United Nations

International Decade for Natural Disaster Reduction

IDNDR Early Warning Programme

Report on Early Warning for

Hydrometeorological Hazards including Drought

Convener of International Working Group, and first author:

Dr. Desmond O'Neill (Consultant)

World Weather Watch Department, World Meteorological Organization

Geneva, Switzerland

IDNDR Secretariat, Geneva October 1997

EARLY WARNING FOR HYDROMETEOROLOGICAL HAZARDS INCLUDING DROUGHT

CONTENTS

FOREWORD

In 1989, the member states of the United Nations declared the period from 1990 to the year 2000 to be the International Decade for Natural Disaster Reduction (IDNDR). Its objective is to "reduce the loss of life, property damage, and social and economic disruption caused by natural disasters, through concerted international action, especially in developing countries".

The fundamental importance of early warning for realizing this objective of disaster reduction was recognized in 1991. The IDNDR's Scientific and Technical Committee declared the subject a program target, by which the success of the Decade would be judged by the year 2000. By drawing on global scientific knowledge and practical experience, the Decade's advisory committee encouraged all countries to ensure the ready access to global, regional, national and local warning systems as part of their national development plans. The IDNDR Secretariat has since coordinated an international multi-disciplinary framework to promote this issue. In doing so, it has been able to draw on the comprehensive views and abilities of the United Nations system, needs and concerns of individual countries, and related global expert knowledge.

The critical nature of early-warning for the protection of vital resources and for addressing national development objectives was highlighted by a technical committee session devoted to the subject at the United Nations' World Conference on Natural Disaster Reduction held in Yokohama, Japan in May 1994. Several of the expert presentations cited the importance of public policy commitment for successful early warning. The primary outcome of the Conference, The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation further emphasized the importance of applied scientific knowledge and the public's awareness of hazard risks as essential components for more effective early warning practices.

The IDNDR Secretariat was requested by the United Nations General Assembly in 1995 to coordinate a review of the existing early warning programs and to suggest means by which global practices could become better coordinated and made more effective. Initial information was conveyed by the Secretary General's Report on Early Warning to the Fiftieth Session of the United Nations General Assembly in October 1995. (UN Document A/50/256, 9 October 1995). At that time, a further examination of new scientific and experimental concepts for accurate and timely short-term forecasting was requested of the IDNDR for the purpose of making recommendations on the applicability and development of more effective early warning in the context of international cooperation.

For the current work, six international expert working groups were convened to study different aspects of the early warning process: geological hazards, hydrometeorological hazards including drought, fire and other environmental hazards, technological hazards, the use and transfer of related modern technologies, and national and local capabilities pertinent to the effective use of early warning. Guiding Principles for Effective Early Warning were also compiled by the conveners.

This following report of the Working Group on Early Warning Capabilities for Geological Hazards summarizes global experience and reviews the current state of knowledge and practice on the subject. Recommendations are also made for improvements and areas that require additional international attention. The conclusions reflect the views of scientific and technical experts as well as those of the United Nations departments and agencies concerned. An effort was made to ensure that views of government authorities, non-governmental organizations and other elements of civil society were also represented, particularly as they relate to factors which determine the efficacy of early warnings.

This report is one of a series issued by the IDNDR Secretariat in October 1997 to review the current state of early warning systems. By the end of the Decade, these views will contribute to final recommendations for improved, and better coordinated, practices in fulfillment of the initial IDNDR program target for the subject. They will first be considered by an International Conference on early warning systems for the reduction of natural disasters which has been held in Potsdam, Germany in September, 1998. This technical and scientific conference focusing on the application of successful warning practices was sponsored by the Government of Germany with the collaboration of United Nations' agencies and international scientific organizations. As a major topical event of the IDNDR closing process and the consolidation of global views, the conference has identified those accomplishments and local experiences which can best improve organizational relationships and practical effectiveness for early warning into the 21st century.

The following titles compose the series of information reports of the IDNDR Early Warning Programme:

Early Warning Capabilities for Geological Hazards
Early Warning for Hydrometeorological Hazards, Including Drought
Early Warning for Fire and Other Environmental Hazards
Early Warning for Technological Hazards
Earth Observation, Hazard Analysis and Communications Tech. for Early Warning
National and Local Capabilities for Early Warning
Guiding Principles for Effective Early Warning

The Secretary General's Report on Early-warning Capacities of the United Nations System with Regard to Natural Disasters presented to the Fiftieth Session of the United Nations General Assembly, October 1995. (UN doc. A/50/526).

The Secretary General's Report on Improved Effectiveness of Early-warning Systems With Regard to Natural and Similar Disasters presented to the Fifty-second Session of the United Nations General Assembly , October 1997. (UN doc. A/52/561).

These reports may be accessed on the IDNDR web site: http://www.idndr.org or on the EWC'98 web site at http://www.gfz-potsdam.de/ewc98/ They also may be obtained from the IDNDR Secretariat, Palais des Nations, CH-1211 Geneva 10 Switzerland. or by Fax: +41-22-917-9098, or E-mail: idndr@dha.unicc.org

EXECUTIVE SUMMARY

In this report, the term "hydrometeorological hazards" is taken to include the wide variety of meteorological, hydrological and climate phenomena which can pose a threat to life, property and the environment. These are probably the most frequently occurring and most extensively and routinely observed hazards. Here, the forecasting challenge presented in providing early warnings spans a continuum from less than one hour for tornadoes and flash floods to seasonal and inter-annual time scales for drought.

Warnings for these hazards can only be provided to the extent that the existing hydrometeorological infrastructure permits. At the global level, the World Weather Watch and Hydrology and Water Resources Programmes coordinated by the World Meteorological Organization (WMO) provide a solid operational framework on which to build improved early warning capacity. For drought, additional infrastructure elements such as Drought Monitoring Centres have also been implemented in a number of vulnerable regions. Within this framework, global and regional capacities are, generally speaking, well developed but weaknesses exist in national and local infrastructures in many developing countries.

Achievement of optimal early warning and response to disasters also requires effective coordination and cooperation between responsible agencies, institutions, officials, the media, political leaders and other players at local, national and international levels. However, weaknesses have been identified in coordination at all levels.

In consequence, achievement of overall improvement in early warning for hydrometeorolgical hazards requires capacity-building, particularly at local and national levels, and improving coordination at local, national and international levels. The recommendations in this report address the two critical issues of capacity-building and coordination.

For capacity building, the Working Group recommends that :

- national governments, National Meteorological and Hydrological Services and drought monitoring agencies urgently review their domestic early warning capacities and use the results to develop and implement prioritized plans to remedy weaknesses, with the assistance of donor countries and agencies;

and, at the international level, that:

- WMO and other relevant international organizations continue to review their global and regional early warning capacities regularly and then use these reviews to develop or update and implement plans for improvements.

Additional recommendations for related international action address the routing of warnings to appropriate international organizations, improving global weather satellite coverage, examining the potential of the WMO Global Telecommunications System for international relay of all types of hazard warnings, the extension of early warning demonstration projects, international training and development programmes, research into hazard prediction and the expanded use of the Internet.

To improve coordination at local and national levels the Working Group recommends that governments ensure that:

- planning for mitigation of disasters is given a high priority;
- mechanisms are created to facilitate coordination and partnership;
- effective liaison is established with governments and agencies in neighbouring countries;
- coordination with domestic and international media is given high priority.

To improve coordination at the international level, the Working Group endorses the development of Guiding Principles for Effective Early Warning along with the establishment of an early warning forum. An option for the latter would be an International Hazard (or Early) Warning Panel comprised of representatives from international organizations and interested countries supported by a modest secretariat.

I. INTRODUCTION

Timely and effective warnings of natural and related hazards coupled with local capability to take avoidance or mitigating actions are fundamental requirements for disaster reduction. The IDNDR Secretariat established five working groups to identify and recommend needed improvements in early warning capacities at local, national and international levels, within the context of its International Framework of Action. This Working Group report addresses these issues with a focus on early warnings for hydrometeorological hazards including drought.

IDNDR Early Warning Objective and Programme

It is a primary goal of the IDNDR to improve the capacity of each country to mitigate the effects of natural disasters, with special emphasis on developing countries. One of IDNDR's original programming targets was that all countries should have in place, by the year 2000, ready access to global, regional, national and local warning systems as part of their national plans to achieve sustainable development. The IDNDR Early Warning Programme seeks to achieve this goal through four strategies:

i) Development of commonly accepted early warning principles.

ii) Linking hazard detection and forecasting abilities through reliable communications to effective and sustained local and national preparedness and response capabilities.

iii) Technology transfer and human resource development.

iv) Institutionalization of improvements to ensure effective early warning capacities for the 21st century.

The issues and problem areas identified in this document as well as its proposals and recommendations are intended to contribute to the implementation of these strategies.

Hydrometeorological Hazards including Drought

For the purposes of this report, the term "hydrometeorological hazards" is taken to include the wide variety of meteorological, hydrological and climate phenomena which can pose a threat to life, property and the environment. The following table lists hazards for which warnings are issued by one or more National Meteorological and Hydrological Services (NMHS), illustrating the broad range of potentially dangerous hydrometeorological phenomena experienced in various regions of the globe.

Tropical cyclones	Thunderstorms	Blowing snow
Typhoons	Hail	Snow squalls
Hurricanes	Lightning	Avalanches

Tornadoes	Thunder squalls	Freeze
Waterspouts	Heavy rainfall	Frost/Glazed frost
Freezing rain/Sleet	Freezing drizzle	Icy roads
Heavy snowfalls	Cold wave/Intense cold	Sudden temp. decrease
Blizzards	Wind chill	Strong winds/Gales
Winter storm	Storm surges/storm tide	Waves
Tsunamis/Seismic sea waves	Heat waves/Excessive heat	Drought
High humidity	Forest fires/Bush fires	Sand storms
Dust/Dust storms	Floods/Flash floods	Fog/Dense fog
Smoke	Volcanic ash	

The spatial and temporal scales of these hazards vary widely from short-lived, violent, phenomena of limited extent (e.g. tornadoes and severe thunderstorms) through large systems (e.g. tropical and extra-tropical cyclones). These events can subject whole countries or regions to strong winds, heavy flood-producing rains, storm surges and coastal flooding or heavy snowfalls, blizzard conditions, freezing rain and extreme hot or cold temperatures for periods of several days. At the largest scale are widespread droughts which may affect huge sub-continental areas for months to years causing famine and loss of life, mass migration, desertification and loss of animal populations along with increased risk of wildfires. Similarly, meteorological and hydrological forecasting requirements for effective early warnings of these hazards span a very broad continuum. These can range from less than one hour in the case of tornadoes, severe thunderstorms and flash floods through short and medium forecast ranges extending from hours through days for tropical and extra-tropical cyclones, heavy rains, extreme temperatures, or high winds. Other phenomena are concerned with seasonal and inter-annual time scales, such as in the context of drought.

While, short-lived phenomena are sometimes locally catastrophic, they are primarily of domestic concern and it is usually left to national and local governments to respond to their impacts. By contrast, large weather systems and widespread droughts may cause impacts which overwhelm the capacities of national governments, requiring international disaster relief efforts. The IDNDR Early Warning Programme addresses the complete spectrum of hazards through its emphasis on capacity building at local and national levels and on improving international coordination and effectiveness in both the forecasting and the ability to use warnings effectively at the local level.

As pointed out by the U.S. National Science and Technology Council, early warning for natural disaster reduction is both an issue of sustainable development and a matter of environmental justice. Physical infrastructure and critical social and economic facilities must be designed to survive the natural hazards that they can be expected to experience. To this end, both new technologies and urban and rural developments must be considered for any new vulnerability that they may create with respect to natural hazards. Equally, it must be recognized that the burden of natural disasters falls disproportionately on poor populations, and particularly people in developing nations, where the loss of life from storms, floods, extreme temperatures and other disasters far exceeds that in the more industrialized countries. The livelihood of the majority of people and the economies of most of the countries in Africa, for example, are predominantly dependant on rain-fed agriculture. Either an early, or a delayed, start of the rainfall season can cause significant losses to farmers and threaten a country’s food security.

This problem is, of course, not restricted to Africa. There is additional concern among many countries which face major disasters, that catastrophic effects on food and water supplies, the overall economy or the social fabric can constitute a threat to national stability. It should also be recognized that burgeoning populations and expanding megacities in developing countries are, in many instances, located in areas vulnerable to hazards such as coastal flooding and storm surges which may be exacerbated by sea level rise due to climate change. For maximum impact, efforts to improve the effectiveness of early warning must focus on these and other areas of high or increasing vulnerability. Consequently, the implementation of effective early warning systems for meteorological, hydrological and other hazards is a critical priority for all societies, but particularly so, for developing nations.

Hydrometeorological Contributions to Early Warning

Hydrometeorological hazards have several unique characteristics which are particularly significant in the context of early warning. Hydrometeorological phenomena are often highly mobile and transboundary in nature and because of this, they can be regional or even global in their impacts. They are the most frequently occurring hazards and also the most extensively observed. This is due to the geographical coverage and around-the-clock capability of the observing networks established to support daily requirements of operational meteorology and hydrology. These hazards are, therefore, particularly appropriate targets for early warning enhancement efforts due to the frequency and scale of their impacts. There is also the advantage that solid global and regional frameworks of observation and predictive capabilities are already in place, and can be upgraded where necessary or appropriate.

The provision of meteorological and hydrological support to early warning is perhaps the most fundamental aspect of public weather services, (including hydrological services), that are supplied by National Meteorological and Hydrological Services (NMHS). As such, this area of activity is a high priority of the World Meteorological Organization (WMO). This support contributes to all four phases of disaster reduction:

i) **Mitigation or Prevention -** long term activities undertaken prior to impact aimed at reducing the risk of occurrence and/or the effects of a disaster.

ii) **Preparedness** - pre-disaster activities intended to increase the effectiveness of emergency response during the disaster.

iii) **Response** - activities undertaken immediately prior to and during impact or the acute phase of an event, to protect lives and property.

iv) **Recovery** - post-disaster activities undertaken in order to return affected communities to a more normal condition.

The application of climatological and hydrological knowledge to the assessment of risk, to land-use planning and to the design of structures contributes to disaster mitigation. The classical forecast and warning role, the provision of warnings of impending severe weather, extreme temperatures, droughts or floods, contributes to preparedness. Updated warnings, forecasts, observations and consultation with emergency and relief agencies contribute to the response phase. Finally, special forecasts and other advice assist recovery operations.

The preceding model also applies to drought hazards. Droughts develop from a complex interaction of factors and, in many instances, can no longer be considered to be purely climatically driven. Other factors include economic conditions, poor farming practices, inappropriate land use and water management practices, long term soil degradation, and human influences due to population expansion beyond the immediate natural environment's carrying capacity. In the case of drought, meteorology and hydrology can assist by identifying vulnerable regions and in assessing the probability of recurring droughts, considering anthropogenic factors such as land and water use practices. This contributes to planning and to the design of mitigation measures. Ongoing monitoring of the components of the hydrological cycle, along with the application of developing seasonal and inter-annual predictive capability, assists in preparedness by providing an indication of the development or likely persistence of drought situations. The development and application of indices of drought can contribute to both preparedness and response by assisting in the detection of emerging drought conditions and by providing an indication of their likely impacts. This latter linkage is essential for drought management practices and related mitigation activities.

Meteorological and hydrological monitoring and prediction programs can also be of value during droughts and in the following recovery phase. They provide scientific knowledge and established procedures enabling governments to assess the extent of consequences, possible developments, and to plan short-term recovery actions and longer term preventive or adaptive measures. Food security decision-makers, for example, require a wide range of qualitative and quantitative meteorological and hydrological information. This includes early warning information which identifies geographical areas where food security crises are likely to arise and the causes and likely severity of these crises. It extends to other types of information, notably meteorological data and weather forecasts. Such information guides decisions about food imports and exports and also substantiates international appeals for food and emergency assistance. Meteorological and hydrological information also is required to evaluate appeals for the design of relief programmes.

Non-hydrometeorological hazards

While non-hydrometeorological hazards are outside the realm of this report, natural hazards such as floods, extreme temperatures, high winds and droughts may, however, cause or exacerbate other disasters. These events include the possible risks of wildland fires, insect or locust infestation, toxic gas releases, oil spills and nuclear accidents. Countries that are heavily dependant on agriculture or pastoral economic systems can be very vulnerable to severe attacks by migratory pests that may be significantly influenced by weather conditions. Therefore, the provision of meteorological advice and products such as trajectory forecasts or advice based on dispersion modelling can represent a valuable contribution to addressing other non-hydrometeorological hazards.

II. EARLY WARNING FOR HYDROMETEOROLOGICAL HAZARDS

A Framework for Evaluation of Early Warning Capacities

Effective early warning systems for hydrometeorological hazards are based upon a number of components. These specific functions provide a logical framework against which to assess early warning capacities and to develop recommendations for improvement. Key functional components of early warning systems for meteorological and hydrological hazards, including drought, are:

- Risk Assessment, including hazard assessment and vulnerability analysis
- Hazard Detection
- Hazard Prediction
- Communications and Dissemination
- Public Awareness
- Coordination
- Post-Disaster Support

Each of these elements are examined to determine where problems or inadequacies may currently exist, and then to provide a basis for recommendations for future improvement.

Meteorological and Hydrological Infrastructure

Substantial national and international hydrometeorological infrastructures have been developed to address the daily requirements of operational weather forecasting and to meet related needs for observational data. These include the many requirements for climatological and hydrological data and databases. Observational networks, prediction centres and telecommunications systems are standard components of existing hydrometeorological infrastructure and they relate directly to the functional elements of the early warning framework. At the global level, WMO's World Weather Watch (WWW), with its integral telecommunication systems and common observational protocols and terminology, comprises the global collection, analysis and distribution of weather observations, forecasts and warnings.

The three components of the WWW are the Global Observing System (GOS) which provides the observed data needed for meteorological services, the Global Telecommunications System (GTS) which relays observations, forecasts and other products and the Global Data Processing System (GDPS) which produces weather analyses, forecasts and other guidance. The WWW is, in reality, comprised of coordinated national systems, each operated by a sovereign government.

The WWW supports other weather, climate and hydrological programmes of WMO such as the World Climate Programme (WCP), the Tropical Cyclone Programme (TCP) and the Hydrology and Water Resources Programme (HWRP). The WCP attempts to ensure access to reliable climate data, research and applications. It utilizes climate models, forecasts and strategies to mitigate potentially adverse effects of climate such as droughts and to support sustainable development activities. The TCP facilitates the provision of advisories, forecasts and warnings regarding tropical storms and hurricanes. The HWRP facilitates and supports a world-wide network of flood forecasting systems operated by national hydrology agencies, along with associated water management and research activities.

The UNESCO International Hydrological Programme (IHP) complements WMO's Operational Hydrology Programme through its focus on improving knowledge of hydrological processes, methodologies for water resources assessment and management and national capacities in related areas. The WMO programme assists countries, particularly those in vulnerable or drought-prone environments, in upgrading their hydrological forecast and warning services. UNESCO together with WMO assists countries to implement sustainable water management practices.

The WWW system also lends support to other agencies engaged in hazard warning through the GTS and Regional Specialized Meteorological Centres (RSMC's). These agencies include International Civil Aviation Organization (ICAO) for volcanic eruptions, UNESCO's Inter-Governmental Oceanographic Commission (IOC) for tsunamis and the International Atomic Energy Agency (IAEA) for nuclear accidents.

Drought

Hydrometeorological infrastructure which is directly relevant to early warning for drought includes the individual and collective capacities of NMHSs and the WWW system along with WCP and IHP contributions. Infrastructure relevant to addressing drought also encompasses the broad institutional capacities and services of a number of major international organizations. These involve the activities of the Food and Agriculture Organization's Global Information and Early Warning System on Food and Agriculture (FAO/GIEWS) and USAID's Famine Early Warning System (FEWS). Equally, it involves the capacities of regional groupings such as the South African Development Community (SADC) Regional and National Early Warning System in southern Africa, and the African Centre for Meteorological Applications to Development (ACMAD). In a similar vein, regional assessments and services are also provided by the WMO-UNDP Drought Monitoring Centres in Eastern and Southern Africa, the Inter-Governmental Authority on Drought and Development in north-eastern Africa, and the AGHRYMET Programme of the Inter-State Committee on Drought Control (CILSS) in the Sahel. There is also a National Drought Mitigation Center and an International Drought Information Center located at the University of Nebraska in the United States which publishes an international newsletter. Outputs from all of these programmes include drought assessments, early warnings and forecasts, that are widely circulated in their respective regions and highly regarded by various policy authorities concerned with agriculture, food security, water requirements and national development issues.

Risk Assessment including Hazard Assessment and Vulnerability Analysis

Disasters happen when a meteorological or hydrological phenomenon of great severity or, in the case of drought, a climate anomaly of unusual areal extent or duration, strikes a vulnerable region. Hazard assessment involves determining the probability of occurrence of such phenomena from observational records and assessing their likely areal extent, duration and intensity. Vulnerability analysis includes mapping areas likely to be affected by hazards, such as areas which may suffer inundation from tropical cyclones and floods, and determining the potential for loss of life and damage to property. In the latter case, it is important that regular review and updating of these analyses is undertaken to capture changes in land use and population which may increase vulnerability.

Risk assessment uses estimates of hazard and vulnerability to determine the likely impact. As emphasized in the Yokohama Strategy and Plan of Action for a Safer World, risk assessment is a required step for the adoption of adequate and successful disaster reduction policies and measures. Consequently, it is an essential component of any well-designed early warning or disaster management plan. Effective early warning includes knowledge gleaned from hazard assessments and vulnerability analyses that is then incorporated into land use planning and structural design. This requires that local, and national political leaders, along with professionals in urban and rural planning, design engineering and related fields, are sensitized to the substantial contribution which risk assessment can make to disaster mitigation. Equally, these individuals and groups need to have ready access to these risk assessments during planning and design activities and to have confidence in the value of the techniques.

Present Realities - Overall Consideration of Risk Assessment

The exposure of people and property to cyclones, storm surges and other phenomena is increasing steadily as a result of economic growth. There has been an inexorable accumulation of wealth, investment, infrastructure and population within inland flood plains and along coastal zones and barrier islands subject to storm surges and coastal flooding, in both developing and developed regions of the globe. Even in societies where town and country planning systems and controls are well established, development trends during the past 50 years have clearly demonstrated increased occupation and a massive rise in loss potential in these vulnerable regions.

Factors contributing to this situation have been a lack of high quality flood plain and flood zone mapping that is trusted by planners, perhaps resulting, in part, from poor communication between flood agencies and town and country planners. In many areas a division of responsibility between water agencies and local planning authorities, or a general bias in favour of development despite the environmental consequences, are to blame. Even a general shortage of land for development can exacerbate these problems. Policy issues also contribute to these problems such as the failure to integrate hazard assessments, vulnerability analyses and flood policies into medium-term land use plans, or the short time horizons of political decision-makers. In the last few years, some success has been achieved in the United Kingdom and elsewhere in addressing these weaknesses through substantial investment in flood plain mapping, ongoing efforts to improve communication between planners and flood agencies and other measures.

To compound this situation of increased risks, in many instances, rapid urbanisation is altering the runoff regime of local rivers, thereby increasing both flood magnitudes and frequencies. This simultaneously increases the probability of flooding (ie. the exposure to the hazard) and the numbers of people and value of property which may be affected (ie. the vulnerability). Where flood mitigation activities are undertaken, they are often primarily structural in nature with little emphasis given to land use planning. Similarly, the pressures exerted by growing populations and by an emphasis on cash economies are placing increasing stress on vulnerable regions through cultivation and husbandry on marginal and drought-prone lands.

From a global perspective, the application of hazard assessment and vulnerability analysis is progressing in a patchy and uneven manner, at best. Considerable weaknesses are evident in the general assessment of meteorological and hydrological hazards, such areas as recording the extent, duration, and intensity of events, and the mapping of vulnerable zones. Yet, the ability to steer urban development away from hazard zones and efforts to encourage the adoption of hazard-resistant building standards depend upon such information. All too often, sufficient historical data simply does not exist to support risk assessment activities. In many African countries, for example, considerable improvement and expansion of meteorological observation and communications networks is required to ensure adequate coverage, collection and transmission of information at both national and regional levels.

Where floods are concerned, the general picture is similarly one of great variability. The wealthier countries in North America, Europe and elsewhere commonly have high quality, long-term, stage and discharge records for major river systems, but even technologically advanced nations often have few, if any, data for smaller catchments which may generate damaging flash floods. In developing countries, there are often substantial gaps in historical flow records even for major rivers, and data on the geographical extent of floods is highly variable in quality and extent. Historical data on hazard-zone development (ie. the number of properties located within flood zones) also appears to be lacking in most countries and this makes it difficult to assess trends in development and increases in vulnerability.

In the face of these realities, international programmes such as the World Bank and WMO-sponsored World Hydrological Cycle Observing System (WHYCOS) are encouraging countries to collect essential hydrometeorological data. Other programmes have undertaken substantial vulnerability analyses related to their particular areas of concern. The World Food Programme, for example, is currently undertaking vulnerability analyses in several African countries and in Cambodia, with further plans to extend these activities over the next few years to additional countries elsewhere in Africa and in Afghanistan, India, Bangladesh and Central America. A number of international conferences, including the 1994 United Nations World Conference on Natural Disaster Reduction held in Yokohama, Japan, have also recommended that countries give greater emphasis to their data collection and risk assessment activities. Progress, however, is still uneven. It must also be noted that current project management policies of cost recovery, payment by users, and related commercial practices mean that, in many countries, such initiatives increasingly must be sold to governments on the basis of their cost-benefit or revenue-generating potential.

Over the medium to long term, the implementation of systematic hazard assessment and vulnerability analysis must be assigned a very high priority as a component of early warning. This is because it is so fundamental to disaster reduction, to the implementation of well-directed initiatives aimed at increasing the resilience of vulnerable communities, and to avoiding other costly disaster mitigation measures. Such analysis facilitates the targeting of early warning systems for optimum benefit in terms of communities at risk. It does, however, require investment in data collection and in skills development. As noted earlier though, to be effective, it also requires genuine political commitment to implement land use planning, control over unbridled growth, and other measures based on analytical results. However, the tenuous economies in many developing countries can be a substantial obstacle to implementation since significant proportions of the population are not within a regulatory system. Consequently, ongoing efforts are necessary to educate the public, political leaders and other decision-makers regarding the social and economic benefits which can be obtained from this essential component of early warning.

Hazard Detection

The meteorological and hydrological forecasting process begins with the acquisition and analysis of observational information. All meteorological and hydrological warning systems start with detection of a hazard, or precursors to its development, and encompass observing networks and systems such as meteorological satellites, weather and climate observation stations, weather radars and river gauges. Early detection of meteorological and hydrological hazards requires that adequate observational networks and systems exist, and are able to be maintained. Equally, it requires that observational data are rapidly delivered to warning centres and that analysis and interpretation of these data is accurate and timely.

Our ability to detect many meteorological and hydrological hazards has been revolutionized by the development of remote sensing techniques. Satellite imagery has added precision to the location and tracking of tropical cyclones, hurricanes and mid-latitude storms adding continuity, expanded areal coverage and detail to the capacity provided by other systems. Satellite imagery is increasingly being applied in monitoring drought conditions through vegetation indices and other approaches. It is also used to determine the areal extent and intensity of rainfall and snowfall, define the extent of flooded and snow-covered areas and in tracking squall lines and other convective phenomena. Similarly, weather radars provide enhanced capability to identify and track smaller scale violent phenomena such as tornadoes and thunderstorms. They also have a significant value in detecting larger storms and cyclones and in defining rainfall patterns. Doppler equipped radars, in particular, have a unique capability to identify and detect precursor conditions for the development of tornadoes.

Present Realities - Overall Assessment of Hazard Detection

From an global perspective, the low density and poor quality of observing networks in some developing countries presents a substantial barrier to improving the effectiveness of early warning. Inadequate and uneven observational coverage provided by some national meteorological and hydrological networks undercuts the ability to warn of even larger-scale severe phenomena. Improvement and expansion of observation and related communication networks within Africa, parts of Asia and in other vulnerable regions is required to ensure adequate coverage, collection and transmission of information at both the national and regional levels. Even good basic meteorological and hydrological networks are generally inadequate to support early warning for small-scale phenomena such as tornadoes and flash floods where high density networks and specialised radar and other systems are necessary for hazard detection. Here, a particular issue common to all countries is the lack of adequate meteorological and hydrometric networks in small catchments from which serious flash flooding may originate. This problem is compounded by rapid development and greater urbanisation which increases vulnerability to this phenomenon, as was noted earlier.

As an additional factor, observational data from neighbouring countries often becomes essential for the detection and definition of weather-related hazards so it is vital that national policies do not inhibit the rapid cross-border transmission of observations and warnings. The free and unrestricted exchange of meteorological and hydrological data is supported and encouraged by the WMO. Unfortunately, some countries treat water resource information as an element of national security and do not easily pass this, or similar, information to their neighbours. In other countries, budgetary pressures and a current emphasis on revenue earning initiatives tend to work against the principle of free and open exchange of hydrometeorological data.

In summary, the establishment and maintenance of an efficient network of observation stations is essential to the production of accurate weather forecasts on which warnings must be based. Consequently, efforts to upgrade observational networks and their abilities to detect hazards must receive a very high priority in hazard-prone areas. This pertains particularly to those countries or areas where vulnerability is high and detection networks are poor or non-existent, or where maintenance problems have allowed their deterioration. At present, the main obstacles are costs, the limited ability of some countries to operate and maintain the required technology, the absence of a secure telecommunications infrastructure and, in some places, a simple lack of access to information and technology.

Prediction

Forecasting requirements for the issue of useful early warnings of meteorological and hydrological hazards cover a time continuum ranging from less than one hour through short and medium terms (hours to days) to seasonal and annual time scales. These requirements are tied to the spatial dimensions, speed of movement and life cycles of the individual meteorological and hydrological phenomena concerned.

The prediction of small or meso-scale hazards such as tornadoes, severe thunderstorms, squalls and flash floods requires the early detection of signatures, a near-instantaneous assessment of the threat and a rapid dissemination of warnings to the population. Forecast techniques for these hazards are still largely extrapolative, being heavily dependent on continuously updated observational information on storm movement, rainfall intensity and/or river stage from real-time networks of radars, satellites, rain and stream gauges and human spotters. The greatest difficulty in providing effective early warnings of these smaller scale hazards is the short warning lead time which is possible even in the best circumstances. As noted above, this problem is exacerbated by the fact that many vulnerable countries and regions do not yet possess advanced or costly technology such as Doppler radar and telemetry systems which are essential to the issue of tornado, flash flood and severe convective storm warnings with useful lead times.

Useful forecasts of the behaviour of larger, synoptic (or near-synoptic) scale, weather systems such as hurricanes, tropical storms and intense depressions can be prepared several days in advance. Prediction of these systems and of the phenomena associated with them is now based on knowledge of atmospheric dynamics and thermodynamics usually expressed in numerical prediction models with observations being used mainly to initialize the model runs. Only at very short forecast lead times (nowcasts) is observation-based extrapolation appropriate for these larger systems. Forecasts of associated hydrological hazards such as widespread flooding and coastal storm surges are also, increasingly, based on computer modelling. It is, however, worth noting that many existing hydrological models have been developed for design purposes and must be adjusted or tuned for use in real-time flood prediction. This requires an ability to update the models in real time as information arrives at the forecasting centre. Only recently have hydrologists acknowledged this fact and true flood forecasting models are now being developed and used in practice. Though forecasting skill for larger weather systems has been improving steadily over the years, it is still sometimes inadequate to provide optimal early warning for even larger scale severe events. In consequence, ongoing, world wide, research efforts aimed at increasing forecast accuracy for these systems have the potential to make a significant contribution to upgrading future early warning capabilities.

For drought, prediction is still heavily reliant on monitoring of observed patterns of monthly and seasonal rainfall, streamflow, reservoir and ground water levels, soil moisture and, in some regimes, snowpack. Widespread drought evolves relatively slowly when compared with other hazards and may persist for months or years and it can be difficult, if not impossible, to predict its end. During drought situations, it is difficult to implement many remedial actions and those measures which can be taken are often site and situation specific. Developing predictive skill for large geographic regions on monthly and seasonal time scales (e.g. Global Circulation Models and similar statistical techniques), however, offers promise for increasingly useful forecasts of the onset, severity and duration of drought. The potential benefits of accurate forecasts on these time scales are evidently enormous.

Present Realities - Overall Assessment of Prediction

As discussed, early warning capability for intense rainfall and flash flooding is frequently inadequate because of difficulty in forecasting convective storm behaviour and in predicting the likely response of river basins to each event. Here, the predictive state of the art requires substantial improvement and the need for costly and complex observational and telemetry technologies compound current limitations.

Many more countries now have access to satellite imagery and to numerical weather prediction products. Consequently, on a global basis, there is a steady improvement in predictive skill for synoptic scale systems on short to medium range time scales. However, there is still a local requirement to be able to interpret the outputs from numerical weather prediction models in the context of what is happening on the ground. In addition, local observations are still essential to validate and tune numerical guidance, particularly at shorter lead times, reinforcing the need for adequate observational networks.

At present, there is at best limited predictive skill where drought is concerned. As indicated earlier, this will, it is hoped, change as the accuracy of seasonal and annual weather forecasts improves. Some promising results have already been obtained on these time scales using relationships to the El Niño Southern Oscillation phenomenon. Both a lack of knowledge of the natural, long-term, climatic variability within a region and the impacts of inappropriate land use on the frequency and severity of drought. In many instances, droughts only become a concern where activities are undertaken without adequate knowledge or consideration of the natural variability of the climate within the region. Some regions such as eastern and southern Africa are already benefiting from programmes that seek to anticipate problems and mutually address drought through Drought Monitoring Centres. These Centres devote substantial human effort and equipment to mitigating the effects of droughts through the generation and dissemination of timely advisories on monitoring, assessing and predicting droughts. In Australia, farmers and other affected groups have been encouraged to recognize that droughts occur naturally and that they should implement farm management and land use practices to deal with such situations.

Where early warnings of severe hazards are concerned, it is vitally important to ensure consistency of advice to government authorities and the public. To this end, a WMO expert group has defined a meteorological warning as *the officially issued bulletin of that (severe weather) event produced by the responsible National Meteorological Service(NMS)*. This reflects the WMO view that all warnings must be issued by the responsible national Meteorological Service (or Regional Specialized Meteorological Centre (RSMC) so that there be only a single authority for hazard warnings within a given area. This concept of a single issuing authority for warnings is particularly important because, on occasion, different predictions of the behaviour of a phenomenon will be made by different forecast centres.

In some regions, hazard warnings from different sources can be accessed by local populations particularly where neighbouring countries share common languages. Even within countries, confusion sometimes arises between locally issued and centrally produced warnings such as, for example, a weather bureau warning and a local police warning issued on the basis of local observation. In addition, the Internet is beginning to pose problems as well as opportunities for early warning, as individuals in some areas have received cyclone warnings and related information from remote parts of the globe which have sometimes proven to be inaccurate. Confusion can also arise when different categorizations are used to describe the same hazard as in the case of cyclone warnings. Where national classifications may sometimes differ, there is clearly a need to address such problems.

The relative priority to be assigned to improving predictive capacity depends on considerations such as how much improvement in accuracy and lead time can be gained and what this improvement will contribute to reducing the impact of an event. The optimum combination of detection, prediction, issue and dissemination of warnings must be sought in individual circumstances. Obviously, however, this component of the warning system must receive a very high priority where the existing prediction capability is poorly developed and well below state of the art. The main obstacles to increasing the accuracy and timeliness of all forms of meteorological and hydrological prediction are lack of funding, the prevailing level of competency and training of personnel, difficulties in access to guidance from specialized centres and, for small scale hazards, the unavailability of expensive and complex technologies such as weather radars and telemetry systems.

On a global basis, a reasonable capability exists to produce meteorological and hydrological guidance and other advice concerning drought but the capabilities to use this guidance needs to be improved at the national level. Some weaknesses also exist in the ability to transfer research results and best practices into operational use. This can be due to the uneven abilities of countries to apply the information because some research is site or country-specific and not easily transferable. There may also be simple difficulties in accessing current information. To illustrate, a general finding from the EURO flood project was that even in Europe, where there is a relatively high degree of information exchanged between flood warning professionals, considerable scope remains for improved transfers of research results and best practices. The situation is undoubtedly even more difficult in many developing countries.

Communications and Dissemination

An effective communications system is a vital component of any effective warning system. Local officials and the public must first hear or see hazard warning information before they are in any position to take avoidance action.

The WMO GTS provides a primary telecommunications network for the relay of warnings, forecasts, observational data and related information within the meteorological community and to some major external users. In some instances, it also supports early warning for non-weather hazards. However, other communication systems are sometimes more appropriate for the distribution of warnings to local populations and external agencies. This applies particularly when speed is essential, where local deficiencies exist in the GTS or where rapidly developing hazards are concerned. In general, the effective dissemination of warnings to the public and local level administrators requires communication systems which have a very broad public reach, such as radio and television stations or community warning facilities. Dissemination of warnings through these external agents and facilities must, however, be carefully coordinated to ensure timeliness and accuracy. As noted, experience confirms that there must be a single official issuing authority for warnings to minimize confusion.

Present Realities - Overall Assessment of Communications and Dissemination

Early warning is still inadequate for most of the world's people due, in part, to inadequate telecommunications capabilities. Even where communications systems are well developed, they must be continuously reviewed to keep pace with technological developments. In many countries, reliance on overhead telephone and power lines and other exposed components such as satellite antennas leaves communications vulnerable to failure during high winds, ice storms and floods. Consequently, backup communications capability is essential for reliable delivery of warnings during severe conditions. In extreme circumstances, all international telecommunications may be lost, as happened in Mauritius during cyclone Hollanda in 1994. In some countries, radio and television broadcasting is increasingly being centralized. This makes it more difficult to place specific warnings on local radio and TV. In many instances, other local warning systems such as sirens, loudspeakers, a distinctive telephone ring or even door to door visits must be used to alert the population, with the result that these community based approaches to dissemination can be highly effective in some circumstances. Jamaican experience with a flood alert system shows, for example, that people have more confidence in warnings provided by fellow residents who are also at risk. It also was noted that people will evacuate more quickly for local community leaders than for government officials. Another factor that contributes to the efficacy of warnings is the value placed on historical knowledge by residents in interpreting flood warnings.

These examples illustrate the point that effective dissemination requires more than the simple relay of warning messages. The U.K. Flood Hazard Research Centre has observed that the design and operation of warning systems in the past often have been dominated by technological considerations. As a consequence, overall effectiveness sometimes is diminished by inadequate attention being paid to the dissemination stage. The performance of warning systems is often assessed primarily by using technical parameters, in contrast to those aspects more important to end users. Matters such as reductions in damage, increased personal security and increased satisfaction, sometimes are ignored. People undertaking technical evaluations can often demonstrate, and genuinely believe, that their systems are working effectively even though research with end users demonstrates that this may not be the case. Since early warning systems are only as good as their weakest link, successful hazard detection and predictions are wasted if warnings are not disseminated swiftly and communicated effectively to the people at risk. The danger of this imbalance has now been widely recognized and is, increasingly, being addressed as an integral part of warning systems.

Dissemination systems for warnings are generally well developed and fairly resilient in major industrialized countries, but this is not the case in many developing nations. In the latter, the main barriers to improvement are high cost, limited technological capacity and inadequate access to maintenance and replacement services. In Africa, for example, many countries use High Frequency (HF) communications systems which can suffer from atmospheric interference and are difficult and expensive to maintain. Among other problems, many trained technicians are being recruited by other organisations or commercial interests which can pay them more. Clearly, achievement of overall improvement in early warning capacity requires that local and national communications systems must be able to provide rapid, reliable and consistent dissemination of warnings to threatened populations. This will require substantial capacity-building efforts directed towards installation of reliable and robust telecommunications networks within a number of developing countries and the training of local personnel to operate and maintain them.

Public Awareness and Understanding

As implied earlier, communication is more than simply the dissemination of facts, as it is effective only after information has been received and understood. Consequently, effective early warning requires that the target population not only receives advance warning of hazards, but also that they understand the content of the message, believe it and then know how to react to it. This suggests that well-designed early warning programmes must include an on-going public awareness component about potential risks. Equally, key decision-makers should be sensitized to develop a broader appreciation of the multiple roles involved in successful early warning programmes.

Present Realities - Overall Assessment of Public Awareness and Understanding

Public awareness and understanding is often weak in communities where severe events are relatively infrequent with much higher levels of awareness and understanding in evidence where events are frequent, learning has been lengthy and cultural adaptations have evolved. Among observed weaknesses are poor understanding of natural processes and of the impacts of human actions such as development which will heighten risk. This can be compounded by poor judgement regarding the magnitude and frequency of hazardous events. For example, a high awareness of flood hazards has been noted among people living in frequently flooded areas along rivers and coasts in Peninsular Malaysia. In contrast, in Mauritius where severe cyclones are relatively infrequent, occurring on average only about every 15 years, the population becomes de-sensitized to extreme conditions and an entire generation can grow up without knowing what to expect in a really severe event.

From an overall perspective, public awareness and understanding merits constant attention and substantial commitment of resources as a very critical component of early warning. While low levels of literacy and educational attainment can create barriers to increased public awareness and understanding of hazards and vulnerabilities, these are compounded, in some instances, by the dominance of overly technocratic perspectives among specialist early warning staff. The relative priority to be assigned to developing public awareness and understanding will, of course, vary with individual circumstances such as the pre-existing knowledge levels and the frequency of hazardous events. One of the major challenges in implementing any effective early warning programme is motivating people to respond in an appropriate manner, since people under threat react in different ways. A further difficulty is that informed advice on when to take specific avoidance action is often not available due to lack of observed data. An example of this is knowing when a particular area should be evacuated before roads are cut by rising water. Many of the current problems in public awareness and understanding are most evident at local or individual levels, and are among the most difficult to address. This is where hazard assessment and vulnerability analysis have a vital role to play.

Coordination

A high degree of coordination must exist within the hazards community during anticipated or actual disasters and in the period following their occurrence. For maximum effectiveness, early warning systems need to be linked to organizations responsible for response actions. This holds true at all levels of administrative levels of responsibility. At local and national levels, coordination is usually achieved through committee structures orchestrated and supported by a municipal agency or lead government department which are able to draw upon the resources and expertise of other organizations and individuals. A key to success is the involvement of the local population and strong support for the coordinator by the local political leadership.

Where meteorological and hydrological hazards are concerned, National Meteorological and Hydrological Services (NMHSs) must be actively involved in inter-agency disaster planning to ensure a regular flow of reliable and authoritative warning information to the public, political leaders, responsible officials and affected institutions. It is also essential that effective coordination is established between neighbouring NMHSs and with private sector players and the media. Coordination with the media must be given a particularly high priority since the public media are a vital element in dissemination of warnings and in increasing public awareness of hazards and of mitigation measures. In some situations, coordination with international broadcasters also assumes great importance as their networks disseminate hazard warnings on a world-wide basis.

Present Realities - Overall Assessment of Coordination

In essence, the whole early warning system depends on getting the right information, to the right people at the right time to enable them to take appropriate avoidance or preventive actions. Maintaining communication and coordination can present a significant challenge because the functions of early warning often cross several levels of government authority (eg. national, state, provincial or local). Inter-organizational coordination may sometimes be ineffective because of communication problems due to differing, and sometimes conflicting, organizational structures, sub-cultures, expectations and even rivalries. Poor communication can contribute to weakness in decision-making. There is a growing sensitivity to understand the needs of disaster response agencies and officials in contrast to previous outlooks which were sometimes based upon a perception of what was thought to be needed rather than upon an actual identification of needs. In addition, situations have been identified where long-established hazard warning systems have failed to adapt to changing requirements. Such an example, is the case of systems designed for a predominantly agricultural economy, but which are currently being used in a rapidly industrializing one with a tourist industry.

Inadequate coordination leading to confusion with respect to flood warnings sometimes occurs between countries, between states within the same country, and even between different agencies within a state due to differing conventions or confused responsibilities. Different jurisdictional arrangements within countries which share the same river system or climatic region can stand in the way of effective coordination. Confusion between countries can be a problem observed in parts of Europe even where a long history of cross border cooperation in flood mitigation and preparedness exists. Experience suggests that these problems can be even more likely to arise in locations where historical antagonisms or differing government practices exist between neighbouring states.

As emphasized earlier, coordination with the media must always receive a high priority since the distribution of warning messages is, in most countries, largely through media broadcasts. In the best situations, NMHSs have fully recognized the importance of embracing the media's assistance in raising awareness, increasing knowledge of warning procedures and appropriate mitigation and response actions as well as for the dissemination of warnings. In the worst cases, there can be a lack of developed familiarity between warning services and the media. A recent compounding difficulty is that emphasis on marketable (priced) weather services in a number of countries appears to be inhibiting the exchange of some information, such as satellite images, which can be particularly effective in raising public awareness. Rivalries concerning on the on-air dissemination of warning information between professional media presenters and NMHS staff, or between NMHS staff and private meteorologists employed by television and radio stations, have also been identified as posing possible obstacles to the achievement of effective partnerships with media outlets. Clearly, these problems need to be identified and constantly addressed where they exist. In some countries and regions where international television weather broadcasts are received, international coordination is also required to ensure consistency of internationally broadcast information with locally issued warnings.

As with other elements of early warning, the relative priority which should be assigned to improving coordination is dependent on the current situation in the country or region in question. Suffice it to say that effective early warning requires the closest possible collaboration and partnership between all members of the hazards community and that the maintenance of coordination must be an ongoing concern for all NMHSs and emergency agencies. This is an area which requires continuous efforts by all concerned parties to ensure that early warning systems function as effectively as possible.

Post Disaster Support

The days immediately following a severe weather or flood disaster can be very hazardous due to swollen rivers, weakened structures, threat of disease and weather conditions which may impede immediate emergency actions. Inclement weather or high water can delay recovery efforts or pose a major threat where adequate shelter, food, water and communications are lacking. In the case of drought, the time frame of the critical post-disaster period is substantially longer and efforts at recovery and re-establishment of affected communities often face even greater challenges.

Useful meteorological and hydrological support after a disaster includes continuing forecasts and the provision of related advice to emergency managers and the public on meteorological and hydrological phenomena, often under adverse conditions. Post-disaster assessments of severe events are of particular value in improving the performance of early warning systems, providing important lessons regarding the dissemination of warnings, the overall management of preparedness and response and public awareness. These assessments can provide additional inputs for hazard and vulnerability analyses and contribute observational data which may assist in improving observing algorithms. Feedback from post disaster assessments is an essential component of the learning process through which more effective early warning capability is developed for future applications.

Present Realities - Overall Assessment of Post Disaster Support

It is clearly vital that forecasting/warning/dissemination systems continue to function after a disaster occurs, even when they may have been degraded due to disrupted data input, or loss of power and telecommunications infrastructure. Doubts have been expressed as to whether sufficient planning and preparation has been undertaken to address this requirement in a number of vulnerable countries. The importance of effective coordination between all members of the hazards community also comes into sharp focus during the period following a disaster. At this stage, there is a particularly critical need for close coordination within and between levels of government, and among communities, commercial interests and the media to ensure that recovery actions are pursued in an efficient and coherent manner.

As with other aspects of early warning, one commonly observed weakness is a lack of resources to undertake post-disaster assessments in the face of the costs and priorities associated with cleaning up after an event, despite the importance of these assessments in developing improved early warning capability for the future. A more technical weakness is a lack of a reliable methodology for readily assessing the impacts that might have occurred if warnings had been either better or worse. Overall, however, some encouraging signs are evident in that preparedness planning is becoming more common and analysis of post-disaster conditions more routine. This progress may reflect the effect of training programs and needs to be reinforced as an ongoing priority.

Infrastructure Capacity-Building

Capacity building initiatives must result in permanent increases in early warning capabilities at local, national and global levels if the IDNDR Early Warning Programme objectives are to be achieved. The key to successful capacity building is to target assistance to areas which are most vulnerable and where needs are currently greatest ensuring that these efforts result in locally sustainable improvements. Effective hydrometeorological early warning systems require:

i) easy access through reliable communications to observed data from adequate local, national and global observation networks;

ii) state-of-the-art domestic predictive capability linked to guidance from specialized regional and global centres;

iii) effective local and national warning dissemination systems capable of alerting threatened populations at all hours;

iv) that populations at risk be educated regarding the content of warning messages and know how to react to them;

v) solid emergency response planning with evident coordination between all agencies involved in hazard warning, mitigation, preparedness and response roles.

Even for a basic level of reliability and effectiveness, early warning functions need to be linked to regularly updated hazard and vulnerability assessment programmes within a coherent and comprehensive disaster management strategy. Ongoing, political support for these commitments are essential if early warning systems are to have their desired effects.

Target areas for meteorological and hydrological capacity-building follow logically from these requirements. Provision of training in risk assessment, preparedness planning, approaches to improved coordination and the exercise and management of preparedness plans are necessary. Equally, the success of early warning efforts is dependent on the provision of resources to acquire, install and maintain adequate technological monitoring and telecommunications systems. When technological systems fail, it is essential that skilled personnel are available immediately to restore the systems. On-going training of forecasting staff contributes to improved predictive capacities. Training is particularly effective when it is combined with enhanced access to data networks and guidance from specialized centres based on the latest forecasting techniques. Equally, training in the design and content of warning messages for greater impact and clarity can make a significant contribution, especially when reinforced by the development of improved public relations and communications skills among staff who must interact with the public. Enhancing media relations capability can be notably effective in gaining better distribution of warnings, as can an increased emphasis on partnerships with telephone systems, public security agencies, amateur radio operators and others. The encouragement of mutual understanding between scientists, media staff, political decision-makers and others can also contribute significantly to long term warning effectiveness. Finally, capacity building initiatives can also assist in the area of public awareness and public education programs with long lasting effects.

Present Realities - Overall Assessment of Infrastructure Capacity-Building

An early warning system is an integrated system and all components must be given attention if the total system is to function efficiently. Clearly, it is impossible to generalize about the most critical weaknesses which exist in early warning capacities at national and local levels. Within specific countries and regions, some aspects will be less developed than others. Small Island Developing States, for example, have specific local problems which may not fit into the more global picture and the solutions required may be individual in nature. In each situation, capacity building efforts should first target the weakest component or components with particular emphasis on the most vulnerable areas and communities. It is important, therefore, that individual governments, with the support of regional or international technical assistance agencies, place an initial priority on determining where vulnerability is most pronounced, and where shortcomings exist in their domestic early warning capacities. Then, a sustained commitment is necessary to develop prioritized plans and progressively to implement capacity-building initiatives to remedy those weaknesses.

From the earlier discussion, it is evident that basic observing networks, telecommunications systems and predictive capability must be adequate to produce and disseminate accurate and timely hazard warnings if any organized early warning capacity is to exist. The infrastructure for hydrometeorological hazard warnings has global, regional and national components under the umbrella of the WWW, HWRP and related programmes. Global and regional components are in place and functioning reasonably effectively and are supported by strong and well-established intergovernmental organizations which exist to coordinate and facilitate their operations. These structures and systems provide a solid base for further development of capabilities at national levels where substantial needs exist for improvements in early warning capacity. As re-iterated throughout this report, basic meteorological and hydrological infrastructure requires considerable strengthening in many developing countries, particularly in Africa, and parts of Asia and South America and in some small island states in the Pacific and Indian Oceans and the Caribbean.

The transfer of technology is inevitably an important component of capacity building efforts, notably in telecommunications, observing and prediction programs. Establishing reliable telecommunications for access to national and global data networks and for the dissemination of warnings and other products is a challenge for nations with limited resources. It is particularly difficult for spatially diffuse island nations and for developing countries in Africa and elsewhere which have suffered from extended periods of political turmoil. Technological assistance, however, needs to be selective to ensure that it truly provides added value and is sustainable. Advanced technologies often bring recurring costs and substantial maintenance requirements and enhancing locally familiar means of communications or using manual approaches to observational programs may sometimes be more effective and sustainable in the long term. At the same time, it must always be remembered that timely warnings for tornadoes and flash floods are only possible with the aid of advanced technologies. Where these hazards present a substantial threat, the establishment of effective early warning capability will require investment in state-of-the-art technology and the development of human skills to maintain and use these systems.

Efforts to improve communication with threatened populations, and to promote a generally higher level of public understanding about hazards have not always received an emphasis equivalent to the more technical and scientific aspects of early warning. Where this holds true, training efforts for early warning staff need to be broadened to include human relations, consultative and communication skills as well as technical and scientific subjects. Efforts which facilitate the transfer of research results and best practices need to encompass both detection and prediction of hazards as well as the social sciences, and areas of human behaviour. While basic observational and prediction systems, including telecommunication networks and modelling capabilities, are legitimate fields for enhanced capabilities, attention also needs to be paid to developing an informed and more aware public. This will necessarily involve consulting with those people most affected by hazardous events and working to establish genuine partnerships with them.

Virtually all early warning programmes coordinated by UN agencies contribute to national or sectoral capacity-building. More broadly, the United Nations Development Programme can support capacity-building in areas such as improved information management, training, preparedness and operational planning. Where meteorological and hydrological hazards including drought are concerned, the training and assistance programmes of WMO and the corresponding programmes of UNESCO's IHP are directly applicable. The WMO Education and Training Programme includes four inter-dependent components, Manpower Development, Training Activities, Education and Training Fellowships, and Support to Training Events. Together, these elements contribute to capacity-building on a continuing basis. The IHP places emphasis on technology transfer through research and development projects combined with field training in different regions, postgraduate hydrology courses for participants from developing countries, computer-assisted learning materials and distance-learning techniques. Substantial progress has been made also in developing hydrological methodologies and in training and education in the water sciences since its inception.

Another WMO initiative, the System for Technology Exchange for Natural Disasters (STEND) is being developed as a contribution to the IDNDR, and holds particular relevance. This programme aims to provide the technology needed for risk assessment, forecasting, warning systems and counter-measures. It builds upon experience gained by WMO since 1981 in operating its HOMS (Hydrological Operational Multipurpose System) programme for transfer of technology in operational hydrology and offers a well-focused mechanism through which to assist in upgrading national early warning capacities. Current IHP plans to prepare information packages to increase public awareness in developing countries are equally promising for involving a greater public involvement in the early warning context.

III. RECOMMENDATIONS

General Observations

The Working Group was asked to develop forward looking recommendations for actions, initiatives and projects which will improve meteorological and hydrological early warning capacities, with particular emphasis on developing countries and on solidifying such improvements for the 21st century. At the most basic level, the critical issues from the Working Group's perspective relate to:

- **Capacity-building**, at local and national levels
- **Improving coordination of early warning**, at local, national and regional levels and globally within the United Nations system.

The achievement of necessary improvements in these two fundamental areas of capacity- building and coordination will increase the overall early warning effectiveness of communities, national governments and international institutions. Working Group recommendations are, therefore, listed under the two critical issues.

Building Local and National Capacities

Some NMHSs in developing countries are facing nearly impossible challenges in providing effective early warnings for meteorological and hydrological hazards due to major shortcomings in their observing networks, telecommunications systems and predictive capabilities. As emphasized earlier, the development of adequate national capacities in such countries is the key to effecting overall improvement in early warning capacity on a world wide basis. Consequently, the highest priority should be assigned to the development of local and national capacities to warn of meteorological and hydrological hazards including drought. To build capacities at the local and national level, the Working Group recommends the following activities:

i) **National governments, National Meteorological and Hydrological Services and Drought Monitoring agencies in vulnerable regions undertake urgent reviews of their early warning capacities**. These reviews should examine:

- the adequacy of their national meteorological and hydrological observing networks;

- the adequacy of their telecommunications systems to deliver timely hazard warnings including the degree of redundancy of those systems;

- the adequacy of their predictive capability including linkages to specialized regional centres;

- the adequacy of their access to current scientific developments with respect to early warning;

- the extent to which hazard warnings are already received by the target population in a timely manner and in a form which is recognized by them to be appropriate and useful;

- the degree to which their people are knowledgeable regarding meteorological and hydrological hazards, the availability and content of hazard warnings and appropriate preparedness and response actions;

- the effectiveness of coordination between all parties involved in early warning for meteorological and hydrological hazards including droughts;

- the adequacy of disaster planning at local and national levels;

- the degree to which risk assessment is being used to support mitigation and response planning and to direct development away from high risk zones;

- the adequacy of emergency planning and management at local and national levels including the degree of involvement of local communities and people in the development, exercise and implementation of emergency plans;

- relationships with domestic broadcast and print media, and, where appropriate, with international broadcasters.

The IDNDR Secretariat, WMO and other international agencies should encourage and assist in these reviews. The WMO-UNESCO publication "Water Resources Assessment, Handbook for Review of National Capabilities" outlines an approach to the assessment of national capabilities which might be expanded for broader application to the assessment of national early warning capacities.

ii) Results of such reviews should be used as a basis for the development of national Strategic Plans to remedy identified weaknesses in local and national early warning programmes.

National governments, National Meteorological and Hydrological Services and Drought Monitoring authorities should place a high priority on implementing these plans and on designating sufficient funds to maintain the improved early warning capacity.

WMO, UNESCO's IHP and other international agencies and donor countries should continue to provide advice, assistance, training and other forms of support in the development and implementation of these plans through mechanisms such as UNDP, WMO VCP, STEND, HOMS and bilateral technical assistance programmes.

iii) Nations vulnerable to drought should continue to place a high priority on the development and maintenance of Drought Monitoring and Prediction Systems, Drought Monitoring Centres and related activities.

This would include the increased dissemination of regional drought indices, sustained public education campaigns, the enhancement of telecommunications facilities and other elements of early warning infrastructure.

iv) Donor countries and international agencies should continue to assist governments and NMHSs to develop their national capacities

This may be accomplished by means of training and human resources development programmes, the provision of technological assistance, by encouraging research about local conditions, by facilitating greater access to research results developed elsewhere and by implementing early warning demonstration projects. It is equally important for there to be increased opportunities for recognized scientific and technical experience to become more involved in the determination of policy and decision-making processes that shape hazard monitoring and disaster prevention activities.

Building Global Capacities

The global contribution to early warning for meteorological and hydrological hazards including drought is, with limited exceptions, to facilitate early warning operations at national and local levels. As outlined earlier, the ongoing, daily requirements of operational meteorology for data, forecasts and other information have resulted in the evolution of the World Weather Watch system. The WWW is a reliable, well-proven and effective system for the generation and international relay of early warning information on hydrometeorological hazards. Since the WWW integrates national, regional and global observational and communications networks and processing centres, its regional components reflect the strengths and weaknesses of domestic capacities within any individual region. Where meteorological and hydrological hazards are concerned, the primary focus must, therefore, be on upgrading national capacities where the highest priority needs exist as this will contribute directly to improving overall hydrometeorological early warning capacity at the regional and global levels. Consequently, the Working Group recommends that:

i) The responsible international organizations undertake regular reviews of global and regional early warning capacities within their individual and collective areas of responsibility and utilize those results to develop or update plans for overall improvements in warning capacity. Where possible, these reviews should, be based on existing in-house information. For meteorological and hydrological hazards including drought, the reviews should examine:

- the effectiveness of existing coordination mechanisms among international agencies, together with, and between, individual NMHS;

- the effectiveness of international telecommunications infrastructure for the timely relay of warnings and data to threatened populations, to national institutions responsible for domestic warning programs and to international humanitarian and emergency assistance agencies;

- the adequacy of internationally coordinated observational networks (eg. weather and ocean satellites, radiosonde and data buoy networks, etc.) to support early warning programs;

- the roles, responsibilities and operational performance of specialized warning centres (such as WMO's Regional Specialized Meteorological Centres (RSMCs) and UNDP-WMO Drought Monitoring Centres) to ensure that these centres are effective in responding to the early warning needs of national governments and populations within their respective areas of responsibility;

- international training and technical assistance programmes such as those of UNDP, WMO's VCP, STEND and HOMS and UNESCO's IHP and others to ensure that these are targeting the areas of highest priority from an early warning perspective.

ii) **For the same purpose, surveys should be undertaken with governments and institutions in regions affected by drought to determine the status of their early warning systems for drought and their experiences with these systems**. These surveys should:

- identify the types of climatic or drought indices currently in use, their reliability and the extent to which these indices are used as triggers for drought management and related actions able to reduce the consequences of the event;

- determine to what extent early warning systems are integrated into existing drought management plans and sustained mitigation programmes at the country level;

- determine how widespread the use of remote sensing data is as a component of early warning systems for drought, and to what degree the reliability or success of these remote sensing programmes serve as a beneficial component of early warning practices.

Related Issues for Building Capacities

During the preparation of this report additional global or international issues were identified. While these issues are, in general, being actively pursued by the relevant organizations and agencies, the Working Group wishes to reinforce their importance. Consequently, the Working Group recommends that:

i) **Efforts should continue to improve global weather satellite programmes to ensure satellite coverage of all areas vulnerable to severe meteorological and hydrological phenomena and drought.** This has now become possible since remote sensing from meteorological satellites has revolutionized the detection of a broad range of these hazards.

ii) **WMO and agencies involved in early warning for non-hydrometeorological hazards should examine jointly the potential, collective use of the Global Telecommunications System (GTS) as a possible means for international relaying of warnings for all forms of natural and related hazards.**

iii) **Efforts should continue to utilize the Internet in support of early warning.** These efforts should address its capability to provide easy access to training materials, for specialized advice or technical assistance, and to obtain recent research results. Its potential should also be examined as a supplemental telecommunications system for the international relay of early warning information.

iv) **Efforts should continue to ensure that warnings of droughts, widespread floods, cyclones and other hazards likely to require international action are forwarded rapidly to international humanitarian agencies and emergency relief organizations as an ongoing operational practice.**

v) **International agencies, in collaboration with donor countries, national governments and private sector partners, should continue efforts to establish and implement early warning demonstration projects for hydrometeorological hazards and drought in vulnerable regions.** Pilot projects can demonstrate technologies, approaches and techniques related to all aspects of effective early warning including monitoring, prediction, communications, public awareness, education and response.

vi) **International training and development programs for early warning of meteorological and hydrological hazards including drought should continue to be given a very high priority by WMO, UNESCO's-IHP, other agencies and donor countries.** These programs should be reviewed to ensure that they incorporate the concepts and issues raised in this report and that they are focused on countries and regions where the needs are greatest.

vii) **Research aimed at improving predictive capability on all time scales should continue to be encouraged and supported by WMO, UNESCO's-IHP, NMHSs and others.** Particular emphasis should be placed on critical areas such as medium and long term prediction of cyclones, floods, extreme temperatures and drought, and the very short range prediction relevant to tornadoes, severe thunderstorms and flash flooding.

Improving Coordination at Local and National Levels

In its Strategy for the Year 2000 and beyond, the 1994 World Conference on Natural Disaster Reduction (Yokohama, Japan) emphasized the need for governments to adopt policies of national self-reliance and to increase their emphasis on coordination and cooperation at regional, national and community levels to save lives and protect property. To these ends, the Working Group recommends that national authorities should take steps to ensure that:

i) **Planning for the prevention and mitigation of meteorological and hydrological disasters is given a high priority** in order to achieve optimum early warning capability within their national territories.

ii) **Appropriate mechanisms such as disaster reduction planning committees and comprehensive national disaster management policies are created to facilitate coordination and partnership** between domestic agencies including NMHSs, officials, political leaders, local communities, the media, commercial interests, and others involved in early warning, preparation, and response to disasters.

iii) **Effective liaison is established between governments and agencies in neighbouring countries to address issues related to cross-border, or regional, hazards**. These may include means to facilitate timely cross-border relay of warnings and observational data, as well as arrangements to encourage improved bilateral or regional coordination of early warning efforts.

iv) **Coordination with domestic and, where required, international media should be a high priority** to achieve timely and accurate distribution of official meteorological and hydrological warnings and drought advisories. Such relationships would also encourage a greater participation of the media in public awareness and education initiatives.

Improving Global Coordination

The 1994 World Conference on Natural Disaster Reduction also drew attention to the need to strengthen international coordination and cooperation in early warning activities, while emphasizing the sovereign responsibility of each country to protect its citizens.

It has, subsequently, been suggested that development of internationally agreed guiding principles for early warning could be helpful in facilitating international cooperation and coordination. Experience in areas of successful international cooperation such as aviation, maritime transportation and meteorology suggests that adoption of an "open architecture" approach can be valuable in generating acceptance of the need for an agreed set of principles to facilitate international cooperation and coordination. This approach is built upon the idea of cooperation for mutual benefit and on utilizing national infrastructures, systems and processes to the greatest possible extent.

This view brings into focus the need for some minimum set of standards, protocols and nomenclature sufficient to facilitate international communication and coordination between national systems or, in other words, for a set of guiding principles. They may be used to form the basis of common criteria for multiple assessments, or as an indication of priority planning requirements based on the needs of individual countries. When adopted, such an approach also leads to a generally recognized requirement for a coordinating mechanism, that could be comprised of a forum of country representatives supported by a secretariat. In practice, such an international coordination mechanism could vary widely in size, ranging from a modest panel of representatives from interested countries, supported by a one person secretariat seconded from a larger organization or donor country, to what could be a departmental function accommodated within an existing UN agency’s mandated responsibilities.

The Working Group considers that most of the operational aspects of early warning could benefit from the existence of an internationally agreed set of Guiding Principles and suggests, therefore, that **Guiding Principles for Early Warning** should be developed to assist in clarifying objectives, responsibilities, roles, procedures and standards and to facilitate communication and understanding. These Guiding Principles should, logically, build upon the Principles contained in the Yokohama Strategy and Plan of Action.

Looking ahead to the future needs of global early warning, the Working Group believes that some form of international early warning forum would be valuable in facilitating coordination between countries and with the various international organizations involved. The Working Group, therefore, suggests that an **International Hazard (or Early) Warning Panel** might be established, comprised of representatives from interested countries and international organizations and supported by a modest secretariat. This panel could draw together the many institutional players engaged in various facets of early warning at the global level to promote a more focused and coordinated approach. The secretariat could be charged with maintaining ongoing coordination and liaison with international agencies, facilitating the development of plans for systematic upgrading of global early warning capacities, and resolving difficulties at the international level. Essentially, it would provide an established forum to concentrate on the collective interests for improved early warning, and therefore could be able to act as a focal point for information and access to better coordinated technical assistance programmes.

IV. REFERENCES

BUREAU OF METEOROLOGY AND AUSTRALIAN EMERGENCY MANAGEMENT INSTITUTE (1993): Guidelines for Effective Warning, 5 pp.

EMERGENCY MANAGEMENT AUSTRALIA (1995): Flood Warning: An Australian Guide, 47 pp.

UNITED NATIONS (1995): Yokohama Strategy and Plan of Action for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation: World Conference on Natural Disaster Reduction, Yokohama, Japan, 23 - 27 May 1994, 22 pp.

UNITED STATES NATIONAL SCIENCE AND TECHNOLOGY COUNCIL, SUBCOMMITTEE ON NATURAL DISASTER REDUCTION (1996): Natural Disaster Reduction: A Plan for the Nation, 50 pp.

WORLD METEOROLOGICAL ORGANIZATION (1997): World Weather Watch: Eighteenth Status Report on Implementation, WMO - No.855, 73 pp.

WORLD METEOROLOGICAL ORGANIZATION (1997): Mobilizing Resources for Technical Cooperation: The WMO strategy for the development of national Meteorological and Hydrological Services in support of sustainable development, WMO - No.863, 24 pp.

WORLD METEOROLOGICAL ORGANIZATION (1996): Guide to Public Weather Services Practices, WMO - No.834, 106 pp.

V. LIST OF CONTRIBUTORS

The contributors to the report of the Working Group on Early Warning for Hydrometeorological Hazards including Drought are listed below:

Dr. Desmond O'Neill (Convenor, and Author)
Consultant to World Weather Watch Department of WMO
c/o Donmec Consulting Inc.
110 Johnson Crescent, Lower Sackville. NS. B4C 3A5, Canada
Tel: 1-902-865-7208, Fax: 1-902-864-2919, E-mail: oneilld@ns.sympatico.ca

Ms. Haleh Kootval
Chief, Public Weather Services and Operational Information
World Weather Watch Department, World Meteorological Organization
P.O. Box No. 2300, Ch-1211 Geneva 2, Switzerland.
Tel: 41-22-730-8111, Fax: 41-22-734-2326, E-mail: hkootval@www.wmo.ch

Mr. Kevin O'Loughlin
Director, Bureau of Meteorology (Victoria)
P.O.Box 1636M, Melbourne, VIC, Australia 3001
Tel: 61-3-9669 4968, Fax: 61-3-9669 4964, E-mail: k.oloughlin@bom.gov.au

Mr. E. Mukolwe
Director, Kenya Meteorological Department
Ngong Road, Dagoretti Corner, P.O.Box 30259, Nairobi, Kenya
Tel: 254-256-7880, Fax: 254-256-7889, E-mail: evans.mukolwe@lion.meteo.go.ke

Dr. William Hooke
Director, Weather Prediction Research Program,
NOAA/ERL, 1325 East-West Highway
Silver Spring , Maryland 20910 USA.
Tel: 1-301-713-0460 x218, Fax: 1-301-713-11459, E-mail: william.hooke@noaa.gov

Mr. Basil Fernandez
Managing Director, Water Resources Authority,
Hope Gardens, P.O.Box 9, Kingston 7, Jamaica
Tel: 809-927-1878, Fax: 809-977-0179, E-mail: basric@infochan.com

Dr. Don Wilhite
Director, National Drought Mitigation Center,
International Drought Information Center,
University of Nebraska,
241 L.W.Chase Hall, Lincoln NE 68583-0728, USA
Tel: 1-402-472-4270, Fax: 1-402-472-6614,
E-mail: dwilhite@enso.unl.edu

Professor Dennis Parker
Director, Flood Hazard Research Centre
School of Geography and Environmental Management, Middlesex University
Queensway, Enfield, Middlesex EN3 4SF, U.K.
Tel: 44-181-362-5000, Direct 44-181-3625515, Fax: 44-181-362-6538
E-mail: D.Parker@mdx.ac.uk
Professor Jiao Desheng
Ministry of Water Resources
P.O.Box 2905, Beijing 100053 CHINA
Tel: 861-06 6320-2621, Fax: 861-06 6320-2978

Mr B.J. Garanganga,
Coordinator, Drought Monitoring Centre
Southern Africa Regional and Drought Early Warning System
Harare, Zimbabwe
Fax: 263-477-4890, E-mail: zimmeteo@harare.iafrica.com

Mr B. Stewart
Superintendent Hydrology, Hydrology Unit, Bureau of Meteorology
GPO Box 1289 K, Melbourne, Victoria 3001, AUSTRALIA
Tel: 613-9669-4522, Fax: 613-9669-4725,
E-mail: b.stewart@bom.gov.au

Mr. Edward M. Gross
Edward M. Gross & Associates
11612 West Hill Drive, North Bethesda MD, 20852, USA
Tel: 1-301-984-1518, E-mail: egross@erols.com

Dr. Liu Heng
Assistant Director/Senior Engineer, Nanjing Institute of Hydrology and
Water Resources, 1 Xikang Road, Nanjing 210024, China
Tel: 86-25-373-5114, Fax: 86-25-373-7861,
E-mail: hliu@nj.col.co.cn

Mr. Pablo Recalde
Vulnerability and Analysis Mapping Programme,
Operational Policy and Support Division,
World Food Programme,
Via Christoforo Colombo, Rome. Italy
Tel: 39-6-5228-2814, Fax: 39-6-5228-2837,
E-mail: recalde@wfp.org