STRATEGY AND ACTION PLAN FOR THE ENHANCEMENT OF COOPERATION BETWEEN NATIONAL METEOROLOGICAL AND NATIONAL HYDROLOGICAL SERVICES FOR IMPROVED FLOOD FORECASTING

STRATEGY AND ACTION PLAN DOCUMENT – SUPPLEMENT

STATUS: 08 JANUARY 2007

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Appendix 1 - Opportunities provided by modern Meteorological and Hydrological Forecasting Practices in use by NMHSs

(Relevant country examples extracted from the Regional Workshop reports)

1. It is the responsibility of the National Water Authority of ***Argentina*** to transmit information about the status of the large rivers of the Rio Plata Basin and provide warnings, as early as possible, related to possible flood situations to national and provincial authorities responsible for the control of water related emergencies, navigation, and for the protection of population and environment. The country is affected by hydrometeorological events occurring in Brazil, Paraguay and Bolivia. The Hydrometeorological Information System that has been developed provides information on a continuous basis. Satellite imagery is utilized to monitor and analyse the impact of the floods in the plain areas. The System was consolidated improving the forecast and data collection processes, as well as the contact and links with the users. ; and of

2. ***Austria*** has undertaken research in the field of precipitation forecasts. An algorithmic synthesis (integrated nowcasting through comprehensive analysis) is applied for the nowcasting prediction. All available data sources (model results, observed precipitation data, radar- and satellite data and high resolution topografic – surface information) are used for this procedure. For longer-term forecasts a combination of the ALADIN-Vienna and the ECMWF model results with a different spatial-weighting is in operation.

3. ***China*** produces its own MRWF. Three to five day predictions provide precipitation forecasts for hydrology for long-term flood forecasting both quantitatively and qualitatively as flood outlooks. The 10-day precipitation prediction is used during the flood season. The real-time flood forecasting system utilizes 6-hourly mean areal rainfall data as input. The actual model used is based on a number of models including Unit Hydrograph models, adapted models such as the SACRAMENTO model, lumped models as well as statistical and empirical methods, depending on the rivers and available data and expertise in forecasting. The Bureau of Hydrology maintains its own precipitation network and meteorological service. The China Meteorological Agency provides 7-days Numerical Weather Prediction to the Bureau of Hydrology. In practice however, NWP is not utilized as of now for flood forecasting, except on experimental basis. China is finding ensemble prediction useful including the comparison of ensemble probabilities versus different model runs (mean, control run and deviations).

4. Uncertainties are inherent in flood forecasting processes and therefore it is a challenge to quantify the uncertainties and evaluate the possible effects on decision making. In ***Denmark*** an advanced Ensemble Kalman Filtering approach in MIKE 11 was developed which allows for accurate estimation of forecasting uncertainty. A major source of uncertainty arrives from the meteorological inputs to flood forecasting models. Through the use of a flexible, low-cost and high-resolution operational weather forecasting system (THOR), the EU research project FLOOD RELIEF has tested the downscaling of meteorological information for use in operational flood forecasting systems like e.g. MIKE FLOOD WATCH. It is evident that the combined use of Ensemble Kalman Filtering together with downscaling of meteorological rainfall prediction can improve the quality of the flood forecasting information and assess the uncertainty related with the forecasts. The technologies are now being implemented in many MIKE FLOOD WATCH forecasting applications world-wide.

5. A watershed simulation and forecasting system is widely used in ***Finland*** for the simulation of the hydrological cycle and for making real-time forecasts. The system is based on watershed model, which is originally the HBV-model and simulates the hydrological cycle using standard meteorological data. The model simulates the whole land area of the country. The inputs of the model are precipitation and temperature and the simulated components of

the hydrological cycle are snow accumulation and melt, soil moisture, evaporation, ground water, runoff and discharges and water levels of main rivers and lakes. The data assimilation algorithm of the model updates the simulation by assimilating real time water level and discharge observations from stations together with snow water equivalent observations and satellite data of snow cover area and flood cover area. The model uses ensemble weather forecast from ECMWF. The hydrological forecast is made by simulating the model with 42 different 10 day weather forecasts after which is used historic weather data to make a 1 year long hydrological forecast. Out of 42 hydrological forecasts a mean forecast is selected and together with mean forecast the uncertainty limits of the forecast is shown. In the case of serious flood an automatic E-mail warning is sent to flood protection officers.

6. In ***France*** a "Risk Law" sets the responsibility of the State for flood monitoring and forecasting on the largest rivers. In the framework of the new flood prevention policy a new system of organising the operations of flood forecasting is being progressively implemented since 2002. It consists of 22 flood forecasting centres (SPC) distributed all over the country. The SPCs are responsible for monitoring and forecasting floods on river basins. A national centre for hydrometeorology and flood forecasting (SCHAPI) has been set up in 2003. SCHAPI provides some technical support to the SPCs and is responsible for producing a flood vigilance map, together with the SPCs aiming at providing the level of risks of flood in largest watercourses in France. Concerning the weather forecasting Meteo-France elaborates a meteorological vigilance map aiming at informing the civil security services and the public about the danger of meteorological phenomena that are foreseen. These two procedures have the objectives to improve the anticipation of severe phenomena to allow the civil authorities to react in time, and also to largely inform on the danger associated to the event. The co-operation between the State (MEDD), and Meteo-France is organized through a framework agreement that sets the contribution of each organization for the flood forecasting improvement. Meteo-France and the SPCs and the SCHAPI have close co-operation for using and maintaining observation networks and data.

7. Since January 2005, gridded precipitation data sets of 1 km resolution are created in near real-time on an hourly routine basis for the territory of ***Germany*** based on the composite of 16 radar and 900 surface stations (RADOLAN = online adjusted radar). The current NWP model system of DWD consists of the own global model (GME, ca. 40 km resolution, forecast up to 7 days) and the nested limited area "Local" model (LM, 7 km resolution, forecast up to 72 hours). In addition, ensemble predictions are used in a quasi-operational mode (ECMWF-EPS, COSMO-LEPS and SRNWP-PEPS). The model chain is in the process of being enhanced by the introduction of LME, offering a 7 km resolution for a larger model area covering most of Europe, and the LMK, designed for high resolution (2.8 km) shortest forecast (from 2 to 18 hours). Flood forecasting models based on precipitation-runoff models (LARSIM) and hydrodynamic flood routing models have been developed, verified and adopted. Operation of the forecast is done in five forecast centres corresponding to the basins of the main rivers. There is still need to improve the accuracy of the forecasts, the quantification of flood discharges, and the communication between the forecasting centres and the local authorities.

8. In ***Hungary*** the flood forecast and warning system utilizes results of international hydrometeorological data collection, combined Hungarian QPF products based on ECMWF, DWD, ALADIN-HU output and subjective analysis of the weather forecaster. The home-developed GAPI – TAPI modelling and forecasting system serves 120 forecast points within Danube proper, Drava and Tisza sub-basins. The distributed version of the system is under installation. Experimental use and hydrological routing of meteorological EPS is on the way. According to ongoing research and development COMOLEPS products and nowcasting output will be used for flash flood warning purposes within 3-4 years to cover hilly parts of the country.

9. Sophisticated weather forecasting information is available in ***Japan*** including up to 6-hour now-casting using NWP products and radar-based precipitation information. For long-range forecasting, including dam management, NWP is used offline using scenarios and includes

typhoon tracking. Other than flood forecasting, MRWF is also used for drought forecasts and drought management and in the context of ensemble forecasting. 1-3 month ensemble prediction outlooks are prepared using ECMWF information. The Japan Meteorological Agency (JMA) jointly with the River Administration Bureau issues flood forecasting to the public. At present several organizations (i.e. Department of Roads) have established own precipitation networks; the data from these networks is shared with JMA. In Japan, NWP is used only for short-term prediction.

10. In ***Mozambique*** the National Directorate of Waters is responsible for flood forecasting. The flood-forecasting model in use is the "FEWS Stream Model", an ArcView application model developed to create data input requested by Famine Warning System (FEWS) Flood Model. The National Institute of Meteorology provides the seasonal forecast, medium range forecast (4 days) and daily forecasts. The latter Institute collects and disseminates daily rainfall data through email to the Water Authorities and Disaster Management Institution. Also satellite imagery is provided every half hour to Water Authorities. A numerical local atmospheric model called RAMS with 40 kilometres of resolution is being tested. Warnings are sent to the print media and local community, to the technical emergency council, to local authorities in the affected areas and decision makers. Press conference and interviews are also held for the public.

11. In ***Nigeria*** organizational responsibilities involve the promotion of a culture of prevention and pre-disaster strategies through monitoring, forecasting for early warnings, and timely dissemination of vital information on the impending disasters. The NMS through an in-house developed rainfall-forecasting model provides early warning and advisory services with good lead-time of one or two months on severe meteorological phenomena, especially extreme weather and climate events that could lead to disasters.

12. Data collection at the ***Niger river basin*** scale depends on information supplied by the real-time hydrometeorological data collection network of 65 Argos satellite based stations installed between 1984 and 1987 under the framework of the NBA/Hydro-Niger project. These stations were phased out as of 2001 and replaced by the METEOSAT system under the Niger-HYCOS Project implemented by NBA. Financial and material assistance is being provided to each Member country to ensure that the network is maintained.

13. Under the aegis of the HYDRONIGER project, the ***Niger Basin Authority*** (NBA) prepares, for the nine basin countries, hydrological forecasts a set of mathematical models: SIP (*Système Informatique de Prévision*) [computerized forecasting system] model, which incorporates four methods: Musik (Muskigum), CLS (Constrained Linear System), SPHARI (*Saisonnière d'Autocorrélation Multiple pour la Prévision d'Hydrogrammes avec Actualisation des Résidus*) [seasonal multiple autocorrelation for hydrograph forecasting with residual update] and ARIMA (Auto Regressive Integrated Mobile Average), in addition to the HYDRONIGER model (designed in 1987). The main forecast products issued by NBA are the monthly hydrological situation bulletin, technical notes and the seasonal prediction bulletin. They are widely disseminated via the NBA and Niger-HYCOS websites, email and DHL courier, as well as during country missions or NBA ministerial sessions.

14. Based on observed temperature and precipitation, the Snow Maps System of ***Norway*** simulates the daily snow balance in a 1x1 km2 grid from 1971 up to date. Based on the simulation, thematic maps for snow water equivalent related to normal conditions, rank of years, runoff and others are calculated for each day. The maps are updated weekly based on observations. In between, daily maps are simulated based on daily weather forecasts. A system coupling hydrological forecasting-, hydraulic- and digital terrain models producing daily maps forecasting inundated areas for selected sites the coming 6 days. It can also indicate the water level along levees and rivers. The system gives an overview and description of a flood situation before and during an event and improves the communication between the flood forecasting service, the local emergency services, press and public. The process of collecting meteorological and hydrological data, producing meteorological forecasts and producing hydrological forecasts is fully automatic.

15. In the ***Republic of South Africa*** a fully-fledged flood forecasting system that is adequately informed by meteorological products exists in the Department of Water Affairs and Forestry (DWAF). A network of 10 radars is in place, covering a wide area of the country. The South African Weather Services' products include seasonal, monthly, 14-days, 7-days, 24 hours, and even smaller time-step rainfall forecast, and other products crucial to flood forecasting. Severe weather warning is disseminated through SMS near real-time. A good network of over 200 real-time water flood-monitoring stations is in place.. Forecasts of rainfall quantities are done, but on trial basis at the moment, and thus this product is not yet available to potential users or public.

16. An integrated information system, such as the SAIH used by the Confederaciones Hidrográficas of ***Spain***, where hydrological, hydraulic and meteorological data are collected in real time and transmitted to the corresponding decision centre to be processed and applied to the solution of water resources management problems, be it under normal circumstances or in emergency situations, has proven to be a fundamental tool to improve hydrological forecasting in the country. Although investment needed is high and the maintenance costs considerable, its pay off is in short-term.

17. In ***Sweden***, one Government Agency is responsible for both the meteorological and the hydrological forecasting. The forecasting process is integrated and starts with the meteorological work with creating a forecast database. The database is grid-point based and contains meteorological parameters up to ten days ahead. The hydrological forecaster then uses the information in the database in order to issue hydrological forecasts and warnings. The most important thing is that the warning information must reach the relevant end-users. There is a well-defined dissemination process for hydrological warnings. The process is well known also by the end-users and includes an early contact between the forecasters and local actors dealing with flood prevention. To ensure the quality of the hydrological forecasts and warnings there are special training and also certification of the forecasters who take part in the forecasting process.

18. The risk estimation of severe events in ***Switzerland*** is mainly based on COSMO-LEPS, which uses ensembles downscaled from the global model of ECMWF. The distribution of warning information to local authorities is done by fax or email via secure transmission. In the ideal case there is a "pre-warning", a "warning" (updated twice a day) and a "end of warning". Unfortunately there is only partly little access to the public via main mass media. The warning includes the indication of the "level of danger".

19. In ***Thailand*** weather forecasting models are used to improve hydrological forecasting including flash flood forecasting. Water level data and forecasting models are complemented by the use of NWP and radar/satellite information. The Thai Meteorological Department is using radar systems for precipitation forecasting. For flash flood forecasting, established rainfall threshold values are used at present. Riverine flood forecasting is built on water level observations using MIKE 11 as forecasting model with complementary radar/satellite precipitation information and NWP-information with a flood-forecasting horizon of up to 7 days.

20. Starting from 2002 ***Ukraine*** has been developing a regional synoptic-statistical model, taking into account microclimate and topography of the various regions of the country based on the results of the global model of the Meteorological Centre Offenbach, 48 hours in advance. This model will allow obtaining results of the calculations of precipitation and other weather parameters in grid format and with a resolution of 10x10 km. The work is expected to be completed in 2006. At present the weather forecasters use calculations of foreign centres (MRF, AVN, DWD, MM5, Bracknell, NOAA), reports on current weather in Europe and satellite information. The basic hydrological models used for forecasting of processes in rivers are conceptual box models of rainfall-runoff transformation (models of the Ukrainian Research I Institute and MIKE11), flood routing, and different versions of "unit hydrograph" method.

21. Seasonal hydrological predictions (hydraulics during months of high flow) for the major basins of the ***West and Central African*** *region* are undertaken from the beginning of the rainy season onwards, by establishing a statistical link between sea surface temperature of particular oceanic zones during the months of April, May and June and hydraulics during the months of high flow (August, September, October) at stations on the major streams of the region. This exercise has been conducted since 1999 by a consortium comprising the AGRHYMET Centre, ACMAD and NBA.

22. In ***Zimbabwe*** the NMS issues daily and 10- day weather forecasts for the general public, as well as meteorological warnings and advisories to TV and radio stations and advisories any time. Forecasts of severe weather are also issued 10 days in advance. This information is derived from data from a network of 1 000 meteorological stations, satellites, four weather radars, and from other countries in the region. One of the radars has been calibrated to give now-casts of volumetric rain rates in millimetres. The National Water Authority has no operational flood forecasting method at the moment, but there are some flood forecasting models that are on trial using satellite rainfall estimate (Cold Cloud Duration (CCD). Flood warnings are issued when river flow levels are dangerously high and when the floodgates of major dams are about to be opened.

APPENDIX 2 - Summary of Main Regional Conclusions/Issues emerging from the Regional Workshops

MAIN REGIONAL CONCLUSIONS/ISSUES	WMO REGIONAL ASSOCIATIONS				
	I[1]	II	III-IV[1]	V[2]	VI
Need to establish or enhance flood forecasting, prevention and protection capabilities	Although there is recognition of the need for FF and political awareness, need to establish such activities particularly in LDC's of the Region since these countries are the most vulnerable to flood disasters	Need to improve flood forecasting products, which constitute an important corner stone for an accelerated socio-economic development. Strong interest of countries and donors to improve existing early warning and forecasting systems.	In general, there is need to strengthen the forecasting systems in Latin American countries.	Flooding issues and how they are addressed within the South-West Pacific vary considerably from country to country. Flash flood problem important for many countries in the Region.	Priority for the region

[1] Comprises West, Central and Southern Africa (SADC) countries of RA I
[1] Latin American countries of RAs III and IV
[2] No country reports or information available for a more in-depth analysis

MAIN REGIONAL CONCLUSIONS/ISSUES	WMO REGIONAL ASSOCIATIONS				
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Established or existing flood-forecasting systems	In the majority of countries such systems do not exist or are very limited. Need to expand the mandate of NHSs to include such activities	Wide range of capabilities both between countries but also on national level between capabilities of the NMHSs	Flood forecasting systems have been established in many of the countries mainly on the main river basins. These are in various levels of operation and make use of a wide range of communication and modelling techniques.	In some countries flooding is a significant problem and some flood warning systems have been installed. These are in various states of operation.	All countries have such systems. Significant differences in the level of performance and outputs exist
Upgrading of existing data collection and transmission networks	A large number of countries need significant upgrading and strengthening of their networks	Urgent need in a number of countries to expand the terrestrial observation hydrological and meteorological networks and to upgrade and improve the existing networks. Further development of established data quality control procedures..	The networks and hydrometeorological information systems are basic elements for an effective flood forecasting and warning. To ensure the feasibility and success of upgraded networks, special attention needs to be put on training of technicians and the maintenance costs of the system.	Many countries of the Region see improved real-time monitoring of rainfall as an immediate requirement.	Some countries need significant upgrading and strengthening of their networks New radar networks to be supported and existing ones upgraded

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Strengthening the application of data management procedures and improved methodologies and models for flood forecasting	Need to strengthen the flood forecasting capacities of the countries, with the availability of real time communications / computing facilities and trained meteorological and hydrological personnel	NHSs need professional guidance in the selection, adaptation, calibration and use of rainfall-runoff models to suit operational requirements	Some countries are in the process of strengthening their flood forecasting methodologies and modelling activities.	Many countries require upgrading procedures and methodologies.	Some countries require upgrading procedures and methodologies
Improvement of well established flood-forecasting systems with high quality products		Ensemble prediction techniques are rapidly developing but need further refinement to put these in operational use. NMHSs should be enabled to acquire the capacity to generate NWPs.	Some countries are taking steps to further improve their systems through the application of new forecasting technologies.		Opportunities to be taken by a number of countries for further improvement through the use of new technologies
Improvement of the forecast quality and better meeting the various requirements of the end users	Need identified in a number of countries of the Region	Detailed user requirements assessment necessary for improved user services.	Need identified in a number of countries of the Region		Need identified in a number of countries of the Region

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Encourage data exchange, in particular meteorological data as input to flood forecasting models.	NHSs and NMSs to align their policies in this area to the WMO Resolutions 25 (Cg-XIII) "Exchange of hydrological data and products", and 40 (Cg-XII) "WMO policy and practice for the exchange of meteorological and related data and products including guidelines on relationships in commercial meteorological activities".	Mechanisms needed for a more efficient exchange of hydrometerological data and information both from different agencies nationally and also internationally. Communication systems need to be developed to allow inter-operability of present-day hydrological and meteorological data communication streams.	Data exchange mechanisms have been implemented mainly in a number of the international basins of the Region.		Data exchange mechanisms have been implemented mainly in a number of the international basins of Europe.
Limitation of financial resources	Need to demonstrate the economic value of hydrological and meteorological data and products to decision makers in order to increase the national budget allocations for flood forecasting activities		This problem is faced in a number of the countries, thus having to rely on international technical assistance.	Major problem facing countries with weak flood forecasting systems.	Major problem facing countries with weak flood forecasting systems

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Lack of specialized training on new technologies	Major problem facing countries with no or incipient flood forecasting systems.	Problem identified in a number of countries of the Region, particularly in specialized areas of meteorology and hydrological modeling.	This problem is faced by a number of countries of the Region, particularly in specialized areas of meteorology and hydrological modeling.	Major problem facing countries with weak flood forecasting systems.	Major problem facing countries with weak flood forecasting systems
Promotion of dialogue, cooperation and exchange of expertise between the meteorological and hydrological communities	Cooperation exists but only to a limited extent in certain countries	Needs to be encouraged in a number of countries of the Region	In some cases institutional difficulties are still an obstacle for the co-operation between the NMS and NHS	Co-ordination of water-related matters is considered a major issue in the region. NMSs and NHSs to make conscious efforts to further enhance cooperation at the national level.	Needs to be encouraged in a number of countries of the Region
Existence of multiple authorities issuing meteorological and hydrological information products Strengthen institutional cooperation between NMSs and NHSs	Closer cooperation is required in a number of countries. A legal framework needs to be put in place, and roles and responsibilities of required institutions defined.	Need for the issue of administrative reforms, as required, to institutionalised cooperation between NMSs and NHSs in terms such as: lines of responsibilities, sharing of specific data and information.	Institutional cooperation needs to be strengthened in a number of countries.		In a number of countries there is need for better coordination among the various suppliers of forecasting in order to ensure consistent information for end users.

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Promotion of cooperation among countries, within countries and NHMS	The issue of data exchange and cooperation among NHSs with regional institutions needs to be examined in greater depth		Needs to be encouraged in the Region to contribute to enhance the quality of flood forecasting		Needs to be encouraged as needed in the Region to contribute to enhance the quality of flood forecasting, through dissemination of successful experiences, regular transfer of information, training and workshops.
Enhancement of technical capabilities	Need to enforce a training and capacity building programme for the meteorological and hydrological personnel, including managers, particularly on the modern trend in hydrological forecasting techniques with special emphasis on flood forecasting. Need for staff career development and retention schemes	Requirement of specialized training on modern methodologies.	Need to continue training and capacity building for the meteorological and hydrological personnel, particularly on modern trends in hydrological forecasting techniques with special emphasis on flood forecasting.	Most countries of the Region identified floods, as one of the three main subject areas requiring education and training. Technician training continues to be the highest priority in the Region.	Training on EPS, nowcasting and other modern methodologies is of high priority

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Concerns in specific international river basins	The Niger Basin Authority provides hydrological forecasts for nine countries of the Niger river basin. The Senegal River Basin Authority provides forecasts to three countries of the Senegal river basin.		Need to continue strengthening the Hydrological Information and Warning System in operation for the five countries of the Rio de la Plata Basin.		For the countries in the Sava River Basin (Albania, Bosnia and Herzegovina, Croatia, Serbia and Montenegro and Slovenia) the implementation of the Sava Initiative project is a tool to achieve a better quality of forecasts.
Impact of climate change on flood frequency and magnitude	Need to improve knowledge		Countries to continue studies on the hydrological effects of El Nino and ENSO.	NHSs need to ensure that water resources continue to be monitored on a long-term basis, so that a regional database is available for future climate change and variability studies and the hydrological effects of ENSO.	
WHYCOS and other regional and national projects	Very useful in strengthening the capacities of NHSs			Strong support for the Pacific-HYCOS as an excellent vehicle for effective capacity building for water resources assessment and management in the South-West Pacific.	WMO, with the countries concerned, to consider reinitiating the MED-HYCOS project

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Application of the concept of IFM/IWRM for Flood forecasting.	Flood forecasting should be treated with a multidisciplinary approach taking into consideration environmental, economic, legal and social aspects		A pilot project underway for integrated flood management on the Cuareim/Quaraí river Basin (Uruguay-Brazil)		
Storm surge issues		Pose a major hazard to many countries in the region. A concerted effort required to further develop and operationalize such systems as soon as possible.		A number of countries identified storm surge modelling as an important need.	