CLIMATE APPLICATIONS AND PREPAREDNESS

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Abstract:
Climate Forecasting Applications and Preparedness, implemented effectively, are important in reducing the losses from disasters such as floods, drought, cyclones and landslides, and thus, in strengthening the sustainability of livelihoods in communities. This is a new field for AUDMP, but there is much to learn from ADPC's Extreme Climate Events Program implemented in Indonesia, the Philippines and Vietnam, and the Program on Climate Forecasting Applications in Bangladesh. Both programs facilitate dialogue between the climate science community and the end users of climate information at the community level to ensure relevant and useable information that is made easily accessible to communities at risk.

El Nino is a Spawner of Hazards

Climate variability associated with the El Niño Southern Oscillation (ENSO) can have dire implications across a range of socio-economic sectors in Southeast Asia. However, recent developments in the science of climate forecasting coupled with growing capacity at national meteorological services and ongoing dialogue with affected sectoral agencies have enhanced our ability to understand the local climatic implications of the El Niño Southern Oscillation. This paper describes a range of related initiatives supported through ADPC's Extreme Climate Events Program in Indonesia, Philippines, and Vietnam. It also aims to stimulate discussion of the potential applications of climate information for disaster management and vulnerability reduction in the urban environment.

In Indonesia, 28 drought years have been recorded since 1877. Of these 20 were associated with strong El Niño events. Of the remaining eight, six accompanied weak El Niño events. Thus 93 percent of drought years over a period of 123 years were linked to ENSO. Moreover, there are strong links between El Niño, Indonesian drought and fire. Over the last two decades, widespread fire activity was consistently associated with strong ENSO events. Analysis of official figures of forest areas burnt indicates a relationship between SOI and the area of forest burnt. In seasons when the SOI remains above -10 the area is relatively small; when the SOI falls below -10 the area burnt appears to increase dramatically.

In the Philippines, records indicate that since 1982-83, El Niño years have coincided with significant shortfalls in rice production, shortfalls in hydroelectricity generation, and drinking water shortages in urban areas. During La Niña years, typhoons are more frequent and have inflicted greater damage to life and property.

In Vietnam, the La Niña phase oscillation poses a greater threat. During El Niño years the number of typhoons affecting Vietnam is less than during La Niña and normal years. The shortfall in rice production during La Niña and normal years is more than El Niño years. This is attributed to more incidences of typhoons and flooding. Analysis for the period 1979 to 1998 indicates that during normal years, average area under paddy cultivation affected annually by natural hazards is 1.1 million hectares, during El Niño years this is on an average 0.073 million hectares.

However, it needs to be emphasized that there are large variations in impacts across seasons, sectors, different regions in each country, and different kinds of ENSO events (based on onset, intensity and duration). It is imperative to understand these variations to the fullest extent in order to move towards the effective application of climate forecasts for development planning and vulnerability reduction. The examples given above from the ECE target countries clearly illustrate the potential to reap huge benefits from the application of climate forecasts in the Southeast Asian countries, particularly forecasts that allow a lead-time of several months for proactive planning and disaster preparedness.

Urban Vulnerability to Climate Variability and Extreme Events

Historically, urban centers have been notoriously vulnerable to climate variability and extreme events. Historians and archaeologists commonly argue that climate-related disasters have even led to the demise of many ancient cities. Although, to date, there has been no comprehensive survey of the impacts of extreme climate events on modern Asian cities, great progress has been made towards a general understanding of vulnerability to climate-related disasters in contemporary cities.

Urban vulnerability is complex owing in part to the enormous scale of potential damages, the large populations at risk, the reliance on built infrastructure (energy, water, transportation and telecommunication systems), and the potential economic impacts associated with damage to capital investments and disruption to core economic activities. Yet, despite the potential risks and the apparent sensitivity to climate impacts, some sectors of the urban community are remarkably resilient.

This is not true for the growing numbers of urban poor for whom daily subsistence is already marginal and who often settle in areas of highest risk – along rivers and waterways or on unstable slopes. The International Federation of the Red Cross and Red Crescent Societies of Viet Nam, for example, assessed the flood victims in the Mekong Delta and found that the wealthier inhabitants were more adaptive and resilient. They were better able to withstand floods because they could afford to raise the foundations of their houses above the usual flood level; and, because they did not depend on a daily wage for their economic survival, their livelihoods were not so badly affected. The landless poor, on the other hand, had little room to maneuver. Floods cut them off from food, fuel and income by stopping them from collecting wild vegetables, cutting firewood and working as day laborers (Twigg, 1999[1]). Moreover, problems of the urban poor are exacerbated when refugees flee drought, flood or storm wreckage. The migration to cities following rural disasters thus adds to the number of people at risk in urban settings, stressing already overburdened water supplies and social services.

There are many approaches to assessing vulnerability[2], and considerable advances have been made in developing more sophisticated survey instruments. Many of these begin with a thorough community-based review of risks and resources, emphasizing the importance of dialogue and stakeholder participation in the assessment process. For the purposes of this discussion, a sectoral perspective will be adopted in efforts to highlight broad issues and, hopefully, stimulate interest in more extensive analyses. Food security, public health, water resources and built infrastructure have been identified in a number of assessments as key sectors that are highly sensitive to climate variability and extreme events and will serve as a starting point for discussions in this session.

Food Security

Before the 1980s, maintaining food security was one of the greatest challenges for communities and governments throughout the region. On the one hand, food security is related to crop production and delivery systems. On the other hand, food security is a question of access to the basic nutritional requirements. The latter case was especially challenging for the urban poor, whose livelihoods are so marginalized that any disruption to income earning activities or social networks may leave families hungry. Such disruptions are common when disaster strikes. In addition, the nutritional value of home gardens in urban settings provides a crucial buffer, which can be easily destroyed by disaster or unfavorable climate. In the past decade, however, national and municipal governments throughout Asia have established more effective mechanisms for ensuring the food security of their cities. For example, the government now keeps grain stocks for distribution during crises. Previously, private trading firms used to raise food prices exorbitantly, but government efforts to enforce price controls have been largely successful during food shortages.

Across the region, the agricultural sector is striving to incorporate climate information into its decision-making more and more systematically. Many agricultural departments currently assess climate impacts using indicators such as rainfall distribution, crop growth and water levels in reservoirs. Through perhaps accurate, the short lead-time does not allow for resource management or disaster preparedness intervention strategies. ENSO forecasts now available are able to inform decision-makers about possible climate anomalies with considerable lead-time to enable sector agencies to undertake potential impact assessments and prepare contingency and risk management plans. For example, in a 1999 ECE workshop, Romeo Recide, of the Philippines Department of Agriculture, reported that, upon receipt of

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[1] http://www.bghrc.com/DMU/DEVRISK1/DEVRISK/TWIGG.HTM

[2] See Anderson, Mary. "Linking Relief and Development: A manual to aid in programming assistance to break the cycle of disasters and promote sustainable development"

advisories from Philippine Astronomical, Geophysical, Atmospheric Service Administration (PAGASA), the agriculture department initiates impact assessments based on agriculture production data. The department prepares region-wide scenarios and shares these with agriculture research institutions and other agencies such as water resources, irrigation and food security agencies. Upon receipt of inputs from these organizations on the potential impact assessment scenarios, modifications are made and recommendations are passed on to regional agricultural departments.

In a study of area-specific impacts to ECE indicators[3], declines in gross value added (GVA) and production volume of four principal crops (rice, corn, sugarcane and coconut) were found to coincide with El Nino years, while increases are associated with La Nina years due to favorable rainfall conditions. The sharpest falls in GVA and production volume in the agricultural sector were in 1982-83 and 1997-98, the years of the strongest El Niño events in the 20th century. It was also found that livestock, poultry and fisheries sub-sectors are not sensitive to extreme climate events. Improved aquaculture production in recent years has compensated for losses during warm episodes. Third-order impacts include shortfalls in projected annual economic growth, increased burdens on urban resources as displaced agricultural workers migrate to cities, and increased dependence of agricultural workers on government assistance

Public Health

In many Asian cities, access to adequate medical care is limited and threats to public health are exacerbated by unsanitary conditions, limited access to potable water and overcrowding in poorer areas. In an ECE sponsored study that assessed the impact of climate variables such as temperature and relative humidity, and focused on dengue, cholera, typhoid, measles and malaria in Metro Manila, Eric Tayag reported that correlation analyses of time-series data from 1992-98 revealed a relationship between weather variables and dengue, malaria and cholera in the study area. Though there was a correlation between ECEs and disease outbreaks, other factors may be responsible. These factors need to be fully analyzed before utilizing climate forecast information for disease prevention measures. In the meantime, early warning impending hazards coupled with other local mitigation and management initiatives, can help public health officers and the community to prepare for disaster-related diseases.

There are strong links between the water and public health sectors. One of the biggest impacts on public health has been water-borne illness associated with extreme climate-related events. At one end of the hydrological continuum, droughts can result in decreased water availability, contamination of water resources and saltwater intrusion into freshwater sources. At the opposite extreme, floods may have an impact on public health by overflowing sewage systems and cesspools and by contaminating water with minerals and non-point pollution sources.

More frequent natural hazards such as floods and droughts often create favorable conditions for the transmission of various diseases. Hence, continuous monitoring of the environment, and pathogen and host relationships, needs to be carried out. This monitoring mechanism could be useful for associating ECEs in the disease cycle.

Further research needs to be conducted on identifying the links between disease vectors and climate. Some of the changes may be in community behavior. For example, to deal with droughts, people are taught to store water; however, these stagnant water sources may be breeding grounds for mosquitoes that are the source of dengue and malaria. Reports have been issued that mosquitoes will be "fiercer" in the future from climate-dependent factors. This shows the importance of understanding the links between mosquito-borne diseases and climate effects.

The following water use management and practices driven by emergency situations during droughts and floods could contribute to the outbreak of epidemics:

- The disruption of environmental health services and infrastructure (like water supply and public sanitation) by climatic variations can contribute to a significant rise in water- and food-borne disease.

- The use of booster pumps adds to the contamination of water supply.

[3] Recide, Romeo. 1999. …

- The community's eagerness to store water during emergency situations could provide a breeding ground for vectors carrying pathogens.

Studies can be extended to include other diseases such as leptospirosis, which is found in streams, and may occur as a stream flow factor. In Vietnam, there has been an observed increase in pests during the hydrological extremes. During floods, there are increased numbers of mosquitoes, and during droughts, an increased number of mice; hence, diseases associated with these pests increase.

Water Resources

Water is gold. In many cities throughout the region access to potable water is not universal, and there is a very real risk that the supply needs of growing populations and industrial uses will not be met. Current climate impact assessment methodologies for water resources rely on indicators such as rainfall distribution, water level monitoring on surface water storage structures and stream flow behavior. These indicators give little lead-time to formulate strategies for intervention before the occurrence of extreme weather events like floods and drought. However, by incorporating the ENSO forecasts currently available, water resource managers may gain enough lead-time to pre-assess potential impacts.

In the case of the Philippines, Susan Espinueva reported the assessment strategies adopted by the National Water Resources Board and the National Power Corporation. After the receipt of forecasts from PAGASA, reservoir operation simulations are conducted. These simulations determine the projected available water in the reservoirs and serve as a basis for water releases or allocation to various users. The results of a study[4] using inflow data from five major Luzon reservoirs and a Mindinao lake were presented. This ECE-sponsored study enabled the water resource sector to document past data and relate it to ENSO indices through correlation techniques. The results of this research indicate the potential opportunities to utilize ENSO forecast information for water resource management in the Philippines.

The major conclusion was that significant associations between climate variability (in terms of rainfall) and hydrologic activity (in terms of reservoir inflow) exist at varying magnitudes in the study area. Therefore, improved knowledge on the relationship of these variables would be an initial step in better planning and management of water resources systems, whether they are designed and operated for the purposes of water supply, irrigation, flood control or hydroelectric power generation.

Public Safety and Built Infrastructure

Though generally more vulnerable to the direct physical impacts of windstorms and floods, built infrastructure is also sensitive to climate variability. As already mentioned, the clear link between ENSO, drought and forest fire in Indonesia has been well established. During these fire events, the smoke and particulates released into the atmosphere produced a dense haze that spreads widely across the region. In the 1997-1998 the haze was so bad that airports in Indonesia, Singapore and Malaysia were closed. Two tragic plane clashes have been linked to the poor visibility. Several fatal boating accidents in the shipping lanes between Indonesia and Malaysia were also attributed to the hazardous conditions while road accidents were so frequent that in some areas even overland shipping was disrupted. Seasonal forecasts can be useful in triggering the adoption of stricter fire prevention laws and for supporting a fire danger rating system.

Also, as mentioned earlier, many cities in the region rely on hydroelectricity to meet growing urban energy demand. Disruptions to the power supply can have severe economic consequences. Recognizing this link between climate and the infrastructure that is so vital to urban economies and urban survival is an important step towards reducing vulnerability and should be taken a s a call to broaden the stakeholder community in joint discussions of climate disasters, variability and adaptation options.

Among the capacities in each of these sectors outlined above is potential access to tailored forecast generated by local or district meteorological centers. These tailored climate information products may take the form of real-time weather data, short-term forecasts (up to seven days), or medium- to long-

[4] Espinueva, Susan. 1999.

term forecasts (on the seasonal scale). Similarly, the scope of opportunities to apply climate information ranges from feeding it into early warning systems, which are managed by the sectoral agencies or a national disaster management office, to establishing working groups for utilizing seasonal forecasts at critical stages in the decision calendars for managing food security, water resources, public health, etc. The next sections present some of the possible uses of climate information for disaster preparedness.

Applying Climate Information for Disaster Preparedness: Early and Earlier Warning

The UN International Decade on Natural Disaster Reduction (IDNDR) Conference on Early Warning Systems for Reduction of Natural Disasters (held in Potsdam, Germany in September 1998) declared that the successful application of early warning is the most practical and effective measure for disaster prevention. Early warning for floods and cyclones generally rely on deterministic forecasts released from 48 – 72 hours before impact. Seasonal forecasts offer the opportunity to anticipate climate anomalies, deviations from expected norms, several months in advance and, likewise, indicate the probability of cyclone or flood frequency which have in certain parts of the region been historically correlated with ENSO.

Successful climate forecast applications rely on the technically skilled forecasts that are designed and disseminated in consideration of the decision makers who will use them. Thus, preparation of forecasts for effective vulnerability reduction in urban areas should begin with an assessment of users' vulnerability, capacity and needs. The five general components of effective early warning systems are listed below and distinguished conceptually. This framework may be employed when considering the key elements of successful applications of seasonal forecasts for disaster mitigation. These include:

- Risk Assessment, including hazard assessment and vulnerability analysis
- Hazard detection and prediction
- Formulation of warning messages
- Dissemination of warning message
- Community response

- ***Risk Assessment***

Risk assessment is fundamental to disaster reduction and is an essential component of a well-designed climate forecast application, as it facilitates the targeting of climate information for optimum benefit to communities that are directly and indirectly at risk. According to the IDNDR, risk assessment is essential for policy decisions that translate warning information into effective preventative action. Risk assessment is a composite estimate of hazard and vulnerability. Whereas hazard assessments aim to determine the probability of climate-related disasters based on data from observational records and space-based technologies, vulnerability analyses look from the group up in an effort to understand how and why various sectors of society are sensitive to climate impacts. Thorough assessment of vulnerability, however, looks beyond sensitivity to consider a community's or sector's resilience and capacity to adapt.

- ***Hazard detection and seasonal forecasts***

Given the current state of forecasting skill and technologies, the lead-time for early warning ranges widely - from one hour for tornadoes and flash floods to seasonal and inter-annual forecasts of El Niño. The latest technology on remote sensing has revolutionized the detection of hazards through the use of satellite imagery, which have added precision to the location and tracking of tropical cyclones and monitoring drought conditions. Remotely sensed images are also used to determine the spatial extent and intensity of precipitation. In addition, a network of weather radars has proven invaluable for tracking the development of weather disturbances like tornadoes and windstorms.

Globally, each day, some 20,000 weather observations (temperature, wind pressure, precipitation) are made at the ground surface, on ships, and in the air. These data are shared among national weather services and centers, and used for the preparation of daily weather analyses and forecasts. Currently, the low density and poor quality of observing networks in some developing countries presents a substantial barrier to improving the effectiveness of early warning. Subsequently the observational data from neighboring countries becomes essential for the weather related hazard detection.

Since 1998, the ASEAN Specialized Meteorological Center (ASMC) has been producing Regional Climate Outlooks using electronic communication with international agencies as well as National Meteorological Services in the region. These regional climate forecast products are used by the member countries to generate their own seasonal forecasts. In general, the national meteorological agencies use the regional forecasts in conjunction with past statistical information on local climate conditions and inputs from other meteorological agencies (e.g. BOM, IRI, NOAA, UK Weather Service) to generate national seasonal forecasts.

National scale forecasts however, remain underdeveloped and underutilized. While the regional forecast issued by ASMC indicates rainfall probabilities in five categories (below normal, slightly below normal, normal, slightly above normal and above normal), the national forecasts products indicate rainfall probabilities for traditional three categories. This may perhaps be attributed to the low level of confidence in using the five closely spaced rainfall categories. This may also be attributed to the fact that at the national level, accountability to the users with regards to the accuracy of the forecasts is much higher than at the regional level. Ongoing initiatives of ADPC, IRI and ASMC have contributed substantially to improving local capacity to downscale regional models and enhance dialogue between the producers and users of climate information.

The national seasonal forecasts use geographic boundaries given in regional forecasts and identify existing rainfall stations in each probability zone. Based on historical mean seasonal rainfall at each rainfall station, values are determined for normal, above normal and below normal rainfall and probabilities applied to these values as indicated in the regional forecasts. Currently, through initiatives supported by OFDA, IRI, NOAA, ASMC and ADPC, capacity for generating forecast a higher resolution (i.e. downscaling from the regional to the national level at a scale of 2,500 kilometers and, in cases where predictability is high, to a scale of 500 kilometers) is improving.

In the current socio-economic context of Southeast Asian region, where agricultural activities no longer stick to only the traditional dry season and wet season cropping pattern, the continuous production of regional climate outlook every two months has significant value. However, it would require that the system of producing national seasonal forecasts take adequate advantage of this continuous process. The lead-time provided by these regional forecasts also gives adequate time to anticipate the impacts and mobilize institutions to take necessary action to minimize the negative impacts and maximize potential benefits. However, here again, the effectiveness would depend greatly on how effectively the national meteorological agencies use these forecasts and localize them.

Regional forecasts provide rainfall probabilities for the forecast months. This is certainly a relevant parameter for the Southeast Asia, which is a humid tropical region, where socio-economic activity often depends on rainfall. However, effective application would require that this information is produced in greater detail at the national level and also includes other attributes of rainfall such as onset, distribution and termination of rainfall.

It may be mentioned here that with decreasing dependency on agriculture, in the coming decades the forecasting of other parameters such as temperature, humidity would become more useful. For example, for monitoring and control of urban pollution, monitoring and control of disease outbreak would be greatly helped by seasonal temperature and humidity probabilities.

Current Practices with Respect to Application of Climate Forecasts

Many governments and related disaster management organizations throughout Asia have already initiated Early Warning Systems; though, the systems vary widely in their capacity to produce and communicate effective warnings. The same is true for capacity for generating and communicating seasonal forecasts. [See country reports from Asian Climate Training Workshop]

Prior to 1997, the Indonesian Bureau of Meteorology and Geophysics (BMG) generally used to issue weather forecasts keeping in view meteorological parameters. From 1997 onwards, the BMG has taken the initiative to establish a broad based National Seasonal Forecasting Working Group drawing upon expertise from various sectors. This Working Group comprises BMG, Bureau of Assessment and Application of Technology (BPPT), the National Space Center (LAPAN), Agriculture Research Institute and Water Resources Management Research Institute.

The Working Group draws upon forecast information from ASEAN Specialized Meteorological Centre (ASMC), IRI, BOM Australia and UK Metro Office to prepare seasonal forecast guidance that includes the following:

- Seasonal monsoon onset forecast indicating the dates of onset of monsoon with ten days intervals for 102 meteorological regions across the entire country.
- Monthly forecast of rainfall for 102 meteorological regions for the country.
- Seasonal cumulative rainfall status for the entire season for 102 meteorological regions.

Respective climate sensitive organizations at the national level on receipt of climate forecast information from BMG, process the outlook with reference to past impacts and disseminate processed information to provincial sectoral organizations. At present, these forecasts are used as general alert. The information is received from the field agencies to the national level user agencies only when disaster events occur. The processed forecast information received at the national level is useful for taking general precautionary measures but cannot be used for comprehensive development planning.

Philippines: In the Philippines, (user) Departments of Agriculture, Water Resources and Public Health have well defined mechanisms for receiving forecasts from PAGASA at the national level and processing and disseminating it to the regional and sub-regional levels..

Department of Agriculture on receipt of advisories from PAGASA analyses potential impacts on agriculture production. Based on this information Department prepares a vulnerability maps for each of the 12 regions of the country. These maps are then with agriculture research institutions and other agencies such as water resources, irrigation department and food security agencies. On receipt of inputs from these organizations on the vulnerability maps, modifications are made to these maps as necessary. The final processed information is passed on to regional agricultural departments.

The National Water Resources Board and the National Power Corporation assess the potential impacts through reservoir operation simulations after receipt of forecast from PAGASA. These simulations determine the projected available water in the reservoirs and serves as basis for water releases or allocation to various users.

The Department of Health recently established a mechanism to use the forecast information from PAGASA in planning for contingency measures to deal with water borne diseases.

Although establishment of a comprehensive climate forecasting applications system is well under way in the Philippines, there is still a great need to develop capabilities to process forecast information into more actionable formats at the local level. The information provided by the national agencies falls short of meeting the specific needs of users at the local level.

In ***Vietnam***, until recently, ENSO global forecast information was not incorporated into national seasonal forecasts. The Hydro Meteorological Services (HMS) uses the antecedent's parameters such as Eurasian snow cover, ITCZ etc. for making seasonal forecasts. In recent months after the initiation of Extreme Climate Events Program, HMS has begun to start incorporating long-range forecast information into seasonal forecasts. The long-range forecasts are received from a range of agencies including ASMC, NOAA etc. In view of these developments the importance of seasonal forecast for Vietnam has increased.

The seasonal forecast information provided by HMS is used by climate sensitive sector agencies like agriculture, water resources, Disaster Management Center only as a general alert. These departments have a well-established mechanism to monitor situations created by natural hazards. However, much more work is needed if the potential application of climate forecast information for development planning is to be fully realized.

- ***Formulating and Communicating the Forecast***

Ultimately, the declaration continues, early warning systems must be comprehended by and motivate communities at greatest risk, including those disenfranchised and particularly disadvantaged people who must take appropriate protective actions. In short, forecast production should reflect the needs of decision makers who will use them. Similar to early warnings, an effective hazard warning seasonal forecast should contain the following messages:

Characteristics of the hazard (time of detection, location, strength and speed of movement)
Associated risk and the location of the population at risk (or an identification of the general area at risk
Recommended appropriate action

As forecast may be used by the general public as well as decision makers in various sectors (or disaster managers), it is important that forecasters consider the decision-calendars or the types and timing of mitigative decisions that might be pursued. Further, the forecast should be produced in user-friendly terms.

A key element to effective climate forecast application is established and sustained institutional mechanisms for dialogue between users and producers of climate information. Not only should forecasters understand the potential applications of their work but users should also have the opportunity to learn how to interpret forecast, to understand the assumptions upon which they are premised and the limitations to their application.

Dialogue between users and producers of climate information create an opportunity for joint problem solving in which the relationship between science and policy/decision making is strengthened. Mutual understanding between sectoral decision-makers and forecasters could be supplemented by similar dialogue between forecasters and the media and between forecasters and policy makers.

Framework for exploring the potential urban applications

Please consider some or all of the following points in preparing your presentation:

- Situational analysis of the urban setting, including the vulnerability to climate variability and extreme events
- Disaster history of your sector
- Current practices for urban disaster management
- Critical thresholds identified in the sector (how sensitive is the sector, i.e. how much or how long a rainfall deficit constitutes need for concern or action)
- Institutions involved in disaster mitigation or development for the sector
- Decision calendars or the types of decisions that might be made to mitigate the negative impacts
- Potential applications for climate forecasts/information
- Constraints and opportunities for applying climate information

Organization of the session

The 1.5 hour session will begin with a general overview based on this background paper. The session will continue with three 20-minute presentations, which are likely to include the following

- Someone from the Bangladesh Flood Forecast Warning Center to speak potential applications in Dhakka

- Someone from Phuket, Thailand to discuss applications for water resource management in a drought prone city that relies heavily on mass tourism.

- Someone from the Philippines to speak on potential applications for water resource management and hydropower in Manila.

Presentations will be followed by questions and a general synthesis of the common themes. If possible an additional half- hour could be used to generate discussion on specific opportunities and constraints to applying seasonal forecasts for urban disaster mitigation and to suggest other sectors/cities that might benefit from climate information.

Comments and criticism of this background paper are welcomed and encouraged.

APPLICATION OF CLIMATE FORECAST INFORMATION IN MITIGATING IMPACT OF CLIMATE HAZARDS IN URBAN CITIES OF MALAYSIA WITH PARTICULAR REFERENCE TO MANAGING WATER RESOURCES

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Abstract

Malaysia receives substantial rainfall amount annually. ENSO is one of the dominant factors causing the interannual and intraseasonal variations in the monsoonal rainfall. With rapid urbanization, dry spells in the nineties have caused severe water shortages. Although some of the problem lies with poor management and badly maintained catchment areas, the immediate cause of the water shortage has been identified as prolonged dry spells and failure of the rain to fall over the catchment areas. Using simple statistical parameter of rainfall percentile and compositing all rainfall amounts received corresponding to each major El Nino or La Nina event, it is possible to provide a general seasonal forecast rainfall trend which can be disseminated to the water resource managers. Long-term climatic rainfall trend over the catchment areas and the urban areas should also be carried out to determine the micro-climatic changes that have affected the shift in rainfall.

Introduction

Malaysia, situated within the equatorial belt, receives substantial amount of rainfall annually, ranging from 2000mm to 4000mm. The rainfall is characterised by monsoonal influences, namely the North-east monsoon from November to March and the South-west monsoon from late May to September. Climatologically, the North-east monsoon is the major rainy season in the country whereas the Summer Monsoon is the drier period of the year. The drier region in the country is the northwestern region of Peninsular Malaysia during the months of late December to February. This region is also known as the rice bowl of Malaysia because this is the rice-producing area, irrigated by canals with reserved water in the dams so that double cropping could be carried out each year.

Research carried out has shown that one of the dominant factor causing the interannual and intraseasonal variations in the monsoonal rainfall over the whole country is the ENSO events. (Lim and Ooi, 1999). These interannual variations modulate the rainfall, resulting in drier than normal rainfall in certain years and excessive rainfall amount in other years (Ooi and Lim. 1997). Rainfall deficit during weak monsoons may cause considerable stress on agricultural crops, water shortage and also results in a generally more hazy condition, especially over the urban areas.

Although dry spells has affected the country in the seventies and early eighties, the effects of the dry spells were not felt so badly and generally did not disrupt human activities and did not affect the country's economy as a whole. As the country become more developed and with rapid urbanization in particular areas such as Kuala Lumpur, Penang and Malacca, from the nineties onwards, drier weather and extreme weather events is definitely showing an impact on the population and posing a burden on the government.

Disaster History

The first sign of trouble with potable water happened in early 1991 in the state of Malacca, a small state facing the Straits of Malacca. In this case, the trouble started with contaminated water supply which was subsequently traced to a rubber processing factory located very close to the river. The factory was closed down and the areas around it cleaned up. The water authorities depended on rain and the ability to draw water from further upstream to supply water to the treatment plant. However, the weather was playing up and it was drier than usual resulting in the drastic drop of water level in the upstream of the river as well as the fact that the reservoir is also running dry. Hardly any rain fell and even if it rain, it did not fall over the reservoir or catchment areas. The state government was under enormous pressure to fill up the reservoir and resume normal supply to the people. They resorted to all means, including cloud seeding carried out by the Malaysian Meteorological Service to try to induce rain over the catchment areas. A point to note – 1991 was an ENSO year.

The strong ENSO event of 1997-1998 has indeed affected Malaysians in every walk of life, starting with the thick transboundary haze that shrouded almost the whole country resulting in the declaration of a state of emergency in the state of Sarawak in October 1997. All efforts were concentrated on combating the haze but at the same time, rainfall was also drastically reduced over the whole country. In the early quarter of 1998, the drastically reduced rainfall over the whole country was felt particularly over urban areas like Kuala Lumpur when the water levels in the dams kept dropping day by day with no sign of rain. The monthly rainfall over the dams indicated very much below normal rainfall from January to May of 1998 as shown in Figure 1. Water rationing was imposed, taps run dry and temper runs high. Emergency meetings were convened and the usual question of 'When is the rain coming?' thrown at the Malaysian Meteorological Service (MMS).

The great water crisis has been brewing for some time, as the growth in the use of water has been outstripping the supply capacity. But no one expected the water shortage to be so acute, so sudden, so widespread and moreover, happened in the very heart of the nation's capital, Kuala Lumpur. ***An immediate cause of the crisis is the prolonged dry spell and the failure of rains to fall in the catchment areas.***

For Malaysia, February to March is the tail-end of the North-east Monsoon and climatologically, this period is generally drier for most of the country. After some careful analysis, the MMS assured the water authorities that convective rain activities are expected in the months of April and May when the inter-monsoon set in. The inter-monsoon period, which lasts up to mid-May, is characterized by severe thunderstorm activities in particular over the west coast states of Peninsular Malaysia. The forecast put up by MMS has helped to ease tension and enabled better contingency planning by the water authorities.

Current Practices

In the past, there are hardly any dialogue sessions between the water authorities and the MMS. This could be attributed to sufficient water storage and retentions in the dams and the water managers could meet the demand for water for agricultural purposes and general consumer usage. However, after the water crisis of 1998, the water authorities are much more aware of the need to consult MMS on seasonal forecast so that they can plan the amount of water to be released for the various sectors well ahead before the dams dip below critical levels. The costly lesson of 1998 resulted in more careful monitoring of water levels in the dam, rainfall over the dam areas and regular planning meetings with all the relevant agencies including MMS.

The beginning of this year is a good example. The first quarter of this year saw a sudden dip in the rainfall amount nationwide except for the western part of Sarawak in east Malaysia. The rainfall received is definitely much below normal and with media broadcast that there are signs of El Nino developing, the water authorities immediately called for emergency weekly meetings to monitor closely the rainfall forecast as well as the water levels in the dams and the necessary follow-up actions. Figures 2 & 3 clearly indicate the much below normal rainfall for the first quarter of the year for Peninsular Malaysia and the state of Selangor.

The state of Malacca was again affected and water rationing was imposed in early March. Kuala Lumpur was on the verge of imposing water rationing but called it off after a weather discussion and briefing from MMS that rain was expected after the middle of the month.

The dry spell over Peninsular Malaysia stretched for about 2½ months, from January to mid-March whereas in the East Malaysian state of Sabah, the dry spell stretched for a longer period. Hence, over urban areas, a 2½ month stretch of drier weather has caused a major concern among the water managers.

In Malaysia, water management is very much governed by individual state government. Over the last two decades, the Klang Valley, Penang and Malacca had developed a heavy demand for water due to economic and population growth and the rural-urban migration. However, the population and industrial concentration are in these three states where the water resources is less. In the Klang Valley where Kuala Lumpur is located, there are altogether 6 major dams as follows:

- Langat Dam,
- Klang Gates Dam,
- Sungai Batu Dam,
- Sungai Buloh Dam,
- Tasek Subang Dam,
- Sungai Semenyih Dam

Different agencies are responsible for the management of the different dams. The Tasek Subang, Klang Gates and Langat dams are run by a company called Puncak Niaga. The Sungai Semenyih and Sungai Buloh dams are still under the Selangor Waterworks Department (a government department) while the Batu dam is under the Drainage and Irrigation Department. Each of these dams are actually supplying water to the different areas in and around Kuala Lumpur. The Langat Dam and Sungai Semenyih Dam are serving a much larger population and faces greater consequences if the water level in the dam dip below critical level.

Application for climate forecast

During past major El Nino events such as the 1982-83 and 1997-98 events, the whole country received substantially below normal rainfall. There are large year-to-year fluctuations of standardized rainfall departure for the whole country. Figure 4 show the year-to-year seasonal (Jan to Mar) fluctuations of standardized rainfall for the state of Selangor, inclusive of Kuala Lumpur.

While some dry spells over Malaysia are associated with El Nino episodes, other ENSO episodes do not necessarily result in below normal rainfall. Furthermore, some dry spells over the country are not associated with ENSO episodes.

A simple and useful statistical parameter for measuring the normality (average) of rainfall received is percentile, which is defined and tabulated below:

Percentile Ranges	*Description*
> 80-100	Very much above average
> 60-80	Above average
40-60	Average (normal)
< 40-20	Below average
< 20-0	Very much below average

By compositing all rainfall amounts received in terms of their respective percentile values corresponding to each major El Nino or La Nina event, the impact before, during and after the event becomes immediately evident. Any percentile values ranging from 0 to 40 persisting for 2 months or more can be considered to be significantly below normal.

Malaysia, like most other countries, monitors ENSO development very closely especially the beginning of this year 2002 has yielded far below normal rainfall in many parts of the country. Although SOI has not indicated the appearance of El Nino, there appears to be a lot of anomalous convective activities in the Central Pacific and increasing SST anomaly in the Tropical Eastern Pacific since the beginning of the year.

Hence, a critical factor in the seasonal forecast is the ENSO forecast itself. Using the latest available information and predictions from some of the bigger centers such as the National Center for Environmental Prediction (NCEP), Climate Prediction Center (CPC), European Center for Medium Range Weather Forecast (ECMWF), Japan Meteorological Agency (JMA), etc. , the Asean Specialized Meteorological Center (ASMC) coordinates the regional climate review and prepares a regional concensus climate forecast to be used by policy makers for joint follow-up measures. Based on the ENSO forecast, a rainfall prediction table is put up as follows:

	Apr - Jun 2002	Jul - Sep 2002	Oct - Dec 2002
	Neutral	Weak El Nino	Weak/Moderate El Nino
Peninsular Malaysia	N	N	N
Sarawak	N	N	SB
Sabah	SB	SB	SB

The notation 'N' indicates normal rainfall and 'SB' indicates slightly below normal rainfall.

And based on this general prediction, by compositing the percentile values for the various available observations in a particular region, MMS is able to put up rainfall prediction for the various regions of the country.

Another aspect of climate application is the analysis of rainfall trend over the whole area. During the water crisis of 1998, newspaper headlines have highlighted that heavy rain was reported over the city area but there are hardly any rain over the catchment and dam areas. With deforestation over the catchment areas and heat island effect over the urban areas, micro climatic changes could be taking place and detailed analysis on the apparent change in rainfall trend has to be carried out to support the water resources management.

Benefits

With the rapid pace of development in particular over urban areas, water resources management should constantly review planning of water supply and the management of water storage. In an ideal situation, the reservoir should be full of water at the beginning of the year to ensure constant supply and to allow for more water to be released during the dry seasons (Jan to Feb and June to August).

However, during an ENSO event, the rainfall can be drastically reduced with a weak northeast monsoon, such that the water level at the dam may not be full by year-end. And if the dry spells carry on till the first quarter of the next year, the water level will dip below the critical level.

With advance climate information, the water resources management can plan well ahead the strategies to take and able to control the release of the precious water to ensure sufficient continuous supply throughout the year.

Scope for Improvement

The main constraints for applying climate information is firstly the length of the records may not be sufficient to carry-out more accurate analysis on the rainfall trend for a particular area. Although ENSO events is the dominant factor that will affect rainfall in Malaysia, the ENSO impact on the weather pattern differs during different ENSO event.

In view of some of these constraints, to overcome it, regional efforts such as those carried out by the Asean Specialized Meteorological Centre (ASMC) in Singapore with regular regional review meetings, or the Asian Climate Training workshop on climate information applications conducted by the Asian Disaster Preparedness Center (ADPC) could continue to be carried out so that concerted efforts and resources can be pooled together to improve the understanding of the changing weather and to learn from each other.

Conclusion

With the past disaster history in mind, the relevant Agencies, be it the water resources management, the agricultural authorities or the disaster mitigation and planning authorities are beginning to appreciate the need for seasonal forecast and the need to work together to ensure that water crisis of the proportion of 1998 do not happen again. MMS is also working towards better understanding of the forecasting needs of the various sectors and eventually providing more useful seasonal forecast tailored specifically to the user's needs.

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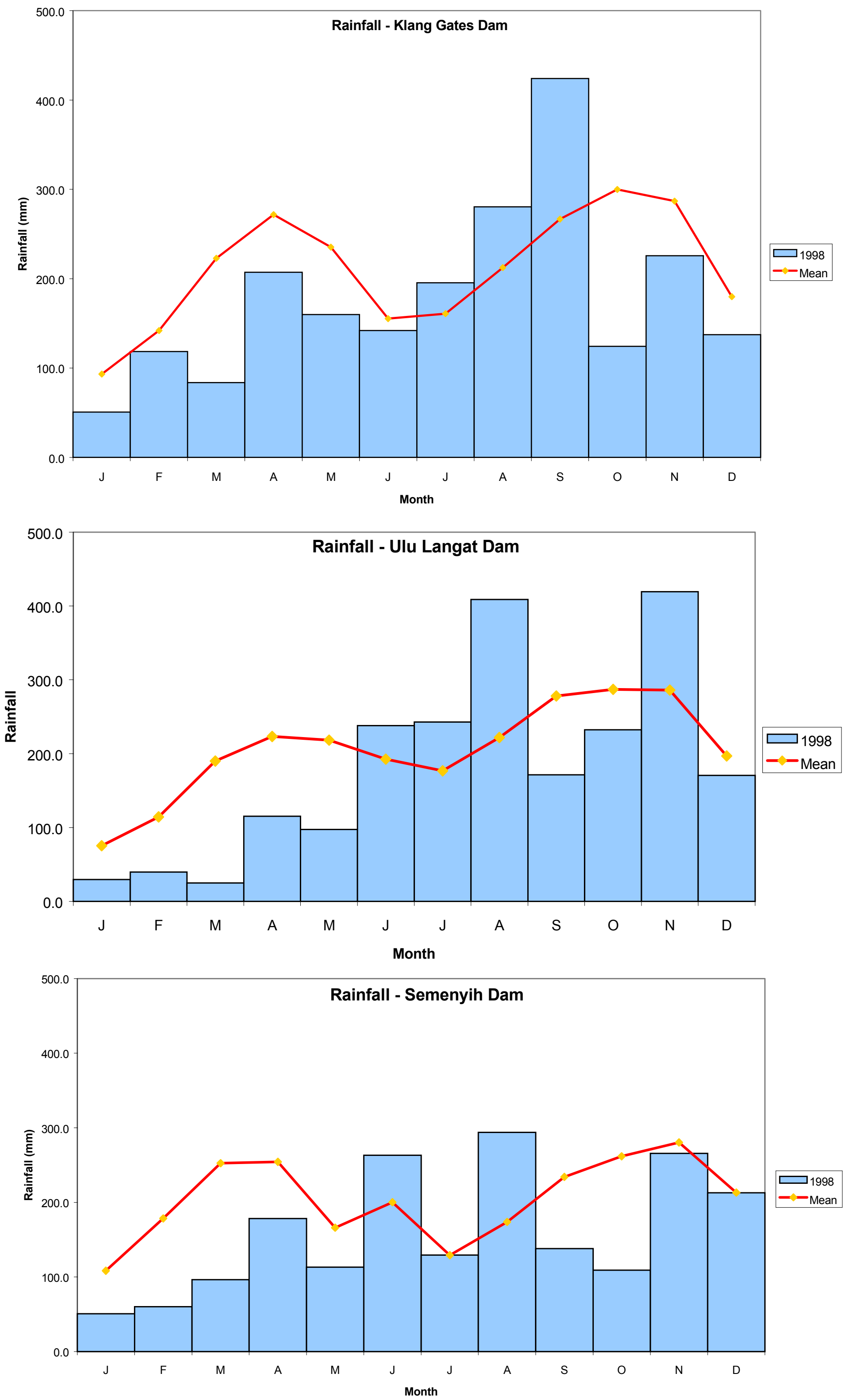


Figure 1: 1998 Rainfall over Klang Gates Dam, Ulu Langat Dam and Semenyih Dam compared to its long-term mean

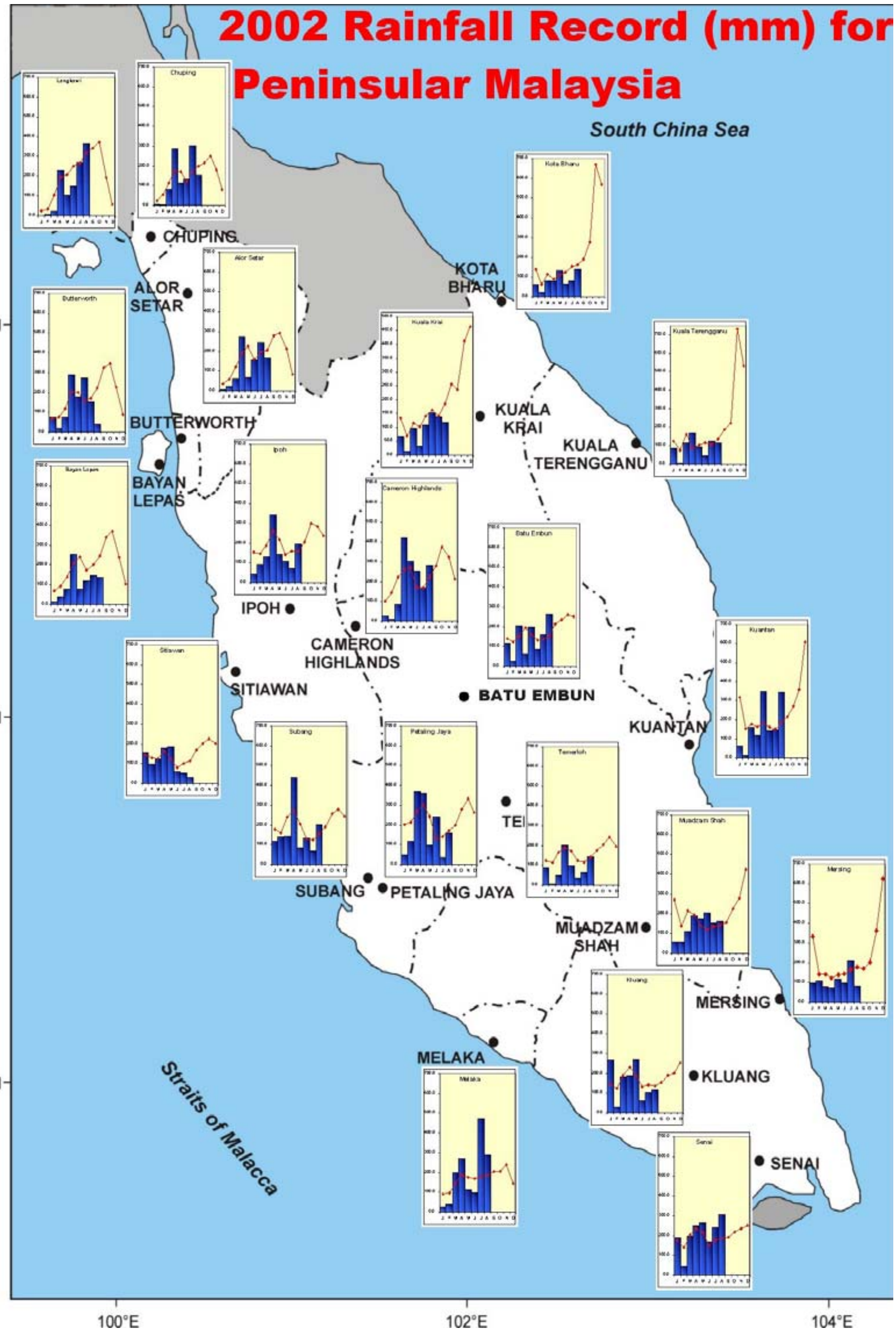


Figure 2: 2002 Rainfall record compared to its long-term

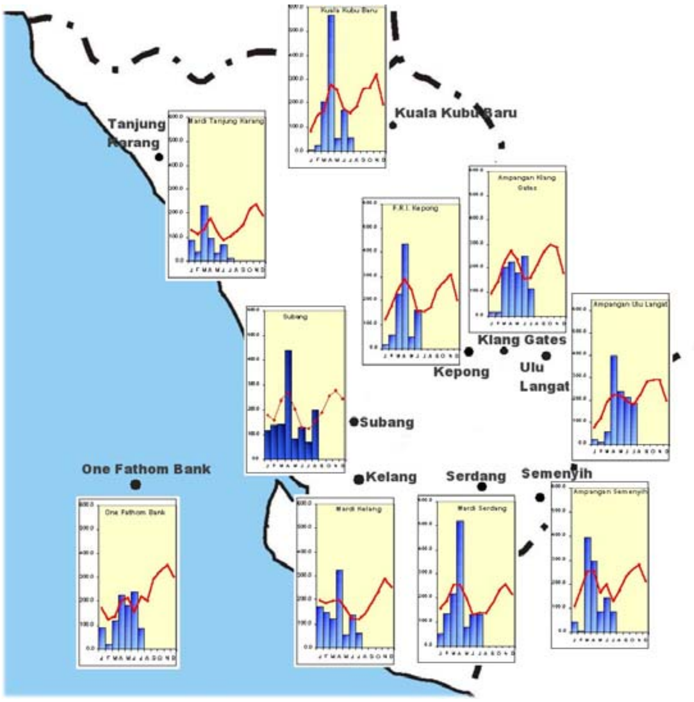


Figure 3: 2002 Rainfall chart over the state of Selangor compared to its long-term mean.

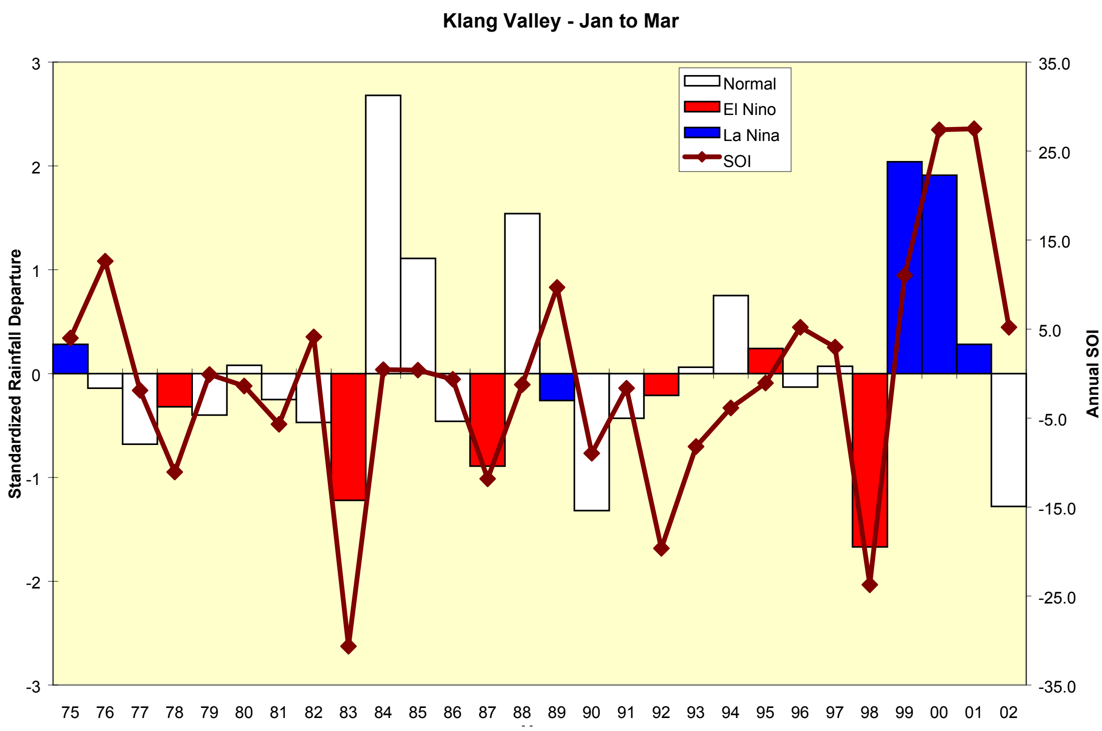
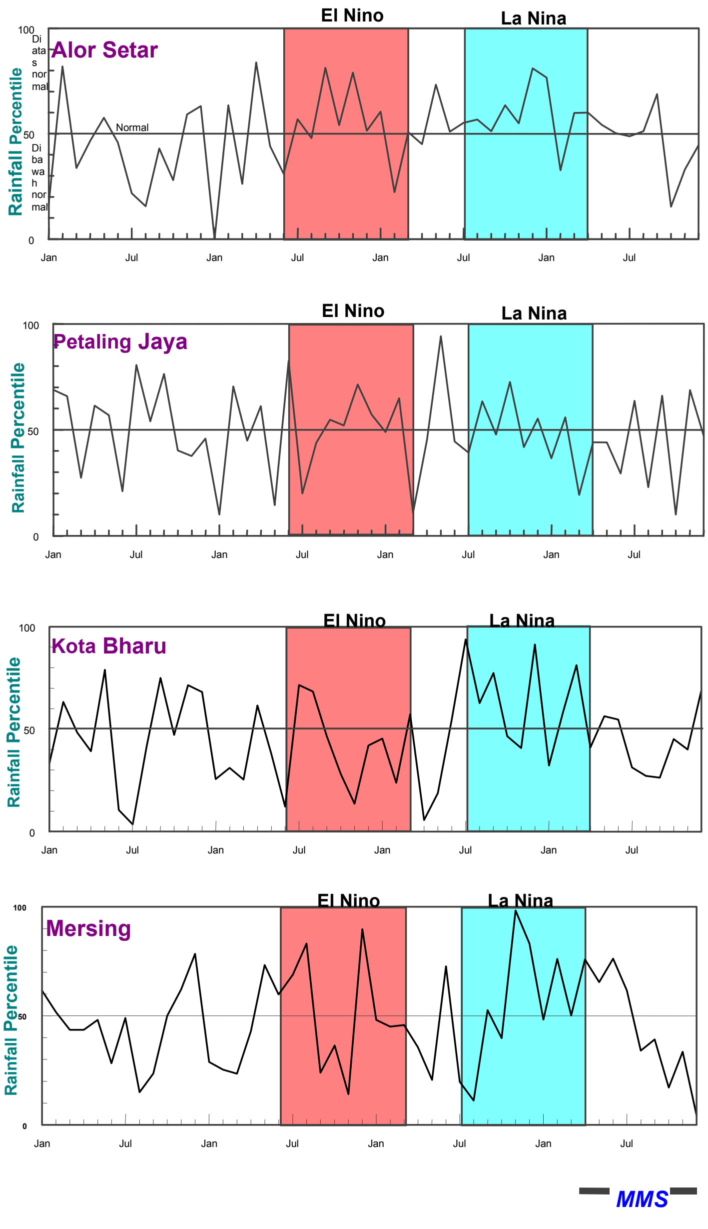


Figure 4 : Seasonal Rainfall Index for Klang Valley

Figure 5: Significant El Nino and La Nina in terms of Rainfall Percentile Index - Peninsular Malaysia



APPLICATION OF CLIMATE FORECAST INFORMATION IN MITIGATING IMPACT OF CLIMATE HAZARDS IN METRO MANILA: CASE STUDY ON THE 1997-1998 EL NIÑO EVENT

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Abstract

Extreme events always leave indelible impacts at varying degrees to different sectors of society. The decline in the growth rate of the Philippine economy to 0.3% can be attributed to the impacts of the 1997-1998 El Niño. One of the sectors that was directly impacted was water resources. Since the demand for water is encompassing, all the other sectors were consequently affected.

In urban areas i.e. Metro Manila, the impacts of climate variability was amplified due to the high demand of available water for industrial and domestic uses. What happened in Metro Manila during the recent El Niño episode has led to the recognition of the importance of using advance climate information in water resources planning.

This paper will present the severity of the impacts of the extreme event with particular emphasis on water supply for Metro Manila, the interventions and coping strategies adapted, the lessons learned and the importance of climate forecast information in managing the water resources of Angat dam, the main source of potable water for Metro Manila.

I. General Description of the Study Area

1.1 Organization and Administration

The general direction of development for Metro Manila is geared towards the alleviation of poverty, generation of productive employment and promotion of a desirable metropolitan environment. This is to address and cope with the rapid population and accelerated urbanization in the area.

The National Capital Region (NCR) or Metro Manila administers 12 cities and 5 municipalities. Before 1975, development and planning was done at the local level (city and municipality). With the growing population and urbanization, more and more problems cropped up. In 1975, The Metro Manila Commission (now called the Metro Manila Development Authority or MMDA) was created to develop policy and plans for the region. The MMDA is responsible of several activities such as garbage collection, sanitation improvement, cleaning and declogging of drainage channels and recently flood control, etc.

The MMDA is headed by a Chairman who is designated by the President of the Philippines. Other government agencies as well as non-government organizations and private institutions are also involved in achieving the Region's development goals.

1.2 Socio-Economic Profile

At present, Metro Manila has a land area of 636 sq. km (0.2% of the whole Philippines) and still growing due to the continuous reclamation projects along Manila Bay. Based on the Population Survey conducted in May 2000, the population of 9.9 M (13.0% of the whole country) is concentrated in the region resulting to a high population density of 15,618 persons per sq. km. The low population growth of 1.0% from 1995 – 2000 (which is less than half of the nation's average growth rate of 2.3% per annum) indicates that the metropolis is saturated with inhabitants.

The NCR accounts for 30.7% of the country's gross regional domestic product (GRDP) in 1999 which corresponded to the country's growth rate of 2.5%. The country's 1999 figure was a rebound from the 0.3% growth rate in 1998 following the country's economic trend. Major indices from 1997 to 2000 showed the slump in the nation's economy in 1998 was brought about by the impacts of the 1997-1998 El Niño event. In the industry sector, the NCR's share amounts to 35% while as much as 41% share was registered in the services sector.

The unemployment rate of 19% in 1999 is higher than the country's average of 14%. Its share in the agriculture sector is only 1% of the total employment as compared to the country's average of 37%.

The average annual family income of the region (P271,000) is more than that of the country's average (P123,000) and the average annual expenditures (P218,000) is also more than twice the nation's average. In terms of expenditures, the share of food expense amounts to a low 36% and that of rent is considered high at 22% as compared to the country's average and other regions.

1.3 Physical Profile

Metro Manila lies along the flat alluvial and deltaic land extending from the mouth of the Pasig river in the west and the higher rugged lands of the Marikina Valley and the Sierra Madre mountains in the east. It is bounded by Manila Bay in the west, the plains of central Luzon in the north and the Laguna de Bay in the south. The location map of Metro Manila is shown in Fig. 1

There are 3 river systems (Fig. 2 that run through the metropolis: the Pasig (with its tributaries, the San Juan and Marikina rivers), the Tenejeros river, and the Malabon river.

Since the 1970's, nearly 95% of NCR residents are engaged in non-agricultural activities. The land use trends were determined according to the socio-economic demands of a growing population.

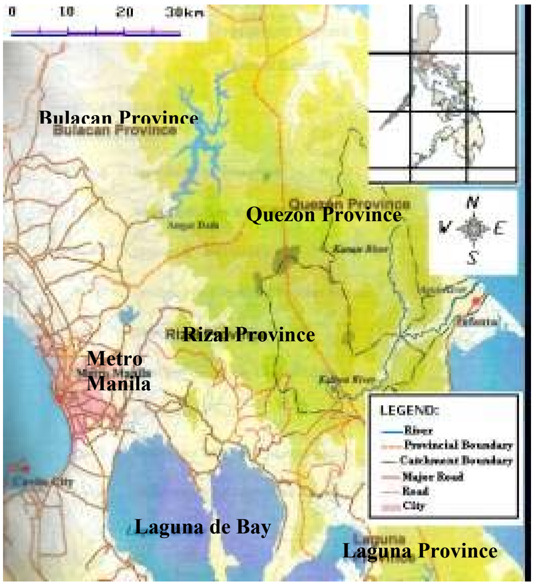

Fig. 1 Location Map of Metro Manila

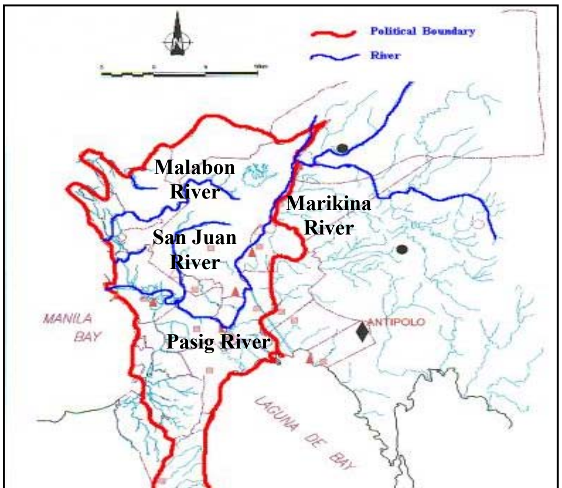

Fig. 2 River System of Metro Manila

The residential land use is the most predominant land using activity in NCR accounting for about 65% of the total land area allocated for housing in 1992. There has been an in-filling of the urban area with high density housing. The residential land use accounts for about 3% of the total land area with commercial activities concentrated along major roads and highways. The industrial land use occupies about 5% of the total land use. The institutional land use concentrates in Quezon City comprising about 5% of the total land use.

1.4 Climate

Metro Manila belongs to the Type I climate (Corona's classification), which is characterized by a dominant rainy season from May to October and dry for the rest of the year (Fig. 3).

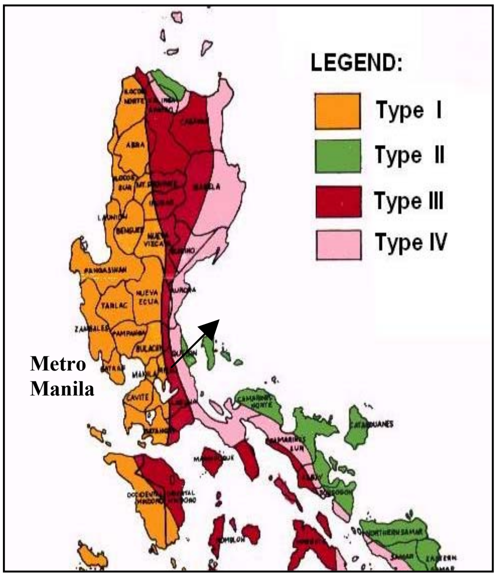

Fig. 3 Climate Map of the Philippines

Annual rainfall ranges from more than 3,000 mm over the Sierra Madre mountain range where the headwaters of the Marikina river is located. On the other hand, from Manila Bay area to Laguna Lake, the annual rainfall is about 2000 mm. About 80% of the total annual rainfall occurs during the wet season, that is from May to October. Rains are due to passing tropical cyclones, the monsoons and local thunderstorms and the inter tropical convergence zone (ITCZ).

The annual temperature ranges from 8 ^{0}C to 32.1 ^{0}C and a mean of 27.4^{0}C . Annual mean relative humidity is 77 %. The range of annual evaporation is from 1,400 mm to 1,900 mm.

1.5 Infrastructures

Road network

The total length of roads is the region in 1985 was about 4,912.4 km including national roads of 719.8 km and provincial roads of 182.2 km There are other privately developed subdivision roads and their share is more than 1/3 of the total length of roads. The ratio of pavement is generally high.

Water supply

Before 1997, the government through the Metropolitan Waterworks and Sewerage System (MWSS) managed the construction and maintenance of water supply and sewerage system in Metro Manila. The MWSS maintained 2 treatment plants namely, Balara and La Mesa dam with a total production capacity of 4,000 million liters per day (MLD).

In 1997, the MWSS awarded a Concession Agreement on the operation and maintenance of the treatment plants to private institutions. The Maynilad Water Services Inc. (MWSI) covers the west zone of the service area while the Manila Water Company Inc. (MWCI) is responsible for the east zone. The west zone includes 8 cities and 3 municipalities while the east zone covers 5 cities and 3 municipalities. The service areas of the 2 concessionaires are shown in Fig.4.

With the growing population, available supply from the central distribution system is currently below the total demand of the service area as shown in Table 1. Fringed areas are subjected to scheduled water rationing particularly during the summer months when insufficient supply and low pressure becomes frequent.

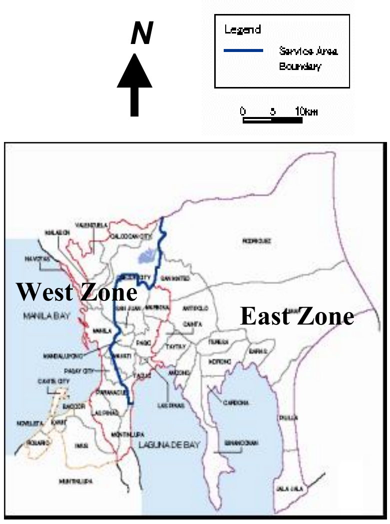

Fig. 4 Service Areas of MWSI and MWCI

Table 1 Service Area and Population Served (NCR)

Item	East Zone	West Zone	Total
Operating Body	Manila Water Co. Inc. (MCWI)	Maynilad Water Services Inc. (MWSI)	-
Area	1,400 km2 (72%)	540 km2 (28%)	1,940 km2
Population	4,562,000 (39%)	7,285,000 (61%)	11,847,000
Pop.Served	3,273,000	4,847,000	8,120,000
Coverage	72%	67%	69 %

Sewerage

There were 2 sewerage system for Metro Manila that were constructed before 1909. One is the central sewerage system with the load capacity to serve 450,000 people. At present, the system covers 1,850 ha with a total length of 240 km and capable of serving 530,000 people. The other system (with a total length of 140 km) is for Quezon City and Makati City which are mostly in subdivisions and commercial areas serving 350,000 people. The rest of Metro Manila discharges its wastewater either into storm drains, septic tanks or directly into the rivers and creeks.

Power

Electric power to the NCR is generated by the National Power Corporation (NPC) through the Luzon Grid. The components of the generated power are coal or oil, thermal, hydropower and geothermal.

About 80% of the generated power is supplied to the Manila Electric Company (MERALCO) which distributes power over the whole region. The annual household power consumption in Metro Manila in 1989 and 1995 was recorded at 2,867 GWH and 3,191 GWH, respectively. The 1995 figure corresponds to almost 40% of the annual electricity consumption for the whole country and more than 10% increase from the 1989 data.

Flood Control and Drainage

The Master Plan for the Flood Control and Drainage System for Metro Manila was put up in the 1950s. It has been implemented continuously through foreign assistance and local funding benefiting more than 1.9M people. The construction /improvement /upgrading /repair /rehabilitation and operation of flood control structures have been implemented by DPWH to alleviate perennial flooding problems in Metro Manila (in July 2002, flood control activities have been transferred to MMDA through a directive from the Office of the President). Of the total 63,600 ha of the land area, about 10,600 ha (1/6 of the total area) are flood prone.

Major flood control infrastructures include the Mangahan flood gates and the Napindan Hydraulic structures whose operation is managed by the Effective Flood Control Operation System (EFCOS) shown in Fig. 5.

The region is equipped with 18 large and 24 small pumping stations with a capacity of approximately 300 cubic meters per second (cms) and capable of draining 6,000 hectares of flood prone areas in the metropolitan area.

The core of the NCR's flood mitigation works is a network of drain pipes (mains and laterals), canals, esteros and rivers that convey the flood waters to Manila Bay. At present, this network is composed of 44 km of mains, 1,200 km of laterals, 290 km of esteros and canals and 153 km of rivers and major streams.

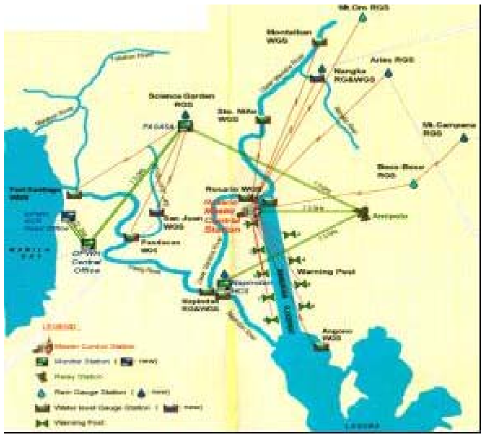

Fig. 5 Effective Flood Control and Operation System

1.6 Major Problems

Rapid urbanization is a phenomenon affecting adversely the quality of life in NCR. Some of the direct impacts include environmental degradation, severe traffic congestion, air, noise and water pollution, proliferation of squatters, uncontrolled garbage, flooding in many areas of the metropolis and high crime rate.

The main causes include the overbanking of water of the Pasig-Marikina and other rivers and poor capacity of the drainage system. This condition is aggravated by indiscriminate garbage disposal and the encroachment of squatters on the creek or along river banks. An estimated 95 km of esteros and creeks have been built over or filled. The coastal areas which constitute 1/6 of the total land area frequently experience flooding during high tide. The MMDA identified a total of 411 locations, which are flood prone and experience flood levels ranging from 6 inches to as high as 12 feet.

II. Disaster history of Metro Manila

Due to its geographical location and urban setting, Metro Manila suffers from the impacts of both natural and manmade disaster such as typhoons, floods, droughts, fires, earthquakes, landslides, "garvalance", etc.

2.1 Floods

Flooding is a perennial problem and caused by an interplay of natural, social and environmental factors. According to the survey conducted by the Department of Public Works and Highways (DPWH), the 1943 flood was the biggest with an inundation area of 10,950 ha. The floods in 1966, 1967, 1970, 1972, 1977, 1978, 1986 and 1988 have also resulted in serious damages in the metropolitan area. During the 1990s, flooding became more frequent and widespread. An local thunderstorm can easily flood the low-lying areas of Metro Manila.

2.2 Earthquakes

Although not frequent, Metro Manila is also prone to earthquakes due to the presence of active fault lines that runs across the Marikina Valley. In 1968, a powerful earthquake hit Manila. The earthquake that hit northern Luzon on July 16, 1990, with epicenter in Central Luzon affected the metropolis and caused damage to buildings and other infrastructures.

2.3 Tropical Cyclones

On the average, tropical cyclones occurrence is about 6 cyclones in 3 years. Most often these passing cyclones wreaked havoc to the metropolis not only for the strong winds but also of the intense rainfall these storm bring about.

2.4 Droughts

Other major disasters included the most celebrated 1997-98 El Niño , the impact of which ravaged the Philippines, particularly Metro Manila and the Mindanao area. The prolonged dry period over the Angat watershed where Metro Manila derives 97% of its water supply reduced the availability of water to 4 hours in a day.

2.5 Landslides

The most tragic event was a landslide at the Cheery Hills Subdivision in Barangay San Luis, Antipolo City on August 3, 1999. Three (3) days of continuous rain saturated the cliff at the eastern side of the subdivision causing the collapse of the slopes and buried 440 houses on the estate which left 58 dead and 31 injured.

2.6 Others

The Payatas tragedy in the morning of July 10, 2000 featured a major landslide and ensuing fire at a major dupmsite at Barangay Payatas B, Phase 2 Lupang Pangako, Quezon City. The week-long heavy rains brought by TY Ditang and Edeng caused the 50-foot mountain of trash collapse burying an estimated 300 squatter shanties in an area of about the size of “four basketball courts” (Tubeza, 2000). More than 600 families were affected, while more than 3,000 persons suffered from the tragedy (Dayrit, 2000).

The 1990s could be appropriately referred to as the “decade of natural disasters (Leung, et. al., n.d.) not only for the Philippines but also in Metro Manila. In June 1991, the region suffered from ash falls brought about by the eruption of Mt. Pinatubo.

III. Current practices for urban disaster management

The vulnerability of the Philippines to natural and man-made disasters has required the establishment and implementation of formal and effective disaster management structures. After World War II, the government had developed comprehensive plans that were supported by legislative initiatives which considered more and more the involvement of the public in disaster mitigation. From the Civil Defense Act of 1954 (Republic Act 1190) which created the National Civil Defense Administration (NCDA), now known as the Office of Civil Defense (OCD), all activities and functions, on the national level of various agencies and instrumentalities of the national government and private institutions and civic organizations devoted to public welfare were coordinated. to ensure the maximum utilization of facilities and resources of the entire country for the preservation of people’s life and property during war and other national emergencies (The Philippine Disaster Management Story, 2002).

On June 11, 1978, the National Disaster Coordinating Council (NDCC), Regional Disaster Coordinating Council (RDCC) and the City/Municipal Disaster Coordinating Council (CDCC/MDCC) were created through Presidential Decree (PD) 1566 to strengthen the Philippine disaster control capability and to establish a national program for community disaster preparedness. With reference to PD 1566, the Calamities and Disaster Preparedness Plan was prepared by the OCD-NDCC in 1988. The NDCC is composed of the heads of agencies of all departments including the Presidential Executive Secretary, Chief of the Armed Forces of the Philippines and the Philippine National Red Cross, an NGO.

Disaster management for Metro Manila is an undertaking participated in by quite a number of agencies such as the MMDA, national government agencies, non-government organizations and private institutions. Activities on disaster management are coordinated by the National Disaster Coordinating Council (NDCC) through its implementing arm, the Office of Civil Defense (OCD) and also the city and municipal DCCs (at the local level).

With the proclamation of the 1990s as the International Decade for Natural Disaster Reduction (IDNDR) by the United Nations (UN) General Assembly on December 22, 1988, the activities of the NDCC and the member agencies in disaster mitigation was enhanced following the concerns of the IDNDR.

On July 29, 1998, to raise the consciousness of the Filipinos on disaster management, Proclamation No. 296 was signed and declared the first week of July of every year as the Natural Disaster Consciousness Week. With reference to this proclamation, E.O. No. 137, issued on August 10, 1999, declared the month of July of every year a National Disaster Consciousness Month. As a significant mitigation measure, it recognized the need to lengthen the period of the promotion of disaster consciousness to one month to provide concerned agencies more time to implement their campaign and programs. Also stipulated in the Order was the institutionalization of the Civil Defense Deputization Program which sought to promote the sustainability of the disaster management program of the government as well as to empower the capacity of disaster coordinating councils.

There were several projects that have been launched by the NDCC in 1998 in connection to vulnerability reduction and risk management (Capistrano, 1998), namely:

1) Brigada Kontra Baha (Brigade Against Flood) – a multi-sector initiative which aimed to unclog waterways and drainage system. This project was launched in key cities of Metro Manila, Cebu City and Davao City.
2) Oplan Bangun Mindanaw (Rise Minadanao Plan) – a multi-sectoral rehabilitation program for El Niño affected areas which include the following strategies: a) generating livelihood and household income, b) enhancing health and nutrition services, c) protecting vulnerable communities from the anticipated impact of La Nina, d) agricultural development and modernization, and e) reinforcement of DCCs.
3) Laban La Nina (Fight Against La Nina) – was formulated in anticipation of the impacts of La Nina. The contingency plan was composed of the following components: a) hazard and risk maps for flood/lahar, b) communities and lifelines at risk, c) capacity and vulnerability assessment, and d) strategic interventions.
4) Linis Bayan Program (Clean Your Area Program) – institutionalization of a nationwide clean-up campaign in all government offices, schools, communities and homes to promote cleanliness in the environment as embodied in Administrative Order No. 32.

During the occurrence of high flows of the Marikina and Pasig rivers, the operation of the Mangahan Floodway / Napindan Lock system is synchronized to divert temporarily the inflow from the Marikina river to the Laguna Lake to minimize flooding in the downstream area of the Pasig-Marikina basin. After the flood, the Napindan Lock is opened to flush out the stored water to Manila bay via the Pasig river. Flood warnings/signals are issued to the residents along the Marikina river and its adjoining vicinity prior to the release of excess floodwaters at the Mangahan floodway and Napindan flood gates by the Effective Flood Control Operation System (EFCOS) which is now under the management of the MMDA.

In addition, since the pumping stations cover only 60% of Metro Manila's flood prone areas, the remaining 4,000 ha of the flood prone areas have to be serviced by the DPWH Mobile Flood Teams which are out on the streets as soon as the built up of floodwaters is noted.

Other structural measures of mitigating flooding include: a) Dredging of rivers, creeks, esteros and open channels – usually undertaken every 2 years depending on the degree of siltation; and b) desilting of drainage laterals –a year round activity.

In 1997, the DPWH launched the ***Bantay Estero Program*** to preserve and maintain the cleanliness of identified esteros/creeks/open channels by removing floating garbage and other solid wastes using scow and improvised banca. This program also provided employment to local residents within the vicinity who are hired for this program. The LGUs have been directed to replicate the successful pilot operation of DPWH in all cities and municipalities of Metro Manila.

An NGO initiative on the "Piso sa Pasig" is also an advocacy program to clean the Pasig river.

To help alleviate the plight of squatters or the poorest in Metro Manila, the government through Republic Act 7279 has prioritized the relocation of some 66,334 families residing in danger areas specifically those exposed to serious health hazards and life threatening situations. The implementation of this Act has been given to local government units with the assistance of different national government agencies, namely: the Housing and Urban Development Coordinating Council (HUDCC), the Philippine National Police (PNP), the Presidential Commission for the Urban Poor (PCUP), the Department of Education (DepEd), the DPWH and the Commission on Human Rights (CHR).

To address the garbage situation, the government has taken major initiatives to implement an environmentally friendly solution to Metro Manila's growing solid waste generation by reducing the volume of waste for final disposal and the development/establishment of alternative waste disposal facilities to prolong the service life of existing sanitary landfills. The campaigns on zero waste management and the collection of sorted of garbage has been enhanced. Schedule the collection of each type of sorted garbage, e.g. Mondays/Wednesdays for recyclable materials and the rest of the week for non-recyclable wastes.

As an early warning system, the PAGASA issues the onset of the rainy season to alert all sectors to prepare for the coming rainy season including the issuance of weather forecasts, advisories and outlook.

Intensive public information drives are also conducted by all concerned sectors.

IV. Case Study: Management of the water resources of Angat Dam during the 1997-1998 El Niño Event

The study focuses on the management of the water resources of Angat dam with particular reference on the water supply of Metro Manila during the occurrence of the 1997-1998 El Niño event. During this extreme event, the information on climate forecast became a crucial factor in the utilization of the impounded water in Angat dam.

4.1 Background

The Angat river is located on the southeastern part of Central Luzon originating on the slopes of the Sierra Madre Mountains (Fig. 6) and flowing in westerly direction across the lowland plains of Bulacan before emptying its water into the Manila Bay. It has a catchment area of 781 sq. km. and estimated run-off of 873 MCM.

Fig. 6 Location Map of the Angat Dam

The river was developed in its optimum capacity by the construction of the Angat dam in 1967 for multipurposes: hydropower, water supply, irrigation and flood control. It was constructed and operated by the NPC, however, its primary uses are for water supply and irrigation. The reservoir has a drainage area of 568 sq. km. at the dam site.

The reservoir supplies about 98 % of raw water requirement for Metro Manila through the facilities of the MWSS. It irrigates about 30,000 hectares of farmlands in the provinces of Bulacan and Pampanga under the service area of Angat-Maasim River Irrigation System (AMRIS) of the National irrigation Administration (NIA) and can generate a maximum power of 246 MW. During the rainy season, the dam serves as a flood control facility of about 63 MCM of floodwaters and a buffer for the increased water inflow in the watershed catch basin.

4.2 Hydro-meteorological Features

The Angat river basin is dry from November to April and the wet season during the remaining months of the year. Rainfall is usually intense in May until October. Since the catchment is dependent mostly on rainfall to sustain its inflow, the Angat basin, particularly the Angat dam is highly sensitive to climate variability as manifested in the previous occurrence of extreme climate events. In Fig. 7, the lowest annual rainfall data were recorded in 1983, 1987 and 1998 (El Niño years) while the wettest years occurred in 1972 (normal year) and 1999 (La Nina year). The annual rainfall ranges from 4,919 mm to 1430 mm and an average of 3,126 mm. The extraordinary flood occurred on October 27, 1978 with 2,730 mm of rainfall recorded. It is surprising to note in Fig. 8 that most negative rainfall anomalies started in the mid-eighties and persisted until the nineties.

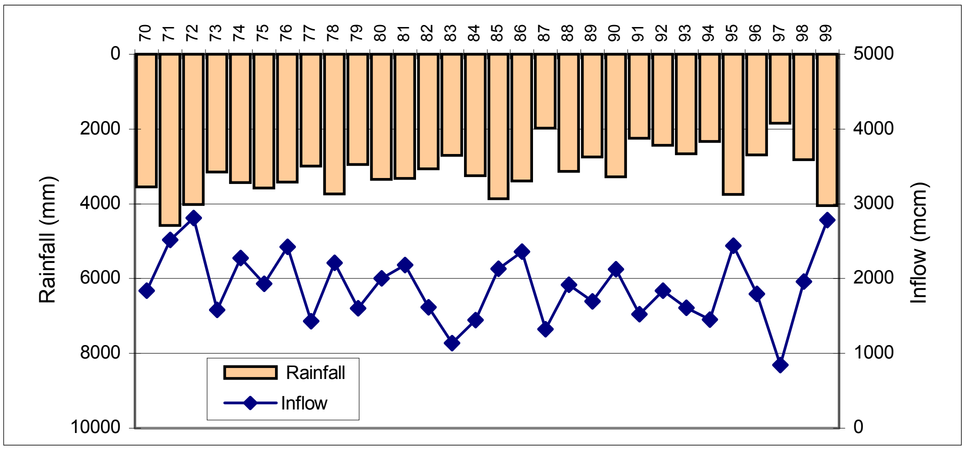

Fig. 7 Annual Rainfall and Inflow of Angat Dam

4.3 Normal Reservoir Operation

The operation of Angat reservoir governed by a pair of rule curves, one for the flood season (May to November) starting at elevation 212 m and the other during the non-flood season (December to April) as shown in Fig. 10. A rule curve is defined as the minimum elevation where water needs for irrigation, water supply and power generation are satisfied. The upper rule curve represents the top of the conservation storage. When the reservoir surface rises above this curve, the excess water is discharged downstream through the powerhouse, spillway or a combination of both. The lower rule curve represents the top of the buffer zone. When the reservoir surface drops below this curve, releases from the reservoir made only through the auxiliary powerhouse for water supply.

In terms of reservoir elevation, the minimum water elevation that the reservoir is capable of supplying the water requirements of the MWSS is 160.0 meters AMSL if the water releases are through the auxiliary turbines, 149.0 meters if the water releases are through the by-pass tunnels and 101.5 meters if the water releases are through the low level outlet.

4.4 Effects of the 1997-1998 El Niño Event on the Angat Reservoir

The Angat reservoir was severely affected during the El Niño 1997-1998. The effect became apparent when the rainy season terminated in July 1997 coupled with unusually high temperature. Furthermore, there were few occurrences of tropical cyclones and weak monsoon activities. The prolonged dry season was evident in the inflow record of the Angat as shown in Table 2.

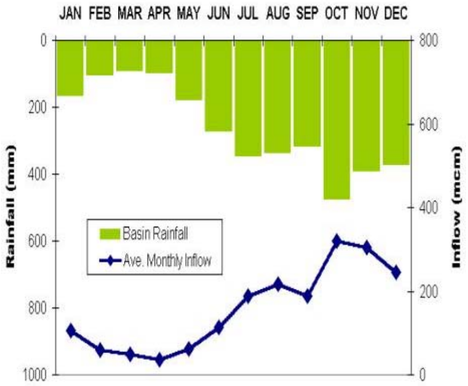

Fig. 9: Average Monthly Hydrograph and Hyetograph of Angat Dam

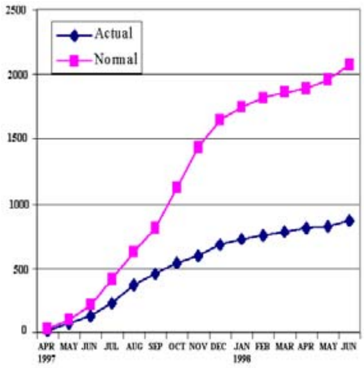

Fig.10: Actual vs. Average Inflow of Angat Dam During the 1997-1998 El Nino

Based on the average monthly rainfall of Angat dam shown in Fig. 9, the maximum rainfall and inflow normally occur in October. The graph also shows the strong relationship between rainfall and inflow to the dam which means that deficiency in rainfall over the catchments (which normally happens during El Niño episodes) will severely affect the operation of the reservoir. In a recent study on the analysis of extreme climate events (ECEs) in major reservoirs in the Philippines, it was found out that there is a 0.50 % to a maximum of almost 20 % decrease (on the average) in the inflow of Angat dam during El Niño events. . As depicted in Fig. 10, the actual inflow was observed to be way below the average monthly inflow.

During this warn episode, there was an 87% reduction in rainfall from June to August 1998. The months of July and August are supposedly the start of heavy rains but observations reveal that rainfall recorded in July and August 1997 amounted to 102 mm and 142.6 mm, respectively, while those in July and August 1998 were 31mm and 57 mm, respectively. Normally, the average rainfall in the watershed during these months are 284.80mm and 293.30 mm, respectively

As a result of the rainfall deficit in the Angat watershed, the total inflow of the Angat reservoir decreased to 842 MCM in 1997 equivalent to 60% below the average annual inflow of 2024.83 MCM.

In terms of water level of the dam, the lowest RWL on record occurred during El Niño years i.e. in July 17, 1992 (158.17 meters) and September 2, 1998 (158.15 meters) since 1968 when the dam was commissioned.

Table 2 Reservoir Operation of Angat Dam

Year	Month	RWL, meter AMSL	Deviation from RC, meters	Monthly Inflow, MCM	Water Releases (MCM)	
					Main turbine (for irrigation)	Auxiliary Turbine (for water supply)
1997	Jan 6	212.75		57.00	78.64	83.24

	Feb 3	207.95		77.20	68.02	83.6
	Mar 1	204.11		31.08	54.22	96.84
	Apr 7	196.35	1.20 up	11.97	12.09	90.25
	May 5	191.73	1.71 down	64.82	0	90.84
	Jun 2	190.76	0.96 up	48.23	29.75	84.69
	Jul 7	185.10	3.41 up	102.39	25.54	84.12
	Aug 4	185.68	2.47 down	142.61	23.66	72.52
	Sep 8	188.56	5.14 down	86.61	36.58	79.24
	Oct 6	187.43	10.44 down	90.23	17.18	90.13
	Nov 10	184.56	18.14 down	43.42	1.64	82.95
	Dec 1	183.54	19.10 down	86.92	0	73.27
1998	Jan 12	182.40	23.55 down	52.07	0.54	69.46
	Feb 2	182.20	21.01 down	28.04	0	62.54
	Mar 2	179.19	20.05 down	20.90	0	67.59
	Apr 6	174.60	20.60 down	31.22	0	64.51
	May 4	171.67	21.88 down	20.83	0	66.10
	Jun 1	167.77	22.73 down	38.98	0	62.71
	Jul 6	164.99	16.46 down	37.10	0	66.11
	Aug 3	161.62	26.36 down	51.74	0	63.80
	Sep 7	158.85	34.70 down	195.62	0	47.38
	Oct 5	175.23	22.50 down	402.67	0	53.34
	Nov 9	200.27	2.43 down	320.29	22.36	76.80
	Dec 7	212.36	6.41 up	761.16	244.72	108.24

4.5 Operation of Angat Dam During the 1997-1998 El Niño Episode

The allocation of water for the various users of Angat dam during this extreme scenario highlighted the importance of climate forecast and information for the effective operation of the reservoir in order to mitigate the impacts of this climate hazard.

The Interagency Committee on Water Crisis Management (ICWCM) which the government created in March 1987 at the height of the 1986-1987 El Niño convened more often to discuss how the weather outlook (PAGASA) will affect the status of the monitored reservoirs (NPC) and consequently on the operations of NIA (irrigation) and MWSS (water supply). Update reports on cloud seeding operation (BSWM) were also presented.

As early as the first quarter of 1997, even if the reservoir water level of Angat was above the rule curve, studies were conducted and inflow simulations were carried out to come up with the projected water elevation for the next 3, 6 and 12 months. Inputs to the simulation were forecast rainfall which is converted to forecast inflow, the actual inflow (for the month) and its occurrence frequency, the elevation of the dam and the requirements for irrigation and water supply. (Occurrence frequency is the percentage of time that inflow data for the same month of all other years exceeds the current data). The projected inflow and water elevation will be the basis for the operation of Angat reservoir. The optimum use of the available water in the reservoir after careful consideration of all the above inputs should be agreed upon by the members of the Committee. Such a decision will be elevated to the Governing Board of the NWRB for approval and implementation.

The early warning of PAGASA the El Niño in 1997 alerted the water-related agencies most especially the primary users of the Angat reservoir. The NWRB conducted several operational studies of the Angat reservoir to determine the available water in the reservoir and to optimize its utilization. The first study in September 22, 1997 showed that if full irrigation requirements were provided, the water supply will last only up to the month of January 1998. It further showed that it was necessary to cut off the release for irrigation in order to reach an elevation of 160 m by the end of June 1998. This study was the basis for the decision not to release water for irrigation for the next 11 months beginning November 1997 to October 1998 (Table 2) to the detriment of farmers in the service area of the Angat-Maasim River Irrigation System (AMRIS) in Bulacan and to cut back the water releases for domestic water from 37 cms to 32 cms. The second major study was conducted in late November 1997 and became the basis to reduce water releases to 27.5 cms. Another study conducted in March 1998 recommended the further cut of water releases to 25 cms. Close monitoring and effective allocation of the remaining water in the reservoir was undertaken to ensure adequate water supply until the next rainy season.

The decisions created heated discussions between the water user agencies but as stipulated in the Water Code in the Philippines, the use of water for domestic purposes should take priority over irrigation or other purposes during emergency situation or extreme events.

4.5 Impact to water supply for Metro Manila

There were quite a number of impacts of the 1997-1998 El Niño episode to various sectors of society. Direct impacts are manifested in the water resources (particularly water supply) and the agricultural sectors. Other sectors that were impacted include health, hydropower, environment, industry, etc. The succeeding discussions will focus on the impacts to water supply for Metro Manila and hydropower generation of the Angat dam.

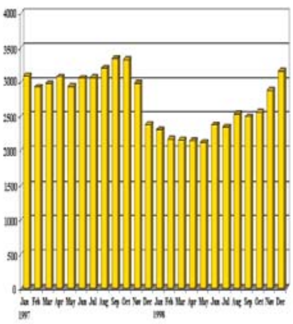

Fig. 11: Actual Vs. Average Inflow of Angat During the 1997-1998 El Nino

The MWSS supplies water in Metro Manila and its adjacent areas. The MWSS through its two concessionaires depends on the water sources from Angat reservoir to meet more than 90 percent of its water supply needs. The remaining requirements are taken from the ground water sources.

Under normal conditions, MWSS requires 37 cms from Angat to supply Metro Manila of about 3,300 million liters of water per day (MLD). However, in the event of drought, the requirement of MWSS could not be met and the water allocation may vary depending on the reservoir level.

From the point of view of MWSS, the El Niño event of 1997-1998 was the worst ever because it started at a most inopportune time – the start of the rainy season – the time when Angat dam must recover and replenish the water used during the preceding dry months.

Corresponding to the cutbacks in Angat releases were the cutbacks in water production. The water production level was at its lowest in the summer months of April and May 1998 when it dipped to 2100 MLD. This represents a 34 % reduction from the normal 3200 MLD. During the summer months, there was practically no contribution from the Ipo and La Mesa reservoirs. Despite the zero water allocation for irrigation in favor of water supply (Table 2), water for Metro Manila was still rationed with a 30% reduction in supply to further conserve the remaining water in the reservoir..

The metropolis and its nearby municipalities suffered from water shortages because of the decrease in water production from 3,200 MLD to 2,100 MLD as shown in Fig. 11. Note that Metro Manila accounts for 13 per cent of the total population of the country. In some areas, water was available only for 4 hours daily while other areas were supplied by the MWSS tankers. About 30 % of the population has no access to MWSS' supply and solely depended from the tankers supplied by private operators, which offered water at a higher cost.

4.6 Impact to hydropower generation

Water use for hydropower generation is non-consumptive but the pattern of water releases has to meet the power demands. Among the major hydroelectric dams in the Philippines, the Angat Hydroelectric Plant (HEP) was the hardest hit with a total deficit of 333.38 Gwh from the second quarter of 1997 up to the third quarter of 1998. Due to the low water elevation of the dam and the curtailment of water releases for irrigation, the main turbine of Angat HEP was not utilized. In order to cover the deficiencies of the hydropower plants, increase in the load of other thermal plants was undertaken which meant additional consumption of fuel oil which is relatively more costly.

4.7 Interventions

4.7.1 Measures on Water Supply Augmentation

To complement the water conservation measures being implemented at the Angat reservoir, steps were taken to augment water supply. The non revenue water (NRW) reduction program of MWSS's concessionaires were intensified. The number of leak repair crews was doubled and the drive against illegal connections was accelerated. About 20 new deepwells were dug and 35 existing deepwells rehabilitated in water starved areas. The MWSS's concessionaires completed the interconnection of the La Mesa By-pass line thereby recovering some 50 to 150 MLD of water that would otherwise have been lost to evaporation and seepage at the reservoir. A pump was installed to recover backwash water at the Balara Treatment Plant to yield some 15 MLD of water.

The low level outlet of the Angat reservoir which was inoperative due to the debris clogging the tunnel have been repaired and upon completion in June 1998, the MWSS was able to draw water up to the level of 149 m translating to an additional supply for Metro Manila up to August 1998.

Furthermore, the completion of Angat-Umiray Transbasin Project was accelerated. This project which was completed in June 2000 will ensure an additional inflow of 9 to 15 cms to the Angat reservoir.

4.7.2 Water supply distribution

To distribute water as equitable as possible, valving operations were conducted by MWSS's concessionaires. The valving operation has been refined so that the number and size of water starved areas were reduced. To deliver water to these critical areas, a system of stationary tanks and mobile tankers were set up. One hundred two (102) tanks of 10 cm capacity each were installed in various areas. To assure water quality in the event of low system pressures, monitoring activities were strengthened and a chlorination strategy was implemented.

4.7.3 Cloud seeding operations

To counteract the decreasing level as a result of the rainfall deficit, artificial rainfall is imperative. Thus, cloud seeding was requested from the Bureau of Soils and Water Management (BSWM). This was done in coordination and cooperation with NPC and PAGASA. During the 1997-1998 El Niño, BSWM conducted four (4) cloudseeding operations of about 280 sorties over the Angat watershed. As a result, the water level of Angat dam increased by 1.8 to 2.5 meters.

4.8 Institutional Responses

The PAGASA, the NWRB, the Interagency Committee on Water Crisis Management and the Presidential Task Force on El Niño were all instrumental in developing and implementing the response strategies. A joint committee among MWSS, MWSS Regulatory Office and MWSS's concessionaires was formed to manage the mitigating measures to El Niño . The NDCC promptly released the calamity fund for the construction of deepwells, the provision of tankers, hypoclorinators, the rehabilitation of Angat's low-level outlet and the depth survey study of Angat dam. The 51st Engineer Brigade of the Philippine Army assisted in the construction of the deepwells while the National Mapping and Resource Information Agency (NAMRIA) conducted a depth-survey of Angat to ascertain the available volume of water.

To manage water demand, an all out multi-media public information and education was launched centering on explanations about the El Niño phenomenon and on water conservation tips.

V. Potential economic benefits for using advance climate information for water resources management

The slump in the economic growth of the Philippines in 1998 as cited in the Study on Water Resources For Metro Manila (November 2001) was attributed partially to the impacts of the 1997-1998 El Niño event. Since many of the direct impacts of this extreme event occur through the hydrologic cycle for which climate is the primary driving force, the use of advance climate information for water resources management will definitely help mitigate the impacts of such events. For an urban center like Metro Manila, the country's major center for commerce and trade, adequate water supply is crucial in sustaining domestic, economic and industrial activities. With the growing population, urbanization and a fragile economy, any disruption i.e. the occurrence of an extreme event will have compounded impacts, hence there is much economic benefits to be gained in giving advance information on the climate to enable planners to develop contingent measures to lessen the adverse impacts of extreme events.

Based on the experience and lessons learned in 1997 and 1998, city officials and planners are more receptive to any information on El Niño hence the potential of using climate forecasts is higher than before 1997.

VI. Constraints and opportunities for applying climate information

The pronouncement of an El Niño or La Nina in the offing is not a guarantee for government agencies to act just like what happened during the 1997-98 El Niño and 1998-99 La Nina events. Some decision makers waited for manifestations of these extreme events before making the move. On the contrary, the society has yet so much to learn on the effect (which is selective) and the response of a particular catchment or basin or locality to El Niño . Perhaps because of the unprecedented impacts of the 1997-1998 El Niño , government agencies and LGUs alike are wanting for El Niño Outlook as an opportunity to ask for more funds.

Understanding the effects and the impacts extreme climate events or ECEs will give decision makers more confidence and opportunity of using climate forecasts. Therefore, documentation of the impacts of ECEs should be institutionalized and should cover all the other sectors not mentioned. For water resources, the impacts on ground water resources should be explored. The lack or scarsity of data on this aspect as well as the numerous agencies handling such kind of data in the Philippines make the documentation process difficult and time consuming.

The 1997-1998 El Niño event has taught lessons both in physical and organizational responses, which are worth documenting and sharing in anticipation of similar occurrences in the future. But perhaps the biggest lesson learned by the government planners and decision-makers is the recognition of the necessity to integrate the advance climate information in the process of strategic planning for water resources development and management.

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VULNERABILITY AND ADAPTATION ASSESSMENTS OF ANGAT MULTI-PURPOSE RESERVOIR TO CLIMATE CHANGE

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ABSTRACT

Global warming is expected to alter the global climate system in the future. Changes in the climate system will correspondingly affect the hydrologic cycle. The country's water resources, which is generally adequate at the moment, could be seriously affected by climate change. Recurrence of the El Niño/La Niña phenomena causing serious droughts and incidents of floods clearly show the impact of climate variability to the country's water resources. Increase in population, pollution and environment degradation could exacerbate the situation. With the application of General Circulation Models (GCMs) results for climate change scenarios and the use of a hydrological model to simulate future runoff-rainfall relationship, a preliminary and limited assessment of Angat multi-purpose reservoir has been undertaken. Results show that changes in rainfall and temperature in the future are critical in Angat's future inflow. Results of several GCMs agree that doubling of carbon dioxide concentration would mean higher temperature in the future, although rainfall estimation varies. Runoff simulation accentuated that rainfall variability would have a greater impact compared to temperature variability. Having recognized the vulnerability of the country's water resources to climate change, adaptation measures were identified that could lessen the potential impacts. Some of the adaptation responses that were identified are enhancement of the monitoring and forecasting capability of extreme events, comprehensive watershed development, and enhancement of irrigation efficiency.

1. INTRODUCTION

Concentrations of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide in the atmosphere have grown significantly for the past several years, brought about by human activities mostly from the use of fossil fuel, land-use change and agriculture. Doubling of GHGs concentration in the atmosphere in the future will lead to an alteration of the earth's energy balance resulting to an increase in global temperature or simply called "global warming".

Based on the estimates of the Intergovernmental Panel on Climate Change (IPCC), a 1^o- 3.5^oC increase in global temperature by 2100 is to be expected (IPCC, 2001). Recent analyses show that global mean temperature has increased by about 0.3^o - 0.6^oC since the late 19th century. Over the last 40 years, global mean temperature has increased by about 0.2^o to 0.3^oC. The 90's decade has been recorded as the warmest decade since 1860, despite the cooling effect of the Mt. Pinatubo eruption in 1991.

Climate change would lead to an intensification of the global hydrological cycle and can have major impacts on regional water resources. Changes in greenhouse gas concentrations are projected to lead to regional and global changes in climate and climate-related parameters such as temperature, precipitation, soil moisture, and sea level. A change in the volume and distribution of water will affect both ground and surface water supply for domestic and industrial uses, irrigation, hydropower generation, navigation, instream ecosystems and water-based recreation. Changes in the total amount of precipitation and in its frequency and intensity will directly affect the magnitude and timing of run off and the intensity of floods and droughts. In the lower latitudes or in the tropics, runoff may decrease due to increase evapotranspiration and decreased precipitation. More intense rainfall would tend to increase runoff and the risk of flooding, although this would not only depend on the change in rainfall intensity but also on the catchment's physical and biological characteristics.

At present, the country's water resource is manageable. Substantial supply brought about by abundant rainfall could very well satisfy the national requirement. However, as viewed from the regional or provincial level, the supply is not enough to meet the demand. Due to uneven distribution of rainfall with time and space, some areas are not endowed with enough water supplies. Occurrence of extreme events such as droughts and floods, which are associated with the El Niño and the La Niña phenomena and passage of strong tropical cyclones have magnified the situation, thus affecting time and again the country's water resources (Jose, 1992; Jose et al., 1993). Domestic sewage, industrial wastes, uncontrolled groundwater extraction, and watershed degradation are some of the threats being encountered by the country's water resources. Trends also show that a significant increase in future demand is to be expected based on high growth rate of population particularly in highly urbanized areas.

2. OBJECTIVES AND LIMITATIONS

This study was undertaken with the aim of conducting a preliminary assessment of the potential impacts of climate variability/change on surface water resources in the Philippines and to be able to identify, evaluate and prioritize possible adaptation strategies in mitigating potential adverse effects of climate change.

Due to limited data availability and time constraint, preliminary vulnerability assessment had been conducted in only two of several existing multi-purpose reservoirs in the country (Angat multi-purpose reservoir and Lake Lanao). Potential impacts of climate change as well as adaptation assessment in other sub-sectors like drainage, flood control, salinity control, fishery, protection of aquatic life, and navigation are not yet examined.

3. ANGAT MULTI-PURPOSE RESERVOIR

There are six major multipurpose reservoirs in the Philippines today, namely; Ambuklao, Magat, Binga, Pantabangan, Angat and Lake Lanao. Five are located in the island of Luzon and one in Mindano. Figure 1 shows the location of these major reservoirs. All of these reservoirs satisfy the various water requirements of their respective areas. Among these reservoirs, the Angat reservoir was chosen as one of the pilot areas for the preliminary conduct of vulnerability and adaptation assessments in view of its socio-economic importance.

The Angat multi-purpose reservoir, located at about 60 kilometers northeast of Metro Manila, has an effective capacity of 640 x 10^6 m^3 and regulates an average annual inflow of 1,700 x 10^6 m^3. The Angat river basin has a total drainage area of 936 km^2 while the upper basin which covers the area from the farthest watershed divide down to Angat Dam is 568 km^2. Figure 2 shows the location map of Angat river basin. It is bounded on the northeast by the Upper Pampanga River Basin, on the southwest by Metro Manila and on the east by the Sierra Madre Mountain range. Situated along the slopes of the Sierra Madre mountain range, the basin is exposed to prevailing southwesterlies during summer and the northeasterlies during winter monsoon. Figure 3 shows the monthly average rainfall, runoff and actual evapotranspiration of Angat reservoir for the period 1968 to 1993. As shown in the figure, rainfall and runoff distribution exhibit a bimodal characteristic. Two maxima occur during the year; one in July and the other, during October. The observed maximum values (July for rainfall and August for runoff) are associated with the activity of the southwest monsoon while that in October, where the highest average occurs for both rainfall and precipitation, is brought about by rains generated during passage of tropical cyclones within or near the basin. Actual evapotranspiration averages 150 millimeters per month during the dry season (January-May) and decreases to an average of 60 mm per month during the rainy season (June-October). The mean annual temperature ranges from 24^o to 28^oC with January as the coldest month and May the warmest..

Average annual precipitation is about 3500 mm. and the reservoir has an annual average runoff of 1690 x 10^6 m^3. Figure 4 shows the comparison of annual rainfall and runoff for a period of 26 years (1968 - 1993). The graph clearly shows the strong relationship between rainfall and runoff. Years such as 1969, 1976 and 1982 with low runoff are associated with low rainfall values thought to be a manifestation of ENSO episodes.

The Angat multi-purpose reservoir serves as primary source of water from three major users in Metro Manila and Bulacan province; domestic, irrigation and power. The Angat Maasim River Irrigation System (AMRIS) of the National Irrigation Administration (NIA) derives water mainly from Angat Dam which provides irrigation water for about 31,000 hectares of farmlands. Occurrences of extreme climatic events generally associated with El Niño greatly affect the operation of AMRIS. Thousands of crop lands can be affected with a significant reduction in yield due to water shortage. For domestic needs, the Metropolitan Waterworks and Sewerage System (MWSS) which is responsible for Metro Manila and some adjoining towns' domestic water requirement, derives almost 90% of its feed water from the Angat water reservoir. The remaining 10% is from underground water accessed through artesian wells. The National Power Corporation (NPC) has operated and maintained the Angat Dam since its construction in 1968. In line with the government policy for optimum water resources utilization, the water releases for irrigation and domestic uses are first routed through the reservoir's hydroelectric turbine generators. For the period 1968 to 1993, Angat has generated an annual average of 500 GWh, which is about 5% of Luzon's power demand. The reservoir can only generate power at an elevation of 180 meters above mean sea level (AMSL) which is considered the minimum operating level while the maximum operating level is set at 217 meters.

4. VULNERABILITY ASSESSMENT

Scenario development for climate change impact assessment is usually performed through the use of four methods, namely; GCM based scenarios, hypothetical scenarios, historical scenarios and analogue scenarios. Since the concern of this study is to assess the applicability of Watbal as a water balance model for climate impact assessment at river basin, the GCM based scenarios and the hypothetical scenarios (incremental change) were chosen for simplicity. Vulnerability of watershed to climate change is viewed in the context of global climatic/ hydrologic situation. It specifically means the liability of watershed to damage or adverse effect of climate change.

4.1 General Circulation Models (GCMs)

Predictions from General Circulation Models (GCMs) based on doubled CO_2 emission were used in this study as the basis for climate change scenarios. Three models were chosen to represent future values of rainfall and precipitation under a double CO_2 scenario. The three models selected were the Canadian Climate Center Model (CCCM) (Boer et al., 1991), United Kingdom Meteorological Office (UKMO) (Wilson and Mitchell, 1987) and Geophysical Fluid Dynamics Laboratory (GFDL) (Mitchell et al., 1990) models. In selecting appropriate GCMs, estimates of precipitation and temperature under $1xCO_2$ (present condition) from these models were compared with existing climatic normals (In na and Hemantha, 1991). As emphasized, comparison was based on large scale temporal and spatial distribution of precipitation and temperature. Results of this comparison showed that the three models; CCCM, UKMO, and GFDL have better estimates of the present condition of the region (Jose et al, 1996).

The CCCM has a higher resolution (3.75^o x 3.75^o) compared with the other simulation models. It has 10 vertical levels, 50-m-deep slab ocean and uses a Q-flux procedure. The UKMO model has a resolution of 2.5^o x3.75^o and considered water content of clouds, penetrating cumulus clouds, diurnal cycle and Q-flux slab ocean while the GFDL model has 30 spectral waves and a resolution of 2.22^o x 3.75^o.

Rainfall and temperature data at present condition from the selected GCMs were then compared with monthly averages of Angat. Figure 5 shows the mean monthly rainfall for Angat as compared with the results from three GCMs under $1XCO_2$ condition. It can be seen that none of the three models has the same bimodal distribution, which clearly demonstrates the inability of the models to capture cyclonic events that contribute significantly to the Angat reservoir's performance. Comparison of Angat's mean temperature and those of GCMs is shown in Figure 6. GFDL tends to underestimate significantly the temperature while CCCM has some overestimation particularly at the second half of the year. UKMO shows the same temperature distribution with that of the mean except for overestimated April and May values. Table 1 shows the temperature change and rainfall ratio between $1xCO_2$ and $2xCO_2$ generated by the three models. Temperature change from the three models show increasing trend which is consistent with the expected warming. The GFDL model has the highest increase in annual temperature (3.1^oC) while the CCC model predicts an increase of 2.0^oC annually. The three models also predicted varying changes in rainfall. The UKMO and GFDL models both predict an annual increase of rainfall over Angat while the CCC model gives a slight decrease in annual rainfall.

4.2 Incremental Change based Scenarios

Aside from the simulation results of the different circulation models, climate change scenarios were created using incremental changes in such meteorological variables as temperature and precipitation.The incremental change scenarios adopted are the baseline, 2^0C increase in temperature with 10% increase in precipitation (T2P10), 2^0C increase in temperature with 10% reduction in precipitation (T2P-10), 4^0C in temperature with 10% increase in precipitation (T4P10), and 4^0C in temperature with 10% reduction in precipitation(T4P-10). For comparison purposes, other models of GCMS and incremental change scenarios were applied.

The scenarios chosen (Table 2) give uniform, annual changes in temperature (T) and precipitation (P). Monthly average values of Angat's temperature and precipitation were used as base temperature and rainfall. These incremental changes were combined with an observed climate database to come up with an altered 30-year record of daily climate with spatial variability.

4.3 Future water demand

Projections of future water demand were also determined since these would be the determining factor if the supply could still meet the demand.

The two agencies, the National Irrigation Administration (NIA) and the Metropolitan Waterworks and Sewerage System (MWSS) both dependent on Angat reservoir have provided projected water demand up to year 2050. Since Angat reservoir also generates hydropower and contributes to Luzon power demand, the National Power Corporation (NPC) also supplied future power demand for the island of Luzon. Table 3 presents the projected water demand of MWSS and irrigation requirement of NIA.

Future requirements for domestic and industrial purposes show remarkable increases. The domestic requirement has the highest growth rate attributable to rapid migration of people in Metro Manila and suburbs, which is expected to persist until the next several decades. Another factor is the projected industrialization of the country which the government hopes to attain in the next century. With respect to irrigation requirement, it is projected that the present demand will remain almost the same until 2050.

The projected power demand of Luzon island, expected to reach 5.9 million GWh in the year 2050, could be provided by other existing hydropower plants in the island (combined outputs of all multipurpose dams in Luzon account for 15% of the island total power demand) as well as power generating plants that rely on oil, coal and geothermal.

These only show that for Angat reservoir, the domestic and industrial needs in the future would be the main problem facing the water management agencies. It is to be noted however, that the projections made by the three agencies did not consider any effects of the expected global warming which could lead to higher water demands.

4.4 Hydrologic Model (WatBal)

In assessing the reservoir's vulnerability to climate change, a lumped conceptual, hydrologic model, WatBal (Yates 1994) was used to determine rainfall-runoff relationship. The WatBal model is an attempt to use simple but widely accepted assumptions regarding water balance and sound physical approaches in calculating potential evapotranspiration. This model makes use of a small number of parameters and incorporates physically sound assumptions for computing potential evapotranspiration, which are appropriate in the climate impact assessment in river basin runoff.

For the Angat dam analysis, the model was calibrated using 18 years of data (1968-1985) and validation was based on 8 years of data (1986-1993). In the case of Lake Lanao, the first sixteen years (1970-1985) were used for calibration and the succeeding nine years (1986-1994) for validation.

5. DISCUSSION OF RESULTS

5.1 Climate change scenarios from GCMs

Table 4 shows the percent change in annual precipitation and temperature and the corresponding change in runoff based from climate change scenarios generated by three GCMs for the Angat reservoir. UKMO and GFDL showed an increase in runoff by 5% and 32%, respectively. The increase in runoff is attributable to an increase in precipitation predicted by the two models. GFDL has the highest percent change in runoff since it has 1.15 percent positive change in precipitation coupled with only 2.4 degree change in temperature. UKMO model predicted only a small increase in precipitation but predicted a warmer temperature with a 3.1 degree change. The CCCM scenario gave a 12 percent annual runoff reduction based on its predicted less annual rainfall and warmer temperature.

Based on historical data, the Angat water reservoir has in the past experienced extreme changes in runoff. The 1971 annual runoff, for example, was 2443 mcm which is a 44 percent increase in the average runoff. This extreme event resulted in flooding of downstream areas damaging crops worth millions of pesos and loss of lives.. The GFDL model results suggest that greater frequency of flooding could be expected under future climate change scenarios.

Again, looking into historical records, the lowest annual runoff recorded was 1102 mcm in 1983, a 35 percent reduction in the average runoff. The drought of 1983, associated with the El Niño phenomenon, affected much of the regions' agricultural crops. The 1997-98 El Nino event again showed the vulnerability of Angat reservoir to extreme climate variability. The annual inflow in 1997 was only 843 mcm, a 50 percent reduction. This resulted to a significant reduction in domestic supply and a total cut down on irrigation demand. If the CCCM model scenario predominates in the future, the expected decrease in runoff would mean more serious problems in water availability, perhaps through more frequent episodes of drought. It should be noted that the monthly distribution of rainfall is far more critical rather than the annual distribution because of the varying monthly demand by the domestic and agricultural users.

5.2 Incremental Climate Change Scenarios

The 14 climate change scenarios using incremental changes and the respective changes in runoff for Angat reservoir are shown in Table 5. The table indicates that runoff is more sensitive to precipitation variability as compared with temperature changes. An increase of 10 and 20 percent in precipitation would mean an increase in runoff by 8% and 18%, respectively. If precipitation is reduced by 10% and 20%, a reduction in runoff by 15% and 25%, respectively is to be expected. This suggests that a decrease in precipitation has a greater impact on runoff as opposed to an increase in precipitation.

On the other hand, the effect of temperature on runoff is not as significant as compared to precipitation. A 1^{o}C increase would only lead to a 1% reduction in runoff. Other scenarios like a 2oC change in temperature and a corresponding increase/decrease of ten percent in precipitation likewise showed an 8% and 15% change in runoff, respectively. These preliminary results do not agree with the assumption that higher temperature would mean higher evaporation thereby reducing runoff significantly.

Further studies should be done to investigate the effect of temperature increase as well as the effect of other meteorological variables on Angat's runoff since this vulnerability assessment assumes that with the increase in temperature and rainfall, other meteorological parameters like relative humidity and wind among others remain constant.

Aside from the expected climate change and its impacts in the water resources sector, there are still a number of external factors that could contribute to the modification of water supply-demand relationship in the future. Evident factors identified are overexploitation of the water resources through ruthless degradation of watersheds, unchecked extraction of groundwater, rapid pollution through industrialization and unreliable wastewater treatment, saltwater intrusion along coastal areas, and sedimentation of reservoirs.

6. ADAPTATION ASSESSMENT

One of the major impacts of climatic change is a significant change in the temporal and spatial distribution of precipitation and temperature in which the resulting runoff or hydrological resource may be shifted in time and space. A change in the distribution of runoff with respect to time and space could greatly affect the effectiveness of existing system. When addressing adaptation in the water resource sector, adaptations could be divided into two major classes:

- Supply Adaptation
  - ⇒ construction of new infrastructures
  - ⇒ modification of existing physical infrastructure, and
  - ⇒ alternative management of the existing water supply systems
- Demand Adaptation
  - ⇒ conservation and improved efficiency
  - ⇒ technological change

Vulnerability analysis showed that the Angat multi-purpose reservoirs would be highly susceptible to the expected climate change. With its sensitivity to rainfall changes, runoff could be dramatically altered with changes in rainfall, both in time and space. With the country's water resource susceptibility to extreme climatic events like droughts and floods, it would therefore be sensible to identify possible adaptation measures both in the short and the long term, to cope with the expected global warming and its consequences. It is to be emphasized that in the identification and evaluation of possible adaptation measures, various government policies being implemented as well as those that are to be implemented related to sustainable development of the country's water resources were considered.

6.1 Supply Adaptation Strategies

a. Comprehensive watershed management

One major concern with respect to water resource sector is the considerable decline of watersheds. Excessive logging and shifting cultivation are common practices in the watersheds triggering widespread degradation of watersheds and consequent accelerated erosion and siltation of and decrease inflows in rivers, lakes and reservoirs. Such is the effect of increasing density of upland population, wanton mining, rapid urban growth, industrialization, use and abuse of the country's watershed.

Watershed management programs of the Department of Environment and Natural Resources (DENR) aimed at rehabilitating watershed areas are key steps in preventing degradation of the country's existing watershed areas. Strict implementation of existing forestry rules and regulations should also be undertaken both by concerned government and private agencies.

b. Water Allocation System and Procedures

Water allocation is a powerful tool for managing the demand for water. In the Angat reservoir, irrigation and hydropower have the priority in time of appropriation over domestic water supply. However, in times of drought or emergency situation, domestic water supply has priority over all others within the limits of its water rights. Conflict arises when MWSS withdraws water from the reservoir over and above its existing water rights expropriating in the process portion of NIA's water rights. Several studies are now being conducted that would provide recommendations on water reallocation and compensation schemes which would meet the demand in the sectors drawing from the Angat reservoir, particularly in the event of drought/floods in the future.

6.2 Demand Adaptation Strategies

a. Enhancement of Irrigation Efficiency

As the greatest consumer of water, the agricultural sector should increase its efficiency in water use such that water saved could be used for other purposes. The problem in the irrigation subsector is low water-use efficiency due to technical and institutional deficiencies, flooding in the wet season and inadequate water availability during the dry season. Irrigation efficiencies have also decreased due to lahar flows particularly in Region 3 and decreasing water supply due to watershed denudation. The dilapidated state of canal structures in the systems and the low water use efficiencies result in water loss which goes back to the stream draining the system.

Some of the possible responses to enhancement of irrigation efficiency in the NIA systems are changing the cropping schedule to reduce the demand for irrigation at the end of the dry season; change in the crops grown; canal lining to reduce water losses; use of shallow well pumps in submerged areas; maximize the use of available water through the construction of reservoir-type projects and redesigning of irrigation facilities to reuse return flows.

b. Introduction of low water use crops and farming practices

At present most farmers resort to planting rice crop, being the staple food of the population. One major characteristic of the crop is that it needs substantial amount of water from land preparation to its reproductive stage. The situation is compounded by poor farming practices that lead to inefficient use of water. Majority of the farmers, particularly from irrigated areas allow their farms to be inundated even at crop stages that do not require much water. With the necessary support and assistance from the Department of Agriculture (DA), introduction of crops such as corn, mongo, watermelon, and sorghum that use less water could be done in areas that are now experiencing inadequacy in irrigation requirement.

Use of drip irrigation, mulching, improved irrigation practices and use of windbreaks to reduce windspeed and evapotranspiration are some farming practices that could be adapted (Baradas and Mina, 1997).

c. Recycling (Reuse) of Water

One valuable and useful tool for water resources management especially in critically water-short areas is water conservation through recycling or reuse of water. Due to recurrent shortage of water , the policy of the government is to encourage reuse of effluent in agriculture and industry. Industries are encouraged to save water and adopt measures to renovate their effluents for other secondary purposes.

In the case of irrigation systems, drainage water reuse is another possibility of extending the supply of water. Installation of drainage reuse systems are now being constructed by NIA and the farmers to supply water to areas which cannot be reached by water supply from canals. NIA's program on maximum use of available water includes redesigning of irrigation facilities to reuse return flows.

Water used for power generation as in multipurpose dams like the Angat is reused for domestic water supply and irrigation. Households, during serious water shortages, are likewise encouraged to reuse laundry water for flushing and cleaning toilets and driveways as well as watering plants.

d. Improvement in monitoring and forecasting systems for floods and droughts

One adaptation measure that could costs less and encounter less constraints relative to other adaptation measures is improvement in the monitoring and forecasting capability of future occurrences of extreme events. It has been shown that droughts and floods have tremendous effects in the water resources. With the possible effects of climate change in the frequency of droughts and floods, improvements in the present system of monitoring and forecasting occurrences of such events could be translated to an improved water management. It is worthwhile to mention that monitoring systems will help in coping with these changes and will be beneficial even without climate change.

Enhancement of such existing systems, particularly in drought management, has been one of the major programs of the government, considering the disastrous effects of El Niño related droughts.

e. Use of water pricing policies and structures

Water has been traditionally been treated as a public good and as such, the government is expected to bear the cost of making accessible the supply to the pollution. With the increasing scarcity of water especially in Metro Manila and constraints in financial resources, there is now in increasing tendency to shift to a commodity focus in which water users should bear the full cost of being supplied with water. The MWSS has just raised its tariff rates by about 37% as a demand management intervention to reduce the demand as well as improve the system to reduce system leakage.

6.3 Existing short and long-term adaptation measures

As part of their short-term and long-term plans, the three agencies that benefit from Angat reservoir have already identified several mechanisms to cope up with significant increases or decreases in the monthly inflow.

Manila Waterworks and Sewerage System (MWSS)

Some of the short term adaptation measures being done are; water rationing thru MWSS water tankers to areas which have been affected due to low water pressure and intermittent to no water supply, rotation basis of water supply distribution and distribution effectiveness, water conservation thru people's participation by reporting leaks, illegal connection and voluntary consumers reduction of water consumption, increased supply of water by artificial rainmaking operation of La Mesa reservoir at low level and maximize operation of existing wells, reduction of water waste and losses through repairs of leaks and incentives given for leak reports. For long term measures, the MWSS has been tapping new water sources, expansion of water supply facilities, augmentation or expansion of distribution system , optimization of existing water supply system and reduction of non-revenue water.

National Irrigation Administration (NIA)

The National Irrigation Administration has been implementing the following adaptation strategies particularly during drier than normal conditions: reduction of programmed area of irrigation, adjusting cropping calendar and farming activities, farmers are encouraged to plant crops that require less irrigation, rotational scheme of irrigation and water distribution, optimum utilization of rainfall and interim flows, improvement of irrigation systems to minimize water losses, and conjunctive use of shallow wells. For their long term plans, the Agency is planning to construct a new reservoir to utilize the Bayabas creek.

National Power Corporation

For the power company, some of their short-term plans include: increased power generation contribution from non-hydro power plants, curtailment of power supply to customers during electricity supply deficiency thru manual load shedding (brownout) and voluntary load curtailment by affected industrial customers, and deferment of hydro-power plants maintenance work to compensate the decrease in hydro-electric capacity. Since it its expected that power requirement will significantly increase in the future, some of the long-terms plans are the following: construction of additional non-hydro plants like geothermal , utilization of new and renewable energy sources like solar, biomass, wind and tidal and demand-side management programs

7. CONCLUSION AND RECOMMENDATIONS

The expected climatic changes that could affect rainfall and temperature distribution will ultimately affect runoff to rivers and lakes. Angat runoff depends almost totally on rainfall. The climate change scenarios employed in this assessment such as 10% or 20% increase or decrease in rainfall suggest large differences from present rainfall and runoff. Such variability has been experienced in the past as shown by historical data. Even values reaching 20 to 30% decrease or increase in rainfall have been observed historically. These are greater than the assumed values used in the climate change scenarios. Basing on runoff simulation results, the expected rise in temperature in the future will not be a significant factor in runoff variability, although a deeper study on this aspect is needed. Impacts of temperature increase however, could be manifested in water demand. This leads to a conclusion that the Angat water reservoir, which is already exposed to extreme rainfall variability and its adverse consequences, as in 1992, faces more threats of increased climatic variabilities as suggested by results of selected GCMs.

This study, being the first of its kind, should be expanded and further research is recommended for other existing major reservoirs. Effect of climate change on other meteorological variables should also be done since this assessment presupposes that changes in temperature and rainfall would not affect other parameters such as humidity, wind speed and other related variables. An in-depth analysis on the effect of climate change to population increase, land use activities, desertification practices, deforestation, and future loss of biodiversity is deemed necessary. There are still a number of limitations encountered so as to come up with a comprehensive assessment of how climate change would affect the country's water resources. Adaptation measures identified could still be refined further and with the active participation of various stakeholders, more specific and doable measures would be established.

This study will hopefully serve as an impetus not only for the scientific community to consider climate changes in the pursuit of future researches but to the government policy makers as well, in their quest for the country's sustainable development towards the next millennium.

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Table 1. Rainfall ratio and temperature change between current ($1XCO_2$) and (2xCO2) as generated by three General Circulation Models (GCMs) for Angat watershed.

Month	CCCM		UKMO		GFDL	
	Rainfall Ratio	Temp. Change	Rainfall Ratio	Temp. Change	Rainfall Ratio	Temp. Change
January	***0.69***	***2.0***	***0.62***	***4.0***	***1.11***	***3.1***
February	***1.11***	***2.1***	***2.0***	***3.7***	***1.35***	***2.4***
March	***1.19***	***1.6***	***1.14***	***2.5***	***0.93***	***2.3***
April	***0.75***	***1.9***	***0.53***	***3.5***	***1.09***	***2.3***
May	***1.13***	***1.9***	***1.42***	***2.8***	***1.33***	***2.3***
June	***0.87***	***2.0***	***0.86***	***2.7***	***0.77***	***2.3***
July	***0.9***	***2.0***	***1.06***	***2.7***	***0.93***	***2.2***
August	***1.03***	***2.2***	***1.26***	***2.4***	***1.08***	***2.0***
September	***1.13***	***2.2***	***1.45***	***2.6***	***1.8***	***2.4***
October	***1.03***	***2.3***	***0.92***	***2.4***	***0.88***	***2.6***
November	***0.7***	***2.2***	***0.69***	***3.4***	***1.35***	***2.4***
December	***0.8***	***2.0***	***0.46***	***4.3***	***1.18***	***2.8***
Mean						

Table 2. Incremental Changes Used in Climate Change Scenarios where T=Temperature (oC) and P=Precipitation (mm)

T+0, P+0	***T+0, P+10***	***T+0, P+20***	***T+0, P-10***	***T+0, P-20***
T+2, P+0	***T+2, P+10***	***T+2, P+20***	***T+2, P-10***	***T+2, P-20***
T+4, P+0	***T+4, P+10***	***T+4, P+20***	***T+4, P-10***	***T+4, P-20***

Table 3. Projected water demand ($x10^6$ m^3 / year) of Metropolitan Waterworks and Sewerage System (MWSS) and National Irrigation Administration (NIA).

Year	*MWSS*				*NIA*
	Industrial	*Commercial*	*Domestic*	*Total*	*Irrigation*
2000	**121**	**348**	**805**	**1274**	**872**
2025	**210**	**1133**	**1219**	**2563**	**872**
2050	**339**	**2600**	**1630**	**4567**	**872**

Table 4. Changes in annual precipitation, temperature and runoff for Angat water reservoir from three General Circulation Models (based on $2xCO_2$).

GCM	*Rainfall Ratio*	*Change in Temperature (°C)*	*Percent Change in Runoff*
CCCM	**.94**	**2.0**	**-12**
UKMO	**1.03**	**3.1**	**5**
GFDL	**1.15**	**2.4**	**32**

Table 5. Percent change in Angat water reservoir runoff based from incremental changes in precipitation (P) and temperature (T).

	P0	*P10*	*P20*	*P-10*	*P-20*
T0	***0%***	***8%***	***18%***	***-15%***	***-25%***
T2	***-1%***	***8%***	***17%***	***-15%***	***-26%***
T4	***-1%***	***7%***	***17%***	***-16%***	***-26%***

URBAN VULNERABILITY TO DROUGHT IN THAILAND

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Abstract

Urban areas in Thailand such as Bangkok, Chiang Mai, Phuket etc. are vulnerable to drought. Increase in urban population growth can affect the urban vulnerability. Although the drought less affect to urban population than the other disaster, there are still the various effect to their live. The primary goal of this paper provides the situation of urban drought in Thailand. According to most of the meteorological stations are located in the city which they provide drought affects to the urban citizen. The GMI and decile range methods are calculated to indicate the meteorological drought. The comparison of the year 1979,the driest year, with the year 1997,the strong El Niño year, illustrate that there are more effected areas by drought in 1979 than the year 1997. However there are various effected to urban and rural areas in Thailand during 1979 and 1997. In addition, the seasonal forecast in Thailand is included in the paper such as where the information from, and the constraint of seasonal forecast on drought in Thailand.

Urban Vulnerability to Drought in Thailand

1. General Background

1.1 Geographical Situation and Climate of Thailand

Thailand is located in the tropical area between latitudes 5° 37'N to 20° 27'N and longitudes 97° 22' E to 105°37' E. The total area is around 200,000 square miles. The boundaries of Thailand with adjacent areas are:

North : Myanmar and Laos
East : Laos, Cambodia and the Gulf of Thailand.
South : Malaysia.
West : Myanmar and the Andaman Sea.

According to the climate pattern and meteorological conditions Thailand may be divided into 5 regions i.e. Northern, Northeastern, Central, Eastern and Southern Regions(west and east coast).

The climate of Thailand is under the influence of monsoon winds of seasonal character i.e. southwest monsoon and northeast monsoon. The southwest monsoon which starts in May brings a stream of warm moist air from the Indian Ocean towards Thailand causing abundant rain over the country, especially the windward side of the mountains. Rainfall during this period is not only caused by the southwest monsoon but also by the Intertropical Convergence Zone (ITCZ) and tropical cyclones which produce a large amount of rainfall. May is the period of first arrival of the 1ITCZ to the Southern Region. It moves northwards rapidly and lies across southern China around June to early July that is the reason of dry spell over upper Thailand. The ITCZ then moves southerly direction to lie over the Northern and Northeastern Regions of Thailand in August and later over the Central and Southern Region in September and October, respectively. The northeast monsoon which starts in October brings the cold and dry air from the anticyclone in China mainland over major regions of Thailand, especially the Northern and Northeastern Regions which is higher latitude areas. In the Southern Region, this monsoon causes mild weather and abundant rain along the eastern coast of the region.

The onset of monsoons varies to some extent. Southwest monsoon usually starts in mid-May and ends in mid-October while northeast monsoon normally starts in mid-October and ends in mid-February.

1.2 The Characteristics of Thailand Rainfall

Upper Thailand (Northern, Northeastern, Central and Eastern) usually experiences dry weather in winter (mid-October to mid-February) because of the northeast monsoon which is a main factor that controls the climate of this region. Later period, summer (mid-February to mid-May), is characterized by gradually increasing rainfall with thunderstorms. The onset of the southwest monsoon leads to intensive rainfall from mid-May until early October. Rainfall peak is in August or September which some areas are probably flooded. However, dry spells are commonly occur for 1 to 2 weeks or more during June to early July due to the northward movement of the ITCZ to southern China.

Rainy season in the Southern Region is different from upper Thailand. Abundant rain occurs during both the southwest and northeast monsoon periods. During the southwest monsoon the Southern Thailand West Coast receives much rainfall and reaches its peak in September.

Annual Rainfall (mm) 30-Year Period (1961-1900)

Figure 1.

On the contrary, much rainfall in the Southern Thailand East Coast which its peak is in November remains until January of the following year which is the beginning of the northeast monsoon.
According to a general annual rainfall pattern, most areas of the country receive 1,200 - 1,600 m a year. Some areas on the windward side, particularly Trat province in the Eastern Region and Ranong province in the Southern Thailand West Coast have more than 4,000 mm a year. Annual rainfall less than 1,200 mm occurs in the leeward side areas which are clearly seen in the central valleys and the uppermost portion of the Southern Region.

2. Drought in Thailand

A drought is a period of abnormally dry weather which persists long enough to produce a serious hydrologic imbalance (for example crop damage, water supply shortage, etc.) The severity of the drought depends upon the degree of moisture deficiency, the duration and the size of the affected area. Lack of rainfall for an extended period of time can bring farmers and major metropolitan areas to their knees. It does not take very long; a few rain-free weeks spreads panic and shrivels crops.

The definition of meteorological drought is a measure of departure of precipitation from normal. Due to climatic differences what is considered a drought in one location may not be a drought in another location.

There have been many attempts to arrive at a satisfactory method of objectively defining drought, establishing criteria for its onset, monitoring its course and declaring a drought ended. In Thailand, most of the observation station is located in urban areas. The rainy nature is partly related to the extensive heating of the region and the consequence thermal convection. Cities influence the occurrence and amount of precipitation in their vicinities. Several factors help to explain why an urban complex might be expected to increase precipitation

- The urban heat island creates thermally induced upward motions that act to increase the atmosphere's instability.
- Cloud may be modified by the addition of condensation nuclei and freezing nuclei from industrial discharges.
- The rough city surface lead to low-level convergence and increased upward air motions. Therefore, when rain-producing process are taking place, they may linger over the urban area and increase the city's rainfall.

The meteorological droughts are the representative of urban droughts in Thailand. In general, There was 2 duration that regularly effected to Thailand as follow:
- Drought during end winter to summer
- Dry spell during end June to early July

2.1 History of Drought

The regional historical record of annual rainfall deficiency was examined. It showed that they correspond to the occurrences of severe droughts in Thailand in 1967-68, 1972, 1977, 1979, 1986-87, 1990-93 and 1997-98. Table 1 illustrate the details of drought occurred in Thailand.

2.2 Major Drought

Severe droughts in Thailand are usually caused by a failure of the summer rains and may extend through rainy season. There have been thirteen major Thailand droughts. The 1979 drought was possibly the most intense with respect to the area affected by severe rainfall deficiencies. The historical records indicates the severity and extent of the 1979 drought in term of rainfall deficiency over extensive areas where rainfall for the duration of the drought, approximately three months, was the lowest on record. This was due to a widespread failure of the rainfall amount during rainy season. This drought affected nearly all of Thailand and was particularly severe in Northern, Central, upper and western Northeastern, and upper Southern Regions The another major drought period of 1986-87, 1990-93 and 1997-98 were the most severe in terms of rainfall deficiency. There have been a few other droughts of lesser degree of intensity, but nevertheless causing appreciable loss large areas of several provinces.

3. Drought Monitoring

As a common definition of drought is a deficiency of rainfall resulting from unusual weather pattern, how much rainfall for a given place and period of time is a considerable interest in measuring drought. Three rainfall indices as follow are now undertaken to monitor drought in Thailand.

3.1 Rainfall Anomaly

Rainfall anomaly is the most frequently used indicator of drought in Thailand. It is an actual rainfall for a specific location that deviates from 30 year mean (calculated from 1961 to 1990). This index is the simplest measurement of rainfall and can be computed for variety of time scales. Rainfall anomaly approaching zero is considered to be normal rainfall while negative rainfall refers to mild or severe drought conditions depending on its magnitude.

3.2 Generalized Monsoon Index (GMI)

GMI is one of the drought indices defined as derived numbers which express the degree to which growing plants have been adversely affected by an abnormal moisture deficiency. GMI, developed to assess rainfed crops grown during the southwest monsoon (wet) season, is primarily based on monthly rainfall within that period. As southwest monsoon prevails over Thailand, on the average, during mid of May to mid of October which is the main growing season of the country, the index used will be the GMI for southwest monsoon considered from June to September monthly rainfall. The index is defined as:

$$GMI = 0.125^{*}P_6 + 0.125^{*}P_7 + 0.5^{*}P_8 + 0.25^{*}P_9$$

Where P_i: monthly rainfall (mm.) of the i^{th} month (i.e. P_6 = June monthly rainfall)
*: Crop coefficients that are generally high during reproductive stage

The monthly GMI is calculated and accumulated by the end of each consecutive month during the assessing period. All the raw GMI series at least 15 years obtained from each area are further calculated to be GMI percentile rank (GMI_{pct}) scaled from 0 to 100 and the thresholds for interpreting are as follows:

GMI_{pct}	crop condition
0 – 20	severe drought impact and possible crop failure.
21 – 30	drought impact on crops
31 – 40	moderate drought impact on crops
41 – 60	normal crops
61 – 90	possible above normal crops
91 – 100	possible excessive moisture

The criteria above are only the basis in considering crop conditions. Some other information, such as rainfall distribution (decadal rainfall etc.), local crop calendar and agricultural report, etc., is also used as a supplement input for crop assessment.

3.3 Decile range method

The decile method was selected as the meteorological measurement of annual drought in Thailand. The technique divided the distribution of occurrences over a long term precipitation record into tenths of distribution and called each of these categories a "decile". The first decile is the rainfall amount not exceeded by the lowest 10% of the precipitation occurrences. The second decile is the precipitation amount not exceeded by the lowest 20% occurrences. These decile continue until the rainfall amount identified by the tenth decile is the largest precipitation amount within the long term record.

Decile Classification

Decile range 1	Lowest 10%	Very much below average
Decile range 2	10% - 20%	Much below average
Decile range 3	20% - 30%	Below average
Decile range 4-7	30% - 70%	Average
Decile range 8	70% - 80%	Above average
Decile range 9	80% - 90%	Much above average
Decile range 10	Highest 10%	Very much above average

4. The impacts of El Niño event on Thailand Rainfall

El Niño is characterized by an unusual warming of ocean waters in the Pacific. Its impact on the world's climate varies from region to region, but it typically includes drought in western Pacific nations. A strong El Niño has been developing since April of 1997 and has continued into 1998. It should be note that these impacts do not necessarily occur with any given El Niño episode. The GMI and decile range technique was calculated in Thai Meteorological Department (TMD). Figure 2 (a), (c) and Figure 3 (a), (c) illustrate the drought pattern based on GMI in 1979 while Figure 2 (b), (d) and Figure 3 (b), (d) illustrate in 1997

Table 2. illustrate the comparison of the rainfall decile of 1979 which is the driest year with the rainfall amount of 1997. The first and the second decile were more observed from 1979 than 1997. Factors other than 1997 El Niño may influence regional climate variability (including tropical cyclone, and land surface conditions). Figure 4 and 5 illustrate the drought pattern based on decile rainfall in 1979 and 1997 respectively.

(a) **(b)**

(c) **(d)**

Figure 2. Drought pattern based on GMI (a) June 1979 (b) June 1997 (c) June-July 1979 and (d) June-July 1997

(a) **(b)**

(c) **(d)**

Figure 3 Drought pattern based on GMI (a) June 1979 (b) June 1997 (c) June-July 1979 and (d) June-July 1997

Table 1 Drought occurrences in Thailand (1979-2000)

Year	Period of occurrence	Details of drought impact		
		Province/Region	People (family)	Agricultural area (ha)
1979	second half of July, end of August to the third week of September	Upper Thailand		
1981	October	3 provinces in Southern Part		
	early November	1 province in Northern Part		
1982	April to mid-May	25 provinces in Northern and Northeastern Parts		
1983	summer season	1 province in Northern Part		
		14 provinces in Northeastern Part		
		5 provinces in Central Part		
		2 provinces in Eastern Part		
		2 provinces in Southern Part		
1984	summer season	several provinces in Eastern and Southern Parts		
1985	summer season	at least 37 provinces in various Parts		
1986	summer season	7 provinces in Northern Part	4,470	
		9 provinces in Northeastern Part	92,023	474
		5 provinces in Central Part	5,747	160
		6 provinces in Eastern Part	14,076	49,119
		6 provinces in Southern Part	14	19,328
		Total 33 provinces	116,330	69,081
1987	summer season,	15 provinces in Northern Part	90,795	196,623
	end of June to	17 provinces in Northeastern Part	840,124	842,004
	mid-August	10 provinces in Central Part	42,153	60,057
		7 provinces in Eastern Part	70,174	140,044
		9 provinces in Southern Part	75,027	63,104
		Total 58 provinces	1,118,273	1,301,832
1988	summer season,	6 provinces in Northern Part	36,288	2,426
	end of June to early July	12 provinces in Northeastern Part	325,359	44,073
		5 provinces in Central Part	63,657	4,906
		2 provinces in Eastern Part	14,773	2,161
		3 provinces in Southern Part	1,480	3
		Total 28 provinces	441,557	53,569
1989	summer season,	5 provinces in Northern Part	3,040	5,118
	mid-June to mid-July	15 provinces in Northeastern Part	445,276	194,550
		4 provinces in Central Part	44,493	192
		3 provinces in Eastern Part	3,608	2,004
		2 provinces in Southern Part	185	5,215
		Total 29 provinces	496,602	207,079
1990	summer season,	6 province in Northern Part	23,132	5,282
	June to mid-July	10 provinces in Northeastern Part	220,153	94,111
		7 provinces in Central Part	34,050	6,259
		3 provinces in Eastern Part	47,750	9,519
		13 provinces in Southern Part	86,426	262,438
		Total 39 provinces	411,511	377,609
1991	summer season,	14 provinces in Northern Part	244,768	13,961
	mid-June to mid-July	15 provinces in Northeastern Part	618,749	73,135
		10 provinces in Central Part	77,031	20,828
		7 provinces in Eastern Part	91,187	56,860
		13 provinces in Southern Part	189,681	1,177
		Total 59 provinces	1,221,416	165,961

Table 1 Drought occurrences in Thailand (1979-2000)

Year	Period of occurrence	Details of drought impact		
		Province/Region	People (family)	Agricultural area (ha)
1992	summer season continue	15 provinces in Northern Part	346,031	69,108
	to June	17 provinces in Northeastern Part	1,078,548	336,917
		15 provinces in Central Part	478,078	307,792
		7 provinces in Eastern Part	216,668	54,042
		16 provinces in Southern Part	311,338	85,656
		Total 70 provinces	2,430,663	853,515
1993	summer season,	14 provinces in Northern Part	493,465	5,553
	mid-June	17 provinces in Northeastern Part	1,253,431	177,825
		16 provinces in Central Part	382,560	105,427
		7 provinces in Eastern Part	214,065	31,221
		14 provinces in Southern Part	189,673	6,444
		Total 68 provinces	2,533,194	326,470
1997	June to early July	14 provinces in Northern Part	616,022	
		19 provinces in Northeastern Part	1,509,848	
		10 provinces in Central Part	319,285	
		7 provinces in Eastern Part	251,195	
		14 provinces in Southern Part	397,930	
		Total 64 provinces	3,094,280	
1998	summer season,	15 provinces in Northern Part	711,782	
	mid-June	19 provinces in Northeastern Part	2,019,639	
		15 provinces in Central Part	462,995	
		7 provinces in Eastern Part	384,616	
		16 provinces in Southern Part	706,363	
		Total 72 provinces	4,285,395	
1999	second half of June,	14 provinces in Northern Part	226,897	
	mid-July, first half of	15 provinces in Northeastern Part	491,938	
	August	10 provinces in Central Part	108,208	
		4 provinces in Eastern Part	138,487	
		16 provinces in Southern Part	42,095	
		Total 48 provinces	1,007,625	
2000	January	32 provinces	210,610	
	February	39 provinces	310,983	
	March	41 provinces	465,170	
	April	43 provinces	685,190	
	May	37 provinces	849,062	
	June	29 provinces	251,122	
	December	9 provinces	58,160	
		Total	2,830,297	

Remarks
1. Data obtained from the Cevil Defence Division of the Local Administration Department, the Ministry of Interior.
2. Blank means no report.
3. Thailand is now divided by climatological pattern into 5 parts and 76 provinces; 15 in North, 19 in Northeast, 18 in Central, 8 in East and 16 in South.
4. Summer season is normally between mid-February to mid-May.

Table 2 Rainfall Decile in 1979 and 1997

Station	1979	1997	Station	1979	1997	Station	1979	1997	Station	1979	1997
NORTHERN			**NORTHEASTE RN**			**CENTRAL**			**SOUTHERN (east coast)**		
Mae Hong Son	1	2	Nong Khai	2	7	Pilot Station	-	2	Phetchaburi	-	5
Mae Sariang	5	3	Loei	7	1	Kanchanaburi	1	1	Prachuap Khiri Khan	1	1
Chiang Rai	2	4	Udon Thani	1	5	Thong Pha Phum	2	9	Hua Hin	1	1
Phayao	-	6	Sakon Nakhon	6	6	Bangkok Metropolis	1	1	Chumphon	2	7
Chiang Mai	2	1	Nakhon Phanom	4	9	Klong Toey	-	1	Surat Thani	2	-
Lampang	1	1	Khon Kaen	5	1	Don Muang Airport	1	1	Ko Samui	2	2
Lamphun	-	1	Mukdahan	4	4	**EASTERN**			Nakhon Si Thammarat	1	6
Phrae	1	4	Kosum Phisai	1	2	Prachin Buri	1	1	Kanom	-	1
Nan	1	3	Chaiyaphum	3	1	Kabin Buri	4	2	Songkhla	3	7
Tha Wang Pha	1	3	Roi Et	5	2	Aranyaprathet	2	3	Hat Yai Airport	4	7
Uttaradit	1	2	Ubon Ratchathani	8	5	Chon Buri	1	1	Satun	5	2
Tak	3	1	Chok Chai	4	1	Ko Sichang	1	1	Pattani Airport	3	5
Mae Sot	3	8	Surin	4	8	Phatthaya	-	1	Narathiwat	7	5
Bhumibol Dam	2	1	Tha Tum	4	9	Sattahip	1	2	**SOUTHERN (west coast)**		
Umphang	3	2	Nang Rong	3	5	Lam Chabang	-	1	Ranong	6	3
Phitsanulok	1	1	**CENTRAL**			Rayong	-	1	Takua Pa	-	3
Phetchabun	1	7	Nakhon Sawan	1	3	Chanthaburi	3	1	Phuket	1	1
Lom Sak	4	8	Suphan Buri	1	1	Khlong Yai	8	8	Phuket Airport	3	1
Phetchabun	4	3	Lop Buri	1	1				Ko Lanta	-	1
Kamphaeng Phet	-	1	Bua Chum	3	-				Krabi	-	7
									Trang Airport	2	3

Figure 2 and 3 show drought pattern based on GMI,
Figure 2 (a) in June 1979, the driest year of Thailand. The region of severe droughts were experienced in some areas of eastern part of central region and expanded eastward to eastern region with some areas of upper northern region.
Figure 2 (c) during June-July 1979, some areas of upper Thailand were the most seriously affected agricultural drought.There were more effected areas than June 1979
Figure 3 (a) during June-August 1979, the region of severe droughts were experienced in most areas of upper northern region, lower central region and expanded eastward to eastern region.
Figure 3 (c) during June-September 1979, mainly areas of upper Thailand were the most seriously affected agricultural droughts. There were effected areas likely to June-August pattern.
Figure 2 (b) in June 1997, the strong El Niño year, there were severe droughts in most area of upper Thailand and upper southern region. Except eastern part of northeastern region was less effected than other part.
Figure 2 (d) during June-July 1997, there were severe droughts in most area of central and eastern region. Some areas of western part of northern region were drought. It seem there were less effected areas than June 1997.
Figure 3 (b) during June-August 1997, there were severe droughts in western part of central region and western part of northeastern region. The drought areas were less than June and June-July 1997.
Figure 3 (d) during June-September 1997, there were severe drought in some areas in western part of central region and western part of northeastern region. The drought areas occurred mainly in northeastern region likely to June-August 1997.

From decile range analysis of map of decile values of annual rainfall of 1979 (figure 4) , there was the first decile range covered most region of the whole country especially for the northern and central region. Except the northeastern region, there were the fourth to the fifth decile range in almost region. Figure 5 shows the annual decile distribution for 1997, a strong El Niño year, a year in which severe drought occurred in parts of western part of north region, eastern part of central region and eastern region, reveals some areas in the first decile range.

One result of decile range technique was more effected area by drought in the driest year than the El Niño year. And it is difficult to determine whether El Niño is a direct or indirect cause of certain events, or whether it is a factor at all.

5. Seasonal Forecast

TMD issues winter, summer and rainy seasons forecast by early October, early February and early May respectively. The seasonal forecasts were prepared upon statistical analysis, ENSO (El Nino/Southern Oscillation) condition and seasonal forecast products from various centres (i.e. ECMWF, Unisys).
The constraint of Seasonal Forecast on drought:

1. lack of an appropriate network of observation data
2. forecast skill
3. lack of an appropriate climate model
4. do not understand on complicated drought

Problems coping with the impacts of drought centered on:

1. forecast reliability
2. education and training about drought phenomenon
3. sufficient resources to cope in a preventive or mitigative way
4. lag time between forecast and impacts, responses and reconstruction

6. Urban Vulnerability to Drought

Urban droughts in Thailand generally affect areas dependent on reservoirs for water. Such droughts usually lead to restrictions on water use to what is essential for living. Urban droughts occur less frequently than agricultural droughts.

According to the observation stations of TMD are located in the urban areas. The result of drought which detect in each year was notable for directly effected to urban population even the city, Chiang Mai, Ubon Ratcha Thani, Khon Khan provinces or Bangkok Metropolis where have a good irrigation system and enough to population's consumption. For example, the 1979 and 1997 droughts demonstrated that water users were vulnerability to water supply system from lack of unboiled water to produce water or support the irrigation. During the interval between droughts, response plans usually encourage water conservation through different programs which may be particularly useful during drought.. Most official plans include some type of a response and actions to preserve lives, ensure public safety and health, and protect property and the environment. We have to recognize that the rural areas or the small town where have not good water system are unavoidable from drought even the less intensive droughts.

Beside a shortage water from drought, it is possible that a change in climate is occurring i.e. the increasing in temperature that provides an epidemic, diarrhea etc. Using the past experience of Thailand, droughts occurred more frequently. Urban water users should to realize and cope with affected area by drought that more frequency. In the past, it seem that droughts more effected to the agricultural areas than the urban areas. But in the present, it changed. Urban population must change water activity to familiar with a drought and prepare for a drought occurring in the next dry years.

In addition, a number of programs initiated by official continue to operate in Thailand. These include a long term plan concern with construction reservoir storage. Making specific plans for longer-term drought preparedness is complicated by official. With vulnerability to extended periods of drought increasing, it is critical that preparation and mitigation be given greater emphasis in existing plans. Moreover, periodic drought serves to remind us that water is precious. It is imperative that we address drought in a careful and systematic manner, trying to anticipate and resolve problems and conflicts as they evolve and before they reach crisis proportions.

7. Conclusion

It can be conclude that the urban area effected to drought in Thailand. The report emphasize that during the driest year and the strong El Niño year were closely related to the urban drought condition especially in northern, central and eastern regions. This result clearly demonstrated that it correspond to the specific official plan in the city. Most official plans to preserve lives, ensure public safety and health, and protect property and the environment.

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FLOOD MANAGEMENT OF DHAKA CITY

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1.0 Introduction: Dhaka is the capital of Bangladesh. It is the main administrative and economic center of the country. It is a very old city with a history of about 500 years. The Moghul Emperor Jahangir as a capital of Subh-e-Bangla, i.e. province of Bengal, established it. It was a sleepy small township in the early 20th century has now grown to a mega city. It is surrounded on all sides by a network of rivers, which is connected to again a network of internal drainage systems. Among the natural disasters Dhaka is frequently subjected to flooding. Flood management of the city is very important in disaster mitigation of the city. It is subjected to river flood as well as flooding due to drainage congestion. Flood management of Dhaka City is now a vexing and complex problem.

2.0 Setting of Dhaka City:

2.1 Area: Area of Dhaka City is now about 300 sq. km of which about 170 sq km is built up area i.e. more than 50% area is built up from the low lying land. According to a study the city will be

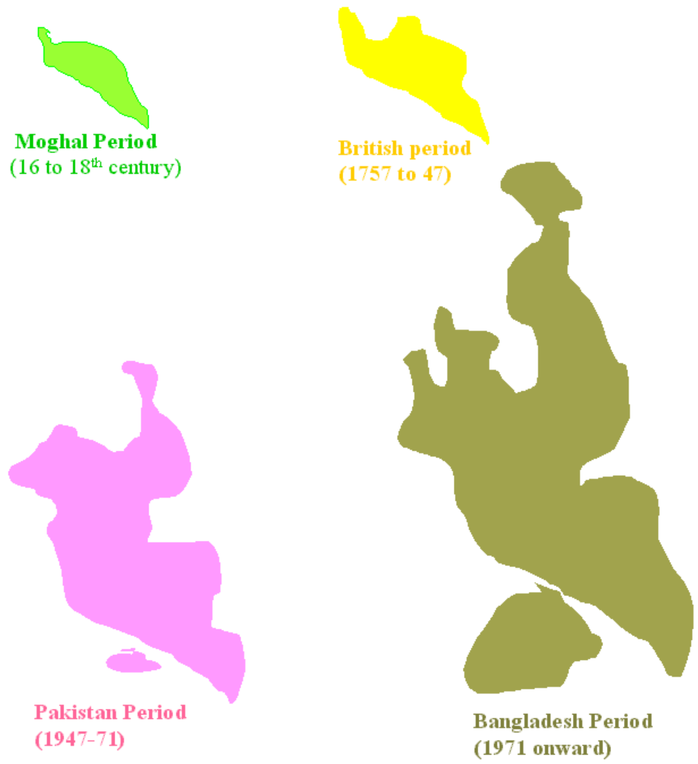

Fig 1: Evolution of Dhaka City since Moghul Period

expanded to about 350 sq. km in 2010 out of which 220 sq km will be built up area. It may be mentioned that the area of Dhaka city during Moghal, British and Pakistan period was 9.38, 19.18, and 63.24 respectively. A picture of gradual growth of Dhaka City since Moghul period is shown in Fig.1.

2.2 Demography: Population is now about 7.0 million. City is growing very fast since last 50 years in terms of both area and population. In early 20th Century it has a population of 105,000. It has been projected that population of the city will increase to 8.58 million in 2010. It started growing when it became a provincial capital in 1947. Growth rate was accelerated when it became capital of independent Bangladesh in 1971. It is pertinent to note that almost 30% of city dwellers live in slums and they are termed as poor. A picture on state of present and future expansion of the city is given in table 1.

Table 1. Present and future expansion of the Dhaka city

1990				2010		2000 (interpolated)	
Area ID	Population	Built-up Area (km²)	Total Area (km²)	Population	Built-up Area (km²)	Population	Built-up Area (km²
Greater Dhaka	4473000	122.1	275	8589000	215.3	6531000	168.7
Narayanganj	1111000	45.6	1001	2558000	75.5	1834500	60.55
Tongi	143000	10.5	37	658000	21.3	400500	15.9
Savar	366000	41.8	243	812000	75.1	589000	58.45
Keraniganj	442000	22.3	170	813000	38.1	627500	30.2
Total	**6535000**	**242.3**	**826**	**13430000**	**425.3**	**9982500**	**333.8**

Source: JICA Study - 1991

2.3 Climate: Weather of the city is influenced by the Indian Ocean Monsoon climate. It has four meteorological seasons e.g. pre-monsoon (March-May), Monsoon (June to September), Post Monsoon (October to November) and Dry (December to February). Average annual rainfall is to the tune of 1700 to 2200 mm. About 70% rainfall occurs during the period from June to September. Mean monthly rainfall during the same period is between 300 to 450 mm. Maximum daily rainfall is about 200 mm. It is observed that average annual rainfall is increasing. Average Temperature range is between 25^0 to 31^0 C. Maximum may rise unto 40^0 C and may go down to 6^0 C. Average temperature is also on increase. Average humidity remains at 80-90%. A picture annual rainfall for different duration and different years is given in fig. 2.

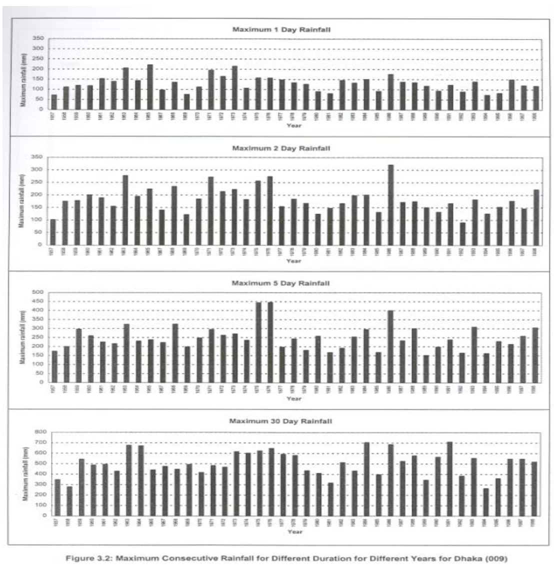

Fig. 2 Picture of Rainfall for consecutive years

2.4 Topography: Ground elevation of the city varies from 0.5 m to 12 m (PWD). Elevation of 60-70% of the city area is 0.5 to 5 m (PWD) i.e. these areas are low lying. These low lands act as temporary detention basin during the flood when the rivers are on spate. Lowlands are continuously being filled up to build new human settlements. In doing so natural open drainage system of the city has been continuously encroached and in some cases being destroyed. Digital Elevation Model (DEM) of Dhaka city is shown in fig.3.

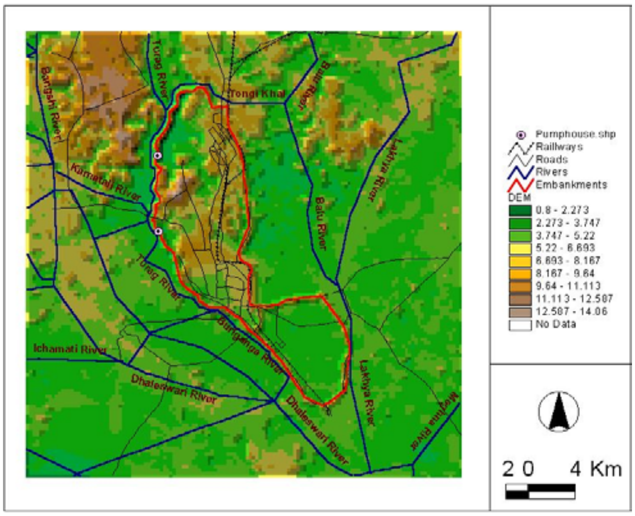

Fig.3 DEM of Dhaka city

2.5 Hydrology: unique river networks surround Dhaka City. These rivers belong to mainly Brahmaputra drainage systems. But the Meghna system has also influences on the water levels of the rivers around Dhaka. In the north flows Tongi Khal, on the west Turag & Buriganga, on the east Balu and Sitalkhya and on south. All these river systems are connected to each other forming a garland around the city. City has also intricate internal drainage system consisting of small to medium khals connecting to the river system on all sides. A picture of peripheral rivers and internal drainage system can be seen in fig. 4.

2.6 Urban Development of Dhaka City: In order to understand the issues of urban disaster management and mitigation of the Dhaka City one will have to understand its gradual developments in recent years and particularly, the process of urbanization in Bangladesh. During the independence from British rule Bangladesh was predominantly an agricultural country having rural population of about 95%. Even at the time of liberation in 1971 rural population was about 90%. After 1971 pace of urbanization has been accelerated tremendously although urbanization in Bangladesh is slow compared to other countries of South Asia. At present about 25% of the population lives in different urban centers. Rate of

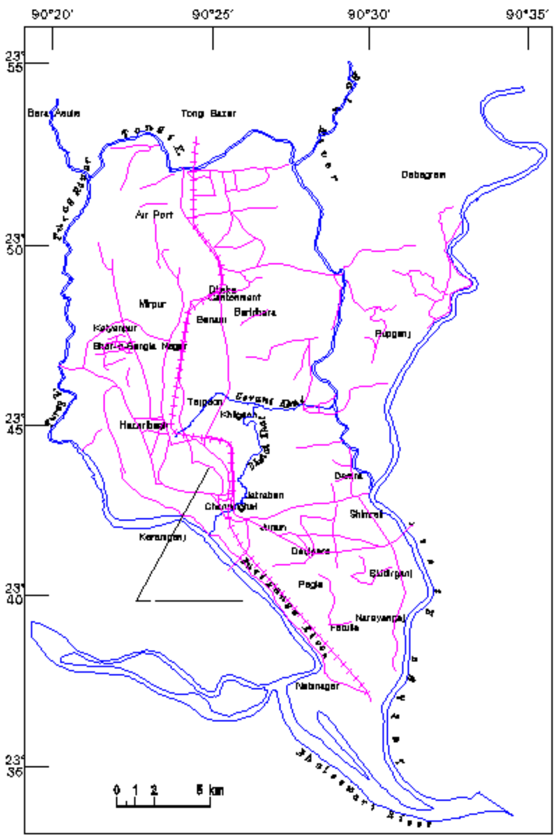

Fig. 4: River systems around Dhaka city

expansion of Dhaka city in-terms of area and population is the highest among all the urban centers. This a common feature in most of the developing countries. Population of Dhaka City has increased about 10 folds and area has been expanded about 4 times because all the economic activities are being centered at the capital city. It is projected that in next 25 yrs. Urban population will increase to 60% and rural population will decrease to 40%. In order to accommodate increasing population of the city, low lying areas around the city are being filled to develop new settlements, which were hitherto acted as detention basin to conserve excess river flow during the flood. Moreover, as the western part of the city has been embanked to make it flood free, many new settlements are coming up in the low lying areas as a result internal drainage in many parts is suffering giving rise to temporary inundation i.e. flooding.

2.7 Drainage and Flooding: Drainage of the city has been deteriorating for last few years in spite of many drainage improvement works. Drainage of the city is dependent on two main factors, i) operation of the sewage system both storm water and domestic and ii) water levels in the peripheral rivers. Flooding of the city is mainly caused by the water level rise in the surrounding river systems. Flood of Brahmaputra mainly governs flood problem of the city. Meghna being in the down stream controls the recession of the floodwater. Sometimes, when the Meghna is in spate backwater effects also causes flooding in southeastern part of the city. Water Levels trends of the rivers, e.g. Buriganga, Turag, Sitalakhya and Balu is given in fig. 5, 6, 7, and 8 respectively. Flooding also occurs in the city due to drainage congestion arising out of intense rainfall. These kind of flooding cause damage to road surface, communication systems and public utility services. If the water remains stagnated for longer duration, it deteriorates sanitary conditions and creates scarcity of safe drinking water. In 1988 almost 95% of the city was flooded disrupting normal life and the area of inundation was 242 sq km. In 1998 area of inundation was 168 sq km because of the flood protection works in the western part of the city. Picture of flooding of the city in 1988 and 1998 is given in fig.9.

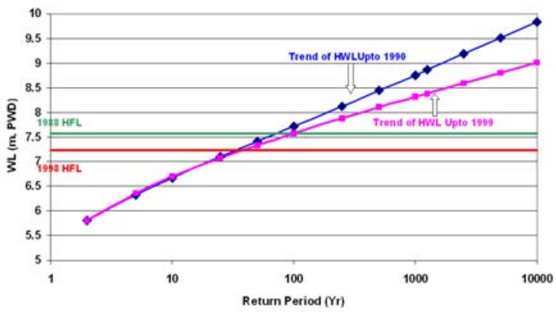

Fig. 5. Water level trend of Buriganga

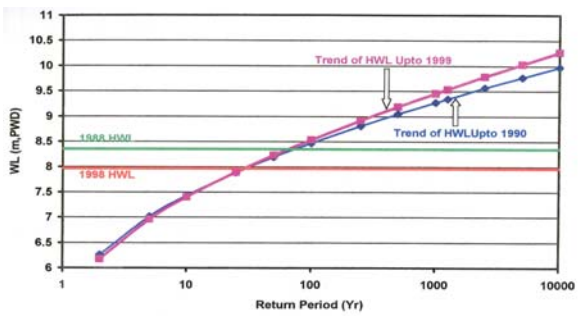

Fig. 6. Water level trend of Turag

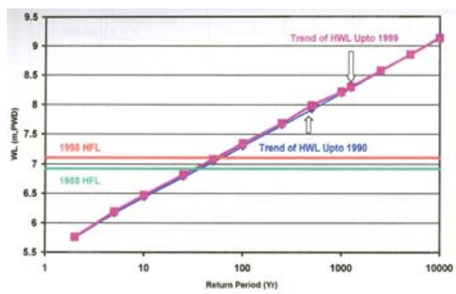

Fig. 7 Water level trend of Sitalakhya

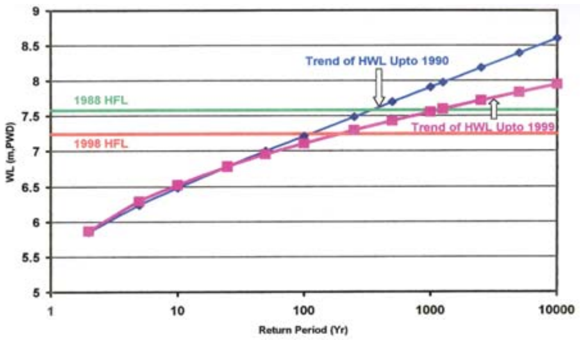

Fig. 8 Water level trend of Balu

3.0 History of Disasters in Dhaka City: Dhaka experienced mainly two kinds of disaster, e.g. Flood and Cyclone. Flood is the most common kind of disaster the city faces in last fifty years since 1954. Again, the city faces two kinds of flooding, one due to rise in water levels in the adjoining river system and the other due to drainage congestion arising out of heavy rainfall. Highest hourly rainfall recorded in Dhaka is to the tune of 162 mm and highest recorded daily rainfall is about 300 mm. three large rivers of the country have total catchments of 1.7 million sq km lying in Bhutan, China, India & Nepal besides Bangladesh. When excessive rainfall occurs in such a large catchments huge run-off is generated. When the excessive rainfall occurs in the three catchments simultaneously, the run-off and rise in water level synchronizes then, the floods of disastrous nature generally occur. Floods of 1954, '55, 1968, 1971,1974, 1987 & '88 and 1998 were of testimony of this fact. All these flood events occurred due to the simultaneous rise in water levels in the three major river systems e.g. Ganges, Brahmaputra and Meghna. Besides, these disastrous floods, almost every year a large portion of the city is inundated when the rivers around Dhaka are in spate during monsoon due to low topography.

4.0 Current Practices of Flood Disaster Management:

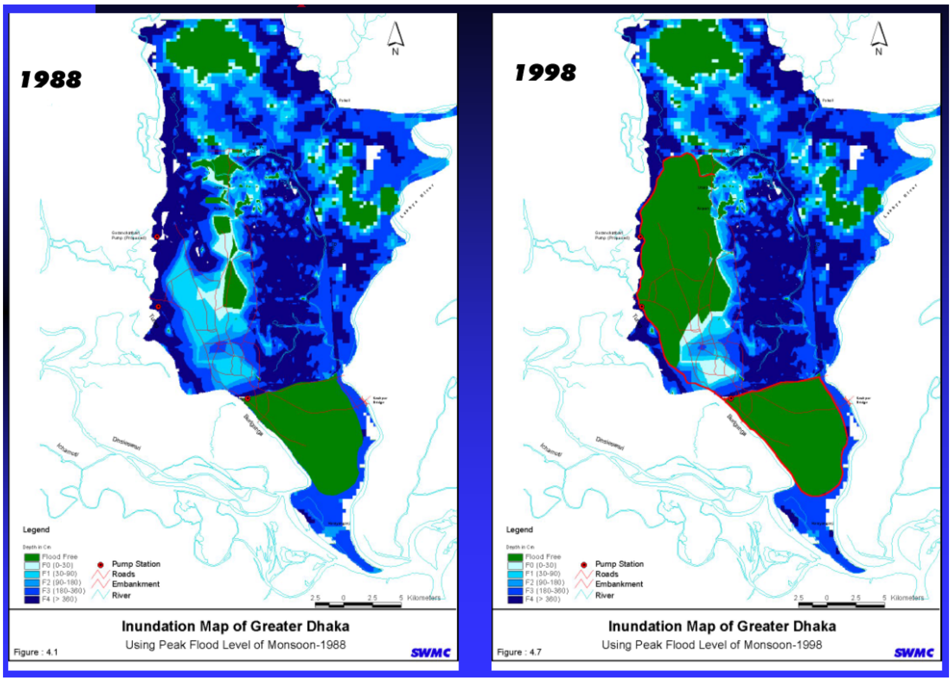

Fig. 9 Inundation of Dhaka city in 1988 and 1998 floods

4.1 Government of Bangladesh has undertaken both structural and non-structural measures to mitigate the flood disaster in the city after the consecutive disastrous floods of 1987 and 1988. Govt. decided to take up Dhaka Integrated Flood Protection Project (DIFPP) to reduce flood vulnerability and to mitigate flooding and drainage problems of the city. DIFPP included Construction of Flood Embankment along the western side, construction of flood walls along west and southern part, construction of Pump Houses along with detention ponds, improvement of drainage through renovation of internal natural drainage channels i.e. khals and construction of piped storm sewer system. DIFPP made an area of 136 sq km flood free. As regards the non-structural means special flood monitoring system around Dhaka City has been introduced where water levels of the rivers around Dhaka is monitored and forecast for 24 & 48 hr. are also given on daily basis during June to September. A picture of daily flood inundation map prepared by the Flood Forecasting and Warning Center is shown in fig. 10.

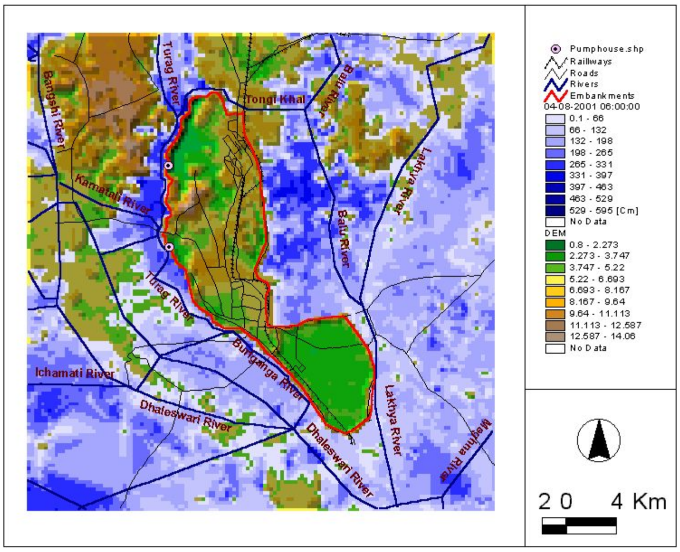

Fig. 10 Flood embankment and flood inundation

4.2 Besides, different Departments and Agencies work closely for flood preparedness and mitigation measures as per General Guide Lines for Disaster Management (GGLDM), where responsibilities of different Govt. Deptt., organizations and agencies are delineated. These guidelines are applicable for all kinds of disaster. Dhaka being a capital and Metropolitan city, many organizations are involved in management of affairs of the city along with the local government for Dhaka City i.e. Dhaka City Corporation. For the purpose of Flood and Drainage Management following organizations are involved:

i) Bangladesh Water Development Board, a nationwide public sector organization: Real Time Flood Forecasting & Warning System, Construction, Operation and Maintenance of Flood Embankment, Flood Wall, Pump Houses etc.

ii) Dhaka Water and Sewerage Authority, a public sector organization: Construction, Operation and Maintenance of public water supply, sanitation and internal drainage system.

iii) Dhaka City Corporation, Local Govt. Institution, construction, operation & maintenance of road communication system, preventive health care, solid waste disposal, environmental protection, disaster preparedness and dissemination of disaster information at community level etc.

iv) Disaster Management Bureau, a central govt. functionary: Dissemination disaster information, awareness building, disaster preparedness etc.

v) Directorate of Relief: Supply of essentials to the disaster victims through City Corporation, NGOs and other bodies,

vi) Bangladesh Telephone and Telegraph Board, a public sector organization: To maintain all kinds of telecommunication during any disaster,

vii) Civil Defense and Fire Services: To organize search and rescue operation during any disaster,

viii) Department of Health Services: To ensure preventive measures to stop spreading of diseases and to undertake curative measures for the disaster victims

5.0 Application of Climate Forecast: Bangladesh Meteorological Department (BMD) is the only organization responsible for dissemination of weather and climate information. Based on the information of BMD and through real time hydro-meteorological data collected by the Hydrological Services of BWDB, Flood Forecasting Warning Center (FFWC) issues forecast and warning on flood. FFWC also consults medium and long range weather forecast provided by the European Center for Medium Range Weather Forecast (ECMRWF) to provide probabilistic forecast on the flood. FFWC also consults any other weather or climate information available on the web specially information provided by the Indian Meteorological Department (IMD) daily basis during monsoon.

6.0 Constraints and Opportunities: Bangladesh being a lower riparian and an agricultural country, both short and long range climate forecast have many applications e.g. agriculture, fisheries, horticulture, poultry, livestock etc. apart from flood. Now-a-days agriculture, horticulture, fisheries, livestock have become capital intensive and advance weather information may play a vital role in optimizing their productivity and profit. During the flood early warning may save lots of investment. Government now recognizes this fact but at the users' level the awareness has not been developed to that extent as yet. At present, the people responses quickly to cyclone warning in the coastal areas. They have also started responding to the early warning on the flood in certain areas where flood is an annual event. Regarding the flood information people wants area specific early warning as well as long range forecast. In this context the constraints are also noteworthy. Institutional Development and Capacity of the institutions involved in climate and flood forecasting is not sufficient to meet the growing demands of the society. Dissemination of information at right time to right places has not been properly developed. Value adds of the information lies in its wider, efficient and better utilization. With the climate change and variability becoming a reality the importance and demand of climate information will increase.

References:

1. FAP Studies 8A & 8B, 1986
2. JICA Study 1991
3. Annual Flood Report, BWDB, 1987, 1988, 1998
4. Greater Dhaka Flood Control and Drainage Project, Sir William Halcrow & Partners, 1970.