In Time for the Flood

A METHODOLOGICAL GUIDE TO LOCAL FLOOD WARNING SYSTEMS

WMO/GWP ASSOCIATED PROGRAMME ON FLOOD MANAGEMENT

Global Water Partnership
Central and Eastern Europe

Institute of Meteorology and Water Management Poland

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A METHODOLOGICAL GUIDE TO LOCAL FLOOD WARNING SYSTEMS

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From the Director of IMGW

All over the world, providing warnings concerning dangerous phenomena, including floods, is one of the obligations of the state. However, it requires the collaboration of many institutions, including ones from outside of state services and administration, as well as active participation of inhabitants. Probably no one needs to be convinced of the importance of appropriately early warning, delivered reliably to those at risk. But the measure of a warning system's effectiveness is proper response of citizens who are aware of the danger and know what to do.

Among the many institutions whose activity is essential for the effectiveness of a warning system, we need to single out local governments. For this reason, the Institute of Meteorology and Water Management, which runs the National Hydrological and Meteorological Service in Poland, decided to prepare a guide which would facilitate these local governments' building or expansion of local warning systems in areas particularly susceptible to flooding.

The guide has turned out to be a much-needed publication, one assessed favorably by recipients. No doubt it was this interest which inclined the Global Water Partnership in Poland and the directorship of this organization for Central and Eastern Europe to propagate this publication in other countries. Particular thanks for this initiative are due to Prof. Janusz Kindler, the director of the GWP organization in Poland.

The text was written with the Polish reader in mind, and the selection of examples and distribution of emphasis are the effect of the authors' experiences in collaboration and contacts with those local governments which have for some time now been trying to develop this type of systems in Poland. Thus, the relatively extensive chapter explaining the idea, the emphasis on the role of collaboration among various institutions, highlighting of the necessity to include ongoing exploitation and modernization expenses in the total costs of the system, as well as underlining of the significance of educating inhabitants.

On the other hand, the form of the guide was influenced in significant measure by the experiences of other countries, which the authors have attempted to utilize. Looking at it from this point of view, one can say that the guide being presented to you is an attempt to introduce the 'state of the art' in flood warning systems into Polish conditions, and in this sense, it can be of interest to readers from other countries. The belief that this really is the case was the foundation for the English edition which we place today in the hands of our readers.

Prof. Jan Zieliński
Director Institute of Meteorology
and Water Management (IMGW)
Poland
Warsaw, 6 February 2006

Introduction to Polish Edition

The customary introduction to a handbook is supposed to begin with the standard words: 'We present to you…' However, before these words appear, I shall write a few sentences about the motives for the publication of this guide, as well as about the team of authors and other persons who made it happen.

After the flood in 1997, many organizational units of local and central government, institutions and persons who suffered from or merely observed this dangerous phenomenon, wondered how such a tragedy could have taken place in the 20th century. Who didn't do their job? Could something have been done to secure ourselves from the destruction of our property and, above all, from an unnecessary and tragic death?

Many people, in the atmosphere prevalent after 1997, proposed wonderful and infallible solutions. I shall present a few of these and immediately comment on them.

A small retention reservoir and some wooded areas will secure us from any flood—a lofty idea worthy of broad-based support. But nonetheless not for a flood of such catastrophic scale as the one that invaded the Odra basin at that time—at best, for small flood waves. Whoever saw the scale of the destruction, or the floods of mud, water and stones flowing through the forest, will not propose such a solution as the only one.

Let us build many large retention reservoirs—of course, only where and with what money? In Poland, there are not that many places for large water reservoirs, and the cost of building them is enormous. It will suffice to look at the history of the building of the reservoirs in Klimkówka or Czorsztyn, or the yet-to-be-completed building of the Świnna Poręba reservoir, which has dragged on already for many years. Besides this, the hydrotechnology lobby is always at odds with the ecological lobby, and there are equally strong pros and cons on both sides.

Let's add a few meters of height to the embankments—again, we have to ask with what money, and whether we want to live behind huge screens which provide only superficial protection. And that, only when they are maintained carefully and at great cost. And when they break, the catastrophe is much, much greater.

If we deepen the river beds, then any magnitude of water flow will fit into them, and there will be no flood—a completely mistaken and unrealistic assumption. Impossible to do—not to mention, of course, the cost.

We must resettle all the people and businesses from flood plain areas—again, a lack of rationality and realism has triumphed. This task is in Polish conditions immeasurably difficult to carry out, for economic and sociological reasons.

There have been many such ideas. What they have in common is a belief that there exists one best way to mitigate flood damage, and that the danger can be eliminated. I present them here purposely in an extreme form, in order to show the traps which come with an attempt to oversimplify the problem.

Fortunately, the most extreme and unrealistic ideas are gradually disappearing. What has remained, on the other hand, is the organic work which numerous communities have been carrying out for several years now. Another thing that has remained is a slogan which we should all repeat often—to the point of boredom: LET'S LEARN TO LIVE WITH THE FLOOD PHENOMENON, BECAUSE IT IS UNAVOIDABLE.

We have at our disposal many possibilities. Structural solutions are expensive, difficult to execute and time-consuming, but if they are applied in accordance with the principle of balanced development, they turn out to be very effective. Non-structural methods, on the other hand—which, despite being exceptionally effective, are only with difficulty making headway among the previous ideas of the traditionalists—can be applied with a modest financial investment and very discreet interference with the environment.

At the Institute of Meteorology and Water Management as well, discussions continue concerning the tasks and role of this institution in the country's flood protection system.

How and whom should we warn—should we continue to use the same old hermetic official language? Where should we address forecasts and information—only to the central and voivodship levels? Should we limit ourselves only to the nationwide system—which by reason of financial limitations is not in a position to provide hydrological and meteorological protection to communities living near small rivers and streams—or should we perhaps collaborate with those who want to build local systems?

Should we collaborate with the media at a bureaucratic level, or should we, conquering our own mistrust and inhibitions, teach and also transmit to them a broad-based commentary on the forecast—and then carefully authorize every word before it goes to press?

Should we remain in an enclosed world, or should we educate, educate and yet again educate—everyone from children to officials and journalists?

There is no point in hiding the fact that after 1997, the option of the Institute's collaborating with 'the rest of the world' on previous principles was the dominant one; indeed, even today one can often see its strong position. But it was at that time that employees of the Kraków branch of the Institute of Meteorology and Water Management proposed another approach to collaboration with local governments, the media and the community. This team are the authors of the present handbook.

During the realization of the OSIRIS project, entitled Operational Solutions for the management of Inundation Risks in the Information Society (part of the Fifth Framework Program of the European Union), the team solidified and acquired experience in international collaboration. It also began to orient its activities toward contacts with local governments, as well as with the media. Particularly significant is its collaboration with the Kłodzko County government, which during this period proceeded to build a local flood monitoring and warning system. After that, publications appeared which received awards from the Minister of the Environment: the handbook *Collaboration with the Media*, a publication for journalists entitled *Natural Hazards*, and a volume of didactic materials for teachers entitled *How to Cope with a Flood*. This latter item was accepted by the Center for Teacher Training as training material for teachers; and its second edition was financed by the Ministry of National Education and Sports.

We attach great importance to flood education. Education in a broad sense, for the aforementioned didactic materials are intended for use by schools; and previous publications have been addressed to employees of crisis response centers, regional water management boards and the Institute. The local government workshops organized by the team presently operating as the Office for Local Government Collaboration also have already become a tradition and represent a perfect forum for training and discussion—where the leading topic is how to prepare for the inevitable, i.e. for a flood.

During their activities, employees of the Office have stumbled upon numerous problems associated with local flood monitoring and warning systems. Clarifying these problems, helping in the making of a balanced decision, and proper planning of work is the Office's present aim, so that further collaboration will progress properly and with complete understanding, as well as bring mutual benefit. At the same time, we need to realize the significance of the principles of economics—that is, that we need to aim to achieve the assumed goal for a reasonable price.

Here a certain observation needs to be made, and I admit that in these predatory and bureaucratic times, it is a pleasure for me to say that without the sensitivity of the team of employees in the Department of Water Resources at the Ministry of the Environment, and in particular of one person, who could be called the 'guardian angel' of our collaboration, such projects as this compendium could not be undertaken. For many years, we have been collaborating with this Department in modernization operations being undertaken by the Institute, as well as in numerous initiatives permitting us to view flood issues differently than before. In the name of the team of authors and of the entire Institute—thank you very much.

Also important is the role of the National Environmental Protection and Water Management Fund, and the resources which its board and supervisory council designate for purposes such as this one. We have many more good ideas and want to realize them. So we are grateful, and will continue to come with our initiatives to the Ministry and the National Fund, counting on the same sensitivity and understanding shown us so far.

Finally, we would like to thank all of the content consultants, as well as all persons who supported us with their knowledge and experience. It is their involvement which has caused this handbook to take this particular form and be enriched with essential content, especially in the area of psychological, sociological, technological and equipment-related issues. We would like to express particular gratitude to: Aleksander Kruszewski, Anna Lipowska-Teutsch, Krzysztof Przybyszewski, Kazimierz Sołotwiński, Zbigniew Trzeciak, Elżbieta Tyralska-Wojtycza, Zbigniew Woźniak and

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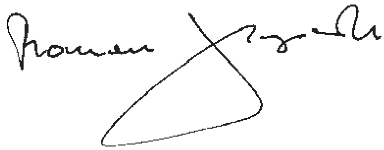
We also warmly thank our reviewers, whose perceptive suggestions permitted us, we hope, to avoid basic errors, though no doubt in this version we have not yet managed to eliminate all of them. We thank especially: Zbigniew Chlebicki, Jan Cunge, Rafał Glegoła, Ryszard Grosset, Janusz Kindler, Jerzy Niedbała, Danuta Partyka, Urszula Podraza, Zenon Sobejko.

Being surrounded by so many professional and sensitive colleagues, I can in closing declare without fear that the Institute of Meteorology and Water Management promises to help all local communities in building flood monitoring and warning systems. I also count on you to, after reading the handbook *In Time for the Flood*, contact the Office for Local Government Collaboration, and on us all to continue working together to prepare the inhabitants of Poland to live with the flood phenomenon.

Now we can write the customary introductory words: 'We present to you the perfect material to help in organizing and building a local warning system, and in so doing contribute to flood damage mitigation.'



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From left: R. Konieczny, M. Siudak, M. Barszczyńska, R. Bogdańska-Warmuz, P. Madej

Effective flood hazard management requires the collaboration of many institutions, as well as constant exchange of knowledge and experiences among them. Such an assumption was the basis for the decision of the Institute of Meteorology and Water Management (IMGW) to found the Office for Local Government Collaboration at the end of 2004. Since that time, a team comprised of several persons has been working at IMGW Kraków, involved in the following tasks:

- Studying the needs of local governments in the area of collaboration with IMGW;
- Organizing series of meetings between IMGW and local governments (local politicians as well as crisis intervention forces), with the aim of exchanging experiences;
- Executing research and implementation projects in the area of applying non-structural methods of flood damage mitigation on a local and regional scale;
- Preparing informational materials and handbooks, as well as conducting educational and training actions in the area of natural catastrophes;
- Collaborating with Polish and foreign partners, focusing on execution of joint tasks in the area of flood damage mitigation on a local scale;
- Collaborating with other IMGW organizational units in preparing informational materials, as well as a line of Institute services and products attractive to local governments.

Aside from research and development work executed as part of large projects, such as OSIRIS (*Operational Solutions for the management of Inundation Risks in the Information Society*—IST-1999-11598), financed by the Fifth Framework Program of the EC, the team is involved in many local projects. These meet the needs of municipalities or counties—the smallest basic local government units in Poland—and encompass both concepts for local flood warning systems, and flood damage mitigation plans or educational programs. The team has to its credit several publications addressed to these communities—among others, a handbook concerning collaboration with journalists during crisis situations, as well as didactic materials for teachers which enable them to conduct lessons on flood issues in schools.

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Introduction

It is inevitable that for the next few years, in all discussions, plans being prepared and actions being taken concerning floods, we will think in terms of the catastrophe of 1997 in Poland[1]. We will analyze the losses it caused, we will ask ourselves questions about the weaknesses of the flood protection system existing at that time, as well as about what could help to avoid such great misfortunes in the future. But above all, we will refer back to our experiences from that time, because they were what made us so clearly aware that the existing flood protection system was ineffective. Not only because there were too few retention reservoirs in Poland, or because, in many cases, its embankments were in bad condition, but mainly because the system was oriented towards responding to a catastrophe, and not towards prevention in a broad sense. The law did not make it possible to limit development of flood plain areas; institutions and structures responsible for flood protection did not provide inhabitants with information on how to prepare for a flood; and in mountain and foothill areas, there were no systems solutions guaranteeing sufficient advance warning to persons and institutions at risk.

Since that time, a lot has changed. And though many of us no doubt think that these changes are insufficient, at various levels of administration and at many institutions, an array of interesting attempts to modernize the existing system has been undertaken; changes have been introduced in the operational principles of these institutions; and above all, there is an effort to improve collaboration among institutions.

One example of such activity are local flood monitoring and warning systems (known by the acronym LFWS in English) being created by municipalities or counties. Many of them have been built in Poland since 1997—either thanks to various national and international projects, or thanks to local initiatives. Experiences associated with their building and exploitation have inspired employees of the Institute of Meteorology and Water Management to prepare the present handbook.

In designing it, we have decided to depart from the standard layout, which leads the reader through the successive stages of the building of an LFWS. Such a handbook has a chance of being written only a few years hence, when both our experience and knowledge, and that of those who are building or are going to build an LFWS, is greater and richer. When there is a universal awareness that the secret of success lies

1 The flood in July 1997 was one of the greatest noted in the history of Poland. In some places, the probability of occurrence of such a flood was about 0.1% (a so-called ‘1000-year flood’). The flood encompassed approx. 15% of the country’s surface area, mainly the upper and middle Odra catchment area, 54 persons lost their lives. Total losses have been estimated at 2.3–3.5 billion USD.

not only in measurement sensors installed, but also—and perhaps above all—in collaboration of institutions and services/forces responsible for protection of life and property, with entities at risk.

We have determined that for today, the foreground should be occupied by those problems and warning system elements which are new, or which were omitted in systems presently being built, or which were executed with bad solutions which thus now require special treatment. In consequence, the proposed text layout is more a handbook on issues which are important today than an orderly handbook applicable to all times.

So, what does the handbook contain? It has been divided into several parts, each with its own clearly-designated task.

Chapter One contains an attempt to define fundamental matters: operational principles of warning systems in 1997, characteristics of the ideal system—more effective than those presently existing—as well as Polish and foreign examples of solutions undertaken in a similar spirit to that ideal system.

Chapter Two concerns the most important data and information which need to be obtained, thought through or prepared before one begins to plan the building of an LFWS. This includes analysis of the structure of possible flood losses, the amount of response time that must be provided to entities at risk, and the costs of both investment in and exploitation of monitoring and warning systems.

Chapter Three is a compendium of knowledge concerning the elements of the system. It presents both the principles for building a precipitation and water level monitoring system and preparing forecasts and disseminating warnings, and the things the local community should know so that its members' responses to warnings will be effective.

Chapter Four focuses on one of the most important elements guaranteeing system effectiveness—collaboration. Not only with institutions, such as the Institute of Meteorology and Water Management (IMGW) or the Regional Water Management Board (RZGW), but above all with the mass media and the local community.

In the last part, we have placed three appendices containing information to supplement knowledge in the area of measurement devices, notification techniques and education.

For whom is this handbook? We have written it mainly with the thought of local governments which have to deal with flash floods—where what is at risk is, above all, human life. However, this does not mean that it will not be useful where the onset of floods is less rapid—in such places, the individual elements of the system will have differing significance. There, most likely, it will not be necessary to think about building their own monitoring system, because information from IMGW and preparation of effective notification methods will be sufficient.

We hope that the knowledge and information resource proposed in this handbook will not only clarify many misunderstandings concerning local flood monitoring and warning systems, but also help in making decisions whether it is worthwhile to build such a system—and if so, what kind. Above all, we are concerned that the thoughts contained herein be an inspiration for readers to develop their own solutions adapted, on the one hand, to the needs; and on the other, to the capabilities of the local community.

Photo: A. Iwańczuk / REPORTER

WHAT CONSTITUTES AN EFFECTIVE WARNING SYSTEM?

Warnings are of limited value unless they are delivered in a timely and effective manner and property owners and residents in the flood-threatened area believe the warning and take appropriate action in advance of being flooded.
[Bureau of Meteorology (Australia), 2005]

HOW ARE WE WARNED TODAY?

An assessment of the present situation in the area of flood warning can be carried out in many ways. One can present the results of studies which talk about the operations of the individual services and forces responsible for the elements of the warning system. One can also objectively analyze the reasons which cause some of the elements to malfunction. It is this that the reader will find in the successive chapters of this guide. However, for improvement of existing systems to be possible, we must know what ordinary people—those affected by flooding in recent years—think of these systems. Below, we present their opinions in the form of a news report based on our notes from conversations carried out with inhabitants, and on reports on the flood published in the press.

No one warned them

'I was watching Force 10 from Navarone*—that scene in which the water breaks through the dam—and suddenly I see that water is pouring into my foyer. I just went dumb,'* reports one housing development inhabitant. *'I grabbed my child, then the TV, and rushed upstairs. (...) No one had informed us it could be so bad. I don't know why, because people were saying there could be a flood, but it didn't even cross my mind that the water could come up to here.'*

There were many such homes, at first dozens, then hundreds and more. It was a complete surprise. And even if people knew about the flood hazard, even so they either didn't believe that it concerned them too, or they had no idea what to do with that knowledge. They were scared, ran back and forth from furniture to car, not able to decide what to rescue first. They brought some stuff out, ran with the kids to their neighbors'. Most often, they just waited.

'Rain had been falling for a few days. On Sunday, water began to flow out of the cracks in the floor. We removed some furniture and waited, not realizing that this was only the beginning of "hell". There was more and more water. We were up the whole night. We were completely helpless. And afterward, at 5:40 AM, something happened that I had only seen in catastrophic films. I heard a huge bang, and water flooded the entire apartment all at once. We escaped from the by now deep water to a nearby preschool.'

It was strange that no one had notified or warned people, no one had told them what to do. The flood did, after all, last for many days, the phones were working; but despite that, during the first few days, crisis intervention forces only gave sporadic warnings. They responded only when it was really bad. We asked ourselves the question: Why? Conversations with the mayors of flooded municipalities showed that there was a lack of proper preparation, information and forecasts, there were breakdowns in communication. One of them spoke at length about the dilemmas that the municipal flood team had had during those days. When asked if they were warned earlier by the meteorological services, he answered hesitantly:

'Yes, a warning did come in concerning precipitation, but it did not translate this into the exact amount of water we would have. For several days, we had also known that something was going on in the Czech Republic. But the Czech Republic is "far away". Only when I myself began to check—went up the river, above the dam—then I understood what was happening.'

'Did you warn people?'

'No, we evacuated them. It was difficult to make the decision, for how were we to know that what flows down from the mountains will flood the town? But after what I saw, wet earth, landslides on slopes, water overflowing through the dam—I had no doubts about what to do. I preferred to have people laughing at us for evacuating them needlessly, than to have someone die. We were the only ones in the area who decided to do it. And it was already night-time, so it was not easy to find buses to evacuate people, places for them to sleep... But we did it.'

Not everywhere did it turn out so well. In many places, where the flood occurred over a few, sometimes a dozen hours, forces didn't know what to do. Their activities amounted to attempting to coordinate operations. Crisis response plans didn't contain instructions about how to warn people—whom first, whom next. They did not contain maps with designations of places which could be flooded, dangerous sections of embankments. Thus, sometimes it happened that people were led into error.

'My family didn't have time to take anything with them. No documents, valuables, family mementos, radio, television, or even the toys at that time most precious to me. It happened like this because shortly before the water overflowed the river bed, the authorities had assured my parents and neighbors that the wave which would go through the city would not be high enough to get into homes located so far from the river.'

Do these experiences show anything? Perhaps it is worth thinking about what went wrong and what can be done so we won't be so helpless in the future. One young boy taking part in the flood competition wrote for one of the competition tasks:

'Since the power of water is so terrible and nothing and no one can stop this machine once it has started, we should be more humble before the forces of nature. But at the same time, we can't just do nothing. This flood was a great lesson in humility for people. Are we able to draw conclusions from it for the future???'

Patrycja Zun

WHY AREN'T EXISTING SYSTEMS EFFECTIVE?

Existing warning systems serve mainly to warn crisis intervention forces, not inhabitants and flood plain users at risk.

The tragic effects of events from 1997, presented in the previous chapter, which were experienced both by people affected by the flood and by local government crisis intervention forces, perhaps could have been avoided if care had been taken to ensure the effectiveness of the warning system (its flaws could have been corrected easily), but above all, if the very traditional warning system philosophy, already rejected in many countries, had been dropped.

The traditional warning system philosophy

The model warning system is comprised of several basic elements: structural devices to measure precipitation and river water levels, and tools enabling forecasting of the flood process and its effects, as well as means of warning. At first glance, there is nothing disturbing in this definition; but if we add that up until this time, it has been assumed that warning systems are tools to assist crisis intervention forces, then it is easy to understand why during recent floods, the majority of inhabitants were not notified of the impending danger. While it is true that warning of inhabitants was among the duties of local crisis intervention forces, these—for fear of being compromised on account of having the forecast prove to be incorrect—informed inhabitants of the danger and the necessity of evacuation only at the last minute, when it was no longer possible to do anything. Many inhabitants refused to evacuate themselves and their families, furthermore for various reasons: some of them did not know that they lived in hazard areas; and the majority—not knowing the competency areas of local institutions in this area, the response plan (rules for evacuation, evacuation points), means of protecting homes after leaving them—preferred in this situation to stay at home. The plans encompassed the organization of evacuation by services and forces, but did not provide for either early warning of inhabitants, or a system to support their activity.

After the experiences of recent decades, which have abounded in floods, people have begun to think about flood warning differently. It is presently assumed that its main aim is to induce a proper response of people to the warning. And this means a complete change in the way of thinking—in new systems, the problem is not 'production' and distribution of information (warnings), but elements which are conducive to people's proper reaction. These latter require a focus on such issues as, for example, the amount of time needed for people to respond properly, message content which will support decision-making about what to do, reliable methods of reaching different risk groups with warnings (e.g. tourists on campgrounds, drivers on roads, etc.) as well as knowledge on the part of those at risk concerning how the system works, who will be warning them, where the information can be checked, what to do after receiving a warning, where to evacuate to, etc.

A few weaknesses of warning systems

Looking through this prism at existing systems, it is worthwhile to think about what is missing from them, as well as what their flaws are:

Centralized structure for information and warning flow making it difficult to reach at-risk inhabitants with the information in time

The organizational structure of the existing warning system in Poland is hierarchical: warnings prepared by the Institute of Meteorology and Water Management (IMGW) and transmitted to the voivodship crisis response team (WZRK) are forwarded to the county crisis response teams (ZRK)—and only from there, to individual municipalities. In the case of mountain areas and the flash floods (short period of barely a few hours between precipitation and flood wave culmination in a given river cross section) which occur there, this path is too long. It causes warnings to not arrive at all, or arrive too late to be able to secure one's property. This situation is slowly changing, because more and more often, IMGW is providing warnings directly to municipalities at risk.

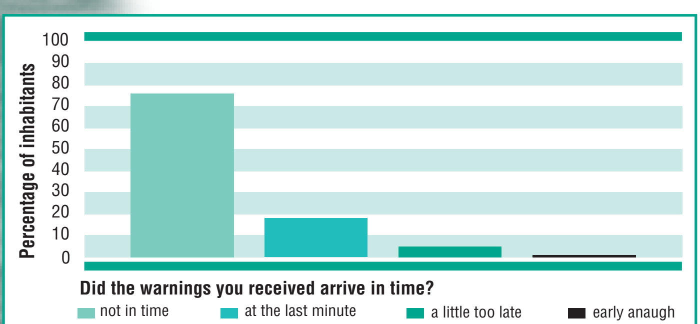


***Fig. 1** Time of flood hazard warning receipt in 1997 [IPS PAN, IMGW, 1999]*

The majority of inhabitants of areas affected by flood damage in 1997 did not receive a warning about the impending flood; and in the case of those who were notified, the information arrived too late to be able to evacuate or take any kind of action to secure their family and property.

Lack of solutions and tools to facilitate decision-making as to when and how to warn inhabitants and other users of hazard areas

A fundamental problem of local crisis intervention forces (mainly in areas where flash floods occur) is—and always will be—the uncertainty of the forecast. Too-early warning in an uncertain situation is risky for the forces because of the potential for loss of credibility if the forecast turns out to be incorrect. Warning too late—when the flood is now certain—limits inhabitants' chances of saving themselves and their property. Forces left without counsel in this area or tools which could help in making the right decision choose the worst possible variant of warning—they warn only when a flood is already approaching.

Application of solutions which do not motivate people at risk to take action

It is characteristic that not many flood plans contain elements associated with assisting the activity of inhabitants in the area of flood preparedness (securing buildings, furnishing their homes) or behavior during a flood (securing property, self-evacuation). In crisis response plans prepared by crisis response services and forces, inhabitants and flood plain users are treated rather as an object that must be evacuated from hazard areas when a flood is inevitable, and not as an active party who should be helped to undertake safety measures independently in advance. This is no doubt one of the reasons for inhabitants' not believing that they themselves can influence the magnitude of their own flood losses—and consequently, a cause of passivity on their part. [IPS PAN, IMGW, 1999].

Lack of prior identification of hazard areas, and consequently, lack of knowledge about entities which should be warned

Many towns to this day do not have even makeshift maps with areas indicated which could be prone to flooding. This makes it difficult or even impossible to determine precisely who is at risk for flooding, and establish a warning plan. We must admit that since the flood in 1997, the situation in this area has improved greatly in Poland. Many municipalities have prepared maps of the extent of inundation from recent floods; and recently, maps prepared by regional water management boards (RZGW—see p. 74) have appeared. Nevertheless, they are rarely utilized to determine who is really at risk, or to inform inhabitants that they live in a flood plain area.

Lack of an effective system for warning dissemination among inhabitants

Among crisis intervention forces, the conviction prevails that a cheap and effective method for transmitting warnings to inhabitants of flood hazard areas is to use alarm sirens. Experience shows, however, that they are effective only in areas that are densely developed—and that, on the condition that there exists a second channel of transmission, e.g. police and fire brigade, to reach inhabitants and inform them of the hazard. Without such support, people understand sirens rather as a fire warning than as a flood warning.

Lack of an education and information system which would make inhabitants aware that they as individuals can save themselves and their property from flooding

Surveys [IPS PAN, IMGW, 1999] carried out by IMGW among inhabitants show that the majority of them represent passive attitudes: they consider local authorities to be responsible for their safety, that the most effective means of flood protection are embankments and retention reservoirs, that their role in mitigating their own losses is not very important. They also have almost no knowledge concerning methods of securing themselves against losses. They also do not trust institutions involved with flood issues in Poland. This all contributes to their lack of a response to warnings, as well as causing frequent refusals to evacuate in catastrophic situations. In solving this type of problems, education could help, but studies carried out in about 300 municipalities [OSIRIS, 2001] indicate that local authorities do not attach much importance to it.

HOW CAN A PERSON, FIRM OR INSTITUTION BE WARNED?

Floods are catastrophes which cause the greatest of misfortunes—the death of many people and losses reaching into the tens of billions of dollars. Securing ourselves from their effects and results, which also includes warning systems, is a problem on which teams in many countries of the world have been working for years. We have gathered as many Polish and foreign examples of local warning systems as possible, as well as unique solutions for their elements; these have served as material for the writing of a report, similar to the one included two sections earlier, describing the ideal warning system—which perhaps even exists somewhere.

Are we going to wait for the flood? Maybe not...

'Hello, hello...', whispered the man in the front row into his telephone. At the same time, the county governor greeted those gathered for the ceremony to present the telephone flood warning system for inhabitants. The man listened for another moment, after which he straightened up and said to those gathered in the hall, *'Turn on your telephones.'*

'Yes, please do turn on your telephones,' confirmed the county governor. After a moment, a bell was heard in the auditorium, then a melody, then another and then another…

'My name is Stanislaw Czur, I am the county governor. It is my joy to inform you that we have completed the first stage of building the flood warning system for inhabitants. Before each hazard situation from now on, we will inform you that we are at risk for a flood, and if necessary, that we have to evacuate. I am glad we have pulled it off.'

The moved voice of the county governor pronouncing those words was heard by phone not only by the guests gathered in the hall, but in the next two hours by about four thousand inhabitants, owners of companies and shops, and service providers, whose buildings are at risk for flooding. In this way, the telephone system for notification of inhabitants about a hazard situation, representing one of the elements of the county warning system, was used for the first time. It permits a pre-recorded message to be 'sent' by phone within one hour to two thousand people, as well as feedback to be given indicating who received the message, and who didn't.

'No doubt you think it strange that we didn't start that ceremony by the river?' asked the county governor as he showed us around the crisis intervention center. *'Those irritatingly expensive devices which measure water levels and send the data to our computers, we will see later on the screens. By the river, we have cam-*

eras installed to have a view of what is happening there. We just considered it most important to show inhabitants how we will warn them. When we analyzed experiences from the last flood three years ago, it came out in black and white what is most important. To know how much water there is in the river—that is one thing; the problem of how to warn inhabitants in a short time and what to do so that they will respond to the hazard—this is another, equally important, but far more difficult matter.'

The entire system, built over the past few years, can really do a lot: it monitors precipitation and river water levels; at 4 in the morning, if water levels are approaching dangerous levels, it can get crisis intervention forces on their feet and facilitate their decision-making, as well as enable thousands of messages to be sent to the telephones of inhabitants at risk.

'What is really the aim of a warning system?*'* the chief of the county crisis intervention center, Stanislaw Twerski, who was showing us around, asked rhetorically. *'We consider that it is to provide appropriate information to the right people in the time required. One of these groups is us—crisis intervention forces. We need someone to inform us regardless of whether it is day or night, Christmas or Easter, that something dangerous could happen, that heavy storms and precipitation are expected. This is provided to us by IMGW. Then we go on duty and, looking at data from IMGW and our stations, think about whether something is going on. We use computers which help us analyze whether or not the forecasted precipitation could cause a misfortune in our area. If a danger does exist, then we inform the municipal forces, and these, having information from us at their disposal, as well as their own knowledge and experience, notify inhabitants. This is not easy, however, because it is difficult to reach everyone.'*

A problem really does exist—this is proven by the fact that during the last flood, the operational procedures for the forces turned out not to be very effective. The forecast that came from IMGW said that there will be heavy rainfall. People were informed of a danger of flooding, but no one know when it would come or how big it would be. Everyone waited. And then it began to rain and in effect, when the evacuation was begun, water was already coming into people's homes. No one wanted to leave their property, but people had their reasons for that. Those who were informed late tried in half an hour to save something more, taking things up to higher floors. And above all, they were afraid of looting.

The basic responsibility for informing inhabitants of a hazard situation rests on the mayors. This is sensible—they are best acquainted with the area, and know whom to inform.

'The telephone doesn't take care of everything,' says the mayor of one municipality. *'There are several older couples we can't call, because they don't have telephones; we can't call the homeless. There are more such groups whom it is difficult to reach by telephone. These are, for example, tourists putting up tents in places not necessarily designated for that purpose. We have had a lot of meetings with inhabitants and we've determined that in each village, there will be a few people responsible for warning neighbors, including those who don't have a telephone. They will be helped by the fire brigade, which, now that telephone notification has been introduced, will no longer have to run around to every home. They will occupy themselves only with those who really require care, help them secure the library at risk, make sure that trash which could poison everything is removed from hazard areas.'*

A problem not much talked about are automobiles driving through the hazard area. Two years ago, in a neighboring county, four tourists died in a car, and we can only surmise how it happened. That evening, a storm came and the water level in the river rose four meters in one hour. No doubt they drove onto a road inundated with rain and river water and later, when driving became impossible, they couldn't turn around. How to deal with such situations? The county governor dreams of collaboration with cellular telephone operators, who are able to locate each person in possession of a cell phone with precision to within a few meters. It would then be possible to send information about the danger to all who are approaching a hazard zone. But that is still in the future. For the moment, signs have been mounted on such roads with the notice: 'Road at risk for flooding. Turn around if it is raining.'

At the crisis intervention center, we were also shown a flood hazard information system made available via the Internet. All you do is input your postal code, and a map with lines indicating the probable extent of inundation is displayed. Everyone can check whether or not there is a danger that his/her home will be flooded. According to Stanislaw Twerski, this is one of the more important elements of the system. Many people did not want to evacuate during the last flood, because they didn't know that they live in a hazard area.

Information—the same as that placed on the web pages, except in the form of a traditional map with advice attached concerning how to act during a flood—is sent out every year to everyone at risk. Aside from these instructions, there exists much educational material: there is a comic book for little children entitled *How to evacuate Grandpa Wladek?*; there are materials for teachers suggesting how to organize lessons about the flood hazard; there are brochures for inhabitants, containing hints for how to prepare one's home for a flood.

'We have come to the conclusion that it is a good idea to print existing materials and make them available not only for one county, but for the entire voivodship,' said Stanislaw Kram, of the voivodship crisis response team. *'We have also determined that our role is to support municipalities in the area of flood damage mitigation. With all certainty, we can offer them education and training programs.'*

The meeting went on for nearly three hours. Besides the tours, there was also a discussion over coffee about the system: will it be effective, has everything been thought of, won't early warning cause people to panic? The entire thing was received well by the invited guests. Someone even said at the end, *'Well, now there's nothing left to do but wait for a flood.'* Silence fell and only after a moment did one of the mayors speak up, *'Maybe not.'*

Karol Potocki

HOW TO MOVE CLOSER TO THE IDEAL?

The ideal warning system should be based on the needs of flood plain user groups at risk, and utilize their experience. It should be as inexpensive as possible, relatively simple and maximally effective.

Is it possible to build a system like the one described in the previous chapter? The answer is not easy, for the effectiveness of a system depends on so many factors that it is difficult to give a ready-made recipe. But the question posed in the introduction can be divided into two parts. First of all, what characteristics should a system have, which would be close to the ideal; and what elements should comprise it? Secondly, are efforts being undertaken in Poland and elsewhere to create such systems? We should indicate that the formulation 'ideal system' does not at all have to mean an expensive system, based on the latest measurement technologies, satellite communication and automation of all information transmission processes. The 'ideal system' means, in this case, an effective system adapted to the real capabilities of the place and the people who live and work there. As simple and inexpensive as possible.

Elements of an effective warning system

The basic characteristics of modern flood warning systems being built in the world in our time can be described by formulating a few definitions: what is a warning, what are the aims of a warning, how to measure the effectiveness of a warning?

A **warning** is information about a potential or inevitable hazard, provided to people before the occurrence of the catastrophe (or exceptionally, during it).

The **aim of warning** is to incline people at risk, faced with an approaching catastrophe, to take action to reduce the risk to life and property.

Warning effectiveness should be measured by actions taken at the appropriate moment by crisis intervention forces, community services, owners of structures, and inhabitants of flood plains, to protect life and property.

In consequence, to fulfill these requirements and aims, the warning system should include:

- Environmental monitoring—both by the nationwide system, and by local systems (precipitation, water levels, ground moisture, temperature, etc.)—as well as checking whether the values measured exceed values considered to be dangerous (volume of precipitation, river water level, etc.);
- Forecasting of the possibility of a flood's occurring at selected points (water level and time when it will happen), on the basis on data originating from the precipitation monitoring and forecasting system;
- Analysis of scenarios for development of the situation and determination of the predicted extent of inundation for each of them, as well as designation of which structures are located in the hazard area and who is in danger (lists of firms, institutions, inhabitants at risk);
- Preparation and dissemination of warnings to services, inhabitants, owners of firms and institutions, utilizing all means of communication to guarantee that all groups at risk will be reached;
- Confirmation of both warning receipt and warning response;
- Preparation of procedures for assessment of system effectiveness and development.

Also included in the system's functions should be ensuring an appropriate knowledge level on the part of inhabitants, crisis intervention forces and other flood plain users, which knowledge will help them to respond to the flood in a manner leading to mitigation of losses.

It should be emphasized that building of an effective system depends on the collaboration of many entities:

- IMGW's nationwide monitoring and forecasting network, which monitors hydrological and meteorological conditions, and forecasts phenomena for larger areas of the country;
- Counties or purpose-driven groups of municipalities which want to build their own warning system;
- Coordination and information centers at the Regional Water Management Board (RZGW) (see p. 74), which are to play an important role in the area of planning and operational activities in the future;
- Municipal services and forces which are responsible for warning and safety of people;
- Inhabitants as well as owners of firms and institutions at risk for flooding.

Finally, it is worth emphasizing that there is no one simple recipe for building a local flood protection system. In undertaking its building or expansion, one needs to take into account the needs and possibilities of the local community, and aim to utilize the experiences and resources of institutions associated with flood protection and crisis management.

Experiences of other countries

It is worthwhile to see how other countries which have been developing warning systems for years (so that they have much experience in this area) deal with these issues.

Great Britain

In Great Britain, flood warnings are among the obligations of Environmental Agencies (EA) financed by the state. The Agencies exploit a precipitation and water level measurement network, utilize data from radar, and collaborate with the UK Met Office, which prepares weather forecasts. Warnings are disseminated among inhabitants, local authorities and institutions which manage elements of public infrastructure.

One of the strategic decisions made by the government of Great Britain in recent years is to include at least 80% of hazard areas in warning systems, and by 2010, attain 85% effectiveness of these systems. This effectiveness is measured by the degree of inhabitant response to warnings.

WARNING SYSTEM FOR THE RIVER THAMES

The warning system for the River Thames is managed by the Environmental Agency of England and Wales. The decision to warn is made at on the basis of meteorological forecasts and data from the hydrological measurement network. Depending on the degree of the hazard, one of the following messages is sent: flood watch (warning of possible flooding), flood warning (warning of expected flooding), severe flood warning (warning of expected serious flooding), or all clear (message that situation has returned to normal and there is no danger).

In this system, many ways of transmitting warnings and messages to inhabitants are utilized. Among them are: automatic dissemination by telephone of voice messages (up to several hundred recipients simultaneously), direct transmission of information by volunteer flood wardens, utilization of sirens and megaphones, publication of messages on the Internet (updated every 15 minutes), transmission of information via the mass media, provision of special info-lines where one can hear all flood warnings and obtain information, as well as transmit information about the current situation.

United States of America

In the USA, the National Weather Service—NWS is responsible for meteorological forecasts. Its task is to collect, compile and analyze hydrological and meteorological data for flood protection purposes. The NWS prepares and provides forecasts and warnings for over 3100 municipalities in the country. It also collaborates with 900 municipalities which have their own warning systems. One can distinguish two types of systems which are maintained and managed by local governments, and supported by the NWS: observer-based systems, and automatic ALERT systems.

SYSTEMS BASED ON TRADITIONAL METHODS

NWS helps many municipalities to develop their own monitoring systems based on traditional measurement devices read by volunteers. Data from these systems, transmitted by observers via telephone to NWS regional centers, permit preparation and provision of forecasts as well as warning of inhabitants. At the beginning of the 1990's, about 540 such systems were in operation in the USA. Besides simplicity, they have the advantage that they get local communities involved in their operation, which then makes warning easier, as well as raising the knowledge level of inhabitants in the area of response to extreme phenomena.

ALERT SYSTEMS

In mountain areas, to ensure an appropriate amount of advance warning time, the NWS promotes the building of local ALERT systems, equipped with automatic measurement, transmission and storage devices. These are inexpensive systems, powered by solar batteries and transmitting data only when rain begins to fall, or when water in the river reaches a predetermined threshold level. In consequence, their requirements are modest—this concerns in particular their power source, which enables them to be located at any appropriate point in the catchment area. Measurement data, after reaching the threshold values determined by local forces, are transmitted automatically by the stations to the crisis intervention center. Forecasts prepared on their basis concerning the development of the flood situation are utilized afterward by local communities for warning and initiation of safety operations.

ALERT SYSTEM FOR THE CITY OF MILFORD, CONNECTICUT (USA)

Milford is a working-class city located on the Atlantic coast. About 57% of its inhabitants live on the so-called 100-year flood plain. In 1993, after one of the heavier floods, an ALERT system was installed there. Also carried out was an inspection of all buildings at risk from the standpoint of depth of potential inundation, and classification of the buildings into different risk level groups. An address database of the owners of all structures was prepared, which is the basis for the rapid automatic telephone warning system for inhabitants. This work, in conjunction with information and education activities (procedures for notification and warning response), as well as a system of evacuation route signposts, permits rapid response of inhabitants at risk.

The cost of the entire system amounted to 130 000 USD. Since the time of its installation in the mid-1990's, the system has been mobilized 20 times. Analysis shows that it has paid for itself already several times over; the effectiveness coefficient (i.e. the ratio of the amount by which losses were reduced, to the costs actually incurred) is 4.

Local warning systems built in Poland after 1997

Some of the local systems which were built in Poland after the flood in 1997 were initiated by the Flood Recovery Project, financed with resources from a World Bank loan. Some of them are very simple; others, normally county-wide or catchment area-wide, are highly-developed systems designed by professionals—consultants from the universities or from IMGW. Several examples of independent actions are presented below.

Kłodzko County Government—Since 2002, an automatic monitoring system has operated at the county government office, comprised of 19 measurement points for river water levels, and 20 measurement points for precipitation. Transmission of data takes place automatically via radio. Also set up here is a prototype decision-making assistance system for notification of municipal services/forces and inhabitants, based on analysis of possible variants for the development of the flood situation. Warning of inhabitants is provided by Poland's first system of telephone flood hazard notification, with productivity of about 800 notifications per hour.

Żywiec County Government—As part of the Flood Recovery Program, a monitoring system comprised of a network of 34 measurement stations was built in 2002. In terms of the manner of measurement, it is a mixed system: measurements and information transmission take place at some points automatically; at others, the data (water levels) are read on staff gauges by an observer. The hydrological and meteorological monitoring system comprises 9 climate stations, 9 precipitation stations, 6 precipitation/water level stations, 5 automatic water level stations and 5 staff gauges. Transmission of data takes place automatically via radio. The total cost of the system was about 1 000 000 PLN.

Nowa Ruda City Hall—Warning system is based on a citizens' network of river water level observers and cellular telephone technology. When the existing weather situation or the forecast from IMGW indicates a possibility of heavy rainfall, the system operator orders observation of water levels on staff gauges located along the course of the river. The decision to inform inhabitants at risk (via SMS) is made by him based on analysis of the rate of increase in river water levels and on his own observations of the meteorological situation. The basis for a decision is, thus, not any formalized model, but the intuition and experience of the system operator.

Brzesko City and Municipal Hall—As part of the Flood Recovery Project, a monitoring system was built based on three automatic precipitation stations and three water-level stations. Information from the stations is sent via radio to a database located in a computer operating at the fire brigade. Incoming information is analyzed on an ongoing basis by the operator on duty, who makes a decision about notifying inhabitants and executes this via a system of electronic sirens which permit transmission of sound signals as well as voice messages.

Świdnica County Government—As part of the Flood Recovery Project, a Weather Warning and Monitoring System was built, whose task is to provide hazard alarms after certain designated threshold values are exceeded. The system comprises five precipitation and four water level stations. Each of the stations, after exceeding the acceptable magnitude of precipitation or water level, automatically informs the appropriate municipal services and forces of this fact. Communication with the measurement stations is based on cellular telephone technology.

City Hall in Kędzierzyn-Koźle—The basis for this system for warning inhabitants and flood plain users, which was prepared after the flood in 1997, is water level information obtained from an automatic measurement network. The system makes use of several modern, remote-control alarm sirens and speakers (switched on and off via a mobile control center), distributed over the entire area of the city.

Photo: A. Iwańczuk / REPORTER

CHECK WHAT KIND OF SYSTEM YOU NEED

Planning and maintaining flood warning systems are time-consuming tasks, and they often require a greater and more continuous effort than do operational responses to floods. They also require the commitment of funds to developing the various components of flood warning systems. This does not mean all components are technical and costly to devise; several elements can be set up inexpensively because they involve defining arrangements and tasks rather than investment in hardware. In fact, many of the problems associated with operating flood warning systems relate to the lack of such definition.

[Emergency Management Australia, 1999]

WHERE TO BEGIN?

Sources of risk, possible extent of inundation, structures at risk and time necessary to save life and property, as well as the weak points of the existing system—this is the basic information needed to plan a warning system.

There is no universal recipe which would facilitate making the decision of whether to build a warning system, or be content rather with what already exists. This is dependent on too many factors; in addition, as experience shows, the subjective element means a lot in the taking of a position. However, it is worthwhile to ask oneself a few questions which will later significantly facilitate analysis of the situation and provide a rational basis for making a future decision.

The research showed that more effective public participation could help build trust and understanding between the public and the professionals.
[Richardson *et al.*, 2003]

The basic questions concern: local flood risk, needs in the area of warning, weak points of the existing warning system, benefits which will be brought about by its modernization, and costs we will have to incur. This information will also be priceless in conducting conversations and during consultations with other entities (local governments, IMGW, RZGW, fire brigade, etc.), whose participation in building or exploiting the warning system is essential for at least two reasons:

- The groups mentioned can bring their own knowledge and experience into the process of planning the system (identification of problems, assessment of solutions, etc.);
- Participation of representatives from among user groups and inhabitants will facilitate acceptance and later implementation of the system.

It is necessary for everyone who could potentially be interested in such a system to be involved from the very beginning in its preparation and, if possible, take part in all phases of the building the plan. Otherwise, the entire work could end in failure or at very least problems.

Characteristics of the flood hazard

The scope of the materials to be prepared as a point of departure for building a warning system should be quite broad—this will facilitate understanding of the causes and magnitude of the hazard, as well as enable identification of the land areas which are most at risk for losses. It is easiest to characterize the hazard by answering a few basic questions:

- What represents a hazard—is it only water overflowing banks, or sudden heavy rainfall, or perhaps structures, e.g. unreliable embankments whose breakdown could be more dangerous than overflow of the river?

- What is at risk—does the flood present a danger to the lives of inhabitants, or to their property, or to community infrastructure?
- Where does the flood hazard occur—in what land areas; what could be its cause; and what is its character?

In completing the answers to these questions, it is worth remembering that in the initial phase, what is important is not so much details—for these will appear during collaboration with inhabitants, municipalities or other partners—as rather general information facilitating definition of what we would like to change, and what effect we would like to achieve.

Sources of the hazard

In preparing a warning system, we must take into account, above all, two types of hazard: **flash floods**, in which the catchment area response time is less than 6 hours; as well as floods caused by river overflow, with an advance notice time of 6 to 48 hours. In each case, the obtainable amount of advance notice, with which we are in a position to disseminate a warning, imposes different tasks for the warning and response system. In the first case, the warning system should be oriented chiefly towards saving human life; in the second, we can also think about salvaging property.

In analyzing the hazard, it is also worth taking into account other causes than the standard river overflow, e.g. the previously-mentioned embankment break, or a flood caused by bad retention reservoir management, or failure of such a reservoir. The determination of where such a break or overflow can occur, and what areas will be inundated as a result, will represent for us key information which should be assessed, and to which we should then assign specific actions to be taken.

Flash floods
are characterized by a short time of occurrence (the accepted value is less than 6 hours), counting from the cause, which can be heavy rainfall, a dam or embankment catastrophe, or sudden ice jam break. These are the chief causes of deadly accidents.

Extent of the hazard

The hazard can occur in several areas simultaneously; and for each of them, it is necessary to figure out the possible extent of inundation. The source from which this information should be obtained depends on the local situation. If a larger-scale flood has occurred in the last few decades, then one can and even should utilize knowledge and memory of what happened, drawing extents of inundation onto historic maps, as well as recording information about the flood process. If there was no such flood, then one needs to hire a professional firm to analyze the extent of inundation and, on this basis, prepare a flood map.

Another important task is to designate, if only approximately, zones in which human life is at risk. In texts published on this subject, it is possible to find various criteria for the designation of such zones. One source [Green *et al.*, 2000] gives the information, for example, that these are areas where water is at least two meters deep, or its velocity exceeds 2 meters/second, and buildings are of weaker, e.g. wooden construction, and do not represent safe shelter. More often, we meet with opinions that a better measure of the hazard is the quotient of depth and velocity of the water; an area where water that is one meter deep moves at a velocity of 1 m/s presents a danger to human life. These zones can be determined in collaboration with inhabitants who remember previous floods.

Who and what is at risk?

Within the pre-designated flood zones, it should be determined who and what is at risk. This information will be needed to determine how to warn various user groups so that they will have the appropriate amount of time for a proper response (evacuation of persons or securing of property). For each of these groups, one must determine individual needs in the area of warning: means of reaching them with the warning, response time needed, sometimes attitude towards uncertainty in warnings. The following are the standard groups:

Inhabitants and flood plain users—permanent and temporary residents, employees of offices, industrial factories, the service sector. Particular attention should be paid to people whose age or state of health make them particularly vulnerable to the hazard.

Owners or administrators of production, service and public structures—persons responsible for the safety of production- or service-sector structures, public facilities, such as government offices, museums, libraries, schools, hospitals, guest houses, hotels, etc., as well as for the safety of elements of community infrastructure (transportation, power, gas, telecommunications networks, etc.).

Owners or administrators of special structures—sewage treatment plants, waste storage areas, fuel stations, storage facilities for agricultural production supplies, chemicals, pharmaceuticals, etc.

Persons without a permanent residence—tourists on official or unofficial campgrounds, homeless persons.

Only some of this information can be found in the notebooks or computers of municipal or county government offices; compilation of the rest requires contact with inhabitants and flood plain users.

Weaknesses of the existing warning system

An important element of the initial analysis should be a determination of what has not worked in the existing warning system. In many places in Poland, it has turned out that in the majority of cases, affected persons were not warned; or even if they were, a large fraction of them did not respond properly—they remained with their families at home, putting the life and health of themselves and their loved ones at risk. In such a situation, it is necessary to figure out why this happened. Is the cause a warning that came too late, or is the blame for such a state of affairs borne by an improperly-functioning system for warning inhabitants? Or perhaps on top of that, there is a lack of knowledge about what to do when a warning or information about the necessity to evacuate arrives?

The answers to these questions can be found by analyzing the operation of the existing system step-by-step—from gathering and transmission of data about the meteorological situation, to ‘awakening’ of local services and forces, decision-making concerning warning of inhabitants, to transmission of this information and confirmation of people's response.

Inhabitants themselves can also be another important source of information. Surveys or interviews conducted among them can concern, on the one hand, an assessment of the existing system; or on the other, ways of behaving and causes thereof in such situations as a flood.

The effect of this analysis should be a list of defectively-operating elements in the existing warning system.

KEY ELEMENT—RESPONSE TIME

Determining the time needed for individual groups at risk to save themselves, their loved ones and their property, will increase the guarantee of the system's effectiveness.

As was mentioned earlier, the fundamental aim of a local flood warning system is to induce inhabitants to respond properly to flood hazards. To succeed in this, we must know what they need in order to take rational action. We must also know what expectations associated with the warning system they could, and what the system must guarantee them. To simplify a bit, we can assume that they need the following elements:

- Time essential for effective response (depends on many factors, among others what is to be saved or secured);
- Certainty that the information will reach those at risk regardless of the time of day, or the peculiar character of the life and activities of the different groups at risk;
- An appropriately-prepared warning, containing a description of the hazard that has developed, as well as suggestions concerning actions to be taken immediately;
- A level of knowledge and experience acquired during drills sufficient for those at risk, users and crisis intervention forces to be able to respond in a rational manner, e.g. evacuate their family and property to predetermined points (this concerns, among other things, knowledge of the system's operation, evacuation points and routes), secure community structures, etc.

U.S. Bureau of Reclamation studies emphasize the importance of lead time. Improving lead time to 90 minutes or more appears to reduce fatalities by over 90 percent.
[Flood Control District of Maricopa County, 1997]

All of these elements will be described in subsequent chapters, but at this point it will be worthwhile to devote a little more attention to the first item on the above list. Time is a critical element for a warning system. It is essential both for systems built in areas where the flood process is slow, and for those built where the flood process is rapid and every minute counts toward success or failure.

Time also determines what kind of warning system there should be, and even whether there is any sense in building a system. The Scottish Environmental Agency finances the building of a system only when it is effective from the viewpoint of the cost/benefit balance implied by its building, as well as when the amount of advance warning time is greater than three hours. Other rules have been adopted by the English Environmental Agency, which speaks of two hours for England and one hour for Wales.

Practice shows, however, that in the case of risk to human life, one must be able to deal with even shorter times. The authors of a handbook for American meteorological services [NOAA, 1997], devoted to the topic of local warning systems, consider that the threshold time, from the perspective of protecting human life, is 30 minutes. This obviously concerns situations where it is impossible to do any more than that. This information aims to make people aware that even when little time remains before the catastrophe, it is worth doing everything to save human life.

Much more time is required to salvage one's property. Australian papers give the information that to salvage the most valuable items, one needs at least two hours. According to the same sources, in 12 hours, one can salvage almost everything except real estate.

But such guidelines do not solve the problem. The best way out is to determine the times necessary for effective response for individual user groups. Different user groups will have different expectations in this area. With all certainty, the needs of inhabitants who need to evacuate their family, property and themselves will be different from those of warehouse owners, who must often remove several dozen tons of goods, or from owners of production factories, or from, for example, hospitals.

BENEFITS OF BUILDING A SYSTEM

In making the decision about building a system, it is worth remembering that the benefits are not only protection of the life and health and of people. It is also important what the system will allow us to salvage.

Evaluating the benefits of building a flood warning system is not simple. Most often, the following are mentioned:

- Avoidance of injuries and deadly accidents;
- Mitigation of losses to private and public property;
- Mitigation of losses to agriculture, industry and services;
- Mitigation of indirect losses;
- Improvement of local safety;
- Avoidance of political effects deleterious to local authorities, caused by flood damage.

Practice confirms the great economic effectiveness of local warning systems, because the costs of such systems are relatively small in comparison with the benefits which they bring in practice. The parameter by which such effectiveness is measured is normally an index consisting of the ratio of benefits (loss mitigation) which the system yields, to the expenses involved.

One example of the economic effectiveness of local warning systems is the small (50 000 inhabitants) city of Milford, Connecticut (USA), where for the period since 1993, when the system was built, the ratio of gains to costs incurred is 4, which means that each dollar invested brought 4 dollars of savings in flood losses. For the warning system built for the Susquehanna River catchment area, the coefficient is significantly more favorable, amounting to 20, so that every dollar invested has brought 20 dollars in savings. However, such favorable effects are in practice rarely encountered. The Australians think that we should rather expect coefficients on the order of 3–10.

But this is only one side of the medal, because we could also give many examples of systems which do not bring benefits, i.e. they are a failure—for the most part, as a result of improper design.

The question comes up as to how to estimate the future economic effectiveness of the system. We can do this only when we have specific variants for a solution. But here, we must remember that economic effectiveness is only one way to assess them. In many cases, for example in areas where we have to do with flash floods, what is important are the people whom we can save with the help of such systems.

COSTS OF BUILDING AND MAINTAINING A SYSTEM

The costs of a system are comprised of several elements: cost of preparing the plan, cost of building the system, and cost of maintaining it. The last element is key—it is normally the factor which decides whether or not the system will survive the next few years.

The decision about building a warning system should be preceded by a cost analysis. Such an analysis, compared with previously-determined needs, will help us answer the question of whether or not it is worth it to build a system. It can be done with more or less precision, but should encompass:

- **Costs of building the system**—costs of purchasing, execution and testing of all elements, training of personnel, information campaign, etc.;
- **Costs of exploitation**—costs of maintaining the system, including costs of sending and disseminating data and warnings, payments for electrical power, repair and replacement of equipment, costs of personnel training and user education, costs of monitoring the effects of the system's operation, etc. etc.

To this should also be added the cost of preparing the concept for the system—but it represents a small part of the investment costs, so that at this stage, it can be omitted.

Building costs

It is presently very difficult to determine the costs for elements of the investment, because up until now, the small demand for warning systems in Poland has meant that few firms offer such services. In consequence, prices vary widely, and are often higher than in countries in which such systems are more popular. One of Poland's first systems, comprised of about 40 automatic measurement stations, a system for radio transmission of data, a system to support the work of the decision-maker, and a system for telephone notification, built in Kłodzko County, cost about 625 000 USD (these costs do not include work performed by IMGW and the county government as part of the OSIRIS project, which was financed by funds from the EU and the Ministry of Science and Information Technology).

A system for 6 counties in the area surrounding Denver was built for less than 100 000 USD. Obviously, you can spend more, if you have greater requirements. But you have has to remember that monitoring, i.e. devices, are only one element of warning. The rest depends on people—properly trained(...). And that costs a lot more." (Kevin Stewart) [Konieczny, 2000]

The warning system does not have to be created all at once in its final form. One can, and even should begin with simple solutions and expand them after gaining experience, and as funds become available. The building of one of the bigger and perhaps most effective American systems, for the Susquehanna River, was begun with a budget of 500 USD. Today, it is one of the most frequently-described warning systems in the United States. Thus, it is worth remembering that a stage-by-stage building process for the system should be taken into account already in the phase of system concept preparation, because otherwise, the entire undertaking could turn out to be economically ineffective.

Regardless of the difficulties in determining the costs of building the system, it is worth knowing what elements comprise the total cost. With this knowledge, it will be easier to draw up a bid specification, or speak with a potential contractor for the project. Among the most important costs to be considered are:

- Costs of hydrological and meteorological analysis (preparation of precipitation-stage relations and stage-stage relations, discharge characteristics, estimation of alert-level and maximal precipitation, etc.);
- Costs of designing the system (also comprising costs of purchasing maps for design purposes, fees for various types of permits, provision of power supply etc.);
- Costs of measurement stations, together with their setup and accompanying work (construction, installment of power lines, purchase of land, etc.);
- Costs of data transmission system (automatic radio transmission, utilization of cellular and land-line telephone networks);
- Costs of providing crisis response teams of main and local centers with equipment permitting collection, compilation and processing of data (computers and communications equipment);
- Costs of data management software to support 'awakening' of services and forces and perhaps also warning of inhabitants;
- Costs of testing the system and training the personnel who use it;
- Costs of preparing informational materials and education for inhabitants.

So as not to leave readers without detailed information, we give the investment cost structure below for one of the first warning systems in Poland (the portions concerning monitoring, compilation and transmission of data), built by the Kłodzko County Government. The costs of systems built subsequently in Poland were a bit lower, and we can suppose that presently, such solutions could cost even less.

Task	Cost (USD)	Percent
Equipment (40 measurement stations, dispatch stations, communications equipment)	249 920	43.0
Execution of measurement platforms, antenna infrastructure, power connections, cable network, together with designs	229 160	39.0
Placement of measurement stations on measurement platforms	28 800	5.0
Installation of dispatch stations (3 county and 11 municipal)	32 830	5.5
Connection of stations to local flood warning system, launch and testing of system	24 610	4.0
Training of dispatchers	3 020	0.5
Preparation of documentation	15 620	3.0
Total	**583 960**	**100.0**

***Table 1**. Costs of building local monitoring system in Kłodzko County*

The following tables contain detailed costs for execution of a telemetric river gauge station, as well as a staff river gauge for the system built in Żywiec County.

Staff river gauge	Unit cost (USD)
Execution of hydrometric cross section and design	500
Building of river gauge, installation of benchmarks, geodetic reference	925
Total	**1425**

***Table 2.** Costs of execution of staff river gauge in Żywiec County*

Telemetric river gauge station	Unit cost (USD)
Execution of (hydrometric cross section) gauging section, geodetic images, river gauge design	500
Building of river gauge, installation of benchmarks, geodetic reference	930
Water level measurement sensor	1060
Telemetric station in cabinet, CPU module, battery recharger, surge protection, accessories	750
Radiotelephone with modem	760
Antenna installation	260
Antenna mast	210
Connection to power network	300
Installation and launching	500
Total	**5270**

Table 3. *Costs of execution of telemetric river gauge station in Żywiec County*

Exploitation costs

Observation of flood warning systems build after the flood in 1997 shows that local decision-makers, in the majority of cases, do not fully realize the scale of the venture they are undertaking. They normally make the assumption that this is rather a one-time action similar to, for example, the purchase of a refrigerator—not a process which comprises not only investment effort, but also permanent actions to guarantee its maintenance in a constant state of readiness.

The problem is serious enough that for the system to be operative not only at the moment the investment is delivered for use, but also 10 years later, a great effort is needed; from then on, it will require a guarantee of a specific amount of money in the annual local government budget, as well as the introduction of many new actions to crisis team work plans. Omitting these elements in making a decision leads consequently to serious problems in the day-to-day exploitation of the system, and represents a threat to its effectiveness. Thus, before a decision is made about proceeding to build, it is worthwhile to be aware of what permanent obligations and what costs this implies.

Exploitation costs comprise many elements, dependent on the type of system, tasks which it is to perform and solutions adopted, as well as other factors; but among the most important are:

- Costs of maintaining devices in appropriate condition (e.g. cleaning of rain gauges, inspection of communication connections between center and forces, or center and stations, etc.), including also costs of repair, replacement of worn-out system elements, removing effects of vandalism;
- Costs of verifying sensors (especially expensive is calibration of rain gauge sensors, which must be done by specialists), as well as other system elements (e.g. updating rating curves, address bases of persons at risk, etc.);
- Costs of training programs and tests of total system effectiveness (e.g. at least once a year—before the flood season and after);
- Costs of maintaining an appropriate level of knowledge for teams involved with the system (organization of training programs, exchange of experiences and participation in meetings devoted to these issues, which will take place in other regions of the country);
- Costs of maintaining contact with local leaders of communities at risk;
- Costs of conducting or facilitating information and education activities for the population in the area of warning system operation and proper warning response;
- Costs of modernizing system elements—because of aging on the part of the advanced technology used (e.g. computer operating systems);
- Costs of power, telephone service and other exploitation expenses.

In designing the system, one can estimate its exploitation costs in a simplified manner, using an index which describes the annual exploitation costs as a proportion of the investment costs.

Hydrological and meteorological services, e.g. IMGW, assume that exploitation costs per year amount to nearly 10% of the costs of building the system. But this applies mainly to maintenance of the measurement network and ongoing exploitation costs of the network. On the other hand, information obtained from administrators of local warnings systems which have been built in Poland in recent years is completely different. They speak of exploitation costs on the order of 2–3% of investment costs (see sample costs for Kłodzko County system).

Item	Percent of total cost
Maintenance work	71.7
Computer service	11.6
Electrical power	9.1
Service and maintenance of a power generator	6.0
Fee for radio band use	0.9
Land rent	0.7
Total	**100.0**

Table 4. *Exploitation cost structure of Local Flood Warning System in Kłodzko County for 2004 (costs incurred for exploitation: ca. 15 560 USD)*

The problem, however, is that the costs they have taken into account include only basic elements such as: electricity bills, equipment inspection, other inspections, maintenance of services on the Internet. There is no mention of expenses for maintaining the team at a particular level of knowledge, or of stream gauging costs; there is also no money set aside for rebuilding the system after vandalism to equipment, nor for system modernization.

Many such systems fail after a certain time, because exploitation costs were not taken into account. It is difficult to convince people that annual exploitation costs can amount even to 20% of costs of buying and installing the system. This is an amount which is to cover costs of not only exploiting the system, but also modernizing it in tandem with developing technologies.

Photo P. Krzemiński / REPORTER

HOW TO BUILD A LOCAL WARNING SYSTEM?

Flood warning systems need continual improvement just to maintain current levels of service. Warnings are increasingly expected by those at risk and they are expected to be timely and accurate. There appears to be less tolerance for what are viewed as mistakes—even though we may regard errors as inevitable given the complexities and inherent uncertainties surrounding the warning task. This is in effect a steadily rising standard.
[Handmer, 2002]

ELEMENTS OF THE WARNING SYSTEM

A flood warning system comprises many elements; in some, a dominant role is played by technology; in others, by social science. More and more often, we hear specialist opinions that in the process of building and exploitation of such systems, structural elements take up too much of our attention and financial resources, which has an adverse impact on warning effectiveness.

A flood warning system is sometimes called a flood forecasting, warning and response system; sometimes adjectives meant to emphasize the system's completeness—for example, 'integrated' or 'total'—are added to the basic name. This results from the fact that effective warning requires coordinated actions encompassing both the building and exploitation of structural elements of the system, associated with monitoring, forecasting and analysis of potential flood damage and dissemination of warnings; and educational/informational activity; as well as creation of an atmosphere of trust and collaboration. The elements of a local flood warning system are presented in the figure below.

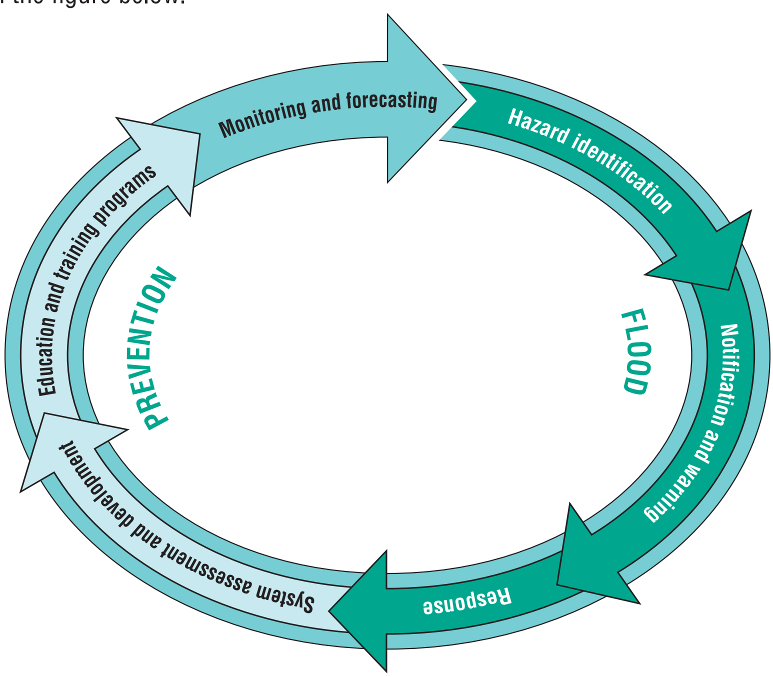


Fig. 2. *Diagram of flood warning system*

Below, we signal the most important problems which need to be solved, concerning individual elements of the local flood warning system.

Monitoring and meteorological/hydrological forecasts

Analysis of needs in the area of monitoring as well as meteorological and hydrological forecasting requires knowledge of the causes of flooding in a given area, as well as knowledge of the areas at risk. Knowledge of the causes of flooding (precipitation, elevated river water levels caused by precipitation in the upper portion of the catchment area, ice jams, melting, wind-driven waves) permits us to determine what meteorological and hydrological elements should be the focus of our interest; on the other hand, linking information about causes of flooding with knowledge of which areas are at risk, defines the area for which we should consider monitoring and forecasting of weather phenomena and river water levels. The needs established in this manner should now be compared with the existing measurement network and possibilities for obtaining forecasting information. For both of these elements, a basic source of information—but not always the only one—is the state hydrological and meteorological system (PSHM).

In deciding to create a local monitoring system, we will have to consider whether to build an autonomous system, which will fulfill local needs independently; or on the other hand, merely supplement the existing, nationwide monitoring network, in those places where it does not meet our needs. We also have to make a decision as to whether measurement and data transmission are to take place automatically, or whether we will rely on human observers; and then, whether we will conduct observations year-round, seasonally, or perhaps only if precipitation occurs, or if threshold water levels are exceeded.

The issues are similar in the case of forecasting information. If what is available has turned out to be insufficient, we must consider the possibility of supplementing it. It is worthwhile to begin with a consultation with IMGW. In deciding on independent exploitation of forecasting tools, we must take into account the staffing capabilities which will permit us to ensure the essential service for the chosen tool. We must also remember that building forecasting tools requires measurement data to enable their calibration and verification; thus, normally, it will be possible to include them in system exploitation only after a longer period of functioning, thus, in subsequent stages of building the system.

A common frustration among operators of flood warning systems is the difficulty in evolving from a data collection and monitoring system to one that saves lives and property from flood threat.
[Flood Control District of Maricopa County, 1997]

Assessment of a potential hazard

Measurement and forecasting of precipitation or water levels does not provide direct information about who/what is at risk, and where. We obtain such information only by interpreting measurement and forecasting information, taking into account knowledge about the formation and development of the area in question. We can take this knowledge from the past (historic floods), or else we can rely on flood-wave simulations. It is important for the information to be compiled in an orderly manner, and for it to be constantly updated. Only then can it represent support for decision-makers, assisting them on an ongoing basis in assessing flood hazards and making decisions about warning.

Appropriately-processed historical experiences or scenario analysis data, based on similarity in the hydro-meteorological situation, permit us to draw conclusions about flood damage—and in particular, identify inhabitants potentially at risk. A simple example could be determination of a measurement station water level at which, on the basis of experience from the past, the danger of an evacuation route being cut off appears. Analysis of potential flood damage can also be carried out on an ongoing basis—directly before or during a flood. However, this requires advanced modeling tools (among others, GIS), which is not always possible or feasible.

Analysis of potential flood damage is to bear fruit in taking actions at the appropriate moment to limit risk. Among these actions is, first of all, dissemination of information about the possible danger.

Warning dissemination

Effective warning is a multi-stage process. It should be precisely defined, known to recipients and agreed-upon with them previously. We can divide warning recipients according to functional, geographic and many other criteria (e.g. language, independence). In many cases, the simplest division—services/forces and inhabitants—could be too general. The proper division of those at risk is therefore the first problem faced by entities responsible for warning. The second represents determination of warning stages. Aside from the initial 'awakening' of crisis intervention forces, it would be good to take into consideration at least two warning phases, i.e. flood watch—a notification that there is possible danger of flooding, which should result in a state of preparedness; and flood warning—a notification that flooding is inevitable, meaning that warning recipients should now take concrete action. After the danger has passed, it is worthwhile to announce a return to normal conditions.

We must not take the content of the warning message lightly. It should be understandable and contain a description of the current situation, a forecast of its development, and suggested actions to take. The means of disseminating the message should ensure that warnings reach recipients in a timely and reliable manner. Inhabitants should also be provided with access to a source of additional information about the current situation. In choosing means of warning dissemination, we should also take into account whether they enable us to receive confirmation that the message reached the recipient.

Response

Two-way communication between transmitters and recipients of warnings makes it possible to keep track of and, if need be, influence the response of services/forces and inhabitants to warnings. However, for a proper response from recipients, what is most essential are the prophylactic and preparatory actions taken before the hazard situation occurs.

The local flood warning system must be adapted to the crisis response system in a given area; thus, it is important to take the warning system into account when preparing a crisis response plan. Inhabitants must know how their local flood warning system works, what they can expect from it and when. It is also important that they trust local authorities and crisis intervention forces.

Proper warning response depends not only on the credibility of the warning source, but also on the recipient's awareness level. This, however, requires constant informational and educational activity during periods between floods. The aim of education is to achieve an appropriate level of knowledge on the part of inhabitants, in the area of actions which must be taken to minimize risk to life and health, as well as mitigate individual losses. Simultaneously, we must conduct systematic training programs for services and forces.

Procedures for assessing the system and its development

A local flood warning system, like any other system, should be subjected to periodic assessment on the basis of experiences from everyday exploitation, surveys of warning recipients and operational testing of the system. Particularly essential is analysis and assessment of its operation in a situation where hazards occurred. Beyond this, constant development of the system should be adopted as a rule—in the sense both of improvement and modernization of tools, and of constant upgrading of personnel qualifications.

KNOWING ABOUT AN IMPENDING HAZARD SITUATION

Availability of information about the existing and forecasted situation is basic for diagnosing the danger of a flood event. We build monitoring networks and forecasting systems in order to predict a hazard situation more precisely and with greater advance notice.

Hydrological and meteorological monitoring

Nationwide measurement network

Monitoring of meteorological and hydrological elements on a nationwide scale is provided by the National Hydrological and Meteorological Service (PSHM) conducted by the Institute of Meteorology and Water Management (IMGW), which exploits a nationwide network of land-based stations measuring, among other things, amount of atmospheric precipitation, water levels, temperatures, velocity and direction of wind, as well as other meteorological and hydrological parameters. Aside from land-based observation, IMGW's measurement network includes **teledetection** measurements based on a system of meteorological

Teledetection—observation and measurements of the properties of structures such as clouds, with the aid of measurement tools which are not in direct contact with these structures.

radar devices, as well as on a system for detection and localization of lightning discharges. It permits us to, among other things, keep ongoing track of the movement of clouds (precipitation cells), determine their water content, localize lightning discharges and observe storm movement. Beyond this, the Institute utilizes measurement data from international exchange, as well as satellite images. The density of the nationwide measurement network is not sufficient to protect all areas potentially at risk; however, in solving local needs in the area of monitoring, we should always take into account measurement information available at IMGW.

At the same time, it is also worth remembering that the PSHM measurement network is not the only available source of measurements. Current measurement point information, though on a much smaller scale, can also be found, for example, at the Regional Water Management Boards. Utilization of such single points for meteorological and hydrological measurement is possible on the condition that the information from them is available in real time, and that it is possible to compare it to data from National Hydrological and Meteorological Service or a local measurement network.

Local measurement networks

In analyzing needs at the local level, we must start with areas (places) at risk for flooding, and answer the question of whether the diagnosed scope of available measurement information will be sufficient for us. The answer to this question is not simple, and requires analysis of causes of flooding in the areas in question, as well as consideration of the possibilities for obtaining forecasting information. Thus, it is worthwhile to utilize specialist assistance. For example, an area located in a small catchment area, with a short reaction time, will require ongoing information about amounts of precipitation (and even better, forecasts thereof) in that particular place; while an area adjacent to a large river, at risk in case of its overflow, can be warned successfully on the basis of observations from river gauges located upstream, providing enough advance notice for forecasting and warning before an incoming flood wave.

To summarize, based on analysis of causes of flooding in the area in question, as well as localization of hazard areas, we establish the places in which we want to know current and forecasted amounts of precipitation, water levels etc. Next, we compare existing measurement points with local needs. If the analysis shows that existing measurement points do not fulfill our needs, we consider supplementing the existing measurement network, or building a separate local monitoring network.

MEASUREMENT STATIONS

One of the possibilities for providing ourselves with additional measurement information is **supplementation of the nationwide network** with local stations operating to the PSHM standard, i.e. based on sensors compatible with these standards, and operating in continuous mode. In choosing this solution, we should conclude an agreement with the institution which exploits the nationwide monitoring network. This contact would be for the purpose of establishing the possibility of collaboration, as well as the technical conditions that need to be fulfilled. The solutions utilized by the nationwide service are high-class: very reliable and at a high technological level, but also relatively expensive. Additional stations operating for local needs could be, after settlement of financial conditions, serviced by IMGW. This would give the creators of the local flood warning system additional benefits in the form of solving exploitation problems associated with data transmission and maintenance of devices, especially in the situation at hand in Poland, with an underdeveloped market of firms involved in building and maintenance of local flood warning systems.

If we decide on an **autonomous local network**, we ourselves can choose the type and operational mode of the measurement devices. We can also build an automated measurement network. Measurement devices can operate, instead of year-round, only during the flood season; and additionally, we can choose so-called **event sensors**. This solution will reduce exploitation costs, but—on account of overlapping transmissions from individual sensors—can be less reliable in critical situations.

In deciding to build our own local network, we can also utilize data from the nationwide network. Let us remember, however, that if we want to utilize measurements from different networks, we must take into account possible difficulties with compatibility of observations coming from sensors with different parameters.

The above examples are not an exhaustive list of all possible solutions (Appendix 1). We must remember that automatization of measurements is not always necessary or economically justifiable; thus, in considering building our own stations, we must also consider traditional stations where readings are taken by a human being. An example of such an independent local monitoring network, in which we have both automatic stations and stations serviced by an observer, is the solution utilized in Żywiec County, in the upper reaches of the Soła River. Similarly, the city of Kraków, relying on IMGW measurements and forecasts concerning hazards from the Vistula River, has installed traditional staff river gauges on small tributaries to the Vistula, which in case of a hazard situation are read by city watch officers.

Event sensor—a measurement sensor transmitting observations only when the measured value, e.g. precipitation or water level, exceeds or changes by a given value.

DATA COLLECTION

Monitoring systems are not only measurement devices, but also solutions providing data transmission to the system's dispatch centers. Here as well, we can choose various solutions (Appendix 1). An example could be a private dedicated radio network. The completely automated monitoring system in Kłodzko County, as well as part of IMGW's nationwide system, operates in this manner; but in many cases, it can suffice for data to be transmitted by an observer (via telephone or radio). In the latter case, we can relay on the Volunteer Fire Brigade, city watch or police. We can also attempt to recruit people among the local community who are interested in collaborating with the local flood warning system, and create a team of volunteers to provide service of the measurement network. Such solutions are used elsewhere in the world. There are also examples of their utilization in Poland. The municipal system in Nowa Ruda, Kłodzko County, operates in this manner, transmitting data via SMS. Other solutions: utilization of the public telephone network, measurement data transmission based on GSM cellular telephone technology (an example is the Świdnica County system) or **GPRS** (used by IMGW). The cellular telephone network has, however, one essential flaw—in a crisis situation, when many subscribers begin to use it simultaneously, it can stop working properly, which will block or impede the work of the data collection system.

GPRS (General Packet Radio Service) is a packet-based service of data transmission in radio networks, e.g. GSM. The theoretical maximum speed of a GPRS connection is 170 kbit/s (in reality it is considerably lower), and the fee paid depends on the amount of data transmitted.

ARCHIVING OF MEASUREMENT DATA

Data from the monitoring system are utilized on an ongoing basis to assess the situation and prepare warnings of hazard situations. Depending on the technological solution chosen, a warning that a value considered dangerous has been exceeded can be sent by the measurement device itself, or by software at the dispatch center which compiles data from sensors. The role of measurement data does not end there, however. It is worth emphasizing this, because a monitoring system is often thought to be identical with a flood warning system. We must remember that monitoring is only the first link in a chain of actions with the aim of inducing an appropriate response from inhabitants, as well as services and forces, to a warning delivered in a reliable and timely manner. It is necessary to constantly combat the myth which says that monitoring systems prevent the occurrence of dangerous phenomena. In reality, they only support the warning and forecasting system as a whole.

It is also necessary to ensure proper archiving procedures, remembering that this is associated with the costs of compiling and maintaining the database. These data should serve the purpose of analyzing and inspecting monitoring system operation (e.g. detection of systematic errors in sensors), or of building and verifying forecasting tools to enable us to extend the amount of advance notice with which we are in a position to diagnose a hazard. Their value increases when we have at our disposal data from lengthier periods of continuous measurement. Data from event sensors can be of lesser value. After all, it is possible to imagine an event-driven system which is mobilized after occurrence of a precipitation value of 5 mm/h; but without archiving the precipitation value, we will not have at our disposal either important information about the beginnings of the precipitation, before occurrence of the threshold value, or data about the precipitation in its declining phase.

ERRORS AND PROBLEMS

In building a local measurement network, it is not difficult to make errors which could in effect raise the costs of the investment, or reduce the effectiveness of the planned solution. Examples of technical errors include:

- Wrong choice of measurement devices comprising the monitoring system;
- Failure to conduct initial measurements of radio wave propagation at the stage of preparing the concept for a radio network for measurement data transmission;
- Failure to figure out beforehand the legal and technical possibilities for installing the projected measurement stations;
- Redundancy of the local monitoring network and existing observation/measurement networks, or building of an ‘excessive’ network, where the priority is a large number of stations, not proper processing of data gathered.

Rating curve—dependency relationship between water level and flow volume in a particular river cross section, shown in graph form.

We must remember that in the case of sensors measuring water level in a stream or river, there is no simple transition from water level to water volume flowing through a given measurement cross-section. Such a dependency relationship, a so-called **rating curve**, while possible to plot in theory, requires verification with the aid of hydrometric measurements; this, in turn, is very time-consuming, and implies a large financial investment.

There are many more such conditions, and for this reason, already at the stage of preparing the concept for the local flood warning system, it is a good idea to consult with a professional with practical experience.

Meteorological and hydrological forecasting

Forecasting information from the nationwide system

On a nationwide scale, forecasting and provision of warnings about dangerous atmospheric phenomena—including floods, high winds which could cause a coastal flood wave, or a sudden rise in temperature which could cause melting—this all, like monitoring, is the task of IMGW.

IMGW's traditional products are forecasts and warnings written in simple, direct language, containing a description of the current situation, as well as a forecast of its development, and normally supplemented with the anticipated numerical range of the forecasted values (precipitation, temperature, water levels). The forecast, as well as the forecasted values, normally concern a large area. More detailed forecasts, e.g. ones of hydrological character, predicting water levels in a specific place, are prepared for a limited number of cross sections. Besides the above-mentioned products, also prepared are **numerical weather forecasts**, providing forecast information (concerning, among other things, temperature, precipitation, velocity and direction of wind) for the entire area of the country, with resolution to 10–20 km, 2–3 days in advance. Beyond this, based on the above forecast data, as well as data from the rain gauge network, radar information, data from the lightning discharge detection and localization system, and others, ultra-short term precipitation forecasts are prepared with resolution to a few kilometers (in a matrix of 'cells' measuring 4x4 km each), 6 hours in advance. These products are partly for general distribution on web pages (www.imgw.pl), partly for the use of IMGW employees. We can assume that not too long from now, on the basis of these products, it will be possible for IMGW to prepare specialized forecasts for smaller areas.

Numerical weather forecast—forecast of meteorological elements (air pressure, precipitation, temperature, velocity and direction of wind, etc.), calculated on the basis of an atmospheric model. These calculations are performed on supercomputers, at network nodes for the Earth's surface, as well as for higher levels of the atmosphere.

This does not mean that the amount of detail in forecasts offered by PSHM is or will be enough for all areas potentially at risk, especially since the possibilities described above concern meteorological forecasts. However, for local crisis intervention forces, in many cases what is key is the hydrological forecast, i.e. the water level forecast. Before we begin to think about independent forecasting, however, we must check what our possibilities are for access to forecasting information. And in the case of independent forecasting as well, it is recommended to collaborate with PSHM in building forecasting tools. After all, the local hydrological forecast will even so be based on a meteorological forecast coming from this system. Collaboration of crisis intervention forces with PSHM should be associated with participation in training programs showing the capabilities and limitations of forecasting products, as well as the capabilities and limitations of the teledetection systems which have provided the basis for the creation of the products mentioned.

Local forecasting models

Models with varying degrees of complexity are utilized successfully by IMGW for larger rivers. Unfortunately, smaller streams, especially those not possessing a sufficient quantity of PSHM measurement stations or lengthy time periods of continuous measurement data, cannot count on such a forecast from the nationwide system. In case of necessity, thus, one must solve this problem on one's own. Assuming that the quantitative precipitation forecast will remain the domain of PSHM, local forecasting models should answer the question 'What water level will be caused by the precipitation forecasted by PSHM in places key for local crisis intervention forces?' In other words, they should forecast river water levels in selected cross-sections on the basis of forecasted precipitation and water levels in cross-sections located upstream. Thus, such a model describes the transformation of precipitation into runoff, and then its motion in the river. An example of such a solution is the forecasting tool based on the HEC-1 model [1], which IMGW and the Kłodzko county government have attempted to implement jointly in the Kłodzko Valley.

If the main threat is a sudden large volume of surface runoff from precipitation, what is most important is to assess what precipitation in given conditions we can consider to be dangerous to a local community. The amount of precipitation considered dangerous depends on elements which are constant or change slowly over time, e.g. the contour of the catchment area, ground cover or soil type; but also on how precipitation was distributed in the period preceding the situation in question. This type of simple dependency relationships, based on graphs or tables, are used by the American meteorological service (tables of the relationship between precipitation, ground moisture and river water level). For an area adjacent to a large river, at risk in case of overflow, we need information rather about the movement of water in the river upstream from this area—here, we are speaking of the results from hydraulic modeling. One simple solution is the so-called stage-stage relation, i.e.—in the simplest case—the relation of water levels at two measurement points on the same river. However, we must be aware that first of all, the scope of applicability for simple methods is limited; and secondly, the precision of such a forecast is not as good.

Do we need a local model—and if so, what kind?

The National Hydrological and Meteorological Service is a basic forecast source for the local flood warning system. The possible decision to build one's own forecasting tools at the local level will result from analysis of needs concerning the amount of advance notice with which the warning must be prepared, but also from a realistic assessment of the possibilities for exploitation of the forecast model by local services and forces, who normally do not have among their personnel specialists in the area of meteorology and hydrology. No doubt for this reason, more often chosen are simpler solutions, not requiring larger amounts of knowledge for their operation, and solutions whose preparation can be entrusted to specialists from outside local services and forces. We should also remember that forecast **model calibration** requires observation time periods that include flood waves, and we will not have such data available in the initial exploitation phase of the local measurement network.

Model calibration—designation of values for model parameters on the basis of physical analysis of the hydrological system and/or optimization methods for the purpose of obtaining the best compatibility between observation data and data generated by the model.

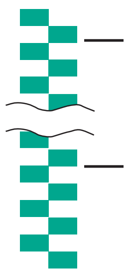
[1] A free precipitation-runoff model prepared by the U.S. Army Corps of Engineers.

How to assess a potential hazard?

Collection of essential information about persons and property at risk

THRESHOLD VALUES

We will know when and whom to warn only once we know what the damages from potential floods of varying magnitude could be. One way which permits these damages to be foreseen operationally, is to determine precipitation or flow values which present a danger in specific places or areas. These threshold values can then be utilized in making decisions about warning. The advantage of this solution is its simplicity; but in order to predict the hazard with appropriate advance notice, we should have access to precipitation and water level forecasts for the places in which we have designated these threshold values. If we do not have such possibilities, then we must take action relying on experience from the past. We can, for example, designate appropriately lower precipitation or flow values, and assign to them the moment to take preventive action (disseminate flood watch notices, etc.), in this way obtaining the time necessary to respond. The figure below shows how this way of thinking was utilized to prepare for a flood at the beginning of the 20th century in Kraków (order of the chief of the Fire Brigade in Kraków, published after the flood in 1903).



When river gauge reads +4.4, must evacuate inhabitants of ul. Retoryka: water has reached level of 1.4 m

When river gauge reads +2.6, must evacuate inhabitants of basement apartments located on ul. Garncarska (even numbers), ul. Felicjanek, ul. Skawińska up to number 10–13

Linking hazards to specific precipitation and water level values in known places is a method which has been utilized for a long time and, one can say, a typical one for flood response plans. A similar solution is quantification of hazards (i.e. division into classes) in the form of scenarios based on historic or calculated maps of flood hazard areas. Such scenarios would then be utilized in case of a hazard situation to compare the current situation with the scenario, as well as to draw conclusions about possible damage from the approaching flood. The level of precision of such analyses (as, furthermore, in the case of threshold values) will depend on the degree of generalization of hazard information assigned to individual scenarios.

FLOOD MAPS

In Poland, maps with extents of inundation are created for larger rivers by the Regional Water Management Boards (RZGW) as part of the realization of their statutory requirement to designate so-called direct flood hazard areas[1]. This means that

[1] cf. Water Law statute

in certain cases, we will be able to utilize ready-made materials. If there are no such maps for our area, we must find out if some institution doesn't plan to execute them, or perhaps we can commission the preparation of such materials. A sensible solution for smaller rivers/streams could be to, independently or in collaboration with outside specialists, designate historic extents of inundation, making use of help from the local community in so doing. Such actions can be taken on the condition that a large-scale flood has taken place relatively recently, and people still remember well the extent of the event.

A certain difficulty in utilizing the ready-made flood maps prepared by RZGW, for local flood warning system purposes, could be too high a level of generalization. The main aim of RZGW's designation of flood risk areas is to influence spatial planning. For the needs of long-term investment activity management, we can utilize a hazard classification standardized on a nationwide scale (e.g. we can adopt extents of inundation prepared for floods whose probability of occurrence is 1%). Operational activities at the local level require greater individualization. Maps for ongoing flood response purposes should be associated rather with local critical points or areas, and not with a specific probability of occurrence of a flood event. These will be essentially scenarios of potential hazards illustrating, for example, the potential damage from an embankment failure in places most at risk, or from inundation of a road.

UTILIZATION OF GIS

Flood risk maps can take the form of a digital database in which information is compiled concerning potential extents of inundation, together with information about development of the area. Data in this form, supplemented with tools enabling their analysis—in particular, studies of spatial relationships among structures to be found in the database—are known as a 'geographical information system' (**GIS**). The advantage of such a solution is that digital maps prepared between floods can be utilized both right before, and during a flood. GIS provides the possibility of obtaining fast answers to the questions of who and what is at risk in changing variants of flood surface area. It could also be that in our area, no analysis of potential extent of inundation has been carried out, but we have available a GIS database with information about the area's development. Then we just have to supplement the database with variants for extent of inundation. We encounter such a situation more often in urbanized areas; the natural place to address questions regarding such information are the geodetic services.

GIS (Geographical Information System)—a system comprised of computer equipment, software, geographical data, personnel and procedures, intended for effective collection, compilation, updating, processing, analysis and visualization of geographically-referenced information.

Utilization of knowledge about potential damage from a forecasted flood to warn those at risk

INTERPRETATION OF FORECASTING INFORMATION

So, how do we utilize operationally the knowledge compiled about flood risk in our area? An ideal situation might look as follows: on the basis of a river water level forecast, and having available a GIS database concerning the development and surface features of the land, we make calculations of the potential extent of inundation;

and then, automatically as well, we determine who and what is at risk. This requires a combination of meteorological, hydrological and hydraulic modeling with spatial analysis. Such solutions can be encountered elsewhere in the world, and one example of a local community in which such a solution has been applied is Fort Collins, Colorado, a city located in the Rocky Mountain foothills.

Considerably more often, however, local crisis intervention forces will be in a situation where both possibilities for flood forecasting and knowledge about the risk area are more limited. In this situation, it is worthwhile to utilize a tried-and-true solution based on threshold values for water level or precipitation, or for increases in those values. These can concern measured or forecasted values. When we are relying on measured values, we must take into account a margin of safety which gives us time to respond. In the second case, we establish the amount of advance notice time, with which we warn of the danger of exceeding the threshold value. To the threshold values, we assign groups of persons and institutions which should be notified of the hazard situation; and in this manner, we have a defined rule of the simplest type for launching the warning process.

THE PROBLEM OF FORECAST UNCERTAINTY

Knowledge of potential hazards associated with forecasted precipitation or water levels does not solve the decision-making problems of persons responsible for the operation of local warning systems. In practice, on account of uncertainty about the future, decision-makers are faced with a dilemma whether to warn considerably earlier, risking an unnecessary operation, or to wait, risking too-late notification about the danger. Elsewhere in the world, they attempt to help solve this problem by adding a measure of uncertainty to the forecasts presented. The problem is, however, complex. One solution is to carry out 'what if' analyses which show decision-makers the consequences of an error in forecasting (this is enabled by the analytical and forecasting tools built for the Kłodzko Valley). Analyses of this type can be carried out during periods between floods, thereby exercising specialists' intuition. One can also carry them out during a hazard situation, if time permits. However, this requires the existence of a local model to forecast water levels based on the amount of precipitation.

WHOM TO WARN ABOUT WHAT —AND HOW?

It is essential to start by finding out the user needs of those at risk and also of the different organisations who will be involved in translating the forecast into a warning and then in disseminating the warning.

[Green *et al.* 2000]

The answer to the question posed in the title is only superficially obvious, for each part of this question represents a problem unto itself. The groups we must warn need to include those who are involved with the safety of persons, those who are involved with local infrastructure (roads, telecommunications, power supply), as well as those at risk and requiring help. All of the groups (each of which is comprised of several sub-groups) need information, but each one expects information of a different type. All groups obviously want to know if there will be a flood, but crisis intervention forces want, above all, to know the precipitation and river water level forecast; inhabitants are more interested in whether the river will flood their home, and how much water there will be; tourists at a campground, on the other hand, want to know where they can safely evacuate, and how much time they have. The problem also arises as to how to provide each group with a warning and additional information to facilitate taking action. The shop owner located in the hazard zone does not always live nearby, so that it would be difficult to look for him at the shop, for example, at night (so that you have to know his home address and telephone). Tourists on official campgrounds can be reached via the campground owners, but that still leaves vacationers putting up tents 'in the wild'. Another problem are homeless people, people who sleep in garden arbors in the summer, and others. For each one, however, we need to find the proper way to reach them with the information.

Warning recipients and their information needs

An important element of a warning system are lists of people at risk, including names and addresses, as well as all kinds of information to enable contact, thus: land-based and cellular telephone, as well as pager numbers, etc. In the case of owners of firms, or administrators of structures, it is necessary to obtain numbers at which they are available outside of normal work hours. After all, many of them do not live in the hazard zone.

We can distinguish several groups of warning recipients, who have different needs with regard to the time which will permit them to make an effective response, the information they expect, and the means of transmitting the warning.

Below we discuss the basic groups of warning recipients. In practice, entities comprising the individual groups will be different in different places, depending on the character of the local community.

Crisis intervention forces

Among these forces are crisis response teams, the police, State Fire Brigade, Volunteer Fire Brigade, health, epidemiological and veterinary services. Their aim is to ensure safety for inhabitants of flood hazard areas. In a hazard situation, they represent a source of help for the remaining groups at risk, and the efficiency with which the rescue action is carried out depends on them. These groups expect, above all, an early forecast of the approaching hazard, and quite detailed information about the possible progression of the situation over time.

Institutions responsible for infrastructure

This group encompasses institutions responsible for key elements of infrastructure: power, gas and telecommunications utilities, water supply companies, and road services. The entities comprising the group require early information about the potential hazard, because the effectiveness of both crisis intervention forces' and inhabitants' actions depends on their activity in this phase. Earlier warning of telecommunications institutions permits switchboards and switching boxes to be secured, and connection failure to be avoided or delayed. Beyond this, it makes it possible to analyze and assess when flooding of certain segments of road, power or gas failure, or breakdown of other elements of infrastructure could take place.

Public institutions, producers

This group includes offices of public institutions, public utility structures, production plants, service provider firms, and warehouses, as well as farmers. In the case of production plants, it is essential to have enough time to secure machines and products, and even to transport them to a safe place. Offices need time to secure or evacuate documents; museums and libraries must transport their collections to a safe place; and farmers, for example, need to evacuate their livestock. This entire group needs mainly information concerning the extent of inundation, the depth and time of the inundation, or—in the case of firms and institutions—the time at which power will be turned off.

Structures causing secondary flood hazards

Among these are sewage treatment plants, waste disposal sites, chemical plants and storage facilities, fuel stations, and storage facilities for fuel, pharmaceuticals, etc. If structures of this type are flooded, an additional hazard and greater losses are possible. Thus, it is necessary to inform their owners/administrators early about the possibility of a flood occurring, so that they will be able to secure the structures and mitigate the negative effect on the environment and on people.

Inhabitants

Among these are persons permanently resident in hazard areas. For members of this group, early warning is important so that they can prepare for the flood: evacuate their family, animals and property, as well as secure whatever must remain in the hazard area. It is essential to have information about older persons, those having mobility problems, those with small children—thus, those who require special help. Inhabitants expect, above all, information about the current and forecasted situation, possibilities for obtaining help (sand and bags, equipment, food, medications), evacuation routes and points (for people, equipment and animals), as well as location of first-aid points.

Volunteers included in the warning system

The warning dissemination system at the municipal level may be based on direct notification, e.g. by village administrators, fire brigade personnel, police, or city watch officers, but also by pre-selected and trained volunteers (flood wardens). This group needs detailed information, from crisis intervention forces, concerning the hazard—among other things, its time of occurrence and forecasted magnitude, as well as areas at risk.

Institutions, firms, persons requiring special assistance during a flood

Figuring among this group are such institutions as hospitals, nursing homes, schools, hotels and guest houses, as well as animal asylums and hospitals. This is a group which, in a flood hazard situation, should be provided with special support, because its members are not able to carry out evacuation independently.

It is necessary to guarantee them special assistance, means of transport, and sometimes special equipment—for example, in the case of nursing home residents, provision of special stretchers for transportation; and in the case of an animal asylum, provision of cages.

Tourists, homeless persons

These are people either who are living in a given area temporarily (tourists) and do not know either the area or the local character of the flood; or for whom it is difficult to identify where they are staying (homeless persons). Because of this, in the local system, we need to take into account a way of identifying places where these people may be staying, as well as a means of contacting them. An additional problem could be the fact that foreign tourists do not know the Polish language. It is also important that the message be understandable for this group. A message with the content: *The anticipated extent of inundation will be the same as in [year]*—is sufficiently clear for the local community, but for tourists, it will be completely unclear.

Media

Among these are: local radio, television, press, Internet services. The media need constant contact with crisis intervention forces for purposes of obtaining and transmitting information about the current and forecasted hazard, progression of the flood, damage and losses, places where help can be obtained, problems e.g. flooded towns, impassable roads, etc. They are at the same time a source of support for local crisis intervention forces in the area of warning and transmission of advice on the best ways to act during the catastrophe. Their needs, beyond the standard warnings, are different from those of other groups. Representatives of the media are also interested in information about what is at risk, as well as—during the flood—losses and specific events. They also differ in terms of their needs as to the form of transmission—e.g. television stations would like the message to be presented personally before the cameras, by persons responsible for warning in a given area.

Warning content

In many cases, we have only a very short time available to prepare a warning and notify those at risk; thus, it is important to prepare a certain message template in advance. In a situation where there is a real hazard and time pressure, this will permit warnings to be drawn up in a quick and easy manner, and at the same time, limit the possibility of making errors.

The message concerning the hazard should contain the following information:

- The current and forecasted situation (it is worthwhile to compare the magnitude of the forecasted flood to that of a previous flood which inhabitants will remember);
- The expected time of occurrence (culmination) of the flood;
- Places/areas at risk for flooding;
- Information about actions which must be taken.

Research [Tunstall, Parker, 1999] shows that a decided majority of inhabitants prefer to have quite detailed information in the warning message. It is worthwhile, for example, to compare the forecasted depth of inundation to historic 'signs of the great water' or floods which people can remember: *The water will be [...] cm higher than the flood in [year]*. Also important is the language used in the warning—it should draw attention, and be pictorial, clear and concise. Technical language should be avoided.

A properly-written message must be short (it should take no longer than 45 seconds to read out loud), and contain:

- **The most important information**—warning content should encompass only the most important information, because this is conducive to recipients' focusing their attention;
- **Positive, direct vocabulary**—words used in the warning should have positive meaning, e.g. remain at home instead of do not leave your home; they should also be addressed directly to the recipient (using informal language);
- **Encouragement of neighborly help and involvement**—the information should encourage an attitude of community solidarity, e.g. by advising the recipient to help his/her neighbor if needed.

If people learn or suspect that they are not receiving the "whole truth," they are likely to ignore instructions about how to respond, and instead respond in ways consistent with their suspicions.
[Mileti, 1995]

Multi-stage warning

In defining a warning system, it is assumed that inhabitants should be warned early enough to be able to take care of their own safety and protection of property. However, as we know from experience, crisis intervention forces are afraid to inform inhabitants too early of a potential hazard. The reason is a fear that if the information about the hazard turns out to be incorrect, the forces will lose credibility in the eyes of inhabitants, who will not want to respond to subsequent warnings—even in a real hazard situation. This problem should be solved by a system of multi-stage warning. The aim of such a system is to transmit warnings dependent on the magnitude of the hazard, to individual recipients—both crisis intervention forces and inhabitants at risk.

In the first stage, the operation of the system consists of 'awakening' crisis intervention forces, which are responsible for warning inhabitants. The next stage concerns notification of inhabitants, firms, institutions, etc. at risk that there is the possibility of a hazard situation occurring (i.e. **flood watch**). Warnings transmitted at this stage aim to increase the alertness of inhabitants at risk for flooding. At the third stage, when the information about the hazard is confirmed, crisis intervention forces transmit warnings to inhabitants about an inevitable flood (i.e. **flood warning**). The last stage is an 'all clear' signal.

Flood watch—threshold water level for a given river gauge profile. Attainment of this level results in crisis intervention forces' going into alert mode, i.e. preparing for possible action.

Flood warning—threshold water level for a given river gauge profile. Attainment of this level results in commencement of flood protection operations.

Below, we show an example of multi-stage notification.

Stage I: 'Awakening' of crisis intervention forces—takes place after transmission by PSHM of a warning that heavy rainfall may occur and/or that flood watch or flood warning water levels may be exceeded. Crisis intervention forces can also be 'awakened' on the basis of information from the local flood monitoring and warning system. In this case, after locally-established threshold values (e.g. amount of rainfall or water level at a given measurement point) are exceeded, crisis intervention forces receive information via SMS, pager or e-mail from the automatic monitoring system, or from the observer.

Stage II: Flood watch message—warning about the possible occurrence of a flood. At this stage, local crisis intervention forces transmit to inhabitants information about the possible or actual occurrence of weather conditions that could cause a flood. The aim of this notification is to increase inhabitants' alertness and prepare them to secure their property and to evacuate.

Sample flood watch message

Message concerning possible occurrence of a flood, issued by the Brener County governor on 12 July 2005 at 8:15 AM.

During the past few hours, in the upper reaches of the Żarnawka River, heavy rainfall has been occurring. In the next few hours, this could cause a buildup of water in the following tributaries: Miłka, Głęboka, Brenka. There is a potential threat of flooding in areas located along these rivers. The Crisis Management Center will be broadcasting messages every hour on Radio Beta and on local TV Alfa. Ongoing information will be available at tel. (012) 123 45 67.

Stage III: Flood warning message—notification of inevitable flooding, together with information about when it will occur, what its magnitude will be—thus, what areas could be at risk, and what actions must be taken.

Sample flood warning message

Flood warning issued by the mayor of Brzeziny Dolne municipality on 12 July 2005 at 11:45 AM.

The rainfall occurring in the upper reaches of the Żarnawka River over the past several hours has caused a rapid buildup of water. In a few hours, the fast-rising water will reach the following towns: Zarnka, Brzeziny Dolne, Młynkowo. The present water level is about 0.5 m lower than the level during the flood in 1998. The following areas must be evacuated as quickly as possible: Żarnka-Przylasek, Żarnka-Dąbrowa, Brzeziny Dolne-Centrum, and Młynkowo-Ruczaj; you should proceed to the evacuation points located at the elementary schools in Byszkowo and Kowal.

Depending on the progression of the situation, in some cases it is necessary to update the warning. Presentation of more detailed information and directions in reference to the area at risk and its inhabitants will increase the credibility of the warnings.

Stage IV: All-clear signal—should be given by the municipality.

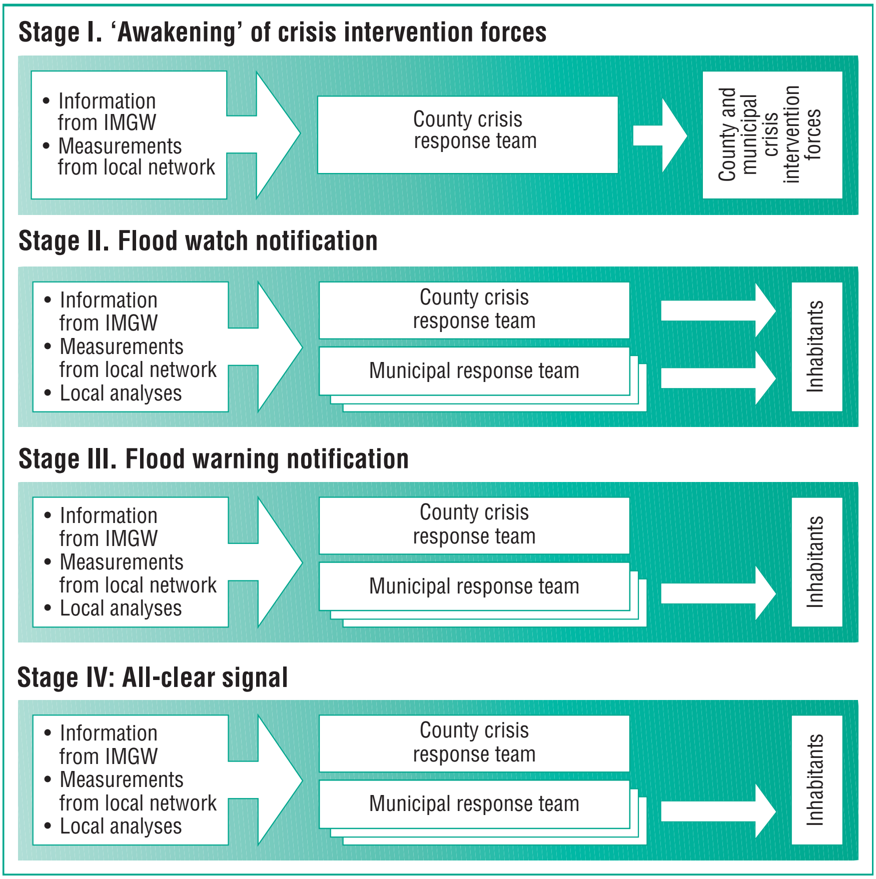


Fig. 3*. Example of multi-stage warning of inhabitants*

Warning methods

Effective warnings use a range of possible channels instead of a single channel. This helps reach as many people as possible in a short time. [Mileti, 1995]

There exist many means to inform inhabitants of a hazard. Among them are: radio communication, local radio and television stations; local services and forces, such as: police, city watch, fire brigade, etc.; permanently-installed sirens and megaphones; mobile megaphones affixed to vehicles; pagers and cellular telephones; volunteer flood wardens; automated telephone systems which disseminate information automatically via telephone, Internet, light screens/boards.

To warn inhabitants, crisis intervention forces presently most often utilize automobiles with speaker systems, telephones, and permanent sirens. Such means of notification are not always effective [OSIRIS, 2000], though—as research results show [OSIRIS, 2000], inhabitants at risk for flooding prefer them. People who were affected by flood damage in 1997 would like to be warned, above all, by alarm signals—thus, permanently-installed sirens or automobile-mounted megaphones (70%);

and then by telephone (55%). However, as local government experience shows, sirens work mainly for warning (notification) of volunteer formations (Volunteer Fire Brigade); they do not work too well, on the other hand, as a means of warning inhabitants—people often treat them as a fire alarm.

The question arises as to how to choose the means of notification which will work best in the local situation (Appendix 2). However, we need to remember that an effective system requires application of many different techniques for warning dissemination. The reasons for this are several. The first is the variety of recipient groups described above. The second reason for the necessity of using several methods of warning dissemination is the fact that after receiving a message which requires a difficult decision (evacuation of home and family), people first of all seek confirmation of that message from another information source. For the warning to be effective, we must therefore guarantee people at risk at least two sources of information.

Simultaneous utilization of several means of transmitting warnings also has its drawbacks. There is a danger that from one warning (using one technique), they may receive old information, and from another (using a different technique), new information. Thus, with each message, it is necessary to give the time and date of origin.

In choosing the means of notification, the following criteria could be helpful:

- Time in which information can reach those at risk (speed of notification);
- Possibility of transmitting a description of the situation and instructions on how to act;
- Selectivity of warning—transmitting the warning only to the group at risk for flooding;
- Ensuring that the warning reaches as large a group of those at risk as possible—regardless of the time of day, place in which they are located, and problems they might have (e.g. deaf persons);
- Reliability—effective operation regardless of conditions (e.g. ensuring operation of telecommunications connections);
- Monitoring of notification—possibility of obtaining confirmation of warning receipt, or notification reports (automated telephone notification system);
- Multi-purpose use—possibility of utilization for other purposes (e.g. to notify of other types of hazards, or to transmit information to other services/institutions).

TELEPHONE ALARM SYSTEM IN THE KŁODZKO VALLEY

The automated telephone alarm system utilized in the Kłodzko Valley, which permits a large number of people to be warned in a short time (over 800 persons/hr), has been very well-received by inhabitants. During testing carried out in 2002, a warning was transmitted to land-based and cellular telephones of inhabitants, owners of firms, and administrators of institutions. Nearly all of those surveyed (95%) who received such a warning, considered this to be a good form of notification; and for 88%, the message was understandable. A significant majority, as much as 91%, declared that they would take action on the suggestions contained in the message. This undertaking was understood as evidence of interest in inhabitants' lot. Since 1998, there has been no larger-scale flooding in this area, and the system has not been tested in real hazard conditions.

Notification techniques need to be adapted to the character of the flood. In the mountains, where flash floods occur and speed of information transmission is essential, different techniques should be used than in lowland areas where speed of information receipt is of secondary importance. Also essential is to pay attention to the size of the area, thus, to the number of persons to be notified (city, village), as well as the type of development (dense, sparse). For a mountain area, for a small town in which the development is as a rule sparse, an optimal solution in the area of notification could be a courier system (Volunteer Fire Brigade personnel); a citizens' system (volunteer flood wardens), or utilization of land-based and cellular telephones for notification. However, in a city, with dense development, it could be best to utilize stationary and mobile megaphones, enabling the message to reach a large number of persons living, for example, in a housing development. In such a case, one can also use an automatic telephone notification system, which will enable a large number of persons at risk to be informed in a short period of time.

Warning response

Conditions for effective warning response

For people to respond properly to a warning, several conditions must be fulfilled:

- The warning must reach those at risk with an amount of advance notice permitting them to take action to mitigate losses (i.e. secure non-movable property, as well as evacuate family and movable property);
- warning content must be understandable;
- People must personally discern the risk;
- People must know how to respond;
- The information source must be credible.

We also know that the main factor contributing to people's proper response to flood warnings is their own experience. This is confirmed in studies conducted by IMGW in areas flooded in 1997 [Diren Centre, 2002]. They show that in 1997, only 18% of those surveyed, after receiving a warning, knew how to respond; while in subsequent years, the situation improved significantly. In 1998, as much as 69%; and in 2000, 71% of those surveyed considered that the warnings had been sufficiently precise for them to make an appropriate decision.

Confirming appropriate warning response

The fact that a warning has been transmitted, and even received by those at risk, does not mean that they will respond in accordance with crisis intervention forces' suggestions. Their responses must be confirmed.

We can distinguish several stages of confirming appropriate warning response. In the first stage, we assess whether the warning reached all persons at risk. Already at this stage, many problems can appear, because—as is shown by research conducted in the United States—only half of those at risk are able to respond. The reasons for this can vary, e.g. the fact that during transmission of the warning, half of those at risk are at work, and the warning does not reach them. A problem also appears when the flood occurs at night—people are asleep, so they may not hear the signals; they are also not watching TV. In such situations, new technologies work—cellular telephones or an automated telephone notification system, via which we can obtain feedback as to who received the message.

At the second stage, it is important to check whether people responded appropriately to the warning. In this case, the activity of volunteer flood wardens is effective; they transmit the warning and, at the same time, check how people responded to it. A neighbor system can also prove very useful—one in which each family from the hazard area is assigned, for purposes of assistance and evacuation, to a family from outside the hazard area. At this stage, we need to pay attention to actions taken by inhabitants to secure their property and evacuate themselves. Keeping track of neighbors' responses should be included in individual action plans for a hazard situation.

For inhabitants to respond appropriately to a warning, they must know what to do, as well as how to secure themselves from potential losses. Thus, it is necessary to carry out broad-based educational and informational activities.

ORGANIC WORK—INFORMATION, EDUCATION AND TRAINING PROGRAMS

The only thing that allows inhabitants to learn to live with flooding is awareness of the hazard, as well as knowledge of loss mitigation methods and proper flood response.

The effectiveness of local warning systems being built by local governments and managed by their crisis intervention forces depends on many factors; but among the most important are awareness of the hazard, as well as inhabitants' and flood plain users' knowledge of how to respond to warnings and how to prepare for a flood. Another guarantee of proper system operation is the knowledge and professionalism of local crisis intervention forces, which should not only utilize the system in a competent manner, but also understand its complexity and know the conditions that influence its effectiveness. Thus, in a natural way, education and various training programs become an important ingredient of flood warning systems.

An effective public education program posits a problem and then says how to solve it—over and over again.
[Nathe *et al.*, 1999]

However, we should be aware that flood education is difficult. Large-scale floods are rare phenomena, so not only do state and local government authorities forget about them quickly, but also those who were themselves affected. In effect, a few years after a flood, very few local governments care to finance education concerning an event which could happen tomorrow; but equally well, only 20 years from now. We also know that people are unwilling to invest in safety measures for such rare phenomena, no doubt figuring that the next flood will not happen within their lifetime.

It would also be naive to think that lessons concerning flood issues will be systematically carried out in schools; that regular training programs will be carried out for adults; and that these issues will interest the media year-round. Rather, we must assume a necessity for local authorities to continuously initiate and stimulate this type of activities.

All of this means that education is a serious challenge for local governments which want to build an effective flood warning system. Especially since, appearances notwithstanding, education is not at all cheap.

In subsequent sub-chapters, we will present hints for how to deal with this problem—how to realize flood education and training programs so that they will help inhabitants to attain appropriate knowledge and acquire the needed skills.

Information is not everything

We know from experience that the most often-used form of knowledge improvement for inhabitants of flood hazard areas is to give lectures or send out brochures—i.e. transmit information. The question arises, however: is this enough? Specialists in the social sciences say it is too little. Even the best, most widely-distributed information will not suffice for flood plain area inhabitants and users to take preventive action, or respond properly to warnings and follow the directions of crisis intervention forces. This state of affairs is made worse by the flood preparation and response philosophy in force in Poland, for it assumes 'citizen passivity'—as evidenced by the lack of any kind of elements in flood response plans to stimulate their activity, whether in the area of prevention, or of flood response. Flood plain inhabitants and users are treated in response plans rather as objects which must be evacuated during a dangerous situation, than as active parties who, with support from services and forces, should be able to deal with the situation themselves. So it is no wonder that inhabitants are passive [IPS PAN, IMGW, 1999], that they still expect help, but do not want to and most often do not themselves undertake any action—either before or during a flood.

The literature shows clearly that the higher the individual interprets the risk to be, the more likely that individual is to evacuate. [Green *et al.*, 2000]

The problem of 'breaking through' passivity and mobilizing people to action appears to be one of the more important tasks of education. It is important for inhabitants to understand that their fate is in their own hands. Crisis intervention forces can only support those at risk by, among other things, giving advice, propagating preventive action, and sending out warnings early enough so that each one can take action to reduce risk to life, health and property.

The best evidence that other behaviors than the ones presently manifested are possible, is the inhabitants' activity in areas where floods take place often. Taught by previous experience, people know how to secure themselves from flood damage, and how to mitigate losses. On the ground floors of their homes, there is no parquet flooring—only ceramic tiling; there are no underground garages, and the furniture on the lower floors is easy to evacuate. We can observe this in many villages and small towns affected by flooding in recent years.

UŚCIE SOLNE. CITIZEN RESPONSE SYSTEM

In Uście Solne, a small town at the mouth of the Raba River, the organization of actions to mitigate flood damage is done by the inhabitants with the assistance of the local Volunteer Fire Brigade unit. All the men participate in work associated with flood response: some patrol the status of embankments on bicycles; others observe river water levels; yet others prepare sand bags and transport them. For actions of longer duration, a shift system is provided for. During breaks, evacuation points for animals and people are prepared, remembering neighbors who require help. If there is an embankment failure, then the leader of the action, equipped with a radiotelephone, notifies inhabitants with sound signals (bells, sirens—hand-operated as well) and light signals (flares).

How to organize education and training programs

What do we need to know?

For inhabitants to be able to prepare properly for a flood, they must possess basic knowledge in this area. In transmitting this knowledge, we must remember, above all, to explain to its recipients in a clear manner three key matters: what losses they can incur, what the danger is that these losses will take place in a given time frame, as well as in what manner they can mitigate losses.

Description of potential losses. If inhabitants have not themselves experienced a flood, they have a difficult time imagining the effect of a flood on their town, home, workplace. In order to overcome people's tendency to conclude that a flood will not happen to them, we must precisely explain its possible consequences.

Definition of the chance (probability) of a flood event. The moment people understand that a flood can affect them personally, they should also understand that it can happen to them at any moment—for example, in the next ten years.

Explanation of how to mitigate losses. When people have accepted the fact that they are at risk for flooding, they should quickly receive advice and guidelines as to how they can mitigate losses on their own, and who can help them do this. Otherwise, they will be discouraged from taking any action at all, on the assumption that nothing can be done.

This is, in the shortest possible outline form, the scope of essential knowledge without which there can be no talk of appropriate action being taken by inhabitants at risk.

Recipients of education and trainng programs

The choice of content and forms of education depends on, among other things, whom we want to educate. In this case, we can take into account several different criteria for dividing the local community into recipient groups.

Needs in the area of knowledge. In this context, we often speak of so-called target groups, i.e. groups of people with similar needs in the area of knowledge and information. A certain indicator of what local groups we should take into account could be the classification presented in the previous chapter. To recall, it includes crisis intervention forces and community services (roads, power), production and service firms, and public institutions, as well as inhabitants. Each of these groups can have somewhat different needs associated with preparation of structures for a flood event, and securing of property during the event itself. These needs should be determined, and education and training programs prepared accordingly.

Potential effect. Organized groups of citizens and flood plain users can play an essential role in promoting knowledge concerning floods and damage mitigation methods for local communities. With their aid, we can also attempt to break through the passivity of individual inhabitants. Particular allies will be NGOs which work for the local community and its safety (Volunteer Fire Brigade, village housewives' circles, housing development and village councils, residential cooperatives and unions, local music or dance ensembles, etc.) Including them in the education system could, on the one hand, facilitate reaching inhabitants; and on the other, enhance the credibility of our actions.

Ease of reaching recipients. It is quite easy to organize training programs or simple forms of education for institutions and production or service firms. Via the leadership of these entities, we can transmit specific information and knowledge at organized meetings with firm employees. However, we should view non-organized inhabitants or farmers completely differently. Reaching them can prove difficult, especially since interest in floods drops greatly if they occur infrequently, and few will take part in meetings devoted to these issues. One of the easier means of reaching this group, a very effective one, is education conducted in schools, which also allows us to activate adults (parents).

Forms of education

On account of the aforementioned peculiar character of flood education, it is necessary to choose very carefully the methods by which we want to transmit knowledge to various groups. We can use techniques which involve inhabitants and other entities actively in the education process (direct techniques), as well as techniques which are only a form for disseminating information and making this knowledge available (indirect techniques).

Individual consulting. Consulting is an effective form of education—it can be organized in the homes of inhabitants at risk, or for all inhabitants of a given town, at a selected time and place. This is a fairly popular method of education, used in the USA, Canada and Australia.

Workshop training programs. The aim of these is to transmit practical knowledge in the form of short lectures and exercises in the area of individual preparation of one's family (firm) for a flood, securing of a structure, warning response and flood recovery. These programs will be most successful at schools or institutions interested in improving flood safety.

Shows and tours. These are normally organized for schools or organizations by crisis intervention forces on the occasion of local events (anniversary of flood, or some kind of celebration). These can be field trips whose aim is to show a monitoring station, the crisis intervention center, existing safety measures for buildings, etc.

Creation of plans and programs. This is the most effective form of education, which consists of including representatives of the local community in creation of flood damage mitigation plans and programs in a given area. A good idea is to, for example, induce residential unions to prepare an evacuation plan for their housing development.

Another form of knowledge transmission are indirect actions, which consist mainly of making information available about the flood hazard, loss mitigation methods, the local warning system and best modes of behavior before, during and after a flood. Among these are:

- Preparation and popularization of flyers, informational brochures, handbooks and other publications (flood maps, posters);
- Organization of exhibitions and lectures taking up various subjects associated with the flood phenomenon: flood history within a village or municipality, methods of floodproofing buildings, operation of various systems whose aim is flood damage mitigation;
- Collaboration with local media for the purpose of disseminating information which, according to local forces and services, must reach inhabitants.

Educational activities should also serve to build inhabitants' trust in local crisis intervention forces, as well as promote activity in the area of flood damage mitigation.

Sample solutions

Flood education for adults should be realized via exchange of experiences and presentation of good examples. Adults learn by confronting new information with what they already know, by thinking through and trying out their own ideas, or by practicing. Normally, they are more willing to take the advice of a friend or neighbor than to follow directions given by local authorities. The best thing to do in this situation is to propagate local solutions utilized in practice by inhabitants, as well as enable them to become acquainted with good examples from other regions at risk for flooding.

Below are discussed several selected forms for education and information of flood plain inhabitants and users. These are methods used successfully in practice.

EXTENT OF INUNDATION

The basic information, which should reach all persons at risk for flooding, tells who is at risk and in what measure. It can be disseminated among inhabitants in different forms, for example, flyers and instructions containing a flood plain map, or designation of extents of inundation in the area with 'signs of the great water', or provision of warnings for drivers. This is particularly essential in an area where flash floods occur. We must also remember about tourists—guest houses, hotels and private accommodations should have this information available for them.

***Fig. 4** Flash flood warning sign (Colorado, USA)*

***Fig. 5** Memorial tablet for the flood of 1998 (Polanica Zdrój, Poland), reading: 'This is the point reached by floodwaters during the night of 22/23 July 1998.'*

KAMIENIEC ZąBKOWICKI. FLOOD ZONES

In the town of Kamieniec Ząbkowicki, after the flood in 1997, three flood hazard zones were designated and indicated on homes with colored tablets. Inhabitants of the red zone, which is flooded every three years on the average, must be prepared to evacuate quickly, and know that authorities will not grant permits to build homes in this area. In the second (orange) zone, where a hazard situation occurs every 10 years on the average, it is necessary to utilize waterproof building materials and special construction solutions. The third (blue) zone is an area which is flooded only during the so-called 1000-year flood. Beyond this, information about the extent of the individual zones is given on four information boards, set up at the busiest points of the city.

THE LOCAL FLOOD DAMAGE MITIGATION SYSTEM

Each inhabitant should know the local flood response system. We can describe and propagate it in the form of a flood instruction brochure containing basic information about: the warning system, its rules of operation, warning methods and signals, actions to take after receiving a warning, evacuation routes and points, useful telephone numbers and addresses, the scope of aid available, as well as institutions providing it, etc. Such brochures have been prepared in Poland by many municipalities: Kłodzko, Racibórz, Kędzierzyn-Koźle and others. Instructions can also be posted in the stairwells of residential buildings, as well as institutions. Effective means of disseminating them are periodicals and city or municipal government web pages.

RACIBÓRZ. INFORMATION BROCHURE

In Racibórz after the flood in 1997, a flood instruction brochure was prepared in three different versions: for apartment-house residents, owners of single-family homes, and farmers. Ground-floor apartment owners received additional flood protection packets containing a first-aid kit, flood instruction brochure, candle and matches. The packets were distributed to inhabitants by secondary-school students, who had previously taken part in a special educational program. The entire action was assisted by the mass media.

A very effective way of educating inhabitants is to include them, for example, in the process of preparing flood damage mitigation plans (including planning and building of a warning system).

FLOOD-PROOFING BUILDINGS

Flood-proofing structures and property after receiving a warning is an effective method of mitigating individual losses. However, it requires prior preparation of appropriate safety measures. The subject matter for educational activities could concern, among other things: means of sealing a building (raising thresholds, use of special coverings for windows and doors during a flood, mounting of sewer backflow valves, etc.), means of flood-proofing the interior of a building to which water is being 'admitted' in a case where the anticipated depth of inundation presents a threat to its construction (transfer of valuables to higher floors, use of waterproof building materials), etc. Informing interested persons about methods of flood-proofing buildings can be effected via organization of expert consultation (e.g. on the occasion of festivals and events associated with the anniversary of a flood), collaboration with construction trade schools, a series of articles in the press, propagation of good examples, etc.

UTILIZING THE INTERNET

Completely new possibilities for disseminating information and knowledge are created by the Internet. Previously, there was no special service in Poland devoted to flood issues; now there is the 'Great Water' Portal (www.powodz.info) administrated by IMGW. Not only does it represent a source of knowledge, but it also enables experiences to be exchanged. Portal users can share them by publishing articles, commenting on posted texts, or exchanging views in the discussion forum. The portal also contains much information about non-structural methods of flood loss mitigation.

Units of local government administration which have in recent years built a water level and precipitation monitoring system, often provide Internet access to the data from this system. This applies to two of the largest local monitoring systems in Poland, built by Żywiec and Kłodzko Counties.

THIS IS YOUR STATION—PROTECT IT!

One serious problem in the exploitation of both IMGW's large monitoring system and local warning systems are thefts and vandalism to measurement stations. They are normally installed in places far from developed areas; thus, they remain unprotected. Thefts of station elements are basically senseless, because the refined electronic equipment installed there is of no use for any other purpose. Only the often-used solar panels could be attractive for fishermen and campers. IMGW estimates that the scale of the theft and vandalism phenomenon is large—it affects about 10% of stations annually.

Thus, it is essential to conduct broad-based informational and educational action for all inhabitants to make them aware that this is infrastructure that serves their comfort and safety. All should take part in such educational action: from schools, to the church hierarchy.

Proposed educational activities for schools

It is obvious that flood education should begin already in the schools. It is best for it to be an element of general education, forming a so-called 'safety culture' in the community. However, for the moment, this subject matter has not been introduced on a broad scale into curricula; thus, it is realized in schools only where teachers or supervisory authorities at school consider the flood phenomenon to be a serious problem. Thus, knowledge sources, a trained teaching staff, and educational materials are lacking. Presently, schools conduct lessons concerning flood issues, using programs of their own authorship. They may also utilize the publication *How to Cope with a Flood* [IMGW, 2003]—complex didactic materials for teachers, containing: basic information of use to inhabitants of flood-prone areas (how to prepare one's family for a flood, how to secure oneself from losses, what to do after hearing a warning, what to do upon returning home right after a flood), as well as scripts for lessons and workshops, knowledge tests and proposed flood topics to be realized as part of various academic subjects.

Generally, the subject matter of lessons concerning the flood phenomenon should enable students to recognize its various aspects (such as: the character of the phenomenon, the hazard it causes, protection methods, effect on persons and the environment, etc.), as well as acquire skills which will help them to deal with this hazard in the future (it should be indicated that school is an important place where children are provided with psychological help after a flood).

The subject matter should be linked to simple mottoes, such as:

- Flooding is inevitable;
- One cannot secure oneself from a flood, only mitigate the damage;
- All of us can do something to mitigate our losses;
- Local authorities are there to help us (but not to do everything for us).

Education in schools also has one more important advantage—via the children, one can also influence adults (parents). One of the more interesting and effective forms of this type of education is a competition with a special formula which assumes collaboration of local government with the schools (e.g. information collected by students about historic flood events, or examples of individual securing of buildings used by inhabitants). This type of competition is conducive to integrating the local community, parents, firms, organizations and institutions engaged by students in the performance of the competition tasks. A program for such a competition has been tested by IMGW many times in practice (Appendix 3).

'LET'S REMEMBER THE FLOOD' COMPETITION

A competition with this title has been organized annually since 2000 by the Kłodzko County Government. In its first edition, 11 schools took part. In some schools, they were successful in introducing flood issues to the curriculum, as well as engaging parents, who helped gather materials, made photographs available, gave interviews. Information was also given by crisis intervention forces—often in the form of informal talks at school. It is estimated that exhibitions organized by schools to present competition work (among other things, photographs and flood memoirs) were visited by about 10000 people; information about the exhibitions was published in local newspapers and on web pages. On students' initiative, two flood tablets were placed on buildings; city authorities and a private construction firm were engaged in the making of the tablets.

How to ensure continuity of education?

In a situation where local governments lack money and appropriate staff to execute tasks associated with education and information, the matter of ensuring the continuity of these activities during periods between floods (when people forget about the hazard) becomes a non-trivial one. Here, an essential role could be played by institutions which are involved in education in a given area by reason of their statutory purpose, as well as by community organizations (associations, village homemakers' circles, senior citizens' clubs, housing development residents' councils, etc.) We also must not take lightly the role of individual people (leaders). Finding and motivating such people can sometimes be key to a successful education campaign. They could all combine forces to create a Flood Education Forum, whose task would be to prepare an action program and divide up roles for its participants. The tasks of local government would consist of initiating the forum's activity, stimulation and promotion of the joint actions worked out by the forum, as well as assisting in preparation of informational and educational materials.

FLOOD EDUCATION FORUM

A Flood Education Forum was created in Kłodzko County. It was comprised of, among others: the County Staff Training Center, the Kłodzko Education Society, the County Family Aid Center, municipal crisis intervention forces, the media, the Polish Red Cross, social service centers, Caritas, St. Albert's Aid Society, the Polish Scouts' Union, the Adventure Academy, parishes, schools, etc. An action program for the Forum was prepared. It is based on forms of training (lessons in schools, workshops and seminars for adults, etc.), as well as non-training activities, such as: informational and instructional publications, radio and television programs, exhibitions, festivals and contests, subject-related competitions for individual user groups, a touring crisis education park called Water World, informational signs, press articles and web pages, as well as a touring Blue Book with information about losses incurred as a result of natural disasters in individual regions of the County.

Training programs for crisis intervention forces

A separate problem are training programs for crisis intervention forces. New trends in flood damage mitigation are not universally known. Only recently has this subject matter been introduced into training programs organized by the Ministry of the Environment and the National Center for the Coordination of Population Rescue and Protection, as well as some voivodship and county government offices.

The scope of training programs concerning the flood phenomenon, intended for crisis intervention forces, should be much broader than it has been up until now. Above all, we cannot limit ourselves only to flood response. Among the new elements which should be found in the program for such training, we need to mention, among others:

- Non-structural methods of flood damage mitigation;
- Meteorological and hydrological forecasting, as well as forecast uncertainty;
- Decision-making in conditions of uncertainty;
- Human behavior in crisis situations and psychological help;
- Flood education.

IMGW experience in realization of training programs for representatives of municipal and county crisis response teams, as confirmed by a survey conducted among participants, shows that as a form of training, they prefer workshops and are interested in exchange of experiences (including also experiences with building and exploitation of local flood warning systems).

PERFECTING THE SYSTEM—OUR AIM

The local flood warning system is an element of a changing reality, and should develop taking into account changes in our surroundings. A critical assessment of the operation of individual elements of the system should aim to find solutions which will improve its operation, not guilty parties who are responsible for any imperfections it may have.

A local flood warning system requires periodic assessment of its operation and effectiveness. The aim here is to ensure that the system functions in accordance with the assumptions made in building it, as well as that it continues ongoing development and improvement. System inspections should be conducted after every flood, or when changes occur in the environmental or organizational conditions of the catchment area. A regular assessment should also be performed for the purpose of reminding interested parties of their roles in the warning system and enabling them to propose changes. A good opportunity to conduct an assessment of the local flood warning system could be the periodic tests of its operation. System assessment should be complex and apply to all of its elements, both technical and non-technical. It also cannot be limited to an internal evaluation by institutions responsible for the operation of the local flood warning system, but must take into account the opinion of inhabitants, businesspersons, the media and other interested parties.

Learning from our mistakes

As soon as possible after each flood wave, analysis of system operation during the flood should be conducted. Its aim is to identify weak points and determine possible improvements to be made in the operation of the local flood warning system. Assessment of the correctness of forecasts and an inspection of the hydrological and meteorological monitoring system can allow forecasting models to be recalibrated, and the measurement network to be improved. They also create an opportunity to verify the precision of our predictions concerning hazards associated with specific water levels. We also need to check whether our warning messages reached the interested parties in time, and whether they

The views of community members are essential to improving warning systems, and people should be actively encouraged to put forward their opinions on system performance and ways to improve it. [Emergency Management Australia, 1999] were understandable to them; and finally, whether they were effective, i.e. whether those warned responded properly. All of these analyses should answer the question 'Why did the element being assessed work the way it did?' as well as 'Can we improve its operation, and if so, how?'.

Responding to changing conditions in the catchment area

Retention reservoirs, embankments or other structural measures built on rivers and streams covered by a local flood warning system or above change the degree of the flood hazard. A similar situation can occur when there are changes in the catchment area's land utilization. Also, changes in development of risk areas result in a necessity to take the new situation into account in warning procedures. Because of this, institutions responsible for operation and development of the local flood warning system must keep track of these changes and assess their consequences for the system.

Taking account of organizational and technological changes

All organizational changes—from the simplest, such as changed telephone numbers or headquarters of institutions, to changes in competency areas and liquidation of structures, or establishment of new organizational units—all should be noticed and taken into account in the warning system.

New technologies, on the one hand, yield new opportunities to obtain, process or provide information to recipients; on the other, technological progress means that previously-known, but up until now elite solutions become universal and cheap. The local flood warning system cannot remain indifferent to this process, and periodic inspections and assessments should permit rational selection of the moment to change technological solutions.

What else is worth remembering?

Conducting reasonably frequent inspections of local flood warning system operation permits weak points to be eliminated and changes occurring in the system's surroundings to be taken into account.

The system should be assessed both at the general level, oriented toward the operation of the system as a whole; and at the operational level, concentrating on the operation of individual institutions engaged in its functioning.

The dangers which should be avoided are: falling into a routine and treating periodic assessment of the system as a 'necessary evil', or identifying system assessment with assessment of the institutions responsible for its operation. Such an approach eliminates a critical assessment and impedes creation of innovative solutions to improve the operation of the local flood warning system.

fot. A. Iwańczuk / REPORTER

COLLABORATION IS A CONDITION OF SUCCESS

A pervasive institutional myth is that in a flood nobody will do anything until they are told what to do and then they will do what they are told. A flood warning system should not be based on this illusion.

[Green *et al.*, 2000]

INSTITUTIONS SUPPORTING LOCAL FLOOD WARNING SYSTEMS

Development of a flood warning system in an area must involve conscious incorporation of the community and a number of agencies. The system is, by definition, multi-faceted and its components must all operate effectively if sound flood warning performance is to be achieved.

[Emergency Management Australia, 1999].

There are various institutions and organizations whose collaboration is a condition for success in building as well as exploiting a flood warning system. In Poland, these are: the Institute of Meteorology and Water Management (IMGW), the Regional Water Management Boards (RZGW), the voivodship government administration, all levels of local government administration, the mass media, and NGOs.

Institute of Meteorology and Water Management (IMGW)—a research and development entity supervised by the Minister of the Environment. In accordance with the regulations of the Water Law statute, provides hydrological and meteorological services. IMGW is responsible for protecting the country from extreme natural phenomena, including, among other things, disseminating messages and warnings about these phenomena to crisis response teams at the national and voivodship level. In the past year, testing has begun on a similar collaboration with the county level and with selected municipalities.

- *Activities between floods*: assists in design and building of local flood warning systems, education and training programs.
- *Activities during a flood*: provides early warnings to crisis response forces and supports their work by systematically delivering hydrological and meteorological forecasts.

Regional Water Management Boards (RZGW)—catchment-area institutions whose competency area includes assessment and analysis of the flood situation in large- and medium-size rivers, as well as management of the retention reservoirs under their administration. Recently, within their structure, flood protection coordination and information centers (OKI) were founded whose task is to undertake operations, mainly of preventive character, with the aim of mitigating flood damage.

- *Activities between floods*: Engage in flood damage mitigation planning, designate flood plain zones, provide training programs and education.
- *Activities during a flood*: (In the future) will assist local government in analyzing flood damage (extent of inundation).

Voivodship crisis response teams—entities responsible for preparing plans and coordinating operations in the area of response during crises (including floods) at the voivodship level.

- *Activities between floods*: Provide verification of crisis response plans prepared by local government administration, carry out drills to test system effectiveness, organize training programs for local government units, collaborate in design of local warning systems.
- *Activities during a flood*: Assess the flood situation within the voivodship, disseminate IMGW messages and warnings to county and municipal teams.

County crisis response teams and municipal response teams—counterpart of voivodship teams at the county and municipal levels. Their competency area encompasses preparation of plans and coordination of response operations during crises (including floods) at the local level.

- *Activities between floods*: Prepare for building or expansion of local warning systems, participate in training programs organized at the voivodship level, or organize their own training programs for crisis intervention forces, stimulate flood education.
- *Activities during a flood*: Analyze the local flood situation, make decisions about warning or notification of inhabitants, confirm warning response, etc.

Mass media—Press, radio and television stations are interested in varying aspects of a flood event, depending on whether they are local, regional or nationwide media. In the case of local government actions, it is best to maintain contact with local media.

- *Activities between floods*: Assist in educational activities by promoting knowledge about the hazard, as well as about ways of preparing oneself for a flood and responding to a hazard situation.
- *Activities during a flood*: Inform and warn inhabitants of the impending flood, transmit advice on how to act during the flood and what to do after it is over.

NGOs—These are a very varied group, for they encompass both professional associations and charitable organizations, as well as many others. Some of them can play a very substantial role during various phases of a flood.

- *Activities between floods*: Assist in building of local warning systems, provide education for children and adults, as well as consulting services.
- *Activities during a flood*: Assist in warning and confirmation of warning response, engage in flood recovery and humanitarian activities.

All of the institutions described above have important functions to fulfill in the system as a whole, although a certain impediment to defining their roles is the fact that the scope of their activities and responsibilities in the area of flood issues is subject to constant change and not yet clearly designated. IMGW runs the nationwide network for monitoring and forecasts being prepared for larger areas, as well as realizing early warning of crisis response services. Thus, in many cases, it will be a fundamental source of measurement and forecasting information for the local flood warning systems. For several years, IMGW has been promoting local flood warning systems, participating in their building, as well as conducting educational and training activities. Local government administration, especially at the county level, can become the inspiration for the building of local systems by promoting collaboration of municipalities located within the same catchment area. Central and voivodship government administration should, on the other hand, support the idea of building local flood warning systems, especially in the area of financial assistance and training. In the future, the coordination and information centers (OKI) at RZGW are to play an important role in flood damage mitigation planning, as well as in operational activities. NGOs will be useful as a partner in education and consulting, but they can also organize volunteers to help with warning. The mass media will always be an important partner during all phases of flood damage mitigation.

In planning to build a flood warning system, it is worthwhile to think about which of these institutions can be our main partners during the individual phases of flood management, at the same time remembering that collaboration must be based more on agreement than on legal obligation.

EXAMPLES OF INSTITUTIONAL COLLABORATION

Collaboration agreement in the area of data exchange and development of the flood monitoring system for Żywiec, signed between the Żywiec County Government and IMGW Kraków (a similar agreement was signed by IMGW with the Kłodzko County Government).

Agreement in the area of educational and flood warning activities, signed between the Racibórz City Hall and local broadcaster Radio Vanessa.

Agreement in the matter of preparing a flood damage mitigation plan for the village of Gorzanów (including warning), signed by the municipality of Bystrzyca Kłodzka, the Kłodzko County Government, RZGW Wrocław, and IMGW Wrocław.

INHABITANTS CAN ALSO HELP

Potential advantages of developing flood warning systems with the involvement of local people are that this will ensure that warning messages are understandable and appropriate and that dissemination methods meet the needs of local people.

[Green *et al.*, 2000]

Benefits of inhabitant participation in building the system

If we have assumed that the aim of a warning system is to create such conditions for flood plain inhabitants and users as will enable them to take effective care of their life, health and property during a flood, then it is difficult to imagine planning and building the system without their input—all the more so that their absence from the planning process could adversely affect the quality and effectiveness of these systems in the future.

Information from inhabitants can improve the quality of decisions made in the process of planning the warning system. In particular, this concerns:

- Information about the causes of flooding and its progression in hazard areas. Often, the cause of inundation in a given area is not at all overflowing of river banks, but too-small culverts, neglected drainage ditches, etc.;

- Information about ‘safe’ places useful in organizing evacuation points for people, animals and property. An example could be the town of Uście Solne, invaded by floods many times, where for years, inhabitants have been moving their livestock out to the same place during hazard situations.;

- Information about locally-active informal systems of information transmission in crisis situations, which can, and even should be included in the flood warning system. An example could be a town in the Kłodzko Valley, in which a telephone system for transmission of information ‘from house to house’ is in operation, taking into account even weak points in the chain such as quarreling families.;

- Information about persons or families requiring help during a hazard situation—this concerns people who are older, disabled, etc.

Representatives of inhabitants could also help in preparing some elements of the warning system, and improve the quality of warning response. We can consider organizing:

- A network of volunteers who observe river staff gauges or devices to measure rainfall, and then deliver this information to the crisis intervention center (an example could be the local system designed in Nowa Ruda, based on such observations and transmission of information via cellular telephone network);

- A network of neighborly notification which would represent a second source of information about the risk to inhabitants and would supplement the formal notification system (such systems operate in England and Australia);

- Various types of neighborly help (in one town in Brzesko County which is often invaded by floods, each family living in a flood hazard area has an assigned caretaker—another family which helps them to evacuate in a hazard situation).

Additionally, including inhabitants in the planning process has enormous educational value—it is a much more effective way of improving people’s knowledge and awareness than, for example, a lecture or flyer.

To sum up: it can be said that community involvement is an element essential enough that in the final balance, it can decide the success or failure of the entire undertaking.

Community involvement—how to do it?

It is difficult to give a universal set of instructions telling how to organize community involvement well. After all, it depends on local needs and the specific character of the place in which we are undertaking such activities. However, we can rely on a sequence of several standard activities described below, treating them as basic.

Founding a warning system building and exploitation committee. The committee should include not only representatives of investors and the administrator, but above all, representatives of those groups which will be using the system (county and municipal services/forces, etc.), and those to which it is addressed (inhabitants, owners of such structures as shops, wholesalers, etc.) It would be a decision-making organ, but above all, a platform for exchanging views among people who look at the same problem from different viewpoints.

Gathering information about needs of entities at risk, utilizing various techniques, e.g. surveys distributed by village administrators, or interviews conducted by municipal government employees. The aim of gathering this information is to identify areas at risk; the degree of risk; the time essential to evacuate people, animals and movable property; the most effective ways of transmitting warnings, etc.

Conducting meetings to identify local problems with the participation of flood plain inhabitants and users at risk. These should be organized in the initial phase, after preparation of the results from the studies described above. In the meeting program, we need to include provision of initial information about the plans of the investor (local government), presentation of data gathered, as well as discussion concerning their correctness and credibility. The meetings should enable inhabitants to express their real needs and present their preferred solutions, as well as any doubts they may have concerning the warning system.

Conducting meetings concerning the system concept with participation of flood plain inhabitants and users at risk. These are meetings organized with the aim of discussing and then evaluating variants of the concept for building the system, including warning of inhabitants and support of their response, as well as organization of informational and educational campaigns.

Information campaign concerning the warning system. Completion of building should be associated with a broad-based information campaign concerning solutions adopted (rules of system operation), addressed to inhabitants and users at risk. A campaign is most effective when it uses all available means of communication: brochures, flyers, local press, radio and television. To disseminate knowledge about the system, we should also utilize routine meetings, for example of municipal and county councils, as well as meetings with NGOs.

The community factor should also support the system in the exploitation phase. Besides periodic assessments of its effectiveness, undertaken by the building and exploitation committee, we can contact all interested parties in many other ways. We can, for example, meet with firms at risk, aiming to verify their needs as well as remind them of the hazard and actions which would need to be taken. Beyond this, we can also conduct campaigns of educational character, realized in conjunction with local media, village administrators, NGOs and schools.

Expected difficulties

A proposal to modernize an existing warning system or build a new system will not necessarily encounter a positive reception on the part of inhabitants or local government authorities. The reasons can be many. Inhabitants can understand the information coming from local authorities—which can read more or less as follows: *Taking care of life, health and property depends on you. We can, in building a warning system, only help with that*—as an attempt to dump the responsibility for safety on inhabitants. Local authorities, on the other hand, can be afraid to build a local warning system, because this represents an obligation to warn everyone at risk—on top of that, early enough for each one to be able to take effective action. In view of the above, we should think about how to ensure ourselves the favor of inhabitants (and consequently, their local government representatives) for the project to build a warning system.

The social sciences involved in implementation suggest that a local community's readiness to implement changes is influenced by several factors:

- Extent of dissatisfaction with the existing state of affairs;
- Precision in describing the aims of the system (awareness of what we want to achieve);
- Experience associated with previous efforts in a similar direction;
- Costs of implementing changes—in the form of financial investments, but also of associated emotions, energy expended, etc.

To put it most simply—if dissatisfaction with the existing situation is great (there was a recent flood), the aim of the system is precise and clear, and in addition, local government has already taken actions which were received well by inhabitants, then the local community can conclude that the benefits of building such a system will be greater than its costs. Then it will no doubt approve its building.

This is, of course, only a simplification; but it does draw attention to the elements that can influence people's feelings, and consequently, their willingness or lack thereof to become involved in implementing the idea. Thus, it is worthwhile, in undertaking attempts to involve local communities, to provide for certain mechanisms which will:

- Facilitate personal acceptance of the system and identification with its aims, by: making people aware of the scale of dissatisfaction (presentation of survey results), showing positive experiences, and proving that the actions being undertaken serve inhabitants' safety—and not, for example, the political goals of a few people;

- Enable local communities to freely present their fears and real anxieties, as well as freely criticize ideas and solutions—both during building and later, during exploitation of the system.

Such organization of work, however, requires great openness on the part of local government with respect to inhabitants, patience during the system design phase, and hiring of experts who will help carry through the entire process.

MASS MEDIA ARE OUR ALLIES

We should not demand that journalists accept our point of view. We have to understand their needs and prepare information which meets those needs.

A very important supporting role in informing the population of hazards is played by the mass media. The law in effect in Poland says that in a hazard situation, the media—at the request of a person responsible for human safety—are required to provide informational and warning messages immediately and free of charge [Law on Natural Disaster Status, 2002]. At the same time, we know that outside of a crisis situation, the media can also play an essential role, mainly in the area of education and promotion of proper preventive behaviors.

Effect of media on the community

Local and national broadcast media are an increasingly important and credible means of flood warning dissemination. Therefore, the establishing of a good understanding between forecasting and warning agencies and the national and local media is important.
[Green *et al.*, 2000]

The media transmit information, opinions and assessments. On account of their speed of action and their enormous numbers of recipients, they represent a force which cannot be taken lightly; thus, they are often called the 'fourth branch of government'. They are a difficult and demanding partner. They can provide a check on centers of authority. Journalists are perceived by many as independent, and they often enjoy great authority. The majority of recipients treat the media as a credible source of information, and they are willing to repeat opinions and assessments published by the media. Thus, it is worthwhile to be in good contact with them.

A condition for good collaboration with the media is communicative openness: frequent and rapid transmission of information formulated in an unambiguous, simple and exhaustive manner. Then the media will not have to independently seek information, or make choices of what to use from the large pool of often mistaken information available. This will prevent situations in which the media present information of little significance from the standpoint of crisis intervention forces, and pass over or treat lightly key information. The best effects come from collaboration with one journalist personally known to us, who has already specialized in flood issues. At the moment of a hazard situation, we will be able to just turn to him/her.

Previous practice shows that concluding agreements, especially with local radio or television broadcasters, is a very good solution. An example is the city of Racibórz, where during the flood in 1997, a representative of the local radio participated on an ongoing basis in the work of the flood protection committee.

How can the media help?

There are many areas associated with flood issues in which the media can be useful. Below, we give a few examples illustrating the role of the media, the first of which concerns Bangladesh; and the rest, Poland.

Transmission of warnings. In 1970, in southwest Bangladesh, a tropical cyclone swallowed up 300 000 victims. Fifteen years later, in a similar cataclysm, far fewer people died—10 000. The chiefs of their crisis intervention forces explained: *This time, warnings got to people, and they were much better prepared to respond.* The early warning system utilized, among other means, radio stations, which broadcast messages announcing the coming cyclone.

Informing about various events. Both in 1997 and in 2001, local flood protection committees utilized the media to correct misinformed gossip and pacify frightened inhabitants. Radio broadcasters explained that there had been no break in the dam on the Dunajec River in Czchów or in the embankments on the Vistula River. In 2001 in Gdańsk, on the other hand, a lack of reliable information was the cause of panic—no information was transmitted to the media concerning the disinfection of the city, and inhabitants mistook military rescue officers for NATO soldiers who were about to close off their district of the city.

Propagation of the idea of building a local system. The municipality of Brzesko, in preparing a local flood warning plan, made sure to include a plan for informing inhabitants. It assumed, among other things, collaboration with media popular in the area. In the regional daily newspapers (*Dziennik Polski* and *Gazeta Krakowska*) and electronic media (Radio Kraków and TV Kraków), materials about flood hazards occurring in the municipality appeared. The local *Brzeski Magazyn Informacyjny*, as well as Tarnów's Radio Plus, conducted a series of conversations with specialists who explained the need to build a local warning system.

Maintaining memory of the flood. In 1999, local newspapers published in Rzeszów devoted a lot of space to the flood of the previous year. Many publications described the conclusions which local governments drew from this catastrophe, and presented the experiences of affected families. The Rzeszów supplement to the *Gazeta Wyborcza* published a series of articles on the salvaging of the historic buildings of Sandomierz's Old City and castle hill, which had suffered during the flood.

Education, propagation of desirable behaviors. The aforementioned collaborative operation with the media in the municipality of Brzesko also brought an additional effect—during five years of the local flood warning system's existence, there were no acts of vandalism. The community was informed on an ongoing basis about work on the system and the benefits resulting from its existence. When the operation was discontinued, on three occasions there were thefts of solar batteries and accumulators from measurement stations.

Collaboration in organizing aid for flood victims. The scale of aid for affected persons which can be organized by the media is huge. After the flood in 1997, many trucks with gifts arrived thanks to appeals from journalists. But the division of gifts is a very delicate matter and requires close collaboration of the media with organizations involved professionally in humanitarian aid, as well as with local authorities.

Understanding the media

The examples presented earlier show that depending on the aim we want to achieve, we should choose the appropriate type of media. They differ from each other in:

- Manner of reaching the recipient—voice, voice and image, text;
- Manner of preparing material—as a rule, journalists in electronic media are perceived as more superficial; and press journalists, as more thorough and precise;
- Amount of time to reach the recipient—from the radio, which can give information the fastest, to periodicals, which are characterized by a longer route to reach the recipient;
- Hours of highest level of reception—daily newspapers are as a rule morning media; television stations broadcast news programs in the afternoon and evening; and the radio, a 24-hour medium, is most often listened to in the morning;
- Area of operation—nationwide, regional, local media;
- Status—public media, commercial media.

In a crisis situation, when it is necessary to disseminate information quickly, the media that will work best are local radio and television broadcasters (including cable TV). With these, it is worthwhile to conclude an agreement of collaboration. Local media of all types can also become an ally of local governments in the idea of propagating the building of their own local flood warning system. Here, it is difficult to count on the support of nationwide media. These, on the other hand, work best in campaigns to organize aid on a larger scale. If we plan to utilize media in the area of education, it seems that every type can play an important role.

We also should not forget about the Internet. This medium operates 24 hours a day, information can be uploaded quickly, it is also less transitory than the radio. Besides, Internet portals enjoy growing popularity, and access to the network is more and more universal.

Worth remembering

- We must prepare for contacts with the media, and understand their unique character—only then will we be able to achieve benefits in collaboration with them;
- We should not demand that journalists become experts in the field we represent;
- The language we use in contacts with the media cannot contain specialized expressions. It should, on the other hand, be understandable, and the information always accurate and concrete. It is best to formulate the information in such a way that there will be no doubt as to its proper meaning;
- It is a good idea to prepare procedures for contacts with the media appropriate for a crisis situation and for a post-crisis situation, when we should remind recipients of the flood problem and ensure prevention. During a crisis, it is worthwhile to authorize one or several people to make contacts with journalists;
- In catastrophic and natural disaster situations, it is important that the media have full information. When they do not receive it from official sources, they will look for data on their own. This poses a danger of incomplete, distorted information being transmitted to public opinion, which could cause undesirable results: panic, unfair assessments, etc.;
- The media also form an image of the victims which sometimes strengthens the conviction that these are people who have been hurt, are helpless, cheated, left to their own devices, at risk for destitution and psychological disturbances. This makes it more difficult for inhabitants of areas at risk for flooding to regain a feeling of being active parties in the situation and taking responsibility for their own safety. For this reason, in these situations it is worthwhile to, together with the media, promote all active attitudes, good examples of action, self-organization of local communities, as well as presenting leaders.

NO GOOD WARNINGS WITHOUT METEOROLOGICAL AND HYDROLOGICAL SERVICES

Collaboration with experts leads to better preparation to make decisions about warning.

Forecasting products for local needs

IMGW is the only institution in Poland which conducts nationwide hydrological and meteorological monitoring, gathers and interprets measurement data on an ongoing basis and in continuous mode—24 hours a day, 7 days a week, 365 days a year. IMGW also has 'exclusivity' in delivering information about approaching dangerous phenomena to crisis intervention centers and other services. For this reason, the Institute fulfills an essential function in the early warning system.

Unverified forecast—results of calculations from a digital weather forecasting model.

Verified forecast—a forecast, most often graphic, including corrections made to the model results by a synoptic meteorologist.

The meteorological forecasts essential for a local flood warning system are quantitative forecasts of precipitation and air temperature, as well as wind velocity and direction. The forecasts presently prepared at IMGW concern larger areas; thus, they do not entirely meet the needs of local warning systems. Hope is awakened, however, by the modernization of the nationwide warning system carried out in recent years, including the forecasting system, which should in a short time enable the following types of forecasts to be ordered from IMGW for specific areas:

- Ultra-short term, quantitative precipitation forecast in a grid of 4x4 km cells, utilizing data from the radar system (6-hour time horizon);
- **'Unverified' quantitative forecast** of precipitation and air temperature, with time horizon 72 hours, from a meteorological model grid with cells 14 x 14 km)
- **'Verified' quantitative forecast** of precipitation (average sum) with time horizon 24 hours, for individual catchment areas, e.g. the San River, the Nysa Kłodzka River.

Such quantitative meteorological forecasts will be particularly useful to local systems if they are subjected to further processing, utilizing even the simplest methods of hydrological forecasting, which will enable their operators to obtain forecasting information not available from IMGW (the Institute prepares hydrological forecasts for a limited number of cross-sections on larger rivers).

Assistance in building and exploitation of an LFWS

Local governments can count on IMGW experts' support in building their own warning systems. This support can be provided at many stages of building the system.

Preparation of the LFWS design

IMGW employs experts involved in forecasting (preparation of warnings) and building of hydrological and meteorological monitoring systems. They possess knowledge of a type which at this point commercial firms active on the Polish market do not have available. This knowledge can be useful in selecting local target solutions, especially in determining the types of measurement needed, and in localizing measurement stations.

Compilation of hydrological characteristics, precipitation forecast

Local systems, especially in the initial phase of exploitation, have too little of the measurement data essential for determining hydrological relations. Thus, it is necessary to supplement this data, especially in the first years of the local system's operation, with data from IMGW. Aid in preparing the aforementioned relations can be found in IMGW's expert assessment and consulting units, as well as in academic groups specializing in flood issues. One must also be aware that for early warning, precipitation forecasts will always be needed, and these cannot be prepared on the basis of data from local monitoring systems.

Exploitation and maintenance of an LFWS

There exist certain principles for the exploitation and inspection of measurement stations, as well as periodic performance of additional measurements, for example, flow or geodetic measurements. IMGW's many years of experience in using its own observation and measurement network, as well as good technical resources (among other things, the Central Measurement Apparatus Laboratory), can be a support for local systems in this area.

Propagation of knowledge

It is worthwhile to take advantage of training programs conducted by IMGW. These concern, among other things:

- General knowledge in the area of meteorology and hydrology, as well as forecasts in this area;
- Products available at IMGW, from the hydrological and meteorological observation and measurement network, the POLRAD meteorological radar system, the lightning detection and localization system, numerical meteorological models, hydrological and meteorological forecasting offices;
- Building and exploitation of local flood warning systems;
- Non-structural flood protection methods.

These training programs should help employees of municipal and county government offices to better understand and utilize the products offered by IMGW (Customer Service System) on IMGW's pages—www.imgw.pl.

A SYNOPTIC'S OPINION

It is disturbing to see the faith many employees of municipal and county government offices place in the capabilities of meteorological radar, and their lack of knowledge about its limitations, as well as about the physics of certain meteorological phenomena. Many times, in a period when there were problems with access to data from the radar station in Pastewnik, employees of the Meteorological Forecasting Office in Wrocław encountered the opinion that if this image had been available, then they would not have had to stay up all night, because checking the image of the situation in the evening would have ensured a good night's sleep. There is nothing more deceptive, because the tempo of movement of precipitation zones is often very fast, and in this case, a 200-km radar range is insufficient for forecasting over a period longer than two or three hours.

Collaboration with local governments

The Institute is open to all types of collaboration with local governments—of which there are many examples.

Since the flood in 1997, IMGW has undertaken many activities together with local governments. An example could be the joint undertaking, based on signed agreements, in the area of local warning system planning and exploitation in Kłodzko and Żywiec counties. The Institute has set up regional hydrological and meteorological stations in those voivodships where there are no regional forecasting offices. This is intended to enable closer and—most importantly—more rapid collaboration with local crisis intervention forces. While it is true that these stations do not perform independent forecasts, they are able to interpret them and make them more detailed, which will be helpful for local crisis teams.

A good step on the part of local governments will be to initiate closer contact with the nearest IMGW field station—direct collaboration with this station is invaluable. Already today, we have many positive examples in this area, for example in the field of education.

EDUCATIONAL ACTIVITY OF IMGW STATIONS

Nearly 70% of the approximately 60 stations in existence collaborate with schools at different levels, conducting classes for children and youth, enabling students at specialized secondary schools and institutions of higher learning to gain professional practice, as well as hosting field trips. Some of the stations prepare special programs, publish brochures and books, organize shows, help schools to start so-called meteorological gardens. The record-holders in this area host about 30–40 field trips per year. From 1000 to over 2000 people pass through these stations. Nineteen stations organize or take part in the organization of training programs—mainly for local government employees, crisis intervention centers, teachers and journalists from local media.

Finally, we ought to emphasize that at the end of 2004, at IMGW Kraków, a special unit called the Office for Local Government Collaboration was founded. Among its tasks is monitoring of local government needs, collaboration in the area of building LFWS, as well as organization of training programs and support for education. The employees of this team can always help in contacting other units of IMGW.

Photo K. Jurczak / IMGW

APPENDICES

Merely because technology plays a very important part in war, it does not follow that it alone can dictate the conduct of a war or lead to victory.
[Martin van Creval]

APPENDIX 1

Measurement devices for LFWS needs

MEASUREMENT DEVICES

An essential element in the building of an LFWS is the utilization of appropriate measurement devices. At the stage of preparing the concept or technical specifications, it is best to turn to specialists, consultants or firms which have practical experience associated with design, building and implementation of meteorological measurement systems. The effectiveness and reliability of the entire system, which represents an important link in a Local Flood Warning System, depends on proper choice of apparatus.

In selecting measurement apparatus, we need to take into account, among other things:

- Environmental conditions at device location (operation in both summer and winter);
- Type of river or stream (river in a plain-type area, mountain stream);
- Measurement range (as implied by estimated or anticipated magnitude of changes in measured values, e.g. stream or river water level);
- Required precision of measurement (the very precise apparatus which is used in national laboratories or systems is not required);
- Value of apparatus (which is directly related to costs of maintenance, security and insurance, as well as costs of exploitation);
- Standardization (important so that the apparatus is compatible with generally-accepted standards, because this facilitates exchange of information with other measurement systems, utilization of interchangeable devices, etc.).

In the table below, we have compiled the most frequently-encountered apparatus for the needs of hydro-meteorological measurement.

DATA TRANSMISSION TECHNOLOGIES

One of the more difficult problems in building a measurement network is delivery of measured data from measurement stations to the place where they will serve the purpose of conducting necessary analyses. In practice, many different information transmission technologies are used.

In selecting means of transmission, we need to consider, among other things:

- The existing teleinformatics infrastructure (land-based and mobile telephone systems, information and communication technology service providers in a given area);
- Physical features of terrain (possibility of building a dedicated radio network);
- Costs of maintenance and exploitation.

In the table below, we have compiled data transmission solutions commonly encountered.

Measurement Device	Application	Advantages and disadvantages
Staff river gauges	Measurement of water level in measurement cross section	Reliable measurement, but not suitable for automatic systems
Volumetric containers	In an exposed area, for measurement of precipitation	Approximate measurement of precipitation volume
Rain gauges	Measurement of precipitation volume	Suitable for automatic measurement systems, requires constant maintenance
Bubble sensor	Measurement of water level	A precise measurement device, suitable for automatic measurements, easy to install, suitable mainly for application in lowland areas, for slowly-progressing floods
Submersible pressure sensor	Measurement of water level	Used for automatic measurement in large measurement systems, requires separation of measurement signal and use of surge protectors
Ultrasonic sensor	Measurement of water level without contact	Used for automatic measurements, sensitive to changes in the environment (humidity, fog, low temperatures)
Radar sensor	Measurement of water level without contact	Used for automatic measurements, not sensitive to changes in the environment, new technology, expensive solution

Data transmission technology	Application	Advantages and disadvantages
Land-based telephone system	Voice messages, reports filed by observers	Most often-used, but unreliable, especially during a flood
Modem transmission via land-based telephone system	Remote-controlled access to measurement devices, used in automatic measurement stations	Quality and reliability dependent on operator, access to land-based telephone line necessary, costs of exploitation dependent on subscription plan used
Modem transmission via mobile telephone system	Remote-controlled access to measurement devices, used in automatic measurement stations	Quality and reliability dependent on operator, costs of exploitation dependent on operator, slow transmission
Modem transmission via permanent Internet connection	Remote-controlled access to measurement devices, used in automatic measurement stations	Fast transmission, costs of exploitation dependent on operator, need access to permanent connection and additional protection of network access
Modem transmission via GPRS network	Remote-controlled access to measurement devices, used in automatic measurement stations	No need for access to a permanent connection, high costs of exploitation, depending on operator, need additional protection of network access
Dedicated (private) radio network	Remote-controlled access to measurement devices, used in automatic measurement stations	Low costs of exploitation, high investment costs, complex procedure for obtaining formal legal permits, need to ensure continuous technical supervision.

Prepared by Zbigniew Trzeciak

APPENDIX 2

Notification techniques—Strengths and weaknesses

There exist many techniques for transmitting warnings to flood plain inhabitants and users. We can use traditional means for this purpose, such as notification by fire brigade or police personnel; but we can also utilize the latest technologies, such as mobile telephone systems. In selecting them, it is worthwhile to take into account the peculiar character of the given area—whether it is a mountain or lowland area, and whether the places where people at risk live are densely or sparsely developed, as well as how many inhabitants we will have to transmit warnings to.

At any rate, we must adapt our means of notification to local conditions.

Radio communication

- *Advantages*—reliable operation
- *Disadvantages*—limited mainly to crisis intervention forces, lack of a common frequency for individual forces (crisis response teams, police, fire brigade, ambulance service, etc.)

Local radio and television

- *Advantages*—possibility of fast delivery of information to a large group of recipients, accessibility
- *Disadvantages*—effective only at peak viewing and listening times, susceptible to power outages

Local forces and services such as police, city watch, fire brigade, etc.

- *Advantages*—high credibility level, possibility of detailed description of situation, influence on recipients' response
- *Disadvantages*—time-consuming, takes services and forces away from preparing and conducting flood protection operations

Permanently-installed sirens and megaphones

- *Advantages*—rapid notification, if sirens operate on an automatic system
- *Disadvantages*—only effective in densely-developed areas, low effectiveness because system is utilized to notify of other types of hazards

Mobile (vehicle-mounted) megaphones

- *Advantages*—possibility of fast delivery of information to a large group of recipients
- *Disadvantages*—effective mainly in densely-developed areas, takes services and forces as well as means of transport away from participation in other operations, possibility of giving only a short message, limited audibility inside buildings

Pagers and cell phones

- *Advantages*—rapid and accurately-targeted notification, possibility of informing people at any location

- *Disadvantages*—high system costs, possibility of devices being turned off (as a result of network overload), notification can only reach those who have pagers or cell phones

Volunteer fire brigade

- *Advantages*—rapid and credible warning transmission, possibility of transmitting a detailed description of situation, influence on recipients' response
- *Disadvantages*—cannot always fully rely on volunteers, necessity of conducting training programs.

Automatic telephone systems disseminating information by telephone

- *Advantages*—rapidity, possibility of notifying a large number of people in a short time (even those not at home), warnings very accurately-targeted
- *Disadvantages*—possibility of giving only a short message, can only inform people who have land-based or cellular telephones (if they are turned on), possibility of phone line breakdown.

Internet

- *Advantages*—access to information from any location, possibility of presenting magnitude of hazard in graphic form, rapid updating of information
- *Disadvantages*—small group of recipients—mainly crisis intervention forces, susceptible to power failures and breakdowns in telephone connections

Light screens/boards (installed in public places)

- *Advantages*—possibility of transmitting precise information, possibility of rapid modification
- *Disadvantages*—limited scope of effectiveness.

APPENDIX 3

Let's remember the flood competition for schools

Flood education for adults is difficult. One effective means is to educate adults via their children. The selection of such a solution also has the advantage that flood education should start as early as possible—already in primary school.

One form of education for adults via their children, tested successfully by IMGW at the Kłodzko County Government, is an interscholastic competition with a special formula which assumes that:

- The competition is initiated by local authorities, and the subject matter of the competition tasks concerns concrete flood problems presently being solved by the local government;
- It reaches as many groups of inhabitants as possible—thanks to involvement in performance of contest tasks of both children and youth on the one hand; and on the other, teachers, parents, local firms, institutions, etc.;
- Competition tasks are of practical character and possess a local dimension.

Aim of competition

The main aim of the competition is to draw inhabitants' attention to the permanent flood hazard, as well as acquaint them with the operational principles of the local protection and loss mitigation system. In crisis situations such as a flood, the effectiveness of the flood protection operation depends in large measure on collaboration of inhabitants with each other and with crisis intervention forces. Thus, the competition also has the aim of integrating the community by solving local problems together.

SAMPLE COMPETITION TASKS

The competition tasks should maintain so-called 'flood memory', making inhabitants aware of its inevitability, as well as showing ways of mitigating individual flood losses.

Task 1—Collect information about historic floods in the area where your school is located (historic documents, 'signs of the great water' (i.e. flood markers), photographs, memories of parents, grandparents, neighbors, etc.). From the collected materials, prepare a school exhibition and present it to friends, teachers, parents and invited guests.

Task 2—Describe the most beautiful or interesting structure located in your flood plain area (library, museum, residential home), together with its history. As part of the task, prepare photographs or drawings as documentation for the structure, speak with its administrators or inhabitants, and describe their experiences.

The aim of the task is to make students aware how interesting and valuable structures located in flood plains are.

Task 3—Gather ideas for how to memorialize a flood. As part of the task, propose the form and content of a flood marker (tablet, color slide on a wall, etc.), as well as its location and your reasons for choosing this location, or some other way of permanently memorializing a flood.

Task 4—Describe examples of how to secure your home from flood damage, used by your parents, neighbors or friends in areas which were recently flooded.

Task 5—Acquaint adults with the results of the competition—organize an exhibition of all competition work at school. Besides your parents, invite inhabitants, local authorities and the media.

More information concerning the *Let's remember the flood* competition can be found on the Great Water Portal (www.powodz.info).

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The Global Water Partnership (GWP), established in 1996, is an international network open to all organizations involved in water resources management: developed and developing country government institutions, agencies of the United Nations, bi- and multilateral development banks, professional associations, research institutions, nongovernmental organizations, and the private sector.

GWP was created to foster Integrated Water Resources Management (IWRM), which aims to ensure the coordinated development and management of water, land, and related resources by maximizing economic and social welfare without compromising the sustainability of vital environmental systems. GWP promotes IWRM by creating fora at global, regional, and national levels designed to support stakeholders with their practical implementation of IWRM.

Currently, the GWP network consists of fourteen regions: Caribbean, Central Africa, Central America, Central and Eastern Europe, Central Asia and Caucasus, China, Eastern Africa, Mediterranean, Pacific, South America, South Asia, Southeast Asia, Southern Africa and West Africa. The GWP Secretariat is located in Stockholm in Sweden. The mission of GWP is to "support countries in the sustainable management of their water resources."

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