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Climatic hazards and water management in the Mediterranean region

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SUMMARY - The Mediterranean Sea Basin lies in the transitional zone which falls under the influence of the subtropical high-pressure system during the summer and under the temperate low-pressure system during winter, drawing in cyclonic depressions from the Atlantic Ocean. These depressions penetrate almost unobstructed the entire length of the Mediterranean Sea to the Middle East and beyond. The Mediterranean climate produces many beneficial effects which, throughout the ages, have led to economic progress, stemming from the flowering of a succession of centres of civilization. The extremes of this climate, however, have often turned into destructive forces, manifesting themselves in the form of rainstorms, severe thunderstorms, snow storms, floods, droughts and dust storms. This destructive impact has increased over the years on account of the growing population and expanding economy. The climatic hazards in this region sometimes coincide with other natural disaster-producing forces such as volcanic eruptions, earthquakes, and landslides, as well as with man-made events such as accidental air and water pollution. This paper looks into the origin and nature of the climatic hazards, mitigation of their impacts, and proposes cooperative regional studies and projects.

Key words: Flood, flash flood, forecast, climate change, probable maximum precipitation.

LES RISQUES LIES AU CLIMAT ET LA GESTION DE L'EAU
DANS LA REGION MEDITERRANEENE

RESUME *- Le bassin méditerranéen est situé dans la zone de transition, sous l'influence du système subtropical de haute pression pendant l'été et du système tempéré de basse pression pendant l'hiver, attirant des dépressions cycloniques de l'Océan Atlantique. Les dépressions pénètrent, presque sans rencontrer d'obstacle, sur toute la distance de la Méditerranée au Moyen-Orient et au-delà. Le climat méditerranéen produit beaucoup d'effets bénéfiques qui, durant toute l'histoire, ont contribué au progrès économique, favorisé par l'éclosion d'une série de centres de civilisation. Les manifestations extrêmes de ce climat se sont cependant souvent transformées en forces destructrices sous forme de tempêtes de pluie, d'orages violents, de tempêtes de neige, d'inondations, de sécheresses et de tempêtes de poussière. Ces incidences destructrices se sont accrues au cours des ans, du fait de la poussée démographique et de l'expansion économique. Les risques liés au climat dans cette région coïncident parfois avec d'autres forces naturelles dévastatrices, telles que éruptions volcaniques, tremblements de terre et glissements de terrain, ainsi qu'avec des événements causés par l'homme, tels que la pollution accidentelle de l'air et de l'eau. Cet exposé examine les origines et la nature des risques climatiques et l'atténuation de leurs incidences, et propose des études et des projets régionaux coopératifs.*

Mots-clés: *Crue, crue éclair, prévision, changement climatique, hauteur maximale probable des précipitations.*

MEDITERRANEAN CLIMATE

Along the western borders of the continents north and south of the Equator, roughly between the latitudes of 30° and 40°, lies the transitional zone falling under the influence of the subtropical high-pressure system during the summer and under the temperate low-pressure system during winter, drawing in cyclonic depressions from the west. In the Mediterranean region, these depressions penetrate almost unobstructed the entire length (3700 km) of the Mediterranean Sea from the Strait of Gibraltar to the Middle East and beyond. A warm temperate climate, known as the Mediterranean type, experiences dry, hot, sunny summers, and alternating sunny and rainy spells at other times. The rain comes mainly with the cyclonic depressions from the Atlantic that often produce warm south winds (e.g. sirocco) in their van and cold north winds (the mistral in France and the bora in the Adriatic) in their rear. In spite of the occurrence of severe cold spells (it can snow in Jerusalem), the winters are mild; but the difference between the winter and summer temperatures nevertheless remains considerable. As a rule, summer drought succeeds the meagre winter rain. However, this climatic regime varies considerably from west to east: **progressive continentality**. The mild winter in Portugal resulting from the oceanic influences (Lisbon: 10.6°C in January, 22.2°C in August; mean difference 11.6°C) becomes continental in Greece (Athens: 8.9°C, 27.2°C, 18.3°C respectively). This climate has acquired a high reputation for the abundance of fruit and flowers it produces, and many of the world's great holiday resorts have been established in this region. The tides in the sea are small and the general sea circulation is counter-clockwise.

To the south of this relatively dry region lies the world's biggest and driest desert, the Sahara. Within it, the orographic effect of the vigorous topography formed by the Atlas and the Alps enhances precipitation, which is the main source of surface water. A large part of this precipitation also recharges the vast aquifers lodged in the edimentary geological structures. Both sourcesof water have been used to irrigate the piedmont and the plains since ancient times and are nearing exhaustion.

CRADLES OF CIVILIZATION

Climatic extremes produce many beneficial and hazardous effects for the whole socio-economic spectrum and development; but the tradition of economical and efficient use of the limited water resources is often considered to be a moving force of the multiple cultures and civilizations that have arisen in the region from the very distant past. These cultures spread deep into climatically hospitable areas, particularly Europe and many parts of Asia, but only to a limited extent into Africa on account of the formidable barrier formed by the great Sahara desert.

The Egyptian and the Phoenicians civilizations were succeeded by those of the Greeks, the Romans and the Arabs. In the salubrious climate of North Africa there emerged Carthage, which the Romans erased completely in order to have control over the wheat production of what became known as the "granary of Rome". The latter seem to have amalgamated all previous cultural and technological advancements which witness hydraulic geniuses such as Leonardo de Vinci a few centuries later.

The particular climatic conditions in which neither plant growth nor the outdoor activities of man need cease, permitted the Mediterranean region to maintain sustained economic progress until the beginning of the twentieth century, when the situation started to evolve rapidly because of the population pressure and the consequent development policies, which had a positive impact overall, but a negative effect on both the environment and water resources. At the level of development and population density hitherto, the climatic extremes, though significant, could be tolerated. In the present situation, even extremes of lesser intensity often turn into disasters, depriving communities of food and shelter.

CLIMATIC HAZARDS

The destructive force of climatic hazards, which manifest themselves in the form of rainstorms and severe thunderstorms, floods, dust storms and droughts, appears to increase every year. Intensive development in the region to meet the needs of the rapidly increasing population is apparently the main reason for the high level of damage. Whether change in the climate is also a causative element is still a controversial issue. The relative significance of climatic hazards in the region is illustrated in Fig.1.

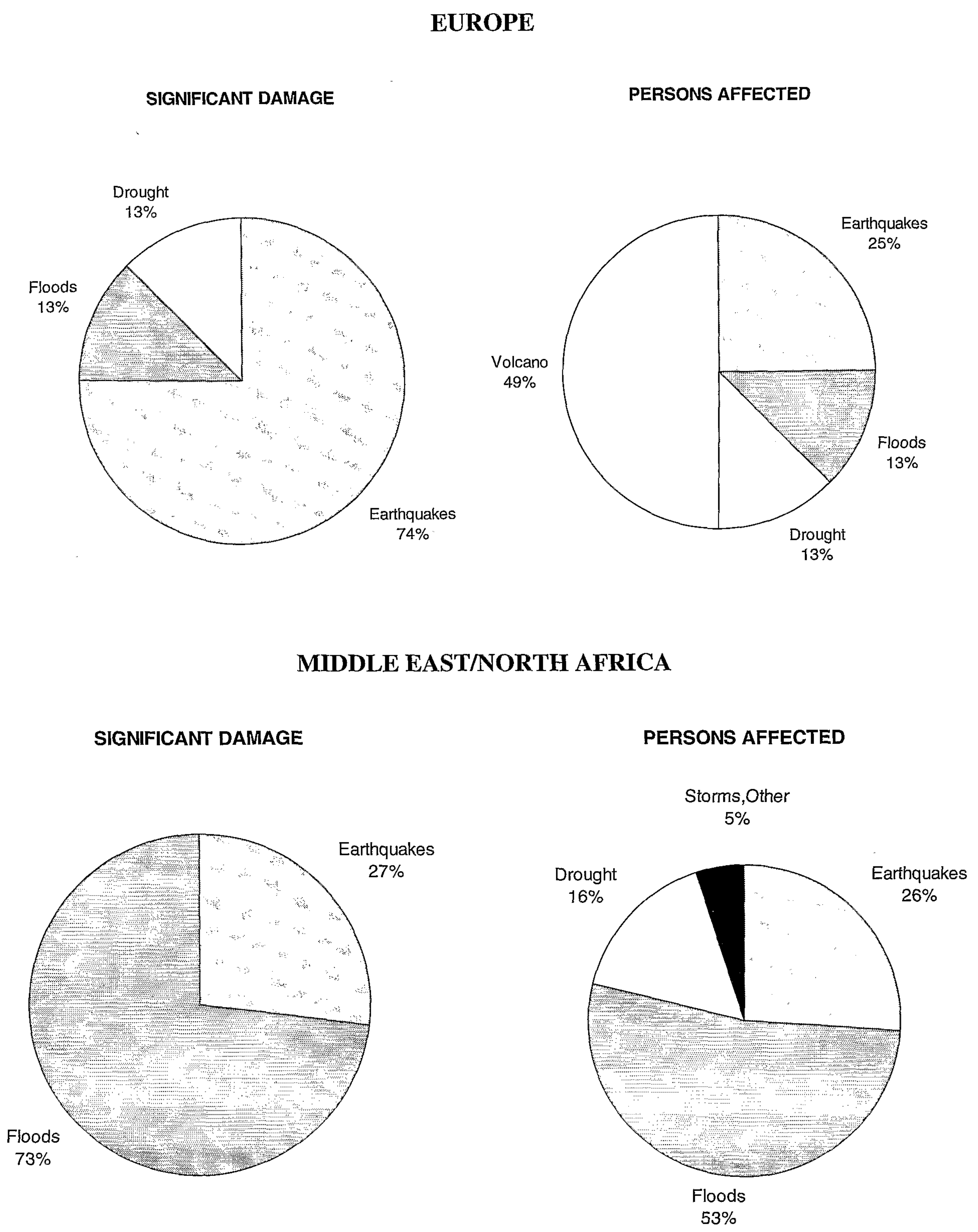

Fig. 1 *- Major disasters 1963 - 1992*
Source: UN/DHA (1994)

HAZARDS AND WATER MANAGEMENT

Climatic hazards can be seen as a cycle involving four overlapping functional phases (Wernly, 1994):

1 Mitigation	3 Responses
2 Preparedness	4 Recovery

The first two are "**pro-active**" phases and the other two "**reactive**". Since most climatic hazards can be forecast, a relatively simple warning dissemination system can not only considerably reduce loss of life and property, but also enhance the effectiveness of reactive measures. This paper focuses on the pro-active responses.

Long-term responses pertain primarily to the overall understanding the nature of the climatic hazard in the context of water resources management. They constitute studies and evaluations, such as defining each climatic hazard and making a **vulnerability analysis**. The short-term pro-active responses consist of activities directly geared to the operation and management of the water resources system and all those using and/or affected by the system. The best example of such an activity is **forecasting** and **warning** systems and **response planning** efforts.

CLIMATE CHANGE

It is a commonly held belief that the world climate is changing as a result of the greenhouse effect, although it is as yet difficult to predict the consequences of such a change on water availability and quality, mainly because of the uncertainties in modelling the atmospheric circulation. However, significant changes in the pattern of rainfall, soil moisture, storm frequency and intensity can be expected to occur. The Mediterranean region, situated at the northern border of the great desert, is extremely sensitive to climate change. The region uses water in an unsustainable manner (Falkenmark et al., 1993) and the shortage of water may soon seriously limit economic growth. Even a minor change in climate can seriously endanger the fragile ecosystem, with repercussions on the people and economy. The situation calls for pro-active anticipatory water planning rather than waiting for serious water shortages. Some of the long-term measures are reafforestation (deforestation is often linked with increased frequency and intensity of floods) and erosion control; control of catchment land use; improved site selection and design for reservoirs, irrigation schemes and hydropower plants; flood water harnessing; underground storage of flood waters; and regulation of flow of springs, which are highly vulnerable to drought and variability in precipitation. (For example the flow of the Fijch spring, the main source of water supply of Damascus, varies from 1.5 to 28 m^3s^{-1}).

Rain and floods

Severe floods in many parts of Europe during the last two winters were produced by extreme rainfall amounts resulting from a series of very low pressure systems. While the normal frequency of occurrence of westerly flows is about 40% of all winter days, the 1994/1995 winter witnessed a 60% occurrence. The previous winter also had an abnormally high frequency (55%). Similar situations have arisen in the past and are a natural feature of climate variability in the region. They cannot be interpreted as an indication of any underlying, long-term climate change. Nevertheless, the issue of climate change should not be dismissed. With respect to climatic hazards, there remain many uncertainties about how any human-induced climate change will manifest itself, particularly in the Mediterranean region. The relationship between river floods and precipitation depends, among other factors, on the nature, frequency and intensity of the precipitation events. Will, for example, the rainfall increase, or will rainfall spells become more frequent, or will both of these occur? It is necessary to undertake two types of study as a cooperative activity of the countries in the Mediterranean region:

- Analysis of changes in atmospheric circulation that affect the region and their associated weather patterns and extreme events in response to anthropogenic climate change and their impact on future river runoff and flooding;

- Research on the natural variability of climatological values, elaboration of homogenized time series and frequency of occurrence of extreme phenomena (ECSN, 1995).

Water scarcity and droughts

Scarcity of freshwater has been an age-long nightmare of the water managers in the region. One major way of meeting the demands has been the continued re-assessment of the available water resources. Hydrologists have lengthened the data time series and increased the number of observing stations. In this way they were able to estimate the renewable water resources more realistically, especially in the Maghreb, as shown below (Latrech, 1995).

Country	Year of estimate	Amount (billion m^3 $year^{-1}$)
Morocco	1955 1968 1980	13.2 25.0 30.0
Algeria	1972 1987	14.0 19.0
Tunisia	1970s 1980 1985	3.0 4.1 4.35

The hydrologists' understanding of the climatological and related hydrological factors has improved thus enabling the managers to ward off the hazard of extreme water scarcity. But the improvement in estimates is bound to level off and the future water demand appears ominous.

FLOODS

Many are the cases where historical records and the memory of older inhabitants provide evidence that an area is liable to flooding. It is a well-known sociological fact that memories are short. The evidence is ignored, the land is intensively developed and for 20 years no problems arise. Then, with further urban development upstream and after a number of days of rain, a violent storm causes what was a minute insignificant river to rise to a level which it has not reached for 100 years. It breaks out of its man-made confines and reclaims its ancient flood plain, causing millions of dollars worth of damage and drowning a number of people.

The main aim of water management is to balance the water regime using technical means. The hydraulic structures designed for this purpose are intended to reduce disaster risks: but they might, in certain circumstances, increase the risks. For example, if a dam is not constructed with an adequate safety margin and properly operated, it can fail under severe conditions. The total damage can be much higher than if it does not exist. Another example: when engineers construct flood dikes (levees) along river courses, they may increase the flood level in the main stream and at the same time impede lateral inflow, causing drainage inundation. Every technical development has, like the Roman god Janus, the two-faced aspect which must be considered in the design of new schemes. When flood risks are reduced, the population moves to the "safe" zones. Cities and industries grow, requiring higher degree of protection. If a dam ruptures or a levee break occurs, however, the damage to life and property is much higher in such zones since evacuation becomes almost impossible even if a good forecast is issued.

The Mediterranean region is particularly prone to the phenomena of increases in flood levels as result of two factors:

- Changes in the river catchment resulting from intensive human activities;

- Climate change.

While the impact of climate change might not be discernible in the short term, the impact of change in catchment is rapid. In the past, evaluation of this risk has been considered as part of the design of hydraulic structures. A re-evaluation of flood probabilities and flood control and warning measures should be immediately initiated. The responses to flood-hazard management and the action that should be taken by the authorities, scientists, engineers and environmentalists to mitigate damage are best illustrated by describing a well-documented flood that struck the city of Florence, Italy, in 1966.

Florence under flood

The city of Florence has experienced floods since ancient times. The catastrophic flood in the Arno river on 4 November 1966 moved the entire world, and many rushed to help in restoring the invaluable cultural heritage. Ubertini (1994) outlined the pro-active measures, long-term and short-term, taken in order to mitigate flood impacts on life and property in the future.

(a) The first scientific study on the generation and the propagation of floods was completed in 1977.

(b) Thresholds of two bridges were lowered by one meter to increase the discharge capacity from $2900m^3/s$ to $3200m^3/s$, which is still less than the 1966 flood flow estimate of $4300m^3/s$.

(c) Within the overall plan of increasing the peak flow retention capacity in the upper catchment, one reservoir was constructed. It is still difficult to determine the statistical risk of a 1966-type flood. The return period was improved from 120 to 150 years; but the risk coefficient remains much greater than that used in the construction of an aeroplane or a nuclear power plant.

(d) In order to reduce the risk a number of non-structural measures were taken:.

- Publication of a comprehensive Civil Protection Plan in 1986;
- Installation of a telemetered flood-warning system started in 1966 followed by a new flood-forecasting system in 1990 based on 45 rain gauges and eight water-level gauges feeding data in real time into a model, considerably increasing the forecasting time;
- Some specific scientific studies and introduction of new technologies:

(i) A mathematical model transformed the 1966 flood to determine flood level in the city streets, and it can be now used for more effective planning of interventions and rescue.

(ii) A quantitative precipitation-measuring radar was installed in the Arno catchment. It provided valuable information during the October 1992 flash floods.

(iii) Satellite imagery has been applied to determine distribution of rainfall in advance. The information so produced is input to a runoff simulation model to forecast river levels and flows.

Flood forecasts are useful only if they are disseminated to all concerned parties who are ready to take the necessary action. Some practical tests have been carried out to evaluate the response times. A lot more needs to be done in this respect.

Flash floods in deserts

The size and type of catchment of the Arno River are typical of the Mediterranean region. They require classical arrangement suitable for slow response river flooding, as well as special forecasts required for an area subject to flash flooding. In the flash-flood situation the time interval between the observable causative event (rainfall or snowmelt) and the flood is usually less than four to six hours (WMO, 1988). The classical arrangement does not apply to an urban or drainage flood, a flood resulting from rainwater ponding at or near the point where it falls because it is falling faster than the drainage system (natural or man-made) can carry it away.

In both the above cases, very intense rainfall in a short time over a small area leaves little time for the collection of data and issue of forecasts. Hence the normal forecast or warning lead time is frequently non-existent or very short indeed. Such situations produce treacherous flash floods with relatively high peak discharge. Vulnerability to flood damage in small catchments has dramatically increased in recent decades. Considerable effort and research have been focused on finding solutions which would enable the meteorologist in collaboration with hydrologist to produce reliable forecasts and warnings. The new solutions are usually based on the combined use of weather radar and satellite data (WMO,1994).

In one trial application, a rainfall event was analyzed with a real-time flash-flood scenario utilizing the new GOES-1 Interactive Flash Flood Analyzer (IFFA) software. Satellite-derived rainfall estimates were generally accurate as regards amount and location when compared with detailed observed rainfall analyses available from the national meteorological service. The key to detecting rainfall producing flash floods is cloud pattern recognition, upper-air analysis, and a knowledge of the techniques required to convert the resulting information into flood forecasts. Once such a system becomes operational, the meteorologist will have a capable tool to determine precisely where a potential flash flood might occur (Jackson et al.,1992).

Intense rainfall, often very localized, resulting from deep depressions and enhanced by the pronounced orography of the Mediterranean region, produces flash floods which are unpredictable, infrequent and short-lived (Fig. 2). Even ephemeral streams are efficient conveyors of large amounts of sediment (EOS, 1994). This explains why reservoirs in the Mediterranean region have suffered from underestimated sedimentation problems. It is difficult to forecast flash floods. However, radar and satellite imagery coverage of socio-economically important centres can provide cost-effective solutions.

In Egypt, in the days of the Pharaons the High Priests retained their power by being able to prophesy whether there would be floods or drought in the coming season. They did this by sending emissaries into Ethiopia to observe the severity of the summer rains. The consequences of an error in their forecasts were extremely severe. Flood forecasters nowadays are not liable to the same penalties if they are wrong, but the accuracy and reliability of their forecasts are no less important.

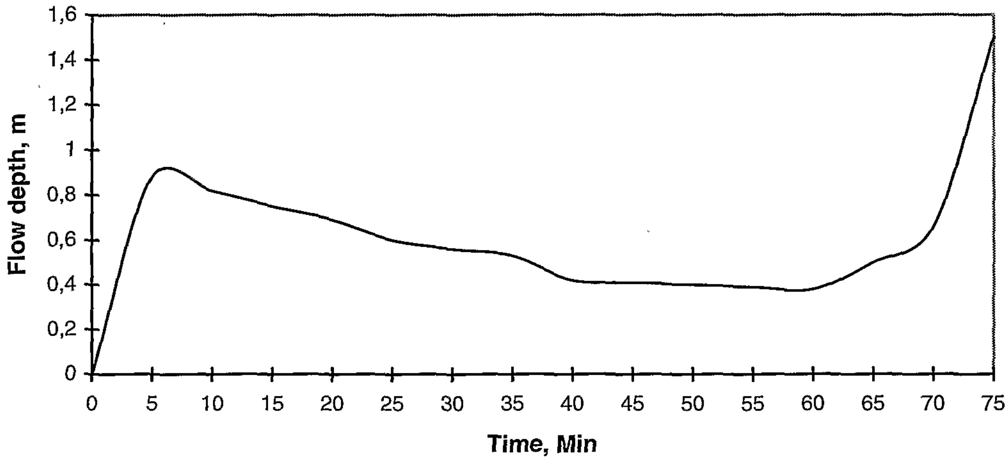

***Fig. 2** - Stage hydrograph of flash flood in the Nahal Eshtemoa (Israel) Nov. 11,1993*
Source: Reid, et al. (1994)

CHANGED REGIME OF FLOODS

The increase in population has also resulted not only in increasing urbanization but also in the conversion of forest to pasture and arable land. Less water is retained in the upper reaches of basins and it flows more rapidly to the plains. Floods have become more frequent, more severe and arrive with less warning. The extreme example is also the most dangerous and is, sadly, becoming very common: flash flooding in urban areas. Buildings and roads cover the land surface, rainfall cannot infiltrate into the soil and so almost all of it runs off immediately over the smooth artificial surfaces. Where once a heavy storm would moisten the earth and water the grass and trees, the landscape now becomes in a matter of minutes a raging torrent sweeping all before it. Man-made structures designed to drain away storm water under normal conditions even speed the process. What was a "100-year flood" for which an embankment or a dam was constructed 40 years ago might now have become merely a "ten-year flood", which means that the dams and levees will be overtopped frequently and, if thus destroyed, lead to even greater flood damage than would have occurred in their absence. The second change, therefore, is in the floods themselves: man has altered his physical environment to suit his purposes and, in so doing, has frequently established conditions which generate more severe flooding.

Probable Maximum Precipitation (PMP)

Just as modern technologies have assisted the hydrologist to improve the accuracy of his assessment of the available water resources, a number of design data techniques are used to reduce the risks of existing and planned hydraulic structures and water-related schemes. Probably the most important is the estimation of the probable maximum precipitation (PMP) and its translation into the probable maximum flood. PMP is the greatest depth of precipitation for a given duration meteorologically possible for a storm area of a given size at a particular time of year. The PMP estimation procedure is described in the *Manual for Estimation of Probable Maximum Precipitation* (WMO, 1986). In view of the increasing rate of occurrence of climatic hazards aggravated by human activities and possibly by climate change, PMP estimates of the Mediterranean region have become a necessity. Judiciously used PMP estimates, especially for re-evaluating the design safety of the existing water schemes, and designing and operating new water resources systems, can save life and property, particularly in urban centres, as well as safeguard the region's precious cultural heritage.

Procedures for estimating PMP cannot be standardized as they vary with the amount and quality of data available, basin size and location, basin and regional topography, storm types and patterns producing extreme precipitation, and climate. For this reason, the WMO *Manual* mainly discusses procedures that have been found generally applicable in the middle latitudes in orographic and non-orographic regions. In 1992, WMO failed to launch this study in Algeria as a collaborative efforts among some national and regional institutions because it was difficult to find adequate expertise in one person. With the start of the World Bank/WMO Hydrological Cycle Observing System for the Mediterranean region (MED-HYCOS) it should be feasible to pool human and financial resources to undertake PMP estimates for the region as a cooperative project.

WATER QUALITY AND FLOODS

Elimination of pollutants produced by industry in the countries short of fresh water is an acute problem and is an added hazard, especially during flood. For example, the liquid waste of more than 60 industries located in the catchment of the Zerba river in Jordan is discharged into the principal channel. During floods deposited wastes are washed from the heavily polluted stream bed into King Talal Dam reservoir (Khouri, 1994).

CONCLUSION

Although it not possible to prevent natural disasters, it is within our capabilities to lessen their impact on people and structures. The International Decade for Natural Disaster Reduction (IDNDR) has proposed that by the year 2000 each participating country should have:

- Comprehensive national assessment of the risks from natural hazards, these assessments being taken into account in community development plans;
- Mitigation plans at the national and/or local level, involving long-term prevention, preparedness, and community awareness;
- Ready access to global, regional, national, and local warning systems and broad dissemination of warnings.

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