

Disaster risk reduction under current and changing climate conditions

by Heather Auld*

Introduction

Evidence from around the world indicates that the costs of disasters, particularly weather-related disasters, are increasing. From the 1950s to the 1990s, the annual direct losses from all natural catastrophes rose from US\$ 3.9 billion to at least US\$ 40 billion at the 1999 dollar rate (Munich Re, 2007), while population grew only by 2.4-fold. In reality, these losses from predominantly weather- and water-related disasters are larger by a factor of two, when losses from less severe events are included (Munich Re, 2007). Accordingly, other recent studies have suggested even higher losses (IPCC, 2007(a)). While the number of lives lost to natural disasters has declined over the last 30 years, thanks to better disaster preparedness and prevention programmes, the number of people affected by natural disasters through injury, homelessness or hunger increased significantly to average over 211 million people per year (Red Cross, 2006). The largest rises in impacts occurred in developing countries.

Disasters as a result of weather, climate and water events account for the majority of all natural disasters, as shown in Figure 1. Indeed, hydrometeorological hazards accounted

for close to 90 per cent of the lives lost in natural disasters during the last decade (WMO, 2004(a)). These rising impacts highlight a need for National Meteorological and Hydrological Services (NMHSs) to play an even greater role in disaster management.

While increases in extremes are claimed to be contributing regionally to the escalating disaster losses, it is also known that changing socio-economic and demographic trends have contributed to rising vulnerabilities (IPCC, 2007 (a)). Some of the changing socio-economic factors include increasing populations, urbanization, development in higher

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risk locations (e.g. coastal zones), increasing poverty in poorer regions, increasing prosperity in developed regions, increased dependence on infrastructure and services, ageing

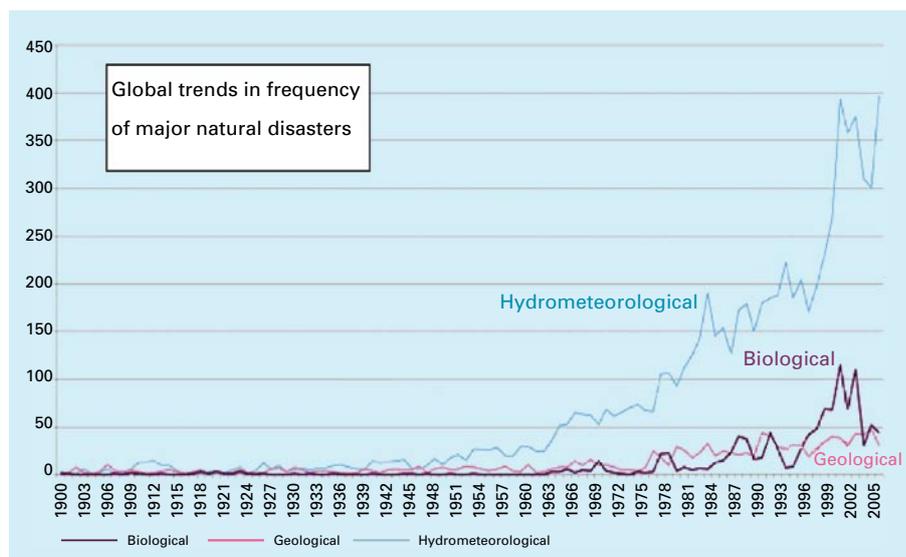


Figure 1 — Number of great weather and hydrological disasters for each year in the EM-DAT database for the period 1900-2005 (from EM-DAT (2006): *The OFDA/CRED International Disaster Database* (www.em-dat.net), Université Catholique de Louvain, Brussels, Belgium)

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infrastructure, an inability to afford good climatic guidance for engineering codes and standards, ecologically unsound development and regional environmental degradation.

While it is normal to expect large year-to-year variations in the number and intensity of weather and hydrological hazards, it is not normal for the costs of these hazards to continue rising. When a natural hazard becomes a disaster, the result is as much a function of the way that the community does business or adapts to the hazard as it is of the natural hazard itself. The fact that both insured and uninsured losses from weather and water related disasters have been rising rapidly in constant monetary terms reflects a failure of communities and society to adapt well enough to current climate variability and extremes.

Roles for the NMHSs in disaster management

National Meteorological and Hydrological Services have many roles to play in disaster risk management, as shown in Figure 2. These roles can be summarized under two windows for action:

- Pre-disaster or risk-management actions through the pillars of:
 - Disaster risk mitigation or prevention
 - Emergency preparedness
- Actions imminently before, during and after disasters—crisis management—through the pillars of:
 - Emergency response and relief
 - Disaster recovery and rebuilding.

Effective end-to-end management of disasters requires the coordinated and comprehensive integration of actions over these four pillars.

In most countries, natural hazard policies traditionally focus on crisis management actions (i.e. emergency preparedness) that minimize the impacts during a disaster and provide immediate relief and support to victims. Although disaster response is important, it can fail to address the causes of disaster losses. The World Bank has estimated that every dollar spent in preparing for a natural disaster saves seven in response (World Bank, 2004).

NMHSs are well-placed to help reduce weather- and water-related disaster

losses under current and changing climate conditions through risk-management and crisis-management actions. These actions include:

- Provision of hazard information for community risk assessments and land-use planning
- Improvements to climatic and hydrological design information for safer infrastructure and communities
- Development of environmental prediction and risk products for interpretation of impending risks
- Monitoring to detect hazards and emerging threats
- Forecasts and timely early warnings for operational emergency response actions and for recovery and rebuilding operations
- Assistance with risk-management education and capacity building.

Risk management measures: targeting risks

There is a saying that “forewarned is forearmed”. When we know the threats we face, we are better able to prepare for them” (Klaus Töpfer, Executive Director of the United Nations Environment Programme). Although natural disasters are not always predictable, they are most often foreseeable and can be planned or risk managed beforehand. Many natural hazards can be foreseen or anticipated using past experience, climatological analyses of atmospheric hazards, analysis of vulnerabilities, forensic analyses and guidance on future climates.

The role of the NMHS in developing atmospheric hazard information

A critical part of a disaster risk-management strategy is the completion of a vulnerability or hazard identification and risk assessment

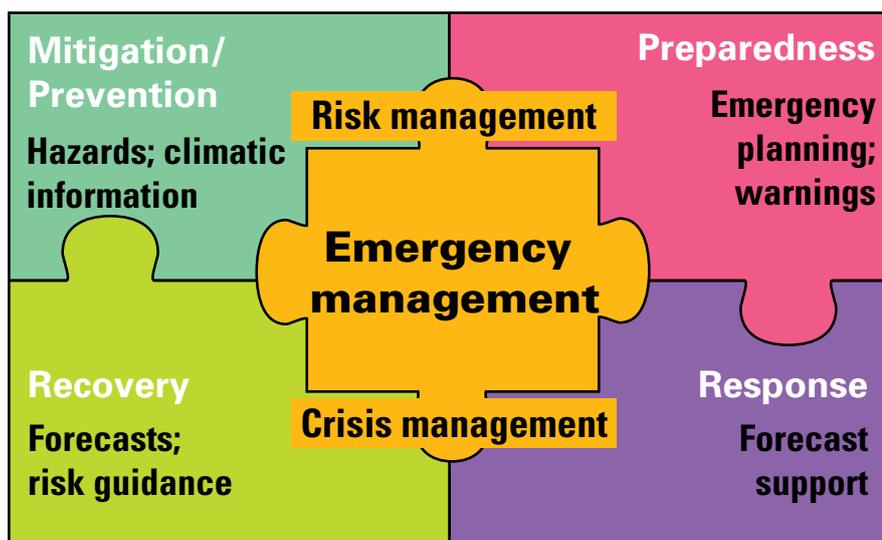


Figure 2 — Potential roles of the NMHS in disaster/emergency management systems through four pillars of action: risk management actions through the pillars prevention/mitigation and preparedness; and crisis management actions through the pillars emergency response and recovery and re-building

(HIRA) process that integrates the probability of hazards with critical infrastructure vulnerability and risk assessments. In Canada, for example, the province of Ontario passed a provincial Emergency Management and Civil Protection Act in April 2003, requiring all municipal and regional governments to identify and prioritize various hazards and risks to public safety (Government of Ontario, 2004). This Ontario Act requires completion of a HIRA process, identification of vulnerable groups and infrastructure, prioritization of likely risks, planning for potential interventions identified and completion of comprehensive disaster-management planning under deadline (Auld *et al.*, 2006(c)). Other provinces have adopted or are considering similar legislation.

The HIRA process recognizes that each municipality has different and distinct hazards and risks. It assesses the frequency of hazards and their net impacts as a function of hazard probabilities and consequences (impacts and vulnerability). Because capabilities vary greatly among municipalities, the Ontario HIRA process uses a simplified system to evaluate the probability and consequences of a hazard, as well as the municipality's response capability. The HIRA system ranks risks according to the following parameters (Emergency Management Ontario, 2004):

- Frequency or probability of the hazard, ranked from 1 to 4, where "1" reflects a low occurrence and "4" reflects a high occurrence of the hazard within the past 15 years;
- Impacts or consequences, ranked from 1 (negligible) to 4 (high). The degree of impact can be determined through expert opinion and consultation with experts. A "high" consequence score reflects a likelihood of severe consequences, including fatalities and the loss of essential infrastructure and services;

- (Optional) community response capability or adaptive capacity: response capabilities are ranked from 1 (excellent) to 4 (poor) and can modify the assessment of impacts for low-probability but high-impact events, where response experience and capacity may be limited. The net result of a reduced response capability is a higher priority risk needing greater disaster-response planning and risk-reduction actions.

In support of this HIRA system and in collaboration with its disaster management partners, Canada's Meteorological Service developed an Atmospheric Hazards Website (www.hazards.ca) for regional emergency managers (Auld *et al.*, 2002, 2006(c)). The Hazards Website and publications include information on the probability of occurrence of hazards and provide tools for the spatial and temporal comparison of hazards across regions.

The Hazards Website consists of peer-reviewed or "defensible" maps and databases of various hydro-meteorological hazards, their trends and documentation on historical high

impact events. Figure 3 illustrates a sample hazards map from the Website. Hazardous events include extreme heat and cold, drought, extreme rainfall, blizzards, hurricanes, ice storms, tornadoes, windstorms, smog, ultraviolet radiation, etc. The maps and databases contain information on frequencies for selected periods of record, average days per year with conditions exceeding thresholds, extreme precipitation and temperature records, probabilities of an event at a location, most recent occurrences of extremes, return period estimates and climatic design values for engineering, as well as weather warning criteria and potential impacts of specific hazards (Auld *et al.*, 2006(c)). All materials need to be scientifically defensible (e.g. journal publications, data meeting international and national standards).

The Website also allows the assessment of multi-hazard risks using co-recognition software capable of "stacking" maps from a variety of formats together, even though the maps might have different scales and projections. The Website accommodates map formats ranging from a simple hard copy map scan (e.g.

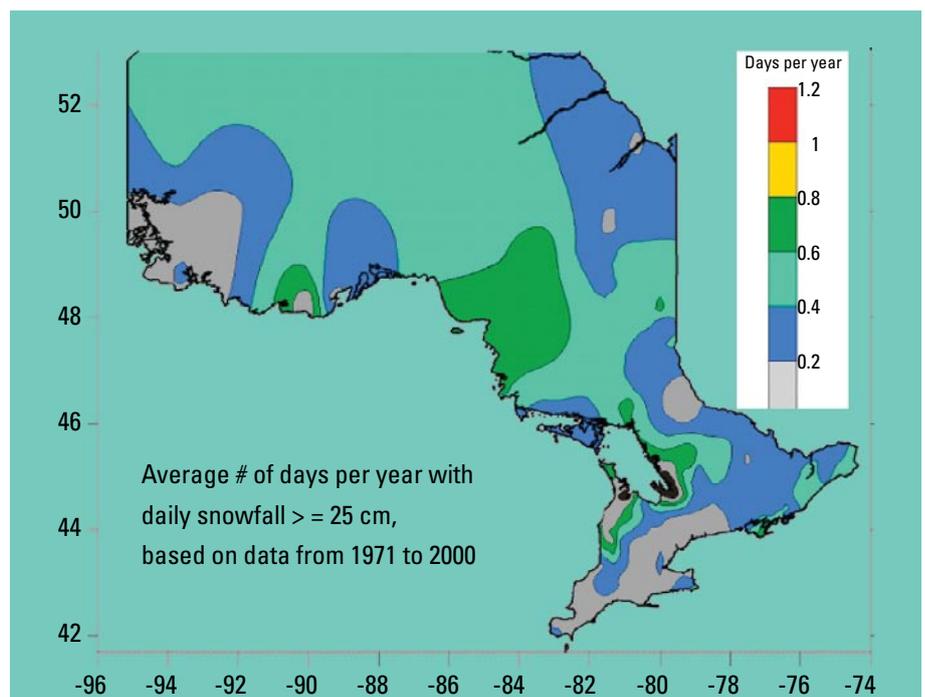


Figure 3 — Average number of days per year with daily snowfall ≥ 25 cm, based on data from 1971-2000 (Provincial Overview) (from Environment Canada, 2006)

gif) through to more sophisticated Geographic Information System (GIS) outputs. The software was designed to address widely varying capacities of municipalities and can run on much older and slower computers, as well as state-of-the-art equipment. Since technological capabilities vary greatly among municipalities, a variety of formats and media were chosen to deliver the hazard information (e.g. publications for political decision-makers, CD-ROM materials for remote jurisdictions, Web pages, etc.).

New and evolving threats (e.g. changing climate hazards, health pandemics) need to be considered in the HIRA process. In these cases, historical trends, as well as climate change scenarios, are included to highlight changes and increasing risks from hydrometeorological hazards. Authorities are encouraged to use the best information available in determining probabilities and trends (Emergency Management Ontario, 2004).

The benefits to NMHSs in making hazards foreseeable and understandable are multiple and include an improved appreciation of the information needs of decision-makers for disaster management, as well as the identification of science gaps, conflicts and priorities for updating weather and hydrological products. As illustration, the assessment of tornado-probability maps for central Canada revealed inconsistencies in products over time due to changed methodologies, assumptions and data-collection procedures. The process also revealed significant gaps in drought-risk information for central Canada, with the result that new drought and low-water response indices were developed and calibrated in partnership with users. The new drought information is able to better meet new consolidated legislation for low-water response planning and actions.

A challenge in designing a hazards Website is the need to satisfy a wide

variety of users ranging from the well-trained planner to the simple user, while balancing requirements for accuracy and comprehensiveness. In essence, precise scientific hazard information is of little value if it cannot be understood in the rural municipality by the clerk with responsibilities for disaster management planning. Likewise, scientific hazard information that is so highly simplified that it does not accurately convey the actual threat is of diminished value for the professional consulting firm hired to advise another municipality of risks and priorities. The challenge is to communicate complex scientific information on hazards simply to all users and to ensure that information is scientifically defensible in spite of its simplifications.

The role of the NMHS in infrastructure protection and disaster risk reduction

It has also been said that “the house is the first line of defence against hazards”. Forensic analyses often reveal that structural failures of infrastructure (e.g. houses, electrical distribution lines, communications structures, dams) result when climate extremes approach the structure’s critical design values and then exceed

its safety limits (Auld *et al.*, 2006(a)). Forensic studies show that, above critical thresholds, small increases in weather and climate extremes have the potential to bring large increases in damage to existing infrastructure. These studies indicate that damage from extreme weather events tends to increase dramatically above critical thresholds, even though the high-impact storms associated with these damages may not be much more severe than the type of storm intensity that occurs regularly each year (Munich Re, 2005; Swiss Re, 1997; Coleman, 2002). In many cases, it is likely that the critical thresholds reflect storm intensities that exceed average design conditions for a variety of structures of varying ages and conditions.

An investigation of claims by the Insurance Australia Group (IAG), as shown in Figure 4, indicates that a 25 per cent increase in peak wind gust strength above a critical threshold can generate a 650 per cent increase in building claims (Coleman, 2002). Similar studies indicate that, once wind gusts reach or exceed a certain level, entire roof sections of buildings are often blown off or additional damage is caused by falling trees. Typically, minimal damage is reported below this

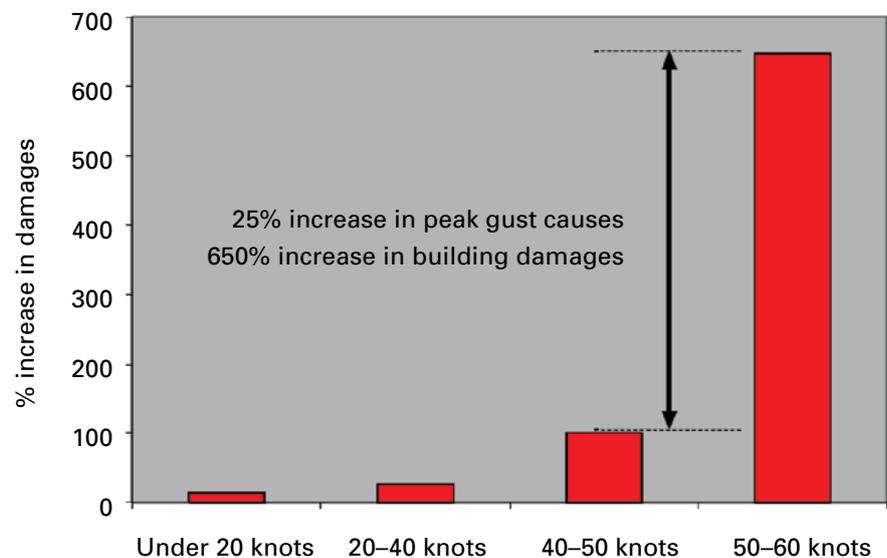


Figure 4 — Building claims as a function of peak gust speed (Australia) (Source: Coleman, 2002)

threshold (Munich Re, 2005; Swiss Re, 1997; Freeman and Warner, 2001; Coleman, 2002). Similar results have been obtained for flood and hailstone damages (Freeman and Warner, 2001; Munich Re, 2005; Swiss Re, 1997. Not surprising, the quality of construction also strongly influences the extent of damage.

Climatic design values used for the design of reliable and economical infrastructure include quantities such as the 10-, 50- or 100-year return period “worst storm” wind speed, rainfall or snow conditions and are typically derived from historical climate data. Almost all infrastructure today has been designed based on historical climate information, assuming that the past will represent conditions over the future lifespan of the structure. While this assumption worked in past, it will hold less as the climate changes. Regions where the climate trends are encroaching on design limits will require increases in climatic design values for new structures and reinforcements to existing structures that have been identified as “at risk” (Auld *et al.*, 2006(b)).

Crisis management: moving from weather prediction to risk prediction

One of the most effective measures for disaster readiness and emergency response is a well-functioning early warning system that delivers accurate information dependably and on-time. Warnings buy the time needed in advance of hazards to evacuate populations, reinforce infrastructure, reduce potential damages or prepare for emergency response. But warning systems are only as good as their weakest link and only accomplish their goals if accompanied by effective hazard response policies and actions.

All too often, warnings are issued without the NMHSs having an appreciation of the relative severity and potential impacts of the forecast

hazard. As a result, warnings can—and frequently do—fail in both developing and developed countries for any of four primary reasons (UNISDR, 2001). These include:

- A failure of forecasting, such as an inability to understand a hazard or a failure to locate it properly, in time or space;
- Ignorance of prevailing conditions of vulnerability, determined by physical, social or economic inadequacies;
- Failure to communicate the threat accurately or in sufficient time; and, finally,
- Failure by the recipients of a warning to understand it, to believe it or to take suitable action.

The success of an early warning depends on the extent to which it triggers effective response measures. As a result, warning messages need to suggest the appropriate actions that those at risk should take. This is difficult when information is incomplete, when there are conflicting recommendations or when the liability of the NMHS is of concern.

Forensic analysis of disaster events often reveals “after the fact” that communication with the public was not effective enough and that scientific and technical information (e.g. wind gusts >140 km/h) was not properly interpreted by authorities and the public in terms of risk. Warnings must be received and understood by a complex target audience and need to have a meaning that is shared between those who issue the forecasts and the decision-makers they are intended to inform. Because emergency responders and the public often are unable to translate the scientific information on forecast hazards in warnings into risk levels, future work is needed that can identify general impacts, prioritize the most

dangerous hazards, assess potential contributions from cumulative and sequential events to risks and identify thresholds linked to escalating risks for infrastructure, communities and disaster response.

Tiered and vigilance warning systems

Several NMHSs are investigating tiered or escalating warning systems capable of distinguishing high-impact weather events requiring widespread emergency response actions from other disruptive events falling within “normal” emergency response capabilities. Météo-France, for example, has invested in a meteorological vigilance system that uses four levels of hazard warning and includes new hazards (e.g. heat-wave warnings).

The European Multi-services Meteorological Awareness (EMMA) Programme is based on Météo-France’s vigilance system and uses a similar four-colour code (Gérard, 2002) of green, yellow, orange and red. A green status indicates that no severe weather is expected; yellow indicates a forecast of potentially dangerous but not unusual weather; orange forecasts potentially dangerous and unusual phenomena; and red warning status highlights that dangerous and exceptionally intense meteorological phenomena have been predicted.

China uses a colour-coded warning system for 11 extreme weather conditions. Warnings are flagged as blue, yellow, orange, red and sometimes black in ascending order and requiring escalating actions (Yongping Yuo, personal communication, 2007). For example, shops in China are to remain closed if typhoon warnings change from orange to red. A red warning for rainfall intensity means emergency squads must be ready for rescue operations as rainfall is expected to reach 100 mm or higher in three hours. In Florida, USA, NOAA initiated

a pilot project to graphically display forecasts of daily hazards according to relative “degree of threat” (Sharp *et al.*, 2000).

Recognizing that individual and combinations of hazards (e.g. excessive heat and poor air quality) can result in complex emergency response situations, WMO, its NMHSs and UN partners are working to establish multi-hazard early warning systems. Collaboration is underway with the World Health Organization to develop heat-health warning systems that enhance adaptation to deadly heat waves and malaria while other collaborative work with the UN Food and Agriculture Organization focus on the monitoring and development needed for early warnings of locust swarms (WMO, 2007; WMO, 2004(b)).

Creeping disasters

Some emerging disasters first appear as “creeping” hazards that evolve over a period of days to months. This timing presents different opportunities for prevention, planning, preparedness and response. The creeping hazards of floods and droughts often result from cumulative or sequential multi-hazard events accompanied by an inherent vulnerability. For example, flooding can result from less extreme rainfall when preceded by several days of rainfall and saturated ground conditions. As a result, specific criteria for issuing rainfall warnings may need to consider antecedent rainfall as well as saturated or frozen ground conditions before entering into a rainfall event. The challenge for forecasting flooding risks under antecedent precipitation is the uncertainty in modelling and predicting the preceding soil moisture conditions.

Droughts represent a powerful creeping hazard capable of bringing great losses to very large regions. Measures to monitor and detect creeping drought conditions need to be region-, user- and impact-

specific. Water managers, agricultural producers, hydro-electric power plant operators and ecosystem managers can all require different drought monitoring indices to characterize the severity of drought conditions and needed responses. Consequently, drought early warning systems work best when designed to detect cumulative precipitation deficits using regionally critical thresholds of water-supply conditions (WMO, 2006).

Early warnings and emergency response actions

Whether dealing with fast or creeping hazards, early warning systems are most effective when they provide adequate lead times for the activation of emergency response plans. The United Kingdom Met Office currently provides early warnings of potentially disastrous weather events to emergency responders up to five days in advance. Because prediction of severe weather at this range is difficult, these early warnings are expressed in terms of probabilities and issued when the probability of disruption due to severe weather somewhere in the United Kingdom is 60 per cent or more (UK Meteorological Office, 2004).

Warnings are most successful when they can target the people and regions mainly at risk. In some regions, this includes an appreciation of local and indigenous knowledge. For example, the Bangladesh Meteorological Department recognized the importance of community involvement following catastrophic losses of lives from cyclones in 1970 and 1991. Forensic analysis of the events revealed that warnings were not disseminated to, or believed by, the people at risk (Monowar, 1998). Subsequently, the current warning system involves some 33 000 volunteers spread over all the villages in the vulnerable coastal belt and offshore islands where volunteers disseminate cyclone warnings to every household. In some rural villages, flood warnings are disseminated

through locally recognized means such as flag codes, beating of drums or the use of the mosque microphone than electronic or print media.

The proof of the success of the warning dissemination system was demonstrated in greatly reduced fatalities from a subsequent 1997 cyclone, which resulted in 127 fatalities compared to 11 069 fatalities from a cyclone of similar intensity in May 1985 (Akhand, 1998).

Recovery and re-building

The disaster recovery and re-building phase requires careful integration of services from all of the other pillars. These services include tailored weather warning services to protect affected populations rendered even more vulnerable by the disaster, as well as updated atmospheric hazards and climatic design information to rebuild more disaster-resilient communities. Critical to recovery operations is the restoration of critical infrastructure, including communications infrastructure. It becomes difficult, if not impossible, to coordinate emergency response and recovery operations without the benefit of some functioning communications and transportation infrastructure.

The confusion during the emergency phase can lead to short-term rebuilding decisions that can adversely affect the community’s sustainability in the long term. A step to minimize unintended consequences is to plan in advance for post-disaster restoration, considering existing and changing hazards. The transition from disaster to a return to normal life is best accomplished ahead of time by developing a disaster recovery plan that considers hazards and undertakes a risk analysis and operations impact analysis of the main disaster risks.

Climate change

One of the most threatening aspects of global climate change, even given

the most ambitious of greenhouse-gas mitigation successes, is the likelihood that extreme weather events will become more variable, more intense and more frequent as storm tracks shift and frequencies and intensities increase regionally. A report by the United Nations Environment Programme's financial services initiative anticipates that the global cost of natural disasters will top US\$ 300 by the year 2050 (ISDR, 2004; Berz, 2001) if the likely impacts of the changing climate are not countered with aggressive disaster reduction measures.

"No regrets" adaptation actions taken today to reduce the impacts of weather hazards provide opportunities for regions to reduce current vulnerabilities and become better prepared for future climate-change challenges. Barriers to managing the risks associated with current climate variability are the same barriers that will inhibit regions and nations from addressing future increases in risk due to climate change (United Nations Development Programme, 2004).

The future

While the 1990-1999 International Decade for Natural Disaster Reduction (IDNDR) was dedicated to promoting solutions to reduce risks from natural hazards, the decade ended with more deaths from more disasters, involving greater economic losses and more human dislocation and suffering than when the decade began (ISDR, 2004). As a successor to the IDNDR, the UN General Assembly founded the International Strategy for Disaster Reduction (ISDR) in 2000 to continue the commitment to disaster reduction. The ISDR endeavours to bring people, organizations and sectors together on a multi-disciplinary and multi-stakeholder platform to increase resilience to natural, technological and environmental disasters and to reduce associated environmental, human, economic and social losses.

WMO, as a major partner in the ISDR, is committed to raising awareness on the relation between preventive, proactive risk management strategies and economic development. WMO supports the goals of the ISDR and the achievement of the United Nations Millennium Development Goal to "halve the loss of life associated with natural disasters of meteorological, hydrological and climatic origin". Accordingly, WMO has set a target to reduce the 10-year average fatalities from all natural disasters related to weather, climate and water by 50 per cent (relative to 1994-2003) over the next 15 years (WMO, 2005). It has established the Natural Disaster Risk Reduction Programme to ensure optimization of WMO's global programmes and infrastructure and to integrate its core scientific capabilities and expertise into all relevant phases of disaster risk management decision-making, particularly related to risk assessment and early warning systems (WMO, 2005).

Without the benefits of existing preventive services through WMO's network of NMHSs, it is sobering to think that the disaster statistics during the last decade likely would have been even higher than trends show (Golnaraghi, 2004). In addition, ongoing pressures from the changing climate will likely translate into even more frequent occurrences of extreme weather in one form or another. Without aggressive disaster management actions, it is likely that new and unexpected vulnerabilities will arise from unfamiliar hazards in the future, with surprise having the potential to become the biggest killer yet. Prudent planning for disaster risk management should therefore factor in current and future risk reduction adaptation actions to current and evolving hazards and risks.

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