasting system being implemented for the Upper and Middle Odra basin uses the FLOOD WATCH real-time flood forecasting and warning system. FLOOD WATCH (Ammentorp et al, 1998) integrates the river modelling system in a GIS environment to produce a powerful tool for real-time flood forecasting and warning applications. The GIS environment provides a map-based data editing and presentation module that allows the user to select stations for editing and presentation directly from the GIS map. Results of the forecasts can then be visualised in combination with other stations and maps.

FLOOD WATCH also allows for the automatic import of real-time data and is currently being link to the existing real-time database currently in use for forecasting in Wroclaw. Graphical presentation of the river status, see figure 8 left side, presents the forecasting status to the operational forecaster in a highly visual manner. The graphical view of the catchments features alarm indications for excessive water levels and rainfall intensities.



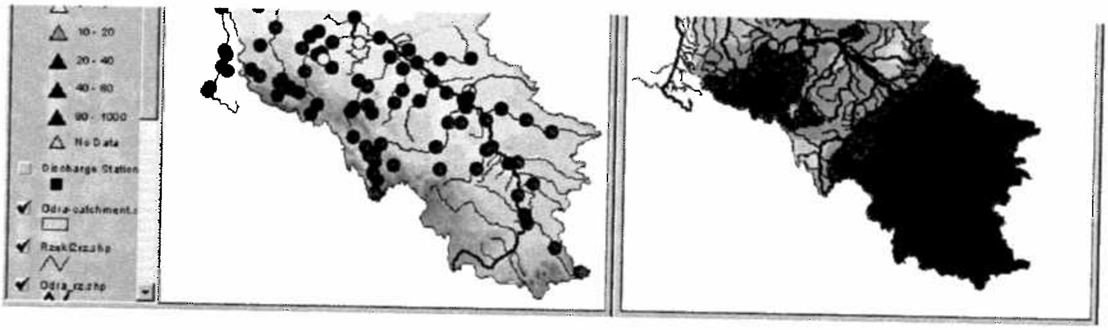


Figure 8. Status of Level Stations and map showing the rainfall distribution in the catchment.

After having established the link to flood watch all real time data can be presented in tables, on graphs or on maps. In addition data can be further processed using the ArcView tools. The rainfall surface map to the right has been prepared by the ArcView spatial analyst surface tools.

7 REFERENCES

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