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NATURAL AND ANTHROPOGENIC CAUSES AND EFFECTS OF FLOODS AND OTHER DISASTROUS EVENTS IN POLAND

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A b s t r a c t. Analysis of natural and anthropogenic causes and effects of floods in Poland is presented in this paper. In general, the flood of 1997 showed that Poland needs, above all, long-term concept for the land development in the basins of the Oder and Vistula, effective legal regulations and development of the hydrotechnical infrastructure. The disastrous flood 1997 made it clear that social and economic losses would have been much smaller if Poland had had a modern measuring, preventing and warning systems, and also proper hydrotechnical edifices, and if the flood prevention infrastructure was in a good condition. It should also be stressed that more attention should be paid to research programmes to improve the system of flood prevention and reduction of damages. Activities undertaken so far with the aim to find the best protection measures and solutions for the flooded areas in Poland can be summered as follows: (i) recording of the effects of the flood; (ii) creation of the National Programme for the Reconstruction and Modernisation of the Flooded Areas, and (iii) undertaking interdisciplinary discussions (researchers, engineers, practitioners, etc.) to select the most urgent and necessary actions for future to avoid similar disasters.

K e y w o r d s: flood 1997, causes, effects, research programmes, future tasks

INTRODUCTION

A lot has been said on the disasters beyond human control, i.e., natural catastrophes. After almost any bigger earthquake, flood, hurricane, landslide, drought, etc., discussions on the statistics, details of the event, losses and preventive measures start anew. A lot of different classifications have been worked out, among other the classification by Ciesielski [1] presented on Fig. 1 or very interesting list of extreme phenomena described by Warakomski [14], presented elsewhere in this book. The list is obviously not complete but it explains most of the extreme events. Not all of them occur over Poland's territory. Some of them, however, create severe problems to man and environment.

In Poland floods that have always occurred in our history both on bigger areas and locally, present the biggest danger. The reasons for floods are either heavy rainfalls or snow thawing or else water spring-jams and storms at the river inlets.

The 1997 flood in southern Poland and Czech Republic or earlier floods in Italy or France, and along the Rhine in Germany and Holland renewed discussions on this complex subject as floods are possible to predict unlike any other disasters mentioned above. Already at the beginning of the 90-ties the European Union pointed out to the fact that floods create very high losses that rapidly increase despite preventive measures that have been undertaken and concluded that a very decisive course of action must be taken. A programme called "River Basin Modelling, Management of Flood Mitigation" - RIBAMOD was started. Also during the last 27th Congress of

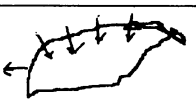
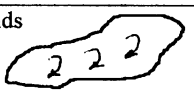
Type of catastrophe	Number of mortal cases	Territory stricken with catastrophe and shape	Location*	Protection	Material harm
Earthquakes	hundred thousands †	Thousands sq. km 	2	A+	H
Tsunami	several dozen thousands †	Dozen sq.km 	4	C	L
Volcanic eruption	Dozens, hundreds †	Dozen sq.km 	5	D	L
Floods	Dozens, thousands †	Thousands sq.km 	4+	D	H
Tropical cyclones & shore flooding	Hundred thousands †	Thousands sq.km 	2	A+	L
Hurricane & tornado	Hundreds †	Dozens sq. Km 	1+	B	L
Landslides	Thousands †	sq.km 	4	C	M
Sand storms	Individuals †	Thousands sq.km 	3	B	M
Snowslide madslide	Dozens †	sq. km 	2+	B	S
Sudden thermal changes, icing	Individuals †	sq. km 	3	C	S

Fig. 1. Catastrophes caused by nature activity (Ciesielski [1]).
*Explanations for the three subjectively determined characteristics: L - possible location (place & time) and mechanism of catastrophe (from 1 - minimum to full recognition and possible prognosis); O - possible protection and evacuation measures (from A - minimum to D - maximum); EM - material losses (from H - high, disastrous through medium - M) to small, local - S.

IAHR on the floods, it was stated that social and economic losses due to floods increase exponentially [6].

It is assumed that there are effective methods of forecasting river swells (freshets) and limiting losses due to floods. However, it requires detailed analysis and decision-making on the problems around the probability of maximum swells, scope of hydrotechnical constructions (basins, dikes, polders) that will limit losses due to floods, hydrological and meteorological monitoring systems, rules and regulations of water management on the national level, for individual rivers, basins, etc.

The fact that Poland was caught unaware by the recent flood created unfavourable opinions not only on the protective systems but also on the efficiency of management, organisational systems, financing, research programmes, etc.

WHAT HAPPENED IN JULY 1997? SOME FACTS AND FIGURES

In July 1997 Poland was affected by a tragic flood. According to the present evaluations, it has been the biggest flood for at least 200 years. According to different authors [4,5,9], probability of occurrence for a flood like that is once in 1000 to 10 000 years.

The distinguishing features of this flood were as follows:

- it took place on a considerable area (10%) of the country, both in the agricultural areas and in towns inhabited by 6 million people, 1.5 million of whom were directly affected by the consequences;
- it flooded and destroyed town districts, villages and farmland, industrial plants, technical infrastructure;
- it created enormous economical, social and moral losses. Fifty five people died. Financial losses have been estimated for 12-15 billion Pl zlotys (3.5-4.0 billion USS);
- it had serious international implications;
- lasted for a long period of time;
- caused pollution of the flooded areas and ground waters.

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Why was the 1997 flood so dramatic?

The answer to this question is not simple. Both natural and anthropogenic factors should be taken into consideration. We should also remember that the size and frequency of swells depends on the hydrological river regime that is formed by the physical and geographical conditions. Geographical location and altitude, terrain relief and geological strata, as well as soil and plant cover form the climate (i.e., the amount of water supplied from the atmosphere and returned to it) and the conditions for water outflow in the basin area [8,9]. It makes some regions more prone to swell that others. Moreover, physical and geographical conditions influence the type of swells the dominate in a given region.

There are two basic types of swells: rainfall swells and thaw swells. Their genesis and formation processes in the basin are different, as well as the methods for their analysis, calculation and forecasting.

Besides natural factors, also the impact of human activity both direct (intentional) and indirect (unintentional) on the natural environment influences the patterns of water outflow from the basin and water flow in the river, and hence formation and course of river swells and floods (Fig. 2), [9].

Natural factors in July 1997 formed a very unfavourable pattern. Due to the meteorological situation there were three series of heavy rainfalls in July with exceptional performance and range (Fig. 3) [12]:

- first series from 3rd to 10th of July;
- second series from 15th to 23rd of July with the maximum performance between 18th and 22nd of July;
- third series from 24th to 28th of July, with the maximum performance on the 25th-26th of July.

The rainfall at the end of June saturated the surface soil layer limiting retention capability of the ground. Already the first series of rain created high water levels on the Oder. The second series prolonged the swell and resulted in the second wave coming from the Oder tributaries. The third series covered mainly the Vistula basin.

The rainfall exceeding 200 mm appeared in the Sudety Mountains and Carpathiens. The highest totals were recorded in the Tatra Range (355 mm). A similar amount of rainfall caused a swell in 1934. In the Upper Oder basin the total amount of rainfall that caused the swell in July 1997 was two or even three times higher any other up until 1997. The objects that were to prevent from flooding were not designed to handle such high flows. For example, the maximum designed flow capacity in

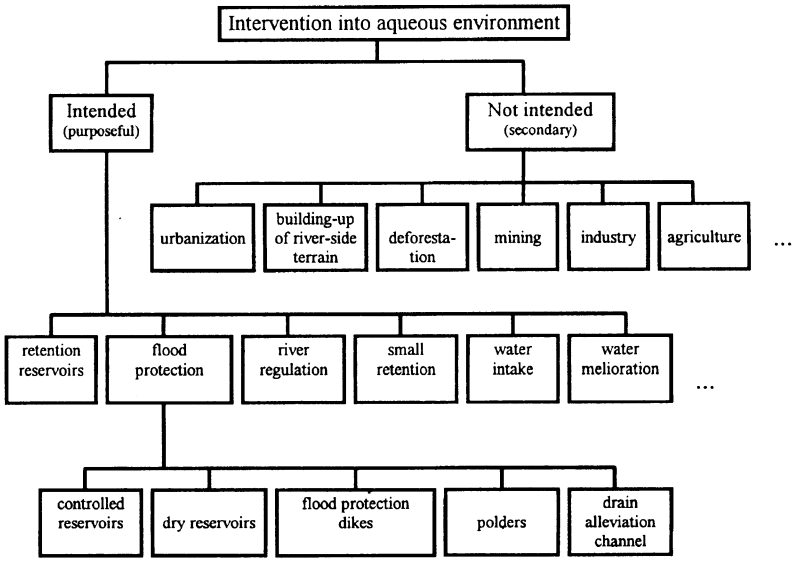

Fig. 2. Forms of intervention into aqueous environmnet (Ozga-Zielińska [9]).

Wrocław was 2400 m^3/s, whereas the maximum flow on the Oder river was 3600 m^3/s. Total capacity of all the controlled basins, dry basins and polders was a few times lower that volume of flood waters [12].

Almost at the same time as the rainfall in the Oder basin there were also rainfalls in the upper Vistula basin, but the effects were not so disastrous. However, the danger was serious in such regions as: the valley of the Sun and the region close to Kazimierz Dolny on the Vistula river [10].

These rapid swells resulting from the human impact on the natural environment in the basins of both rivers were caused by:

- the development of urban areas, even the areas treated as polders before;
- intense farming and development of industry;
- deforestation and the resulting wasteland;
- destruction of objects capable of water retention at the small scale, etc.

Damages to agricultural land

The main damages to agricultural land, caused by the flood, can be divided into two groups as follows [3]: damages to plant canopy and damages to soil, including soil contamination.

The first group of damages is easy to remove, although sometimes the annual crop yields are lost. Soil losses, however, are much more difficult to remove, thus more expensive the remediation is. First of all, soil damages reduce agricultural land productivity potential. The liquidation of these damages is sometimes almost impossible and the land must be withdrawn from the agricultural use. Contamination of soil environment depends on the kind and harmfulness of chemical substances that were present in flood waters. Like soil damages, chemical pollution may cause losses of agricultural land for many years.

The type of damages due to floods also depends on physiographic conditions of the area flooded. For example, specific nature of mountain regions involves severe erosion damages, including surface run-off, rill or even gully erosion, denudation or landslides of surface soil layers. In valley or low areas negative effects occur due to accumulation of sediments.

The negative effects of floods in undulating or flat regions do not only depend on

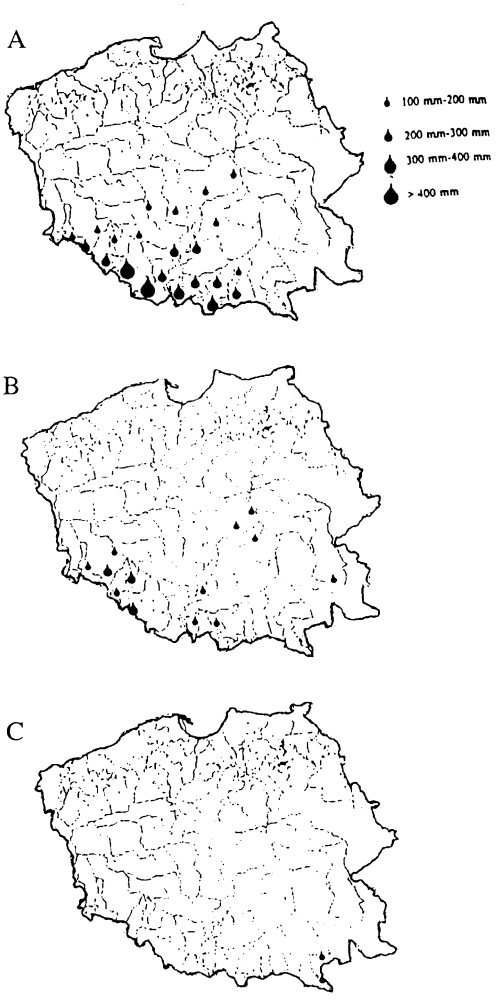

Fig. 3. Distribution of rainfalls (rainfall sums >100 mm) in Poland in July 1997. A) First series of rainfall July 3-10, 1997; B) Second series - July 15-23, 1997; C) Third series - July 24-28, 1997 (Stachy, Bogdanowicz, [12]).

physiographic conditions, but also on human activity. In general, the greatest damages occurred in those areas where river dikes were destroyed, e.g., on the Oder river in such cases the width of the flood wave reached 20 km.

The main damages were recorded in the riverbed and river banks. However, many other disastrous effects were registered, i.e., water erosion of soil and land, silting-up, pollution with biogenes and chemicals on the one side and losses of plant nutrients on the other, biochemical changes due to stagnant water, over moistening of the ground, etc.

Registration of damages caused by the summer flood (although very laborious, difficult, costly and carried out sporadically by various institutions) allowed us to gather information on:

- the range of damages in plant production;
- the state of soil and land degradation;
- the role of agricultural land in estimation of the flood risk over this land (pattern of agricultural landforms *vs* terrain relief affects the course and range of surface runoff which, in turn, forms flood wave);
- the efficiency of technical protection measures against flood on the agricultural areas both within catchment areas and in vicinity of rivers;
- pathways of cumulated water and formation of new water outflow lines in the basin;
- correctness and sufficiency of agricultural routes patterns, which might play a supplementary role in relation to the hydrographic network.

FUTURE TASKS FOR SCIENCE AND TECHNOLOGY

The flood of 1997 showed that Poland needs, above all, long-term concept for the land development in the basins of the Oder and Vistula, effective legal regulations and development of the hydrotechnical infrastructure. The disastrous flood 1997 made it clear that social and economic losses would have been much smaller if Poland had had a modern measuring, preventing and warning systems, and also proper hydrotechnical edifices, and if the flood prevention infrastructure was in a good condition.

Because of the climate variability we have to face the extreme and threatening weather phenomenon more and more frequently. With increasing number of population, especially in the city agglomerations, and intensive land development such phenomena cause huge social and economic losses. It is believed that to reduce those losses we should take advantage of any local government initiatives and also of the free market mechanisms.

Therefore, there were quite many meetings devoted to all the above mentioned issues,

among them most worthy to be recalled here the Scientific and Technical Forum entitled „Flood 1997 - Preliminary Estimation of Reasons, Ranges and Effects" [11]. The participants of the FORUM formed a wide representation of the Polish science, technology, administration and local government, dealing with the water economy in the general sense of this term. They postulated foundation of National Program for Flood Prevention and Rational Exploitation of Water Resources. The program should be prepared and implemented by the National Council for Water Economy, which is to be established in the near future. This council should be endowed with authority and competence.

The future programme shall cover both *technical and non-technical* methods of protection against flood [11]. Among the technical methods a very special attention should be paid to:

- improvement of a system of forecasts, and a hydrological and meteorological monitoring based on an up-to-date automatic measuring apparatus fitted with a reliable communication system;
- construction of storage reservoirs;
- monitoring and repairs of dams;
- erection of polders and outflow channels up-stream the cities threatened with flood;
- increasing of natural outflow capacities of riverbeds, including maintenance of in-between-dams areas, according to their purpose.

The non-technical steps should cover:

- undertaking the necessary actions (in some cases only complementary) connected with the land development in cities, provinces and regions remembering that flood protection is a fundamental factor in providing safety to people and their belongings;
- working on legal regulations which will forbid construction of any buildings on polders, or in-between-dams;
- preparation of the maps of flood-land specifying the level of risk of freshet and losses resulting from the limitations in the man's activity in the endangered areas;
- developing operational connections on various levels, nation-wide, regional and local, respectively;
- improvement of early notification and response system for the citizens;
- general education for the citizens about the danger, risk and rescue methods for people and their belongings and organising training on proper behaviour in the face of danger;
- preparation of methodology of hydrological and meteorological protection for the Country's Rescue and Fire-extinguishing System.

It is also believed that:

- *in the legal aspect:*

it is necessary to analyse the existing regulations and prepare a concept of unified legal foundations for effective actions, which would clearly state the course of action during flood. Such regulations shall be adjusted to the Polish changing economic, social and political conditions.

- *in the economic aspect:*

it is indispensable to analyse and compose a new concept of financing of hydrological and meteorological protection, and operational actions on the national, regional and local levels,

- *in the organisational and technical aspect:*

it is vital to analyse the existing, and develop an improved organisational and technical arrangements for the prevention and rescue actions, basing on the international experience. While doing that we should remember that solid preparation and good organisation is the best way to reduce the outcome of the dangerous situations.

- *in the aspect of research and scientific work:*

it is essential to intensify the research and implementation work, to improve the system of flood prevention and reduction of damages.

The experience of the developed countries proves that the expenditures on such research result in big savings when it comes to covering the costs of the rescue missions and restoration. Financing of the research works should be integral, self-contained element of the Scientific Research Committee budget.

Considering the a/m issues as a basis for the country's development, the participants of forum decided that meetings like this one should take place regularly. Their aim will be to:

- evaluate the progress in accomplishment of water economy tasks;
- continuous initiating new projects and participation in the current ones;
- drawing and keeping public attention to importance of water economy as an integral part of the country's economy.

Also other organisations responded to the above declaration, e.g., the State Committee for Scientific Research, Poland. At the sittings in December 1997 and January 1998, the Committee begun debate on the direction of development of research work especially important for the flood protection. The Committee has selected the following future priority courses of research [7]:

1. Research and analysis summering the reasons, the course and the effects of flood in the water-basins of Oder and Vistula rivers, including the meteorological, hydrological and hydrotechnical conditions, the state of the water-basins and land development.
2. The meteorological and hydrological studies connected with predicting the maximum rainfall and freshet, and the course of flood in the river-basins of Oder and Vistula.
3. To determine the influence of changes going on in water-basins, river-basins, hydrotechnical infrastructure and global changes, on the dimensions and course of maximum freshet.
4. The objective evaluation of risks of losses in anticipation that the freshets as high as the one from 1997 will appear regularly.
5. Methods of control of outflow from the storage reservoirs in extreme situations with a view to forecasts.
6. Research on impact of the man's interference (river engineering, dams, storage reservoirs, polders, water-basins land development, biological build-up) on the freshet dimension and course, and on reduction of damages.
7. Examination of adjustment of hydrotechnical infrastructure, in order to achieve the optimum flood protection in case of a maximum freshet.
8. Assessment of changes in the land development, in the context of long-term and disastrous geological processes in the lowland and mountain water-basins.
9. Evaluation of social behaviour during flood and necessity to shape the rational actions on the local level.
10. Selection of the areas endangered by floods, and proper land development.

FINAL REMARKS AND CONCLUSIONS

It is assumed that there are effective methods of forecasting river swells (freshets) and limiting losses due to floods. However, it requires detailed analysis and decision-making on the problems around the probability of maximum swells, scope of hydrotechnical constructions (basins, dikes, polders) that will limit losses due to floods, hydrological and meteorological monitoring systems, rules and regulations of water management on the national level, for individual rivers, basins, etc. The fact that Poland was caught unaware by the recent flood created unfavourable opinions not only on the protective systems but also on the efficiency of management, organisational systems, financing, research programmes, etc.

Among many research programmes proposed after the flood 1997, and as part of the nation-wide and even broader discussions on the floods, there was also organised an international symposium with the aim to elaborate the principles for the research project on the multi-lateral international co-operation in the area of needs concerning soils in specific rural areas affected by floods and other disasters, to establish the criteria for soil sustainability when soils are flooded as well as to recommend the methods and measures of remediation on the example of floods in summer 1997 in a specific rural areas in European countries. The target of this project is to prepare assumptions and creation of data base and hydrophysical

maps of the characteristics of the arable land in Poland and neighbouring regions [2].

There are also many other important tasks in this respect, for example:

1. Establishing the research work especially important for the flood protection (well-grounded and detailed research in order to estimate the reasons, the course and the effects of flood like that one in 1997), including various kinds of mathematical models which will allow to predict the course of meteorological and hydrological phenomena. Special attention ought to be paid to the land development of water-basins and hydrotechnical infrastructure. Social studies are also significant (in the broad understanding of this term) against a background of flood.
2. It is necessary to know the hydrophysical properties to interpret and predict the course of, practically speaking, all physical, chemical and biological processes that are present in soil. Shaping of those processes requires reliable data about the soil hydrophysical properties which, in fact, are difficult to measure, time consuming and require special, expensive apparatus. That is why, the existing data collections about the hydrophysical properties are dispersed, and located at various scientific institutions in a form of results of their research work. They are also difficult to interpret because of different methodology of research, especially in case of conductivity factor in unsaturated zone.

The very important issue of creation of a data bank about the soil hydrophysical properties was undertaken by the science councils of the European Union. It comprises the following tasks: (i) selection of the representative profiles of the arable land in Poland and their classification; (ii) selection and adaptation of apparatus and measurement methods of the soil hydrophysical properties, and (iii) creation of a data base, complimentary to the ones already created in the countries of the European Union, and preparation of an atlas and computer maps of the hydrophysical characteristics of the selected Polish arable land.

Preparation of such a data base and maps is an essential requirement for using simulation and prognostic models of hydrophysical and hydrological processes, including the water balance which in many countries is a basis for utilisation of water, and also for predicting and preventing threats (environment degradation, extreme water conditions drought, flood). The data base will be incorporated into the national and international systems containing information about the natural environment, and shaping of environmental processes [12].

Activities undertaken so far with the aim to find the best protection measures and solutions for the flooded areas in Poland can be summered as follows:

- recording the effects of the flood;
- creation of the National Programme for the Reconstruction and Modernisation of the Flooded Areas;
- undertaking interdisciplinary discussions (researchers, engineers, practitioners, etc.) to select the most urgent and necessary actions for future to avoid similar disasters.

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