Geofile Online
JANUARY 2007
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Physical Disaster Warning Systems

Warnings of natural hazards are essential as people crowd into ever more densely populated cities on sites vulnerable to floods, landslides, earthquakes and hurricanes. If large-scale death and destruction are to be reduced, it is vital that methods are found to predict and warn of such natural events. The trends in Figure 1 can be attributed in part to current approaches to disaster reduction based on preparedness schemes, which include early warning systems. These are cost-effective and practical, and play a major part alongside risk assessment and political prioritisation of long-term investment policies to reduce hazard impact. It is estimated that over 3 million lives have been saved by early warning and response systems in the last 40 years. Whilst these figures may be influenced by the type of hazard – floods have increased significantly in frequency but typically create more damage than deaths – efforts to reduce vulnerability have been responsible for the downward trend in fatalities.

Figure 1: Impacts of hazards

Years	Number of deaths (millions)	Numbers affected (billions)
1976–1985	2.7	1.0
1996–2005	0.9	2.5

Source: Centre for Research into the Epidemiology of Disasters (CRED)

Figure 2: Platform for the Promotion of Early Warning (PPEW)

RISK KNOWLEDGE (1)	WARNING SERVICE (2)
Prior knowledge of the risks faced by communities • Are the hazards and vulnerabilities well known? • What are the patterns and trends in these factors? • Are maps and data widely available?	Technical monitoring and warning service • Are the right parameters being monitored continuously? • Is there a sound scientific basis for making forecasts? • Can accurate and timely warnings be generated?
DISSEMINATION (3)	**RESPONSE CAPABILITY (4)**
Dissemination of understandable warnings to those at risk • Is there one authoritative voice using multiple communication channels? • Do the warnings reach those at risk? • Do people understand the warnings? • Do they contain relevant and useful information?	Knowledge and preparedness to act by those threatened • Do communities understand their risks? • Do they respect the warning service? • Do they know how to react? • Are plans up to date and practised?

Source: ISDR

ISDR definition of early warning

> 'The provision of timely and effective information, through identified institutions, that allows an individual exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response.'
> International Strategy for Disaster Reduction

For example, people need to choose whether to avoid a hazard by evacuating the area, or to mitigate their losses by protecting their homes and stockpiling emergency reserves. On a timescale of years, knowledge of risk allows people to make long-term preparedness plans and these measures can be part of sustainable development plans as they allow people to remain economically self-sufficient. Without warning of physical hazards, long-term investments are undermined and communities and nations remain in poverty as progress is wiped out by each event. In the past, countries with contingency response plans have focused on post-disaster emergency action, but the measure of success of early warning systems is now assessed by how well they enable people to be proactive and reduce their vulnerability ahead of a hazard threat.

History of international efforts of disaster reduction

1990 International Decade for Natural Disaster Reduction (IDNDR)
1994 Yokohama Conference, Japan – half-way review of IDNDR
1998 Early Warning Conference (EWC-I), Potsdam, Germany
2000 International Strategy for Disaster Reduction (ISDR) – continuing the work of IDNDR
2003 Second International Conference on Early Warning (EWC-II), Bonn, Germany
2005 World Conference on Disaster Reduction, Hyogo, Japan
2006 Third International Conference on Early Warning (EWC-III), Bonn, Germany

International Early Warning Programme – IEWP

The IEWP was launched at the Hyogo Conference in 2005 and is a joint attempt by many leading organisations such as UN, FAO, UNESCO and ISDR to introduce and improve early warning systems. The fact that the conference was held one month after the Indian Ocean tsunami disaster highlighted the great need for this aspect of disaster reduction. Figure 2 shows the four elements that are being developed in all early warning systems.

Risk knowledge

The spatial distribution of most hazards is well understood but it is the timing and intensity of events that scientists are still unable to predict with any degree of accuracy, although this varies depending on the particular hazard. Scientific progress is driven by the need for early warnings and whilst work continues on the physical processes, much recent attention has been given to the socio-economic factors which contribute to the scale of impact. Local communities and scientists require data on past events and risk zone maps enable warnings to be differentiated at a local scale.

Warning service

Science and technology combine to produce warnings, both at high levels of investment such as satellites and supercomputers, but also low-tech solutions such as simple, solar-powered field instruments. Automated systems allow for the possibility of continuous surveillance and monitoring. The ability to make effective warnings is closely linked to scientific understanding.

Dissemination

This is one of the most important aspects being developed in the whole area of disaster reduction. The challenges are to make warnings available 24 hours a day and to have internationally agreed standards so that hazards such as hurricanes or floods, which can have a transnational impact, can be responded to at similar levels. Telecommunications are the key to successful dissemination. In developing countries, possession of a mobile phone is becoming a 'must-have' status symbol and this holds much potential for enabling remote, poor communities to respond to potential hazards. In contrast, in developed nations where advanced technology has increased lead times for warnings, individuals demand more information in the intervening period to better assess their own risk and level of response. Media could be used to give a more educational approach in broadcasting warnings, rather than its traditional journalistic role in reporting news.

Response capability

People's perceptions of risk and their willingness or ability to respond are dependent on their understanding of the warnings and being familiar with preparedness plans. People-centred approaches to lessen hazard impacts should be central to any plans, and should be practised and regularly updated.

Failure in any one of these four components will undermine any early warning system. There are several issues common to all four of these elements which produce shortcomings:

- Lack of political commitment to the implementation of early warning systems.
- Lack of recognition of the connection between disaster risk reduction and sustainable development which are key areas in reaching the UN Millennium Development Goals.
- Inadequate investment, particularly in poor countries where vulnerability is highest.
- Top-down approach, omitting collaboration with all stakeholders.

Figure 3: Major organisations responsible for early warning systems

Hazard	Global warning systems
Hurricane	WMO Global Tropical Cyclone Warning System 6 regional centres: Miami, Tokyo, New Delhi, Honolulu, Fiji, La Réunion
Flood	International Flood Network (IFNet) Global Flood Alert System (GFAS) uses precipitation data from satellites to produce flood warnings
Drought	Most difficult and less developed globally. Global Circulation Models (GCM) Drought Monitoring Centre, Harare Intergovernmental Authority on Development (IGAD)
Heatwave	NOAA/National Weather Service City-based Heat-Health Warning System (HHWS). More deaths occur due to heat in urban areas than from any other atmospheric event. Eg Chicago 1995, Europe 2003
Tornado	Doppler radar system enables a 15 minute warning; only a few countries are at risk
Earthquake	Global Seismograph Network (GSN) Supported by USGS and many global, regional and local organisations
Volcano	International Civil Aviation Organisation (ICAO) and World Meteorological Organisation (WMO) Satellite-based global monitoring but spatial variation in monitoring capacity
Tsunami	Pacific Ocean – Pacific Tsunami Warning System (PTWS) Hawaii, Japan and Alaska bases since 1965 Indian Ocean Tsunami Warning System (IOTWS) Operational since June 2006 NE Atlantic and Mediterranean Tsunami Warning System Operational by Dec 2007
Avalanche	Inter-Cantonal Early Warning and Hazard Information System Developed in Switzerland, after the 1999 season, with bulletins issued twice a day in winter
Landslide	International Programme on Landslides (IPL) Tokyo 2006

Evaluation of progress so far

Whilst warning systems exist for most hazards, their application worldwide is very patchy and is mainly dependent on a country's level of economic development. Even within a country, forecasting systems may only be in place for the dominant hazards and may not cover the whole country. On a global scale, earthquakes (fastest onset) and drought (slowest onset) represent the two most challenging hazards to developing warning systems. These are traditionally based on scientific monitoring and forecasts, but vulnerability and therefore risk assessment is beginning to be included in hazard warnings as the understanding of disaster reduction develops.

Despite progress, significant gaps in warning approaches have been identified:

- Inadequate coverage in time and space of monitoring systems.
- Low-level technical capabilities of instruments and personnel.
- Lack of access to integrated information from multi-disciplinary agencies.
- Lack of easily understood warnings to communities at risk.
- Failure to update plans on the basis of what has been learnt from past events and responses.

Examples of early warning systems

Satellite observing systems and global telecommunication networks have enabled worldwide monitoring and forecasting of most hazards, although there are distinct spatial variations generally determined by the level of economic development, but also due to the type of hazard. Figure 3 outlines the major organisations responsible for monitoring and issuing warnings for particular hazards.

Figure 4: Progress on the Indian Ocean Tsunami Early Warning System

Scientific data and communications technology	**Integrated risk management**
Achievements: • Exchange of seismic data • 26 countries have set up official advisory centres on tsunami risks • 23 sea stations in Indian Ocean fully upgraded into Global Sea Level Observing System (GLOSS) by June 2006 *Shortcomings:* • Specific tsunami co-ordination is lacking • Few countries have their own national capacity to produce and/or transmit tsunami warnings	*Achievements*: • Developing co-ordination between national and local official agencies • Information links with Pacific Tsunami Warning System (PTWS), Hawaii • Inclusion of environmental assessments in disaster reduction programmes *Shortcomings*: • Data not yet available for effective response planning
Community level approaches	**Public Awareness and Education**
Achievements: • Co-ordination of policies at national level • Local authorities have devised and tested local government preparedness plans • Insurance schemes for fishermen and farmers in the Seychelles *Shortcomings*: • Emergency plans have not been devised at community level	*Achievements*: • 10 field libraries on disaster reduction • Workshops • Tsunami awareness booklets in local languages, for adults and children • Teacher information kits • Video clips *Shortcomings*: • These efforts are not widespread – much spatial unevenness

Earthquakes

Traditionally, the priority into research on earthquakes has been for scientific understanding rather than developing early warning systems. Technology has focused on precise, global-wide systems using expensive hardware and requiring time-consuming data handling. Attention has centred on measuring mechanical movement of the Earth's crust by satellite and with strain meters within the crust. Recently, the focus of research has shifted to using satellite technology to monitor electromagnetic phenomena. These occur when crystalline rock structures are deformed or broken under pressure during grinding just before the slip phase of an earthquake. The cracking creates a positively charged electrical current which is easily detected within the ground, on the surface and even from space.

Despite the seeming impossibility of earthquake warnings, given recent examples in Pakistan 2005 and Java 2006, there is optimism that more simple technology can produce an effective early warning system. Researchers at Berlin University suggest using wireless technology and license-free radio frequencies, and constructing a dense network of inexpensive sensors in high-risk areas from which on-line, real-time data can be made available. The reduced accuracy would be compensated for by the denser network of instruments. Individuals could join the network by purchasing a sensor, in the same way as people use smoke detectors. This way, the people most at risk have the opportunity to play a part in reducing their own vulnerability. Although eventual warnings are likely to be less than one minute, the system could automatically shut down services. The main problem would be the likelihood of false warnings and the economic losses if water, gas and oil supplies were cut off unnecessarily.

Volcanoes

Differences such as explosiveness, material emitted and past histories of eruptions means that each volcanic hazard warning must be particular to specific communities at risk. A series of warning levels are used, similar to that employed in meteorological hazards. The danger to aviation due to ash clouds is indicated by a colour code. Seismic activity, ground deformation and gas emissions usually begin days to weeks before an event, although the most accurate warnings are within hours to days. Despite successes in forecasting and evacuation, e.g. Pinatubo, Philippines 1991 and Usu, Japan 2000, it is still almost impossible to accurately predict the most desired information – when, where, type and magnitude.

Tsunami

After the Indian Ocean disaster in December 2004, much work has been done to provide the region with a tsunami early warning system such as that which already exists for the Pacific Ocean. It encapsulates all the principles agreed upon at the Hyogo Conference, in particular its people-centred approach to increasing communities' resilience to hazards. Implementation is expected to be complete by June 2006, using ocean-floor pressure sensors linked to global satellite technologies and international co-ordinating agencies. Figure 4 shows how early warning is being strengthened in Indian Ocean states by a combination of scientific studies, integrated risk management, education and people-centred attitudes to disaster reduction, particularly on a community basis. The scientific and technological aspects are well-established due to their relatively easy transfer from the Pacific tsunami warning system. It is the rapid communication of the warning to affected people and their willingness and ability to respond that requires most development. Warnings must be unambiguous and will be issued via multi-media approaches, using low-tech solutions such as whistles and megaphones as well as radio and television. Education and training drills are essential in order to learn where to direct resources. In a Pacific-wide simulation in May 2006, there was a failure to receive text messages at five emergency centres in Thailand, but knowledge in breakdowns in the system is vital in building reliable warning systems.

However, sophisticated approaches are not always necessary. Although 130,000 people died in the Aceh region, the nearby island of Simeulue suffered only 23 deaths out of a population of 78,000. This was due to indigenous knowledge of natural precursors to tsunamis – oral warnings of strange animal behaviour and a retreating sea meant people had time to evacuate to higher ground inland.

Flood warnings

In the UK, the Environment Agency is responsible for the issuing of flood warnings. After significant flooding during Easter 1998, a new code of warnings was developed and launched in Sept 2000. A month later, they were put to the test during major floods in SE England in Uckfield and Lewes, Sussex and in Yalding, Kent.

Figure 5 outlines the levels of warning issued via the Agency's Flood Warning Direct system. Warnings are broadcast via television and radio, but individual homeowners and businesses located in areas of flood risk can register to receive a free warning service via landline or mobile telephones, fax or pagers.

Figure 5: Flood warning codes in UK

Warning level	Required response
Flood watch Flooding of low-lying land and roads is expected. Keep watch!	• Watch water levels • Stay tuned to local radio or TV • Make sure you have what you need to put your flood plan into action • Alert your neighbours, particularly the elderly • Check pets and livestock • Reconsider travel plans
Flood warning Flooding of homes and businesses is expected. Act now!	As with Flood Watch plus • Move pets, vehicles, food, valuables and other items to safety • Put sandbags or flood boards in place • Prepare to turn off gas and electricity • Be prepared to evacuate your home • Protect yourself, your family and others that need your help
Severe flood warning Severe flooding is expected. There is extreme danger to life and property. Act now!	As with Flood Warning plus • Be prepared to lose power supplies – gas, electricity, water, telephone • Try to keep calm, and to reassure others, especially children • Co-operate with emergency services and local authorities • You may be evacuated
All clear Flood Watches or Warnings are no longer in force for this area.	• Flood water levels receding • Check all is safe to return. • Seek advice.

Source: Environment Agency

The future for early warning systems

The main recommendation from the Hyogo Conference was to develop a global comprehensive early warning system for all hazards using existing networks. All sustainable development plans in hazardous areas should be people-centred and include disaster reduction strategies:

- national and local maps showing zones of relative risk and routes to safety
- early warning systems which are standardised and easily understood
- public awareness of risk and education in disaster reduction strategies
- better urban planning and safer building construction codes to reduce people's vulnerability in their homes
- use of simple technologies to improve warning in remote communities, such as river gauges
- studies of people's perception and their subsequent response to warnings
- community-based schemes to support the elderly and disabled when warnings are issued
- develop and practise evacuation plans.

Whilst early warning systems are vital, there remains a need to reduce people's fundamental vulnerability. If significant progress in disaster reduction and sustainable development is to be achieved, political commitment to resourcing scientific research and community preparedness plans, education and international collaboration will be vital.

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Focus Questions

1. What are the physical and human factors that need to be addressed in any early warning system?

2. For any recent case study, use the model of early warning (Figure 2) to identify strengths and weaknesses of the hazard management in your chosen hazard event.

3. Government officials, disaster managers and homeowners require early warning systems. How would each group react to a warning of hazard impact?