WORLD CLIMATE PROGRAMME

APPLICATIONS and SERVICES

SEVENTH PLANNING MEETING

ON

WORLD CLIMATE PROGRAMME - WATER

(KOBLENZ, GERMANY, 13-16 MAY 1997)

FINAL REPORT

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ORGANIZATION

The WCP implemented by WMO in conjunction with other international organizations consists of four major components:

The World Climate Data and Monitoring Programme (WCDMP)
The World Climate Applications and Services Programme (WCASP)
The World Climate Impact Assessment and Response Strategies Programme (WCIRP)
The World Climate Research Programme (WCRP)

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NOTE

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1. INTRODUCTION

1.1 The Seventh Planning Meeting on World Climate Programme-Water (WCP-Water) was held in the Federal Institute of Hydrology in Koblenz, Germany from 13 to 16 May 1997. It was organized jointly by WMO and UNESCO with the support of the Federal Institute of Hydrology.

1.2 Previous planning meetings on WCP-Water had been held in the Headquarters of WMO (1981 and 1985) and UNESCO (1982 and 1988), IIASA (1990), and the Institute of Hydrology, UK (1993), so it was seen as being very appropriate that the Seventh Meeting should be hosted by the Federal Institute of hydrology which had played an important role in the execution of several projects within WCP-Water.

1.3 The invitees to the Seventh Planning Meeting are listed in Annex and the participants are listed in Annex 2.

1.4 The meeting opened at 14h00 on 13 May 1997. Speaking on behalf of the Director General of the Institute, K. Wilke welcomed the participants to Koblenz and recalled the various WCP-Water projects in which the Institute participated. He stressed the importance that the Institute placed in its work in these projects and confirmed its continued support for the aims of WCP-Water. A. Askew and M. Bonell, speaking on behalf of WMO and UNESCO respectively, thanked the Institute for its generous offer to host the meeting and confirmed that intention of the organizers was that the meeting undertake, not only a study of progress with individual projects, but also a fundamental review of the aims and structure of WCP-Water as a whole. This raised questions as to whether WCP-Water should become more active and whether it should establish closer links with other international activities in related areas.

1.5 The meeting was chaired by H. Lins.

1.6 The meeting adopted the agenda which constitutes the table of contents of this report.

2. INFORMATION ON AGENCY ACTIVITIES RELATED TO CLIMATE AND WATER. INCLUDING RELEVANT DECISIONS OF GOVERNING BODIES

2.0 The meeting reviewed the activities of the various international organizations which were relevant to the aims of WCP-Water, as described below. Where available, the URL and/or e-mail addresses of the organizations are given below their titles so that they might be consulted to obtain further information or clarification on their activities.

2.1 World Climate Programme
(http://www.wmo.ch/wcb/wcp/wcphtml/wcp-home.html)

2.1.1 The World Climate Programme (WCP) was first adopted by the Eighth WMO Congress (Cg-VIII) in 1979 as a major programme of the Organization, with the clear intention that other UN agencies and certain non-governmental bodies would be involved in its implementation. Since then, there have been major changes in the way the world perceives "climate". Governments and industry, at the highest levels, have become concerned about the broad implications of climate variability and change for human well-being, ecosystems and economic systems. This has been especially manifest in questions related to changing atmospheric composition due to human activities and its influence on climate and in a perceived increasing toll in climate-related natural disasters.

2.1.2 Eleventh WMO Congress (Cg-XI) in 1991 recognized that the WCP was established to respond to the world's demand for enhanced information on climate and climate change and on methodologies of application of climate knowledge in various socio-economic areas and for assessments of climate impacts. Therefore, Cg-XI decided that the WCP "should be reconstituted

to provide an inter-agency inter-disciplinary framework to address the full range of climate and climate change issues including research into the economic and social consequences of climate and climate change". In view of this, Congress agreed that the WCP should from then on have the following structure, embracing four major components:

- World Climate Data and Monitoring Programme (WCDMP) - implemented by WMO;
- World Climate Applications and Services Programme (WCASP) - implemented by WMO;
- World Climate Impact Assessment and Response Strategies Programme (WCIRP) - implemented by the United Nations Environment Programme (UNEP);
- World Climate Research Programme (WCRP) - implemented jointly by WMO, the International Council of Scientific Unions (ICSU) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO.

WMO, as the lead agency, provides for the overall co-ordination of the Programme (WCP).

2.1.3 In 1993, the Intergovernmental Meeting on the World Climate Programme initiated the preparation of the Climate Agenda which embraces all aspects of international activities relating to climate, including data collection and applications, climate system research, including the role of oceans, studies of socio-economic impacts of climate variability and change, and effects on ecosystems. To meet the requirements and challenges presented by the UN Conference on Environment and Development (Rio de Janeiro, 1993) in Agenda 21 and the UN Framework Convention on Climate Change, it was envisaged that the WCP and its associated activities should be developed along the thrusts identified in the Climate Agenda, namely:

(a) Climate Services for Sustainable Development;

(b) New Frontiers in Climate Science and Prediction;

(c) Dedicated Observations of the Climate System;

(d) Studies of Climate Impact Assessments and Response Strategies to Reduce Vulnerability.

2.1.4 In order to make these thrusts more evident, the overall objectives of the WCP are therefore formulated as follows:

(a) To facilitate the effective collection and management of climate data and the monitoring of the global climate system, including the detection and assessment of climate variability and change;

(b) To foster the effective application of climate knowledge and information for the benefit of society and the provision of climate services, including the prediction of significant climate variations both natural and as a result of human activity;

(c) To assess the impacts of climate variability and change that could markedly affect economic or social activities and advise governments thereon, and contribute to the development of a range of socio-economic response strategies that could be used by governments and the community;

(d) To improve the understanding of climate processes for determining the predictability of climate, including its variability and change, identifying the extent of human influence on climate and developing the capability for climate prediction.

2.1.5 The purpose of the World Climate Programme (WCP) is to provide an authoritative international scientific voice on climate and climate change and to assist countries to apply climate information and knowledge to national sustainable development and to the implementation of Agenda 21 and associated instruments in order to achieve the maximum possible benefit for national economies and social welfare.

2.1.6 To accomplish its purpose, the WCP embraces the study and monitoring of the entire climate system, which comprises four major components:

(a) The *global atmosphere*, which is the most rapidly variable component and also the most energetically active as it is the heat engine which drives the whole climate system and, in particular, the earth water cycle;

(b) The *world ocean*, which interacts with the overlying atmosphere over periods of months to years, while the deeper ocean responds over periods of decades to centuries;

(c) The *cryosphere*, which comprises the continental ice sheets and ice caps, mountain glaciers and sea ice;

(d) The *land surface* of the continents and its surface runoff and groundwater flow systems which control evaporation from the land surface and water storage in the ground.

2.1.7 The WCP acts as an integrating and catalytic agent to co-ordinate current activities in the areas of climate research, applications, data collection and training, to stimulate new activities in order to achieve its objectives and to mobilize necessary national and international resources.

2.1.8 There are a number of projects within the individual subprogrammes of WCP which deal with links between climate and water. Examples are the Climate Information and Prediction Services (CLIPS) of WCASP; Data Rescue (DARE) and Archival Climate History Survey (ARCHISS) of WCDMP: Global Energy and Water Cycle Experiment (GEWEX]. Climate Variability and Predictability (CLIVAR) and Arctic Climate System Study (ACSYS) of WCRP. Brief information on each of these projects is given below.

2.1.9 In 1995, the Twelfth World Meteorological Congress (Cg-XII) recognized that important advances had been occurring in the monitoring of the global climate system. This referred in particular to the capability to exchange information in near-real-time and to new capabilities and opportunities for climate forecasting. Therefore, Cg-XII decided to launch the CLIPS Project. Climate services are the application of past climatological records, contemporary monitoring and expected future conditions to socio-economic sectors. The concept of CLIPS foresees that the Project will:

(a) encourage the development of operational climate predictions for periods and regions that are feasible and directed towards useful, user-friendly applications;

(b) demonstrate the value and eventual socio-economic benefits of climate information and prediction services, and the connection of those benefits with global observing, monitoring, prediction and applications;

(c) provide an international framework necessary to enhance and promote climate information and prediction;

(d) facilitate the development and strengthening of a global network of regional/national climate centres.

The meeting expressed its satisfaction with the planned implementation of CLIPS, and strongly supported the emphasis on user involvement in all phases of product design and implementation.

2.1.10 The First Session of Inter-Agency Committee on the Climate Agenda (IACCA) was held in Geneva from 29 April to 1 May 1997. The Committee expressed its general satisfaction with the implementation and plans for the Climate Agenda. The Committee noted that WCP-Water activities represent a good example of cooperation across all four Thrusts and across agencies and programmes. It stressed the need for WCP-Water activities dealing with coupled climate-hydrological modelling to be coordinated with similar efforts within GEWEX.

2.1.11 IACCA also noted that the CLIPS project within Thrust 2 of the Climate Agenda had developed a practical strategy and action plan. The accent on training within the action plan was judged appropriate. The Committee stressed the need for CLIPS to collaborate with institutions providing climate prediction products and considered that a successful CLIPS project would greatly enhance the objectives and benefits of Thrust 2.

2.1.12 WMO had arranged for a review of Thrust 2 which had concluded that, in total, it addressed user requirements, but that a clearer subdivision of activities and deliverables was desirable. Plans were being laid to hold a one-day meeting on the Climate Agenda in Geneva in August 1997.

2.1.13 Many projects of WCP-Water are of direct relevance to CLIPS, and it is recognized that it will be important to link both endeavours.

2.1.14 The Data Rescue (DARE) Project is being executed in WMO Regions I (Africa) and IV (North and Central America). By the end of 1994, the DARE I project was running in 30 of the 42 participating African countries, with more than four million microfilmed documents. It is important to recognize the significance of rescuing and preserving original climate data and their associated metadata. The importance of digitizing these data to increase their overall utility is also stressed. In determining the priorities for digitizing data, consideration is being given to filling the gaps in global baseline data sets.

2.1.15 The Archival Climate History Survey (ARCHISS) project has completed surveys of climatological data from five countries (France, Germany, Italy, Spain, UK) in Europe and has recently completed searches for useful climate data that reside in the national archives of Mexico and in Cuba. Preparations are being made for similar searches in several South American countries. Along with UNESCO and WMO, the International Council on Archives (ICA) and ICSU provide support to this project.

2.1.16 The Global Energy and Water Cycle Experiment (GEWEX) is a major subprogramme of WCRP. GEWEX is concerned with the study of fast climate processes which occur mainly in the atmosphere and at the land surface and control the energy balance of the earth and the global hydrological cycle. GEWEX comprises a broad range of research, research observation programmes and major field studies, combining in-situ measurements and remotely sensed data. GEWEX and its continental-scale experiments (GCIP, MAGS, BALTEX, LBA and GAME - see 2.4.6 below) are the activities undertaken within the framework of the WCRP which have the greatest importance for hydrology and water resources. The "water" component of GEWEX requires the compilation of hydrological data and studies of the hydrological cycle. Much attention is now being given to identifying links with the water management community.

2.1.17 A significant development has been the establishment of the GEWEX Hydrometeorology Panel in 1995. The purpose of the panel is to co-ordinate and oversee the Continental-scale Experiments (CSEs) and to consider the global application of the land surface schemes used in the new CSE atmospheric models. The GEWEX Hydrometeorology Panel, which includes

representatives of ISLSCP, GPCC and GRDC as global components, is a very appropriate point of contact between WCP-Water and GEWEX.

2.1.18 The study on Climate Variability and Predictability (CLIVAR) is the second major sub-programme of the WCRP and it is organized around three main scientific foci. The first focus follows on the path explored by the Tropical Ocean/Global Atmosphere (TOGA) Programme and aims to develop methods for predicting seasonal to inter-annual climate anomalies (e.g. El Niño - Southern Oscillation). The second focus aims to describe and understand climate variability and predictability on decadal to centennial time scales, including palaeoclimatological studies. The third is devoted to the understanding of the anthropogenic part of climate change.

2.1.19 The Arctic Climate System Study (ACSYS) aims to describe and develop an understanding based on observations of the coupled oceanic, cryospheric, atmospheric and hydrological processes that control the climate of the Arctic region and the outflow of Arctic Ocean water and sea ice to the North Atlantic. This in turn influences the deep water formation and the world ocean thermohaline circulation. Water-related activities embrace hydrological measurements and data analysis, including the estimation of river runoff into the Arctic ocean.

2.1.20 UNEP facilitates implementation of the World Climate Impact Assessment and Response Strategies Programme (WCIRP), as part of the World Climate Programme, and coordinates Thrust 3 of the Climate Agenda concerning climate impacts and response strategies to reduce vulnerability to climate change.

2.1.21 To this effect, UNEP's Scientific Advisory Committee for the World Climate Impact Assessment and Response Strategies Programme has proposed an International Action Plan for Climate Impact Assessment and Response Strategies to Reduce Vulnerability, which addresses Thrust 3 of the Climate Agenda and the WCIRP.

2.1.22 Five priority areas are identified in the Implementation Plan relevant to all climate impact and water resources activities, as follows:

- Vulnerable regions and sectors;
- Methodologies for vulnerability assessment;
- Adaptations to reduce vulnerability;
- Mitigation response options;
- Public awareness and communications.

It is anticipated that the International Plan will be implemented within the Climate Agenda by relevant specialized agencies and organizations, as well as governmental and non-governmental and scientific institutions. The plan has been widely distributed for comments, and will assist UNEP's Scientific Advisory Committee in developing an implementation plan.

2.1.23 Note was also taken of the availability of the document 'Principles for GEF Financing of Targeted Research' in the event that any proposed climate impact/water resources project is eligible for GEF support. As a GEF Implementing Agency, UNEP can facilitate development of suitable projects submitted for GEF's consideration within a targeted research portfolio.

2.1.24 In addition, UNEP is supporting development of a "Handbook on Methods for Climate Change Impacts and Adaptation Assessments", in collaboration with the Institute for Environmental Studies at the Vrije University, Amsterdam. This handbook will be a useful tool for the Parties to the UN Framework Convention on Climate Change (UNFCCC), to assess climate change impacts and adaptations as part of the national communications required under Article 12. One section of the handbook (released in draft form in late 1996), now being applied through a series of country studies, is devoted to an assessment of water resources. The chapter provides

technical details on the issues, and makes recommendations on the application of existing analytical tools for assessing the vulnerability of water resources to climate change, and to identify potential adaptation options to such changes. An advanced version of this handbook should be completed by early 1998, and will undergo the formal IPCC peer review process prior to its widespread dissemination.

2.2 Global observing systems

2.2.1 Three international endeavours, referred to as global observing systems, have been established with the aim of coordinating the compilation of assembling representative data at the global level for use in climate studies. These are:

(a) Global Climate Observing System (GCOS);
(http://www.wmo.ch/wcb/gcos/gcoshome.html)

(b) Global Terrestrial Observing System (GTOS);
(httl://www.fao.org/gtos/)

(c) Global Ocean Observing System (GOOS).
(htt p://www.unesco.org/ioc/goos/iocgoos.html)

2.2.2 Potentially, all three systems are of relevance to hydrological data. However, at the present stage, these links are most pronounced for GCOS. All global observing systems are interested in collaboration with global data bases, such as those established under the Global Runoff Data Centre (GRDC), Global Precipitation Climatology Centre (GPCC), Flow Regimes from International, Experimental and Network Data (FRIEND) and Global Environment Monitoring System - Water (GEMS-Water).

2.2.3 The Global Climate Observing System (GCOS), launched by Cg-XI, is based on a Memorandum of Understanding between WMO, IOC of UNESCO, UNEP, and ICSU and is considered an essential activity associated with the World Climate Programme. GCOS is intended to meet the needs for:

(a) climate system monitoring, climate change detection and monitoring of the response to climate change, especially in terrestrial ecosystems and mean sea level;

(b) data for application to national economic development;

(c) research towards improved understanding, modelling and prediction of the climate system.

2.2.4 To the extent possible, GCOS is based upon existing operational and research observational systems and data management efforts.

2.2.5 The Joint Scientific and Technical Committee (JSTC) is the principal body for formulating the overall concept and scope of GCOS. Significant progress has been made in defining the key scientific priorities, in identifying the critical parameters and observations to be made, in formulating the strategy to establish an Initial Operational System (IOS), and in establishing an appropriate structure to provide specific guidance, links to related programmes and activities, and continuing oversight.

2.2.6 The scientific priorities identified by the JSTC are given to those observations which are:

(a) needed for seasonal to interannual prediction; and

(b) required for detection of climate change and the attribution of the causes of such change at the earliest possible time.

2.2.7 The JSTC has prepared and published an overall plan for GCOS which calls for a systematic evolution from existing operational and research programmes in a phased manner.

2.2.8 Specific panels have been established by the JSTC to address atmospheric, oceanic, and terrestrial observations, and cross-cutting panels to address data and information management and space-based observations. Individual panels have prepared plans which identify essential observations, provide a rationale for their selection, identify current operational sources of the observations, and if not available, recommends what steps should be taken to secure them.

2.2.9 The Global Terrestrial Observing System (GTOS) is concerned with observations of terrestrial processes. GTOS will focus on five key issues of global concern:

(a) land use change, degradation and sustainability of managed ecosystems;

(b) water resources management;

(c) toxics and pesticides;

(d) loss of biodiversity and climate change.

Hydrological variables are expected to constitute an important part of GTOS.

2.2.10 GTOS was launched in 1996 as a joint venture of FAO, WMO, IOC of UNESCO, UNEP and ICSU. Its activities are overseen by a Steering Committee which is currently seeking to define the role and structure of the system and has established a series of working groups to assist it in this regard. The meeting expressed concern at the slow progress in the establishment of GTOS and the lack of clear definitions of its purpose and the user community that it was intended to serve.

2.2.11 Terrestrial Observation Panel for Climate (TOPC), a joint venture of GCOS and GTOS, has developed the GCOS/GTOS Plan for Terrestrial Climate-related Observations. A system of observations is suggested and guidelines are given on such elements of data collection as accuracy, frequency, resolution, density, spatial coverage. A five-tier system introduced originally for ecological variables is applied also for hydrological variables.

2.2.12 In order to assist in the work of TOPC, an Experts Meeting on Hydrological Data for Global Observing Systems was held in Geneva in April/May 1996. At the meeting, the needs of GCOS and GTOS for hydrological variables were discussed. Hydrological variables of interest to global observing systems were analyzed in some detail, including such issues as choice of variables, spatial and temporal densities and accuracy specification. An Initial Operational System (IOS) was discussed on a variable-by-variable basis. It was stressed at the meeting that the hydrological services in many developing countries are in decline. The meeting agreed on the need to up-grade and/or to rehabilitate existing stations in developing countries which are of primary importance for global observing systems. Some of these stations may not be of great importance for the national needs of a developing country but yet may play an important role in the global context. This was seen as an area where WCP-Water might be of assistance in the future.

2.2.13 The Global Ocean Observing System (GOOS) was initiated by the IOC of UNESCO with the support of WMO, UNEP and ICSU. The development of GOOS was launched in 1991. While little action has yet been taken to develop links with hydrological data, the potential certainly exists. Information on fluxes of water and chemicals supplied via rivers to the world ocean are

of interest to GOOS. On the other hand, precipitation on the sea surface and evaporation from this surface are basic information for understanding the global hydrological cycle.

2.3 Intergovernmental Panel on Climate Change (IPCC) (http://www.unep.ch/ipcc)

2.3.1 The Intergovernmental Panel on Climate Change (IPCC) was jointly established by WMO and UNEP in 1988 to:

(a) make periodic assessments of the science, impacts and socio-economic information on climate change and of the adaptation/mitigation options to address it;

(b) provide, on request, scientific and technical advice to the Conference of the Parties to the UN Framework Convention on Climate Change (COP) and its bodies.

2.3.2 In 1995, the IPCC completed its Second Assessment Report (SAR). In addition to updating the information on the same range of topics as the First Assessment (published in 1990), the Second Assessment includes the new subject area of technical issues related to economic impacts of climate change. The Second Assessment Report is in three volumes and has been produced by three working groups. It is a coordinated effort of thousands of individuals, both authors and reviewers, from many countries and intergovernmental and international non-governmental organizations.

2.3.3 The Second Assessment Report concluded, for the first time, that "the balance of evidence from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature, suggests a discernible human influence on global climate".

2.3.4 Issues related to hydrology and water resources were covered in the second volume of the SAR, prepared by Working Group II. The aim was to clarify what was known and unknown about the following distinct issues:

(a) how sensitive is a particular ecosystem or a socio-economic system to climate change;

(b) how adaptable is a particular system to climate change;

(c) how vulnerable (susceptible) is a system to climate change.

2.3.5 As far as impacts on water resources are concerned. SAR states that:

> "Climate change will lead to an intensification of the global hydrological cycle and can have major impacts on regional water resources..."

The impacts may affect not only mean values but also variability, and in particular, hydrological extremes, and may differ in particular regions:

> "Changes in the total amount of precipitation and in its frequency and intensity directly affect the magnitude and timing of runoff and the intensity of floods and droughts."
>
> "High latitude regions may experience increased runoff due to increased precipitation, whereas runoff may decrease at lower latitudes due to the combined effects of increased evapotranspiration and decreased precipitation".
>
> "A number of simulations in some areas ... show an increase in the probability of dry

days and the length of dry spells (consecutive days without precipitation). Where mean precipitation decreases, the likelihood of drought increases. New results reinforce the view that variability associated with the enhanced hydrological cycle translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places".

"A change in the volume and distribution of water will affect both ground and surface water supply for domestic and industrial users, irrigation, hydropower generation, navigation, in stream ecosystems, and water-based recreation".

2.3.6 There are plans for the Third Assessment to be completed about 2000, with emphasis on regional aspects and adaptation measures and such important issues as the impact of climate change on water resources. Support for the work of IPCC was identified as a possible future focus of WCP-Water.

2.4 Twelfth World Meteorological Congress (http://www.wmo.ch)

2.4.1 As already mentioned above in relation to specific projects, the Twelfth World Meteorological Congress (Cg-XII), held in Geneva in June 1995, made several decisions of relevance to climate and water. It adopted a number of resolutions in this respect, such as those on the World Climate Programme and its coordination, the implementation of the CLIPS project and the continued implementation of the Hydrology and Water Resources Programme.

2.4.2 The resolution on the IPCC contained expressions of gratitude and congratulations for the achievements so far. It also contained a call for the identification of differing but scientifically and technically valid viewpoints.

2.4.3 A resolution on the World Hydrological Cycle Observing System (WHYCOS) invites WMO Member countries and other agencies to support the project. It also encouraged them to participate in the development of a global conceptual basis for the system.

2.4.4 Cg-XII noted that the Global Runoff Data Centre (GRDC) is widely recognized as the principal source of global data on river flows, providing an effective service to an increasing range of users. In Resolution 21 (Cg-XII) on the Global Runoff Data Centre (GRDC), WMO Members are encouraged to support the Centre through provision of the hydrological data sets and related information on river flow and to consider providing support to GRDC in the form of staff, funding and other resources.

2.4.5 Climate studies require global data and thus the international exchange of data is essential. This need has come to the fore precisely at a time of a growing commercialization of services, which has resulted in a trend for increasing charges for data and products. The resolution adopted by Cg-XII on "WMO Policy and Practice for the Exchange of Meteorological and Related Data and Products" includes guidelines on relationships in commercial meteorological activities. In this resolution, WMO commits itself to broadening and enhancing the free and unrestricted exchange of meteorological and related data and products. An annex to the resolution lists the data in question which, in principle, are essential to support WMO programmes. Hydrological data are explicitly excluded from consideration at this stage. Nevertheless, this issue is being actively studied by the hydrological community (see 2.5.5 below).

2.4.6 Congress was impressed by the accomplishments of the Global Energy and Water Cycle Experiment (GEWEX). It noted with interest information on and plans for field experiments in several regions of the world, including GEWEX Continental-scale International Project (GCIP) covering the Mississippi River basin, the MacKenzie River GEWEX Study in the boreal forest and

tundra region of Canada (MAGS). BALTEX in the Baltic Sea region, a combined macroscale and basin-scale study of water recirculation in the Amazonian tropical forest (LBA) and the GEWEX Asian Monsoon Experiment (GAME).

2.5 WMO Commission for Hydrology
(http://www.wmo.ch/wcb/homs/hwrphome.html)

2.5.1 The main aim of contributions by the WMO Commission for Hydrology (CHy) to the WCP is to ensure an effective input from operational hydrology to water-related aspects of studies of climate and the use of climate information for water-resource activities. The objectives are concerned with the effective use of climate data and information in the planning and operation of water-resource systems and with the use of hydrological data in climate-related studies. In this, the Commission's principal recent input to activities under WCP-Water, is described below.

2.5.2 The Ninth Session of the Commission (Geneva, January 1993), established a Working Group on Operational Hydrology, Climate and the Environment which included experts working on the following topics:

(a) GCIP and large-scale hydrological studies;

(b) hydrological data for observing climate and environmental change;

(c) impacts of climate and environmental changes on operational hydrology;

(d) GEWEX and water and energy interactions at the land surface.

2.5.3 At its Tenth Session (CHy-X) (Koblenz, December 1996), the Commission was informed of the aims, structure and recent developments in WCP-Water, with particular reference to such projects as A.2, A.5 and B.3. The Commission endorsed the continuation of WCP-Water and appointed two experts as members of its newly established Working Group on Applications to cover the following fields:

- large-scale hydrological studies;

- climate variability and water resources.

2.5.4 The Commission noted with interest recent developments in the World Hydrological Cycle Observing System (WHYCOS). WHYCOS is being developed by WMO with the financial support of the World Bank and other donors. Its aim is to contribute to the improvement of national and of regional water resources assessment capabilities. The concept of WHYCOS is to establish a global network of about 1000 stations on major rivers to monitor variables characterizing the quantity and quality of water in a river and to transmit the data through geostationary satellites to national, regional and global centres. There are a number of ongoing regional projects within this general framework. Most advanced is the MED-HYCOS project (Mediterranean Rim), with its Project Coordination Centre in Montpellier. The installation of the first set of DCPs took place in 1996 in the participating countries eligible for World Bank support. A site on the World Wide Web was opened in 1996 (http://www.rio.net/medhycos). The implementation of the project may be extended to the Black Sea, if sufficient funds become available. Other regional HYCOS subprojects at different stages of implementation are: SADC-HYCOS (Southern Africa Development Community, AOC-HYCOS (West and Central Africa), Congo-HYCOS (Congo River basin), IGAD-HYCOS (Eastern Africa), Aral Sea - HYCOS (Central Asia) and CARIB-HYCOS (Caribbean region). A BALTIC-HYCOS is under consideration.

2.5.5 The international exchange of data is a prerequisite for research on climate and water and

the international hydrological community is faced with a new challenge: to collect and compile the hydrological data sets needed for global studies. The resolution on WMO Policy and Practice for the Exchange of Meteorological and Related Data and Products, adopted by Cg-XII (see 2.4.5 above) explicitly excludes hydrological data. However, CHy was asked to consider the issue. The matter was raised in September 1996 at the Intergovernmental Council of UNESCO's International Hydrological Programme, which passed a resolution calling for the international exchange of data in support of research. In December 1996, CHy-X prepared a draft resolution on the exchange of hydrological data which would includes a commitment to broadening and enhancing the free and unrestricted international exchange of such data. This draft has yet to be reviewed by WMO's Executive Council and Congress but, if adopted, it will herald a new era of international collaboration within the hydrological community and may have a major influence on the implementation of WCP-Water.

2.6 WMO Commission for Climatology
(http://www.wmo.ch/wcb/wcp/wcphtml/wcp-home.html)

2.6.1 The Eleventh Session of the Commission for Climatology (Havana, Cuba February 1993) appointed Ke-Rang Li as Rapporteur on Water Resources with special reference to drought and desertification. One of his duties was to serve as liaison with CHy. He was a member of the CCl Working Group on Operational Use of Climatology Knowledge whose terms of reference included "to monitor and evaluate customers' need for special services, products and data sets and to identify activities which are sensitive for information on climate and past/present weather in the areas of water resources, drought and desertification". The Rapporteur emphasized in his report to the working group that there is a need to strengthen monitoring activities related to climate and the assessment of water resources, land degradation and drought prediction and to undertake research on the interaction between climate change, water resources and desertification and their socio-economic impacts.

2.6.2 The CCl Advisory Working Group and, in particular, the CCl Working Group on Operational Use of Climatological Knowledge have worked since 1993 on the development of plans for the Climate Information and Prediction Services - CLIPS - project. The main objectives of the CLIPS-project include stimulating the use of sector specific climate and prediction services, as well as actively supporting interdisciplinary and user-oriented research and development in order to generate new applications of climate information and prediction products. One sector which is highly climate sensitive, and which may benefit from this development, is water resource management and thus CLIPS is seen as highly relevant in the WCP-Water context.

2.7 Regional Associations of WMO
(http://www.wmo.ch)

2.7.1 Activities related to WCP-Water are also being conducted by the Working Groups on Hydrology (WGHs) of WMO's Regional Associations.

2.7.2 WMO's RA VI (Europe) appointed eight co-rapporteurs for the study area - climate and water. The outputs of this endeavour were two publications:

- Climate and Water in Europe. Some Recent Issues - E. Kuusisto, R. Lemmelä, H. Liebscher and F. Nobilis, 1994;

- Climate and Water in Europe, Water Quality and Aquatic Ecosystems - E. Kuusisto, R. Lemmelä, H. Liebscher and F. Nobilis, 1997.

2.7.3 Studies of the hydrological consequences of El Niño by two consecutive rapporteurs of RA III can serve as another example of WCP-Water-related activities of the working groups on hydrology of WMO's Regional Associations.

2.7.4 Three Regional Associations, namely RA III (South-America), RA IV (North and Central America) and RA V (South West Pacific) appointed rapporteurs on WCP-Water. In case of RA IV, the relevant work is being undertaken by a sub-group, which met during the WGH meeting in San Juan, Puerto Rico in October 1995. At that meeting, the sub-group noted a number of weaknesses in WCP-Water including:

(a) lack of explicit differentiation among the six activity areas;

(b) little or no coordination of projects;

(c) lack of consistency with the needs and goals of current WCP and related activities.

The Working Group made the suggestion that now may be an appropriate time to restructure WCP-Water. H. Lins, a member of the Group, is compiling materials on GCM outputs for use in assessments of climate variability and change.

2.8 International Hydrological Programme of UNESCO
(http://citel.upc.es/org/unesco)

2.8.1 At its eleventh session in February 1995, the Intergovernmental Council of the International Hydrological Programme (IHP) adopted the detailed plan for the execution of the fifth phase of the Programme for 1996-2001 (IHP-V) entitled: "Hydrology and water resources development in a vulnerable environment". It takes into account recommendations made at ICSU's ASCEND 21 Conference (Vienna, November 1991) and the International Conference on Water and Environment (ICWE) (Dublin, January 1992) and builds upon the UNCED recommendations.

2.8.2 The framework of the IHP-V is based on four concepts: the role of scales in hydrological processes, vulnerability of the environment, integrated water resources management and education, training and the transfer of knowledge. The programme is divided into eight themes:

(a) Global hydrological and biochemical processes;

(b) Ecohydrological processes in the surficial environment;

(c) Groundwater resources at risk;

(d) Strategies for water resources assessment and management in emergency and conflicting situations;

(e) Integrated water resources management in arid and semi-arid zones;

(f) Humid tropics hydrology and water management;

(g) Integrated urban water management;

(h) Transfer of knowledge, information and technology.

2.8.3 Member States have expressed considerable interest in activities under Theme I : Global hydrological and biochemical processes which incorporate the FRIEND project; development and

calibration of coupled hydrological atmospheric models; hydrological interpretation of global change predictions; and strategies for water resources assessment and management under conditions of anthropogenic global climate change. Strong interest was also expressed in Theme 5: Integrated water resources management in arid and semi-arid zones and Theme 6: Humid tropics hydrology and water management.

2.8.4 Several projects are administered jointly with other international organizations; e.g. the ICSU/IGBP core project on the biosphere aspects of the hydrological cycle is closely collaborating with Theme 1. In relation to Themes 4 and 7, particular emphasis has been placed on problems related to urban hydrology, integrated water resources management, environment and socio-economic aspects of water management, and management of large lakes und international basins. In connection with Theme 8, the importance of the network of postgraduate courses has been 7 strongly emphasised.

2.9 International Association of Hydrological Sciences (IAHS) (http://www.wlu.ca/~wwwiahs/index.html)

2.9.1 An international workshop on Continental-scale Hydrological Models: Charting the Future, was convened in Wallingford, UK in November 1996 by IAHS and WMO. WCRP supported participation of two representatives of each of the five major Continental Scale Experiments (CSEs): GCIP, LBA, GAME, BALTEX and MAGS. The concepts, plans, aims and structure of the CSEs were presented and discussed. The meeting was a valuable opportunity to get the hydrological and atmospheric modellers of the five CSEs together and discuss their different approaches and experiences. A report on the meeting would be issued in 1997 in the series of GEWEX reports.

2.9.2 The IAHS/WMO Working Group on GEWEX has met four times since the last planning meeting on WCP-Water: Yokohama (July 1993), Boulder (July 1995), Wallingford (November 1996) and Rabat (April 1997). The activities of the Working Group consist of work of four rapporteurs on such study areas as:

(a) Land surface parameterizations;

(b) Parameterization of soil moisture;

(c) Water and energy balance of high mountains regions;

(d) Flow of freshwater into oceans.

Moreover, the Working Group undertook two projects, that is

(i) Large-scale hydrological models
- which led to the launch of GCIP

(ii) Precipitation measurements
- principally the work of B. Sevruk in Zurich

Items of interest were not concerned solely with what hydrology could do for GEWEX, but addressed also what GEWEX could do for the hydrological community.

2.9.3 Other activities of IAHS of relevance include a number of symposia and workshops organized at IAHS General and Scientific Assemblies. During the IAHS Scientific Assembly in Yokohama (1993) a number of relevant events were organized which were devoted to such topics as:

(a) Remote sensing applications to large-scale hydrological models;
(b) Exchange processes on the land surface for a range of space and time scales;
(c) Macroscale modelling of the hydrosphere;
(d) Use of old hydrometeorological data to study global changes.

Several of the symposia which were convened at Yokohama involved the pre-publication of proceedings as "red books", e.g. "Macroscale Modelling of the Hydrosphere (IAHS publication No. 214). Some were post-published; such as the IAHS Special Publication on "Coupling Large-scale and Atmospheric Models", edited by G. Schultz et al.

2.9.4 The programme of the IAHS General Assembly in Boulder (1995) included relevant events on such topics as:

(a) Clouds, convection and land surface processes;
(b) Remote sensing;
(c) Large scale modelling in mountainous regions;
(d) Global water balance;
(e) Sea level and ice sheet volume changes.

The Boulder Assembly resulted in several IAHS publications, e.g. "Modelling and Management of Sustainable Basin Scale Water Resources Systems": IAHS Publication No. 231.

2.9.5 In November 1996, the IAHS/WMO Working Group on GEWEX collaborated with the Institute of Hydrology in Wallingford, UK to organize a Workshop on Continental Scale Hydrological Models: Charting the Future.

2.9.6 At the IAHS Scientifc Assembly held in Rabat from 23 April to 3 May 1997, the relevant events delt with:

(a) Scale issues in the coupling of hydrological and atmospheric models;
(b) Monitoring and management of soil moisture: integration over time and space.

The Rabat Assembly fostered discussion on scaling issues and several symposia addressed topics relevant to WCP-Water.

2.9.7 It was noted that the XXII General Assembly of IUGG would be held in Birmingham, UK from 19 to 30 July 1999 and that IAHS intended to organize a series of symposia and workshops as part of the Assembly, some of which would be of particular relevance to WCP-Water.

2.10 Framework Convention on Climate Change (FCCC)
(http://www.unfccc.de)

2.10.1 The United Nations Framework Convention on Climate Change (FCCC) was adopted in May 1992 and soon after, at the 1992 "Earth Summit" in Rio de Janeiro, opened for signature. It entered into force on 21 March 1994. As at 6 January 1997, the Convention had received 165 instruments of ratification or accession. The Convention negotiations were inspired in large part by the scientific findings of the Intergovernmental Panel on Climate Change (IPCC), see section 2.3 above.

2.10.2 The UNFCCC's Subsidiary Body for Scientific and Technological Advice (SBSTA) at its fifth session, Bonn, Germany, 25-28 February 1997, called for cooperation with WMO and other organizations participating in the Climate Agenda in identifying, through consultation with Parties, the needs of Parties, in particular developing country Parties, for systematic observations, climate research and capacity building. It recognized the need to improve systematic observations to promote climate research activities, particularly in developing countries.

2.10.3 In accordance with Article 4.1 (g), 4.1 (e) and Article 5 of the FCCC, and within the context of the World Climate Programme (WCP), the Climate Change secretariat, in support of the SBSTA and other Convention bodies, have an interest in the following activity areas of WCP-Water:

3.1 Studies of hydrological data in the context of climate variability and change;
3.2 Studies of the influence of the climate change and variation on water resources;
3.3 Impact of climate on society through water resources;
3.4 Influence of man's activities on climate.

2.11 NATO Special Programme on the Science of Global Environmental Change (http://www.nato.int/science)

2.11.1 The Special Programme on the Science of Global Environmental Change was established by the NATO Science Committee in 1990. The objectives of the Special Programme have been to promote research dealing with potential global changes within the earth's environment system, using the means available to the NATO Science Committee. Its particular aim has been to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system. Its primary goal has been to advance our capability to predict changes in the global environment, in particular those which result from human impacts on climate. The programme was intended to stimulate interdisciplinary exchange and cooperation among scientists who traditionally work with only one component of the global system, and it hoped to fill gaps in fundamental knowledge and address shorter-tem problems of an applied nature.

2.11.2 The Programme was implemented by staff of the NATO Scientific Affairs Division with the aid of an advisory panel of scientists from NATO countries. During the lifetime of the panel 21 different scientists served on it. The panel had an average annual budget of BF 18.24 million during its five funding years. It supported 66 meetings, including 53 Advanced Research Workshops (ARWS), 12 Advanced Study Institutes (ASIs) and one closing workshop. These activities were distributed among the following five themes:

A. The climate system and the hydrological cycle:

- the dynamics of climate change
- atmospheric chemistry and dynamics

B. Biogeochemical processes and dynamics

C. Ecosystems and global environmental change

D. Global environmental changes of the past

E. Human dimensions of global environmental change:

- Social and economic consequences of climate change
- The education and training of global environmental change scientists.

The 54 books resulting from the programme, of which 46 are already published, leave a valuable legacy for future researchers.

2.11.3 Global environmental change includes climate change, ozone depletion, desertification, deforestation and reduction of biological diversity. Society initiates such changes by its activities, and is put at risk from them through increased sensitivity and reduced environmental security. As a science, global environmental change presents special problems due to its wide scope and its

crucial significance to society. The NATO Special Programme on the Science of Global Environmental Change has been highly successful in promoting the necessary multidisciplinary science. It has also been responsive to opportunities and events, and forward thinking about key, future global environmental issues that now need to be addressed.

2.11.4 Though superficially distinct, the global environmental changes listed above all arise from perturbations to the global "life support" systems. The scope of the science encompasses current and past physical, chemical, biological and social environments, issues that are treated at the largest, whole earth, scale. The central task is to use science as a basis for making statements about the possible future course of events. Impacts foreshadowed on food, weather, human health and the natural environment point to clear risks to environmental security caused by global environmental changes. The risk is exacerbated by society's reduced security resulting from an increased susceptibility to change due to ever-increasing population, both numerically and in complexity and interconnections.

2.11.5 Among the Advanced Research Workshops (ARWs) devoted to topics relevant to WCP-Water and organized after the Sixth Planning Meeting on WCP-Water are:

- Global Environmental Change and Land Surface Processes in Hydrology: The Trials & Tribulations of Modelling and Measuring, (Director - Prof. S. Sorooshian, USA), 17-21 May 1993, Tucson, USA

- Global Precipitation and Climate Change, (Director - Dr M. Desbois, France) 27 September - 1 October 1993, La Londe, France

- Diachronic Climatic Impacts on Water Resources with Emphasis on Mediterranean Region, (Director - Dr A. Angelakis, Greece) 17-23 October 1993, Iraklio, Crete, Greece

The list of Advanced Study Institutes (ASIs) comprises:

- The Role of Water and the Hydrological Cycle in Global Change, (Director - Dr H.R. Oliver, United Kingdom) 27 May - 6 June 1994, Il Ciocco, Italy

- Remote Sensing of Processes Governing Energy and Water Cycles in the Climate System, (Director - Prof. E. Raschke, Germany) 1-12 May 1995, Plön, Germany

2.11.6 The Final Report of the Special Programme, from which the above information was extracted, was published in October 1996.

2.12 Food and Agriculture Organization
(http://www.fao.org)

2.12.1 FAO has informed WMO on the decisions taken by its Council at its 111 Session in October 1996. These support the continued association of FAO with the Climate Agenda and encourage FAO's participation in the Climate Agenda's coordinating body (IACCA). However, FAO is not in a position to contribute financially to any activities related to the Climate Agenda.

2.12.2 FAO also infomed WMO of their severe financial constraints and a re-focusing of activities. As a consequence, some activities have been discontinued and a strong emphasis is being placed on the follow-up to the 1996 World Food Summit and to activities in support of food production.

2.12.3 While providing information on projects C.3, D.7 and D.8, FAO stated that the Organization "does not have the resources to further contribute to the exercise". However, one activity being considered by FAO, namely a global digital water atlas, would be of much interest for WCP-Water and could be treated as a follow-up to the WCP-Water Project C.3.

2.13 International Institute for Applied Systems Analysis
(http://www.iiasa.ac.at)

2.13.1 In his letter of 20 January 1997, addressed to the meeting, the Director of the International Institute for Applied Systems Analysis (IIASA) wrote: "It is most unfortunate that IIASA is no longer involved in any water-related studies, meaning that we cannot provide any expertise to participate in [the] ... meeting".

2.14 Comprehensive Freshwater Assessment
(http://www.un.org/dpcsd/dsd/freshwat.htm)

2.14.1 Because of growing concern about the availability and sustainability of global water resources, the United Nations Commission on Sustainable Development (CSD) asked the UN agencies concerned to work with Sweden to undertake a comprehensive assessment of global freshwater resources.

2.14.2 Although the primary aspect of global change therein is population growth and increased water consumption per capita, the potential impact of climate change is also considered, if only briefly. The assessment was presented to the CSD in April 1997 and subsequently to a special session of the UN General Assembly in June 1997.

2.15 Isotopes in precipitation
(http://iaea.or.at) (http://www.wmo.ch/web/arep/arep-home.html)

2.15.1 In collaboration with the International Atomic Energy Agency (IAEA), the Past Global Changes (PAGES) project of the International Geosphere-Biosphere Programme (IGBP) and IAHS, WMO convened the International Workshop on Tracing Isotopic Composition of Past and Present Precipitation: Opportunity for Climate and Water Studies (Berne, January 1995).

2.15.2 Among other topics, the Workshop considered the data collected within the framework of the Global Network "Isotopes in Precipitation" (GNIP) of IAEA and WMO. This network was first set up in 1961 and the data are of considerable value for climate and water studies. IAEA, WMO, IGBP and WCRP are planning to take action to strengthen the network.

2.16 Second International Conference on Climate and Water
(http://ahti.hut.fi/wr/caw2)

2.16.1 The Second International Conference on Climate and Water will be held in Espoo, Finland, from 17 to 20 August 1998. It is being organized by the Helsinki University of Technology and co-sponsored by a number of institutions, including WMO, UNESCO, IAHS and Academy of Finland. The aim of the conference is to bring together experts involved in the study of climatic variability and change and their impact on hydrology and water resources. The objective is to review developments since the first Conference on Climate and Water which was held in Helsinki in 1989. It is believed that the results will not only contribute to the specific projects of the international organizations concerned, but will also constitute an input to the continuing debate, at both national and international level, on the potential impact of climate change on hydrology and water resources.

2.16.2 The Conference will address a number of topics of direct interest and importance for WCP-Water, such as uncertainties in climate change, climate change and extreme hydrological events, hydrological input to atmospheric models and the water balances of big rivers.

3. DISCUSSION OF PROGRESS WITH IMPLEMENTATION OF WCP-WATER PROJECTS UNDER THE SIX ACTIVITY AREAS

3.1. Review of current projects

3.1.1 The meeting considered each of the current WCP-Water projects in some detail. It compiled up-dated and revised project sheets for the projects. These are presented in Annex 3 to this report.

3.2 Value and use of climatic scenarios for hydrological and water resources studies

3.2.1 At the consultation meeting in May 1996, it was decided that a small group of authors be formed to prepare a paper offering guidance to the hydrological community on the value and use of climatic scenarios for hydrological and water resources studies. A number of projects have tried to use scenarios produced by different GCMs at a regional scale and have obtained contradictory results. It is important to advise the hydrological community on the uncertainties involved in using such scenarios. The panel is composed of N. Arnell (UK), Z. Kaczmarek (Poland), E. Stakhiv (USA) and B. Jenkins IUK).

3.2.2 The panel had met later in November 1996 in conjunction with the meeting in Wallingford reported under 2.9.2 above. The WCP-Water Planning Meeting expressed concern that there had been no follow-up to this meeting. The meeting scheduled in March 1997 coinciding with that on the EU project on climate change impacts in Europe did not take place. It was proposed that another meeting of the panel take place in October 1997, in Washington, USA. In the meantime, development of the existing manuscript outline should be undertaken by correspondence.

4. REVIEW OF AIMS AND STRUCTURE OF WCP-WATER

4.1 Aims of WCP-Water

4.1.1 Considerable debate centered on the need for a revaluation of the aims and future directions for WCP-Water. The principal issue was whether WCP-Water should continue to act mostly in a coordinating role or should be revamped to become more pro-active. Agreement was reached on the following:

(a) WCP-Water needs to be restructured to have a broader perspective, including greater attention being given to the user community

(b) the Second International Conference on Climate and Water (17-20 August 1998, Espoo, Finland) would be the appropriate venue at which to identify new technical directions for WCP-Water

(c) there should be two separate groups established as part of the process of reviewing the structure of WCP-Water:

  (i) a Review Panel of experts for rewriting the mission statement and subsequently the structure of WCP-Water

(ii) a Panel of Rapporteurs selected to extract the key issues during the Second International Conference on Climate and Water for inclusion in the revised WCP-Water

4.1.2 The following revised goals and objectives were developed to assist the Review Panel:

Goal To promote the use of hydrological and water resources data, information and methods in the activities of the World Climate Programme and related conventions, to provide the water community with current data and information on climate variability and change over a wide range of time and space scales, and thus to meet the socio-economic needs of users which depend on water resources.

Objectives

(a) to enhance understanding of the relationship between climatic and hydrological processes;

(b) to improve the availability of data required to achieve the objectives of WCP-Water;

(c) to promote more effective use of climate information in water resources management;

(d) to enhance understanding of the impact of climate variability and change on water resources;

(e) to promote more effective use of hydrological information in climate research, analysis and interpretation;

4.2 Structure of the programme

4.2.1 It was recommended that the task of reviewing the structure for WCP-Water and developing proposals for future action be given to a Review Panel composed of H. Lins (USA), A. Hall (Australia) and representatives of the Secretariats of WMO and UNESCO. The following terms of reference were proposed for the Review Panel:

(a) review the current scope of WCP-Water, taking into account the reports of the Panel of Rapporteurs on the Second International Conference on Climate and Water and the present active areas of the Programme;

(b) recommend the appropriate structure for a revised programme, including the definition of verifiable indicators of project suitability for inclusion in WCP-Water;

(c) identify clusters of projects to streamline the Programme;

(d) provide guidelines to manage the Programme in an efficient manner;

(e) develop a routine for project monitoring and evaluation of progress;

(f) the report of the Review Panel will also provide an operational plan for WCP-Water;

The various proposals presented to the Meeting as regards the future structure of WCP-Water were therefore passed to the Review Panel for its consideration. The Panel would also be expected to consider the manner in which projects might be described and implemented in future.

4.2.2 As regards the timing of the Review Panel's work, it was noted that:

(a) The deadline for the report of the Panel of Rapporteurs should be 10 September 1998; the Review Panel's function will be completed after review of its report in December 1998.

(b) The joint WMO/UNESCO International Conference on Hydrology scheduled for February 1999 would provide the appropriate forum to present the revised WCP-Water structure and programme.

It was considered important that the Panel meet in the WMO Secretariat so that it might consult with those most active in other areas of the WCP.

4.3 Identification of projects

4.3.1 As reported under 3 above, the Meeting reviewed the past and current projects and compiled the status reports contained in Annex 3. As indicated there, seven of the original 39 projects had been completed by the time of the Sixth Planning Meeting and since then a further 11 projects had been completed or were no longer active. This left a total of 21 projects that were still active.

4.3.2 Given the recommendation of the Meeting that the aims and basic structure of WCP-Water be reconsidered in the coming months, no new projects were included in the list. The various proposals for new projects that had been submitted to the Meeting were passed to the Review Panel for its consideration. These included the following:

(a) **El Niño - Southern Oscillations**

Hydrological studies linking El Niño - Southern Oscillations (ENSO) phenomena with hydrological variables, in particular characteristics of extreme hydrological events

(b) **Global Digital Water Atlas**

Creation of a global homogeneous water resources and water use data base in GIS format

(c) **Trends in Regional Runoff**

Search for relationships between trends and cyclical fluctuations in runoff and possible shifts in climate for higher latitudes of northern hemisphere, i.e. areas where global models show possibility of significant changes in precipitation regimes

(d) **Social Dimensions of Water Use**

Studies of influence of social phenomena such as urbanization, intensification of agriculture, increase of population density and international financial relations on demand for and use of water resources under climate variability and change

(e) **Three regional projects (Central Europe) analyzing climate change impacts**

- Climate change impacts on flow regimes in Central Europe
- Snow conditions of the Alps and flow conditions of the Danube
- River ice conditions with special regard to the navigation on the Danube

(f) **Application of a Water Balance Model in Hydrological Practice**

Application of a water balance model, capable of assessing climatic change impacts, to drainage basins in Europe.

It was considered important to identify links with CLIPS.

4.3.3 It was roted that an initiative by the University of New Hampshire on a global water data base, that paralleled that listed as 4.3.2 (b) above, had been put forward to IAHS for consideration. No immediate action was being taken by either WMO or UNESCO, pending clarification of the links between the two projects.

4.3.4 In discussions on the search for signals of variability and change in hydrological time series, where WCP-Water Project A.2 is relevant, it was noted that there are a number of methods and software packages available for investigating trends, cycles and breaks in records. Consequently, it was suggested that a small workshop be organized to bring together experts in this particular field to provide guidance on which of these methods might be appropriate to apply in certain circumstances. It was suggested that such a workshop might be held in the UK and that the Institute of Hydrology should be approached in anticipation of WMO and UNESCO support.

5. CLOSURE

5.1 The meeting reviewed and adopted a draft of the report of the meeting and requested the WMO and UNESCO Secretariats to complete the text and circulate it to all participants for final approval.

5.2 The chairman thanked the Federal Institute of Hydrology for its excellent support and hospitality and the participants for their valuable contributions. The meeting closed at 12h10 on 16 May 1997.

ANNEX 1

List of invitees for WCP-Water 7

Mr Bobee (University of Quebec)
Mr Bonell (UNESCO)
Ms Björklund (SEI)
Mr da Cunha (NATO)
Mr Ghazi (EU)
Mr Grabs (GRDC)
Mr Hall (CHy Expert)
Mr Kaczmarek (Polish Academy of Sciences)
Mr Kohler (IHDP)
Mr Lemmela (Helsinki University of Technology)
Mr Lins (USGS)
Mr MacDonald (IIASA)
Mr Najlis (UN/New York)
Mr Roald (NVE)
Mr Rodda (IAHS)
Mr Rudolf (GPCC)
Mr Usher (UNEP) / Mr Rast (UNEP)
Mr Wolter (FAO)
Mr Zammit Cutajar (FCCC)

List of individuals contacted
with request to report of their activities within WCP-Water 7

Mr Beran (TIGER, U.K.)
Mr Fread (NWS, U.S.A.)
Mr Hladny (Czech Hydrometeorological Institute)
Mr Ohmura (ETH Zurich, Switzerland)
Mr Starosolszky (VITUKI, Hungary)
Ms Wiegandt (University of Geneva, Switzerland)

ANNEX 2

Seventh Planning Meeting on World Climate
Programme-Water

Koblenz, 13-16 May 1997

LIST OF PARTICIPANTS

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ANNEX 3

WORLD CLIMATE PROGRAMME - WATER
(WCP-WATER)

ACTIVITY AREAS

AND

PRIORITY PROJECTS

As agreed at the Seventh Planning Meeting on WCP-Water
Koblenz, 13-16 May 1997)

Summary Listing of Activity Areas and Priority Projects for WCP-Water as agreed by the Seventh Planning Meeting on WCP-Water (Koblenz, 13-16 May 1997)

A. STUDIES OF HYDROLOGICAL DATA IN THE CONTEXT OF CLIMATE VARIABILITY AND CHANGE

A.1 Analysing Historical Hydrological and Related Information

- IAHS with cooperation of UNESCO, WMO, ICSU, other interested international bodies and national institutions

A.2 Analysing Long Time Series of Hydrological Data and Indices with Respect to Climate Variability and Change

- WMO in cooperation with the Global Runoff Data Centre (GRDC), Polish Academy of Sciences, IIASA and interested national bodies

(A.3 Distinguishing Between the Influence of Man's Activity and Climate Variability on the Hydrological Cycle)

- Project completed for the present

A.4 Monitoring of Glacier Fluctuations

- ICSI (IAHS) with the support of UNESCO and UNEP

A.5 Collection of Global Runoff Data Sets

- WMO and GRDC

(A.6 Transfer of Hydrology Information to Grid Point or Grid Area Values)

- Incorporated into Project B.3

A.7 Global Energy Balance Archive (GEBA)

- Swiss Federal Institute of Technology, Zürich (ETH) with other national institutions and the World Radiation Data Centre, St. Petersburg.

A.8 Detecting Global and Regional Runoff Trends by Monitoring Discharge of Selected Rivers

- GRDC and WMO.

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* Projects in parentheses are no longer being implemented because they have been completed, or will be completed by the end of 1997, are suspended for the present or have been incorporated into other projects.

(A.9 Monitoring Changes in the Characteristics of Extreme Hydrological Events (Floods and Droughts))

- UNESCO in cooperation with WMO, IIASA, GRDC and national institutions

B. MODELLING OF THE HYDROLOGICAL CYCLE

B.1 Coupling of Physically Based Climate and Hydrological Models

- WMO and national institutions

(B.2 Development and Application of Second Generation Grid-Oriented Hydrological Modelling Techniques)

- Incorporated into Project B.1

B.3 Development of Grid-Related Estimates of Hydrological Variables

- WMO and UNESCO in collaboration with national institutions

B.4 Hydrological aspects of HAPEX

- National institutions, WMO and ICSU at international level

(B.5 Use of Atmospheric Moisture Transport Information for Water Balance Computations)

- Project completed for the present

B.6 Preparation of monthly global gridded precipitation data sets

- GPCC and national institutes

B.7 Comparison study of time series of areal mean monthly precipitation and streamflow of selected catchment areas

- GPCC and GRDC

C. APPLICATION OF CLIMATE INFORMATION IN THE PLANNING, DESIGN AND OPERATION OF WATER-RESOURCE SYSTEMS

(C.1 Application of Climatological Data and Methods to Water-Resource Projects)

- Project completed for the present

(C.2 Application of Climate Information for Water Projects in the Sahel)

- Project inactive for the present

(C.3 Application of Climate Information to Irrigation Water Supply Assessments in Africa Using a Digital Geography Information System Data Base)

- Project completed

(C.4 Application of Conditional Climatological Information to Water Supply Forecasting in the USA)

- Project completed

(C.5 Reanalysis of Hydrological Observations in Czechoslovakia)

- Project completed

C.6 Teleconnection of the El Niño Phenomenon with Extreme Hydrological Events in South America

- WMO - RA III Working Group on Hydrology

C.7 Development of Improved Climatic Scenarios for Water Resource Assessment)

- Project will be completed by end 1997

(C.8 Verification of Probabilistic Streamflow Forecasts)

- Project will be completed by end 1997

C.9 The impact of the El Niño southern oscillation phenomenon on the hydrology of the South West Pacific

- WMO - RA V Working Group on Hydrology

D. STUDIES OF THE INFLUENCE OF CLIMATE CHANGE AND VARIATION ON WATER RESOURCES

D.1 Sensitivity of Water Resource Systems to Climate Variability and Change

- National institutions and WMO with contributions from UNESCO, IIASA and IAHS

(D.2 Use of Climate Data for the Study, Planning and Management of Water Resources)

- Project completed for the present

(D.3 Study of the Impact of Climate Variability and Change on the Occurrence of Droughts)

- Project completed

D.4 Study of the Impact of Climate variability and Change on the Occurrence of Floods in Urban Areas

- National institutions, UNESCO and the International Research and Training Centre on Urban Drainage, in cooperation with WMO, IAHS and UATI

D.5 Testing the Transferability of Hydrological Simulation Models

- National institutions with international coordination by WMO

(D.6 Impact of CO_2 Induced Climate Change on UK Water Resources)

- Project completed

(D.7 Assessment of Impact of Possible Climate Change and/or Sensitivity of Irrigation Systems Including Storage of Irrigation Water in Reservoirs)

- Project discontinued

(D.8 Assessment of Climate Change Impact on Population Supporting Capacity of Land, Based on AEZ (Agro-Ecological-Zones))

- Project completed

(D.9 Impact of Climate Change on Thermal and Ice Regime of Rivers and Lakes)

- Project suspended

(D.10 Impact of Climate Change on Suspended Sediment and Water Quality)

- Project will be completed in 1997

(D.11 Sensitivity of Storage Systems to Climate Change

- Project completed

D.12 Overview of methods for assessing the implications of climate change and variability for water resources management

- WMO, UNESCO, UNEP and IPCC with input from other international and national agencies

(D.13 Climate variation impacts on water balance and water quality of shallow lakes)

- Project completed

E. IMPACT OF CLIMATE ON SOCIETY THROUGH WATER RESOURCES

- No projects proposed at this stage

F. INFLUENCE OF MAN'S ACTIVITIES ON CLIMATE

(F.1 Influence on Water-Resource Projects of Climate)

- Project completed for the present

ACTIVITY AREA A

STUDIES OF HYDROLOGICAL DATA IN THE CONTEXT OF CLIMATE VARIABILITY AND CHANGE

An analysis of historical hydrological data and information, and in particular of long hydrological time series, is being undertaken in order to gain fuller knowledge of climate variability and a better understanding of the processes related to climate change, including the influence of man on climate.

Due to the close relationship between climate and hydrology, hydrological variables and water resources are very strongly influenced by variations in climate. In this respect, hydrological variables, such as surface runoff, can be considered as "climate variables" representing on a large scale in time and space the residual of precipitation and evaporation.

In addition, a continuing inventory of water resources, their supply, demands and their dynamics, is needed to provide hydrological data precipitation, runoff, glacier fluctuations, etc.):

(a) to climate modellers for the validation of predictions;

(b) to researchers studying climate change and variability;

(c) to hydrologic modellers for validation of their models and methods and for use in sensitivity studies; and

(d) for the application to food, energy, economic and health problems.

In relation to (a) above, new methodologies should be developed to relate hydrological and physiographic data to grid points or areas so that they might be used in conjunction with atmospheric general circulation models (GCMs).

Project A.1 Analysing Historical Hydrological and Related Information

1. Background

Historical hydrological and related information, concerning for example floods, low flow periods or river ice periods, is available in many countries in the form of direct information stored in archives or in the form of indirect information such as proxy-data (for example ice core data, dendrochronological data, sediment probes, historical records tied to climatological or hydrological parameters, etc.). This material has been used for specific studies but could be more broadly used to increase our knowledge of variations in hydrological regimes during past centuries and for analysing climate variability and change.

Several organizations, including some working within the framework of the WCP, have undertaken research in these fields. However, there is a need for more co-ordination between the individual research studies.

Research groups need information on existing inventories of historical hydrological data sources including proxy-data. Therefore, it would be necessary to compile information on existing data. Furthermore, a unified methodology is needed in the form of guidance material so that results of individual research groups can be compared.

2. Output

(a) Improvement of methodologies and as far as possible unification of them;

(b) Support for the work of, and provision of guidance and information to, research groups;

(c) Comparison of results using various approaches for specific climatological or hydrological variables and for specific periods;

(d) Increasing knowledge of variations in hydrological regimes during past centuries.

3. Past activities

Circular letters have been distributed by WMO and IAHS to collect information as a basis for a review of the availability of historical hydrological and related information in member countries. Information obtained has been stored in INFOCLIMA. Three rapporteurs of the WMO RA VI Working Group on Hydrology compiled relevant material available from Europe, published as "Studies and Models for Evaluating the Impact of Climate Variability and Change on Water Resources within WMO Regional Association VI (Europe)", WMO/TD-NO. 463, 1992. One IAHS-Rapporteur compiled detailed material on the climate of Europe of the past 500 years. The International Workshop on the Use of Old Hydrometeorological Data to Study Global Changes was organized in Yokohama, Japan, on 15 July 1993.

The International Commission for the Hydrology of the Rhine has published a report "Reconstruction of the Meteorological Conditions in the Mid-Rhine Basin from the Year 1000 up to the recent on the Basis of Historical Hydrological Events" (Report No. 11-9, CHR, Lelystad, 1995). This report was the result of a project which represented an attempt to draw up a history of the weather in the Mid-Rhine Basin by means of historical records.

4. Further Implementation

A Steering Committee meeting was held in UNESCO on 21 March 1997 for the analysis of historical hydrological and related information. It was decided that an improved effort should be made by the International Hydrological Programme (IHP) of UNESCO to support the collection of hydrological historical data, in particular related to extreme events. Fuzzy Iodic methodology will be tested on the data recorded in the Mexican Archives by the end of 1997 with the objective of filling in gaps which exist in this long series data. Colombian and Ecuador archives will be investigated by the end of 1997. An international workshop will be held in 1998 in UNESCO Headquarters, Paris. Representatives of other programmes related to historical data rescue will be invited, to exchange experience and promote co-operation among programmes.

UNESCO organized a workshop entitled "Water, Environment and Society in Times of Climate Change" in Sede Boker, Israel in July 1996. A book based on this workshop will be published by Kluwer in 1998. In addition, UNESCO has commissioned a Cambridge University Press-International Hydrological Series project provisionally entitled "Global Climate Changes During the Holocene", which includes analysis of proxy data and perspective on the effects of society by a historian. This project will be completed in 1999.

Several of the symposia and workshops planned for the IAHS contribution to the IUGG General Assembly to be held in Birmingham, UK in July 1999 will be of value to this project. One proposed on sea level change may provide information on many sources of relevant data.

5. Organizations/bodies involved

UNESCO/IAHS with co-operation of WMO, ICSU and other interested international bodies and national institutions.

6. Tentative time schedule

(a) to (c) Continuing activity.

7. Comments

This project involves the co-operation of many scientists from very different fields of research. This project started in 1983 and became operational only after several years. Liaison necessary with Projects A.2 and A.4.

Project A.2 Analyzing Long Time Series of Hydrological Data and Indices with Respect to Climate Variability and Change

1. Background

In many countries long hydrological time series are available from instrumental records (e.g. of precipitation, discharge, water levels of rivers, estuaries, lakes). From these hydrological variables and relevant meteorological variables (e.g. air temperature), sets of hydrological statistics, such as annual mean, monthly mean, minimum values, threshold crossing characteristics, etc. and indices, such as drought-index can be obtained. This material may be used for improving knowledge of climate variability by being analyzed in that respect. In particular, one is tempted to look for a greenhouse component in a long time series of hydrological signals.

Research groups need information on existing long time series. Therefore, it will be necessary to compile information on such time series and their availability. Furthermore, a unified methodology is needed in the form of guidance material so that the results of individual research groups can be compared.

Long hydrological time series are often influenced by man's activities. These effects have to be identified and eliminated in the time series so as to isolate the influence of climate variability and change. A methodology for eliminating these effects was developed under Project A.3.

2. Output

Results of analyzing such long time series may give more detailed information on the variability of the climate and water systems in time and space. The results will contribute to a better understanding of the physical processes behind climate variability and change.

3. Past activities

During the first phase of this project, a set of statistical tests and a computer program were developed, and a number of long time series of hydrological data were identified and collected for the study. In total, more than 200 time series of data were made available by Members of WMO and were subsequently analyzed by the Polish Academy of Sciences in co-operation with the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. The length of the series varied from 30 to 200 years. The results of the analyses are summarized in the IIASA Collaborative Paper No. CP-92-05 "Occurrence of Climate Variability and Change within Hydrological Time Series - a Statistical Approach" which was published in September 1992.

In order to discuss and identify techniques and hypotheses for stochastic and time series modelling, as well as the principal statistics to be used in studying spatial variability of hydrological data, a workshop was held in the WMO Secretariat from 9 to 13 November 1992. Thirteen national experts from Africa, Asia, Australia and Europe participated in the workshop, reviewed the current state of the field and formulated proposals for further implementation of the project.

Besides being funded from regular budget of WMO, the Project has been supported by Canada through the WMO Special Trust Fund on Climate and Atmospheric Environment Activities (CAEA).

A consultant (Professor George Cavadias) undertook a mission to national agencies in three countries. The expert became acquainted with national holdings of long time series of hydrological data and with national studies in the area. He also explored with national experts how to link the activities undertaken under national projects with WCP-Water A.2. His mission led to recommendations on the future implementation of the Project.

A small expert meeting was held in Paris in September 1995, at which a number of directions for possible future activities were identified.

An initial study of intercomparison of tests for trend detection has been performed under the supervision of Professor Andras Bardossy of the University of Stuttgart. The study contained the following components:

(a) generation of a synthetic data series and choice of observed river flow data series to be used in further work on intercomparison of tests for trend detection;

(b) identification of a number of tests for trend detection;

(c) contamination of the data mentioned in (a) with different classes of trend (jump, multiple jump, gradual; changes in mean and/or in variance);

(d) intercomparison of tests on data produced in (c) and data from catchment with changed regimes.

The output of the above study are a report plus data sets, as in (a) and (c) above, in the form of a CD-ROM.

During the Twenty-first General Assembly of the European Geophysical Society, a session was held devoted entirely to the topic of the A.2 Project during which eleven presentations were delivered and a number of useful comments offered.

4. Further implementation

One of the recommendations of the Paris meeting was that the "methodology of tests needs further work" and "it would be useful to compare the available tests".

A number of suggestions for future endeavours were also given by Professor Bardossy, such as:

(a) extension of the intercomparison of trend detection methods (comparison of test skills for changes of various types, shapes and strengths, and verification of credibility of test results);

(b) combined spatial and temporal studies, to check whether or not rivers of particular regions respond similarly to a broader climatic forcing.

A joint WMO/UNESCO initiative should lead to the preparation of a state-of-the-art paper on the value of climate change scenarios for hydrological studies, with the twin objectives of warning the hydrological community of the uncertainties involved in using such scenarios and encouraging the analyses of long-term hydrological data sets. The work will be submitted to an international journal for publication.

It is also planned to organize a workshop on investigating trends, cycles and breaks in long time series of hydrological records (see paragraph 4.3.4 in the present report).

5. Organizations/bodies involved

The project is being executed by WMO in co-operation with GRDC, and with the participation of those Member countries which have available long hydrological time series and/or which conduct research on the analysis of such series.

6. Tentative time schedule

Continuing activity.

7. Comments

Links with Projects A.1, A.4 and A.5 necessary.

Project A.4 Monitoring of Glacier Fluctuations

1. Background

In some alpine countries glacier fluctuations have been observed for more than a century and internationally coordinated glacier monitoring started in 1893. Since 1960 worldwide glacier observations have been standardized and published on a five-year basis by the Permanent Service on the Fluctuations of Glaciers (PSFG). Six volumes of "Fluctuations of Glaciers" have been published (the last, sixth, volume "Fluctuations of Glaciers 1985-90" was published in 1993).

Since 1976, the Temporary Technical Secretariat (TTS) for the World Glacier Inventory has assembled national or regional glacier inventories using a computerized data system. This project was completed by mid-1985, by which time a joint programme had been developed. This new programme, the World Glacier Monitoring Service, combines the TTS and the PSFG. In 1989 the "World Glacier Inventory - Status 1988" was published, giving an overview of the statistical data basis on the distribution of glaciers over the entire globe. Mass balances of about 50 glaciers are now being reported at two-years intervals with the new publication series "Glacier Mass Balance Bulletin" (the last, fourth, issue was published in 1996).

2. Output

(a) Records of long time series of glacier variations;

(b) Monitoring climate variations in all glaciated regions on the basis of mass-balance studies of reference glaciers.

3. Organizations/bodies involved

(a) ICSI of IAHS with the support of ICSU/FAGS, UNESCO/IHP and UNEP/GEMS;

(b) The ETH in Zurich, Switzerland, furnishes the infrastructure of the secretariat;

(c) National institutions as correspondents.

4. Further implementation

(a) Volume VII of "Fluctuations of Glaciers" is under preparation;

(b) World Atlas of Snow and Ice Resources (Vol. 1) and accompanying technical monograph (Vol. 2); being prepared by the Russian National Committee for the IHP;

(c) ICSI/UNESCO two books to be produced: "Glaciers of the Southern Hemisphere" (based on the joint ICSI/IAMAS/IAPSO Symposium, Melbourne, July 1997) and "Tropical Glaciers".

5. Tentative time schedule

4 (b) 1997
4 (c) post-1997

Project A.5 Collection of Global Runoff Data Sets

1. Background

An international data base of hydrological data is considered necessary for estimating land surface related hydrological inputs/outputs of general circulation models (GCM), for testing grid oriented estimation techniques for such inputs/outputs and validation of GCMs. Increasingly, these data sets are also required for macro- and mesoscale hydrological modelling, global and regional water balances, investigation of regional and global trends, regions studies and assessments, estimation of input of fresh water and other matter into the oceans and coupling of hydrological and meteorological models. Project A.5 provides a general service for the collection and storage of internationally available sets of hydrological data and the generation of data products. This task is performed by the permanent Global Runoff Data Centre (GRDC) - see also the annex to this project sheet.

2. Output

(a) Global data base for surface water runoff from a growing set of stations; daily and/or monthly values;

(b) Support for the development of GCMs;

(c) The Centre provides valuable data and data products to a large clientele of users. It provides hydrological information needed to resolve hydrological problems, e.g. in management of international rivers and to decision makers. GRDC supports, inter alia, international programmes and projects such as the World Climate Programme and World Climate Research Programme, Global Climate Observing System, and a considerable number of institutional research projects. It collaborates with several organizations of the UN system, such as WMO, UNEP, UNESCO, WHO, the World Bank and the Economic Commissions, e.g. of South-East Asia, Africa and Europe, and also such organizations as NASA. Moreover, GRDC provides data and data products to universities and research institutions;

(d) Reports of GRDC.

3. Past activities

(a) Institutionalization of the GRDC as an internationally accepted Centre since 1993 as a continued effort to the activities since its formal setting-up in the Federal Institute of hydrology in Koblenz, Germany in 1988;

(b) Upgrade of the staffing of GRDC to the present level of five staff members;

(c) Development and operation of a PC-based state-of-the-art databank system on INFORMIX;

(d) Development of a series of user tools for the selection of data and a line of data products as input for above mentioned activities;

(e) GIS-assisted visualization of the database and information processing;

(f) Establishing direct contacts with National Hydrological Services of the world;

(g) Establishing close working relationships with GPCC, GEMS/WATER, WHYCOS, FRIEND, GTOS, GCOS, ACSYS and regional Economic Commissions such as EU, ESCAP, ECA, ECOSOC;

(h) Development of a global runoff monitoring tool for the comparative assessment of regional and global areas of water surplus and water deficit;

(i) Development of a software tool for a plausibility check of hydrological data;

(j) Upgrade of the WMO set of statistical routines in hydrology;

(k) Publication of 14 reports since 1993 and the establishment of a Web-page on the WMO WWW-server;

(l) Establishment of an international Steering Committee for the GRDC in 1994 and two meetings of the Steering Committee in 1994 and 1995;

(m) Development of policy guidelines for the acquisition and dissemination of data in 1995;

(n) Adoption of resolution 21 of XII Congress in 1995 urging Members to support the GRDC with data and other needed inputs;

(o) Letter of the Secretary-General of WMO in July 1996, requesting Members to support the GRDC.

4. Further implementation

(a) Update routinely existing data sets and add new data sets, usually on the basis of individual requests;

(b) Seek data from large-scale international experiments in accordance with agreements reached at GEWEX meetings;

(c) Seek closer linkage to National Hydrological Services and regional associations relevant for the GRDC;

(d) Strengthen working relations with FRIEND, WHYCOS, GEMS/WATER and GPCC;

(e) Seek overlapping time-series for the 160 largest rivers of the world;

(f) Monitor continental surface water discharges into the oceans (continuation) using selected gauging stations;

(g) Establish the variability of surface water discharge on a global scale for different time-series;

(h) Check the quality of datasets on a project basis;

(i) Time-series and statistical analysis of discharge data on a project basis;

(j) Network with the science community to create more information from available datasets;

(k) Communicate with data users and develop further additional data products;

(l) Communicate with data providers for feed-back of research results;

(m) Monitor the use of the GRDC data;

(n) Complete the Geographical Information System (GIS) on the basis of available global data sets including digitized basin boundaries of major rivers;

(o) Acquire metadata for GRDC data sets;

(p) Derive grid-based values of runoff and generate map.

The yearly GRDC status reports provide detailed information about past, on-going and planned activities.

5. Organizations/bodies involved

Based on (a) to (p) above:

GRDC in close cooperation with WMO and relevant UN agencies

6. Tentative time schedule

Continuing activity

1997 - 1999 for projects (d) and (n)
1997 - 2000 for project (p)

7. Comments

Liaison necessary with projects A.1, A.2 and A.8, and with B.3 in regard to the derivation of grid-based values.

Annex to Project Sheet A.5

GLOBAL RUNOFF DATA CENTRE (GRDC)

1. Collection of discharge data at global scale

Discharge data are collected under the following criteria:

- large rivers with annual discharge greater than 100m^3/s
- basins with catchment areas greater than 1 000 000 km^2
- basins with more than 1 000 000 inhabitants and basins of high socio-economic importance
- basins with internal drainage
- long-time series of runoff (WCP-Water Project A.2)
- undisturbed areas up to 5 000 km^2
- runoff into the oceans (WCP-Water Project A.8, GEWEX, GEMS/Water, GCOS, GTOS)

2. Aside from these criteria, discharge data are collected on a project basis, e.g. for regional hydrological analysis such as the ACSYS project.

3. Status of the data bank as of March 1997:

- 3,680 stations from 146 countries
- 2,854 rivers
- 71,109 monthly discharge values
- 389,693 daily discharge values

Project A.7 Global Energy Balance Archive (GEBA)

1. Background

The amount and quality of direct measurements of energy balance components has increased substantially after the International Geophysical Year. This development has made it possible to re-evaluate the earth's energy balance, based on the observed values. The GCMs have recently been developed to the stage that the adiabatic processes are taken into account. With such models it is especially important that the computed surface energy balance components are accurate. In regions with insufficient ground observations, and especially for the oceans, the satellite based observations of radiation, surface roughness length and wind offer a new possibility for energy balance evaluation. These methods, however, need ground based data of high quality for algorithm calibration and for verification.

The previously ignored flux of the latent heat of melting and freezing of snow and ice should be taken into account in the global energy balance. This component plays an important role for regions covered by seasonal snow cover and glaciers, not only in the energy balance but in the hydrological cycle. The latent heat of melting is the major heat sink during the summer on sea ice in polar regions.

Recently it has become known that the energy fluxes show secular variations similar to those of air and sea surface temperatures. This tendency has been found in global radiation and net radiation and is considered to be related to the hydrological balance. This means that the secular variations in the hydrological cycle should be considered together with variations in the energy balance. These are new conditions and requirements for energy balance data. Therefore, the Department of Geography of the Swiss Federal Institute of Technology in Zurich has initiated the work of collecting directly measured energy balance fluxes and compiling them into a computerized archive.

2. Output

(a) Computerized global archive of monthly and annual values of global radiation, direct solar radiation, diffuse sky radiation, global radiation, short-wave reflected radiation or albedo, long-wave incoming and outgoing radiation, long-wave net radiation, net radiation, sensible heat flux and latent heat flux, subsurface heat flux, latent heat of melt;

(b) Time series of some of the above mentioned fluxes for selected stations;

(c) Ground truth for satellite-based estimations of energy balance fluxes on the earth's surface;

(d) Validation data for the GCMs;

(e) A new global atlas of energy balance.

3. Past activities

Energy flux data have been extracted from 1500 publications and summarized as monthly means of energy balance components at 600 locations. The total data stored are about 250,000 station months for about 1,600 sites. Among these there are 144 stations with more than one year period of measurement. The data base scheme has been designed and a data entry

application program, including "physically possible" data quality control, has been released for routine data input. The fluxes are assimilated for the period from the beginning of the observations till 1985. The quality control software has been completed. The archiving of UV has been abandoned. This will be done within BSRN/WCRP.

4. Further implementation

Substantial progress was made with respect to the assimilation of new data for the last ten years and the quality control of shortwave radiation.

5. Organizations/bodies involved

Department of Geography, Swiss Federal Institute of Technology (ETH): Building and updating the archive from 1985 and continuing after 1990

Department of Geography and Department of Cartography, Swiss Federal Institute of Technology, Zürich (ETH): Cartographic representation of energy balance, 1989-91

World Radiation Data Centre, St Petersburg

NASA Langley Research Centre, Hampton

BSRN/WCRP (Baseline Surface Radiation, Network/World Climate Research Programme)

6. Tentative time schedule

GEBA will be accessible on the World Wide Web in 1997. The quality control of long-wave radiation will be completed by the end of 1997.

7. Comments

Closely related to Project A.4.

Project A.8 Detecting Global and Regional Runoff Trends by Monitoring Discharges of Selected Rivers

1. Background

It is expected that changes in climate will affect the river runoff regime. Therefore it is important to review on a regular basis updated time series of runoff from selected rivers. For this reason runoff data should be collected from suitable stations on a routine basis soon after they are observed. Stations for this purpose were selected on the basis of the following criteria:

(a) 160 stations close to the mouth of rivers into oceans which represent the discharge from each continent into the oceans;

(b) 160 stations in the headwater area of the aforementioned rivers which represent continental situation.

2. Output

(a) Global monitoring of discharge from each continent and globally;

(b) Early recognition of possible changes to draw the attention of decision makers to the effects;

(c) Establishment of the variability of discharges on regional and global scales;

(d) Visualization of changes on a global scale using GIS-based monitoring tools;

(e) Regular publication of results.

3. Past activities

(a) Selection of suitable stations (re-definition of previous selection);

(b) Verification of the representativity of these stations for continental discharge;

(c) Development of the first operational version of a Global Runoff Monitor based on a comparison of runoff values;

(d) Publication of a report on Continental Freshwater Fluxes into the World Oceans (GRDC Report No. 10).

4. Further implementation

(a) Seeking overlapping time-series for the 160 largest rivers of the world for monitoring purposes;

(b) Regular monitoring of the discharge situation;

(c) Establishment of discharge variability and possible trends;

(d) Establishing suitable contacts and means of communication to obtain near real-time discharge information for selected stations;

(e) Improving the GIS-based monitoring tools;

(f) Establishing a regular update and reporting facility;

(g) Establishing close contacts with information users to develop suitable data products.

5. Organizations/bodies involved

Based on (a) to (g) of 4 above:

GRDC in close cooperation with the WMO Secretariat and interested institutions

(a) Cooperation with National Hydrological Services;

(b) National hydrological services, WHYCOS and FRIEND.

6. Tentative time schedule

(a) to (g) Continuing activity.

7. Comments

Liaison with projects A.2 and A.5 and in particular with the emerging WHYCOS which could provide the necessary real-time links, and with GTOS and GCOS where this project is an important component.

Project A.9 Monitoring Changes in the Characteristics of Extreme Hydrological Events (Floods and Droughts)

1. Background

It is expected that as a result of the greenhouse effect the frequency and intensity of floods and droughts may change. Due to some very severe events in recent years the impression has been obtained that changes have already occurred. However, up to now, there has been no systematic approach to the collection of relevant data or their statistical analysis. Therefore this project aims to develop approaches to the problem of detecting changes in the statistical characteristics of extreme hydrological events.

In the first step of the project available data on floods and droughts should be collected, updated and unified. The initial analysis should be made by existing simple empirical methods. Later on in the project the necessary methods for statistical analysis for comprehensive studies should be developed, taking into account the existence of non-stationarity.

2. Output

(a) Improvement of knowledge with respect to the effects of climate change on the statistical characteristics of hydrological events both as regards their magnitudes and their frequencies of occurrence.

(b) Early recognition of possible changes to allow decision makers to undertake appropriate steps.

3. Past activities

Publication of:

- Discharge of Selected Rivers of the World, Volumes I, II and III. Studies and Reports in Hydrology No. 5, UNESCO, 1971 et seq.
- World Catalogue of Maximum Observed Floods by J. Rodier and M. Roche, IAHS Publ. No. 143, 1984
- Hydrological Aspects of Drought by M. Beran and J. Rodier. Studies and Reports in Hydrology No. 39, UNESCO and WMO, 1985
- Methodology for Distinguishing between Man's Influence and Climatic Effects on the Hydrological Cycle by J. Refsgaard, W. Alley and V. Vuglinsky, Technical Documents in Hydrology, UNESCO, 1989

4. Further implementation

(a) Compilation of relevant hydrological data; i.e. updating flood catalogue and creating equivalent information on drought;

(b) Inclusion of data in GRDC;

(c) Standardization of the material available;

(d) Analysis of the data and interpretation of results;

(e) Workshop to plan future statistical analyses;

(f) A separate but related activity is expected to be the updating of the World Catalogue of Maximum Observed Floods (see 3 above) as a joint IAHS, WMO, UNESCO project.

5. Organization/bodies involved

The project is to be executed by UNESCO within the framework of IHP-IV Project H-2.3 in cooperation with WMO, GRDC and national institutions.

6. Tentative time schedule

It was not possible to undertake the work as set out in 4 (a) to (e) above, but the topic is very important and has been submitted for discussion at the Second International Conference on Climate and Water.

7. Comments

Liaison with Projects A.2, A.5 and A.8.

ACTIVITY AREA B

MODELLING OF THE HYDROLOGICAL CYCLE WITH SPECIAL REGARD TO PROVIDING INPUTS FOR CLIMATE MODELS

The quantitative coupling of climate, hydrologic and water-resource systems can best be achieved within the framework of mathematical models of the hydrological cycle. However, nearly all existing hydrological models are river basin oriented and so are their atmospheric inputs and outputs (precipitation and evapotranspiration). This is one reason for the recent difficulties in coupling hydrological models with atmospheric general circulation models (GCMs), the latter being generally grid oriented with standard grid scales of 1.5 to 2.5 degrees. Even when the hydrologic and climate models are not directly coupled but run in parallel, enormous difficulties exist in providing the required input data from one model to the other. For the same reason, it is impossible to make direct use of observed river discharges for climate studies over an area.

The most practical way of overcoming this difficulty would appear to be by developing and applying a second generation of grid-oriented hydrological modelling techniques which can take account of all land surface related moisture and heat fluxes. Outputs of these models are related primarily to grid areas. However, if one wished to use the outputs for flow components (overland flow, percolation, interflow, base flow, streamflow) in any river basin studies then these outputs must first be related to basin divides. For this reason they must be routed and superimposed with special regard to the storage and delay processes within the different hydrological subsystems of the river basin. This should be taken into account when using discharge records for such studies and, in particular, for validating GCMs.

Thus, intensified research activities are required in the field of hydrological modelling in the framework of the projects listed below. It is quite obvious that for these projects causal physically-based models are preferred. The explanatory power of causal models makes them especially attractive to WCP-Water because they have the potential of making inferences about events and their impacts which are beyond the range of past observations, as well as about the consequences of man's influence on the natural processes involved.

While recognizing the legitimacy of many categories of models, special emphasis should be put on those which are based on the dynamics of the physical processes involved, including the feedbacks between the processes traditionally treated independently of each other. The inclusion of such feedbacks will call for innovative approaches and a re-examination of the traditional dividing lines.

Project B.1 Coupling of Physically Based Climate and Hydrological Models

1. Background

It is considered that the further development and improvement of physically-based mathematical models of the atmosphere would gain greatly from a better understanding of the effect on climate of hydrological processes and an upgrading of the manner in which such processes are incorporated into atmospheric General Circulation Models (GCMS). This would be aided by the coupling of climate and hydrological models. This project is therefore seen as providing direct support to the WMO Global Energy and Water Cycle Experiment (GEWEX).

2. Output

Presentation of practical ways for bringing together results of physical climate and hydrological modelling in order to accommodate the physically based relationships (feed-backs) which are mostly being neglected in the current practice of modelling.

Specifications of input data requirements to be considered by:

- climate modellers;
- hydrologic and water-resource system modellers.

Improved methods (hydrological models) and computerized technologies for estimating water transfer at the land surface, in particular areal evapotranspiration, dependent upon climatic, physiographic and other characteristics (e.g. soil, land use, vegetation, geology).

3. Past activities

Proposals formulated in a number of past activities in this project subsequently became part of the GEWEX Continental Scale Experiments.

The report entitled "Opportunities to Improve the Hydrology of Atmospheric Models" by J.C. Schaake was published in 1993 as Technical Report in Hydrology and Water Resources No. 37 (WMO/TD-No. 539). The report on "Land surface processes in large-scale hydrology" by CHy Rapporteurs on Hydrological Interactions of the Land Surface: J.D. Kalma and I.R. Calder was also published (OHR-NO. 40, WMO Publ. No. 803).

The activities of the IAHS/WMO Working Group for GEWEX contribute directly to this project, including the Workshop on Continental Scale Hydrological Models: Charting the Future, that was held at the Institute of Hydrology in Wallingford, UK in November 1996.

The Tenth session of the WMO Commission for Hydrology approved the publication of a report on the "GEWEX Continental-scale International Project, large-scale hydrological studies and their relevance to water resources agencies" prepared by the CHy rapporteurs Messrs A. Hall and J.C. Schaake in the Technical Report in Hydrology and Water Resources Series. Finally, a project proposal contained in the report "Model Parameter Estimation Experiment (MOPEX)" was presented to the Commission by the same authors.

4. Further implementation

Further development of plans for GEWEX, in particular the GEWEX Continental-scale International Project (GCIP), and the implementation of these plans.

Activities of the IAHS/WMO Working Group on GEWEX, which consist of the work of four individual rapporteurs and two projects, also contribute to this project (see paragraph 2.9.2 of the present report).

However, there are numerous bodies that now successfully deal with this study area (WCRP, IGBP) and WMO need not necessarily play a pro-active role.

5. Organizations/bodies involved

WMO, as lead agency under GEWEX, the WMO Commission for Hydrology and national institutions.

6. Tentative time schedule

Continuous

7. Comments

Liaison with A.5, A.7 and B.3.

Project B.3 Development of Grid-related Estimates of Hydrological Variables

1. Background

No widely accepted methodology exists for transferring information from hydrological stations to grid points or areas. Climatologists work with grids of various sizes, the geo-referenced gridding of runoff is a possibility for linking GCM outputs with runoff. Based on grids, the GCM outputs can be validated, using gridded runoff based on the same grid size. Likewise, global gridded data sets of individual components of the water cycle are needed as long term monthly means as well as monthly time series for the validation of General Circulation Models of the atmosphere and oceans (GCMs) and the assessment of water resources and their possible change of availability with regard to global warming.

2. Output

A methodology and generalized procedure for the transfer of hydrological information, as well as physiographic and other characteristics to grid point or grid area values;

3. Past activities

(a) A state-of-the-art report on grid-point and grid-area estimates was prepared as a draft and reviewed at the Workshop on the Global Runoff Data Set and Grid Estimation (Koblenz, FRG, 10-15 November 1988) (WCRP Report No. 22 (WMO/TD-NO. 302), 1989);

(b) Grid Estimation of Runoff for Central Europe. This project was co-ordinated by WMO and involves Austria, Czech Republic, Germany, Hungary, Poland, Switzerland and the UNESCO FRIEND project. More detailed work began in April 1992, following the Second Planning Meeting on Grid Estimation of Runoff for Central Europe was held in Warsaw, in April 1992. It involved the testing of methods for producing grid maps of runoff, using first the data from six pilot study areas (Weser, Elbe, Sajo, Upper Vistula, Upper Rhine and Upper Danube) and then data from the entire Eastern Europe.

(c) At the Third Planning Meeting on Grid Estimation of Runoft Data, held in Berne in October 1994, results of gridding for Central and Eastern Europe were discussed. It was decided that the available results of the Project should be published.

(d) A German national research project: "Transformation of measured flow data to grid points". The final report of this project has been submitted to the responsible Ministry and an executive summary is being prepared in English. Using the Weser and Elbe (Labe) catchments in Germany, monthly discharge values for the period 1971 to 1980 have been computed on a grid net. A Geographic Infomation System (GIS) is used as a tool for the computation of these data. Data input to the GIS consists of image processed data sets (soils, land use, etc.) from internationally available sources as well as from a digital elevation map of the cited catchments. The grid size can be customized for projects in climatology and hydrology on regional and global scales. Though the results are encouraging, one of the methods being only based on measured discharge data requires a station density which is not available in many countries. Another method consists of a water balance model combined with measured discharge data of selected stations.

4. Further implementation

(a) A report summarizing the results obtained so far within the WCP-Water Project B.3 and offering a review of gridding runoff results has now been prepared by Professor L. Gottschalk and Dr I. Krasovskaia. The report is expected to be published by WMO, in the WCASP series, in 1997;

(b) National activity of Germany implemented by GRDC: The Development of a GIS-supported Water Balance Model as a Tool for the Validation of Climate Models and Hydrometeorological Datasets. In the ongoing study, a grid-based water balance model is proposed following the Thornthwaite-Mather procedure to calculate long term mean monthly and monthly water balance components on a 0.5° x 0.5° grid. Discharge data are used in several steps for parameter estimation as well as validation and verification of the water balance components. The water balance model has so far been applied for a 0.5° x 0.5° grid covering Central Europe. Model validation was carried out for the rivers Rhine, Weser, Ems, Elbe (Labe) and the German part of the River Danube for the period 1971 - 1980. This work is being continued.

5. Organizations/bodies involved

WMO in collaboration with national institutions, in particular BfG, Koblenz.

6. Tentative time schedule

(a) Completed for the present.

(b) Project pending. Further work by the German Federal Institute of Hydrology in Koblenz is foreseen for 1998.

7. Comments

Liaison with Projects A.5, B.1, B.6 and B.7.

Project B.4 Hydrological aspects of HAPEX

1. Background

There is ample evidence of the sensitivity to climate changes of heat and moisture fluxes at the land surface. The purpose of the WCRP project for Hydrological-Atmospheric Pilot Experiments (HAPEX) is to improve our understanding of the processes involved and to provide a basis for developing and testing improved parametric formulations of these processes for use in atmospheric circulation models. HAPEX field studies will collect comprehensive sets of hydrological, atmospheric and related data for a number of specific sties.

2. Output

Sets of original and processed data from large-scale field studies stored at a central repository or repositories and partially available on CD-ROM.

A report on "The GEWEX Continental-scale International Project, large scale hydrological studies and their relevance to water resources agencies" has been prepared.

3. Past activities

Many international large-scale activities have been carried out in the last decade or so, such as:

(a) HAPEX-MOBILHY, S.W. France, 1985-86;

(b) First ISLSCP (International Satellite Land-Surface Climatology Project) Field Experiment (FIFE), Kansas, USA, 1987;

(c) HAPEX-Sahel, Niger, 1992;

(d) European Field Experiment in a Desertification Threatened Area (EFEDA), Spain, 1994 or 1995 (preliminary test 1991);

(e) Boreal Forest Interaction (BOREAS), Canada 1994;

Numerous subsequent activities have been carried out, in particular under the auspices of WCRP's Global Energy and Water Cycle Experiment (GEWEX). Among GEWEX large scale experiments of direct significance for hydrology are such projects as:

(f) GEWEX Continental-scale International Project (GCIP);

(g) Mackenzie GEWEX Study (MAGS);

(h) Baltic Sea Experiment (BALTEX)

(i) GEWEX Asian Monsoon Experiment (GAME)

Several activities are being implemented under the auspices of the International Geosphere-Bioephere Programme (IGBP) of the International Council of Scientific Unions (ICSU) and in particular its Biospheric Aspects of Hydrological Cycle (BAHC) Project. There are also

regional initiatives such as the Northern Hemisphere Land Surface Climate Experiment (NOPEX).

4. Further implementation

Continuation of ongoing experiments and planning of new ones

Through the formal agreement between UNESCO IHP and IGBP (BAHC), the hydrological-hydrochemistry component is being planned as part of the LBA (Large-Scale Biosphere-Atmosphere Experiment in Amazonia) scheduled to commence in 1997. A joint UNESCO IHP-IGBP (BAHC, publication is currently under preparation, entitled "Opportunities for Hydrological Research in Humid Tropics with Specific Reference to the Amazon Basin".

Publication of the report mentioned in item 2 is foreseen in 1998. At tenth session of the Commission for Hydrology of WMO, Mr Hall has been nominated expert on large-scale hydrological studies.

5. Organizations/bodies involved

National institutions, individually or in multi-lateral co-operation, WMO/ICSU under WCRP at international level.

6. Tentative time schedule

Continuing, each experiment having its own time schedule.

7. Comments

Liaison with Projects B.1 and B.3.

Project B.6 Preparation of monthly global gridded precipitation data sets

1. Background

Global precipitation analyses are necessary for climatological and hydrological research, e.g. to investigate the global hydrological cycle, for the verification of atmospheric general circulation models (GCMs) as well as for climate and climate change detection studies.

The purpose of the WCRP Global Precipitation Climatology Project (GPCP) is to derive global gridded data sets of monthly precipitation totals on a 2.5° grid as time series for the period 1986-1995 based on all available observation technologies (Implementation and data management plan for the Global Precipitation Climatology Project, WMO/TD-No. 367, 1990). In the meantime, the GPCP is included in GEWEX, and the GEWEX SSG decided to continue the GPCP and therefore a plan is being prepared for Phase II of the Project. The Global Precipitation Climatology Centre (GPCC) is a central element of this project, with a main emphasis on the earth's land surface. See also the annex to this project sheet.

2. Output

(a) Analyses of gridded monthly precipitation data based on conventional measurements;

(b) Error range estimates for the gridded results, separately for sampling and systematic measuring errors;

(c) Statistical results on variability of precipitation in time (sub-month) and space (sub-grid);

(d) Analysis of snow depth and its liquid water equivalent on a grid;

(e) Annual and quarterly status reports and input data availability;

(f) Service reports on gridded results to the World Data Centres for Meteorology, the other centres of the GPCP and climate research activities.

3. Past activities

(a) Setting up the Global Precipitation Climatology Centre at the Deutscher Wetterdienst, Offenbach, Germany, in August 1988;

(b) Collection of monthly global gridded precipitation data sets for the period of 135 months (January 1986 to March 1997). Precipitation data have been collected from synoptic reports and monthly CLIMAT reports received via GTS and from other sources, based on bilateral contacts, by mail;

(c) Development of a precipitation point data bank, including date from (b) and as well as station meta-infomation, and climatological normals;

(d) Estimation of the raingauge data density required for the calculation of areal means on the grid;

(e) Development of procedures for processing and quality-control of synoptic and monthly precipitation data;

(f) Implementation of a method for the spatial objective analysis and calculation of areal mean monthly precipitation on a grid from raingauge measurements;

(g) Development of a data bank for gridded precipitation estimates of different sources (objective analysis results over land, estimates based on satellite images and accumulated results from NWP model forecasts);

(h) Investigation of the spatial sampling error of the areal mean monthly precipitation totals analysed from conventional measurements;

(i) Development of a blending scheme for merging the analyses based on gauge-measurements with precipitation estimates based on satellite images and NWP model results into global data sets;

(j) Publication of methods used at the GPCC in journals and workshop proceedings; publications of reports of the GPCC.

Existing basic products

With regard to the availability of input-data, three basic product versions have been defined. All three contain monthly areal means of total precipitation on 2.5° grid cells, derived from raingauge data for the earth's land surface, accompanied by estimates of the total quality of the results and information on the error components.

The interim product is based on raingauge-based data from (averaged) 6.700 stations. It was prepared during 1995 to fulfil early requirements of the GPCP, and covers the period 1986 to 1994. The number of available data decreased from about 7,000 11986-1988) to 6,100 (1994) . The interim product has been complemented backwards to 1971 by P. Xie et al. (1996) using the GPCC analysis system and the precipitation data of the Global Historical Climatology Network, complemented by data from NOAA/NCEP (about 6.000 stations). However, a quality-control on the input data, as it is standard for GPCC, could not be performed in this framework.

The climate monitoring product is based on GTS data from about 6,000 stations worldwide. This product follows the interim product from January 1995 and it is available on a routine basis with a delay of two months after observation. The monitoring product additionally provides the precipitation in percentage of the means for the normal period: 1961-1990.

The verification product is still in preparation. It will be based on the additional data from about 40,000 stations.

4. Further implementation

(a) Continuous collection and analysis of precipitation data (synoptic and monthly) received via GTS;

(b) The GPCC database still needs spatial and temporal completion as well as the continuation of data collection. Continued efforts to increase the number of precipitation data available at the GPCC through bilateral contacts;

(c) Including orographic/climatological relationships to improve the spatial objective analysis of monthly precipitation over land areas;

(d) Intercomparison as well as estimation of errors of monthly areal mean precipitation from the different sources;

(e) Implementation of the GPCP analysis to merge the results from different sources for routine operation (raingauge and satellite-based data);

(f) The "verification product" will be based on data from about 40.000 stations, including the additional data which are supplied by more than 130 countries. It will be of high accuracy, suitable for verification of climate models and satellite-based precipitation estimates;

(g) Analysis of snow depth and its liquid water equivalent on a grid;

(h) Calculation of areal mean precipitation for large rivers basins.

5. Organization/bodies involved

- Global Precipitation Climatology Centre (GPCC) operated by the Deutscher Wetterdienst, Germany.
- WCRP Global Precipitation Climatology Project (GPCP).
- National Meteorological and Hydrological Services contribute by providing conventionally measured precipitation data.
- EUMETSAT, JMA and NOAA process data from the geo-stationary satellites, Meteosat, GMS, GOES-East and West, and NASA processes the microwave data from the DMSP polar orbiting satellite for GPCP.
- The satellite precipitation estimates are evaluated by the GSPDC and PSPDC (operated at CPC/NOAA and GSFC/NASA).

6. Tentative time schedule

- twelve test months of the "verification product" by the end of 1997;
- re-analysis of the monitoring and the "interim product" and storage of results on a finer grid, post 1997;
- Development of advanced analysis methods in co-operation with research institutes in 1998.

7. Comments

Closely related to Project A.5 and links to projects A.1, A.2, B.3 and B.7.

Annex to Project Sheet B.6

GLOBAL PRECIPITATION CLIMATOLOGY CENTRE (GPCC)

The Global Precipitation Climatology Centre (GPCC) is a component of the Global Precipitation Climatology Project (GPCP) integrated in the Global Energy and Water Cycle Experiment (GEWEX) (see paragraph 2.1.16 of the main text of the report). It covers the functions of collection, quality-control, correction and gridding of precipitation data measured by raingauges. The NMS of Germany, Deutscher Wetterdienst, will continue to operate the GPCC with regard to continuation of GPCP and to the development of GCOS as well as other international projects related to global climate research. The GPCC is also linked to WCP-Water.

The GPCC has been fully operational since 1995. It provides the research community with monthly gridded precipitation data for the global land-surface, routinely with a delay of two months after observation. The gridded data are derived from observations at about 6,000 meteorological stations. Up to May 1997, the gridded data set of GPCC covered the period January 1986 to March 1997. Information on the errors is delivered with the gridded data.

A new analysis method of combining gridded raingauge data and satellite observations has been developed jointly by GPCP participants but it is not yet fully operational. A pre-operational Version 1 of the combined data set has been published by NASA GSFC.

In order to reduce the sampling error, the GPCC has acquired additional precipitation data from about 40,000 hydrometeorological stations. The data are delivered from more than 130 countries. It is planned to use these additional data in order to achieve gridded areal means of higher accuracy and to verify the current products which are based on 6,000 stations or derived from satellite observations. The crucial problems are the delay of the data delivery to GPCC and the expense for quality control of all data, which needs to be performed by GPCC before the data can be analyzed.

The GPCC is not authorized to disseminate to any other user the data received from individual countries. However, the derived gridded data (products) are freely available.

The current GPCP and GPCC products are monthly precipitation means on a grid of 2.5° by 2.5° geographical latitude / longitude. The GPCC actually interpolates the raingauge data on a 0.5° grid system and calculates the area-means on the 2.5° grid from the interpolated results. In future, the 0.5° interpolated data will also be stored and will enable the GPCC to derive area-averaged precipitation for large river catchment areas.

The GPCC is planning to compile gridded data of snow depth and its liquid water equivalent in addition to total precipitation.

More information on the GPCC and the current status of its products is available on its www home page: http://www.dwd.de/research/gpcc

Project B.7 Comparison study of time series of areal mean monthly precipitation and streamflow of selected catchment areas

1. Background

The largest components of the water balance are precipitation and streamflow. Residuals are evaporation and storage changes. As measuring methods of both precipitation and runoff have specific uncertainties, the results have to be discussed in detail. The difference of precipitation and runoff have to be interpreted as to whether they represent residual components of the water balance or result from measurement errors. Comparison studies on time series of areal mean monthly precipitation and streamflow for selected catchment areas require temporal overlapping of the input data.

2. Output

(a) Time series of areal mean precipitation, water storage in snow cover and surface runoff for selected catchment areas;

(b) Reports and publications.

3. Past activities

(a) Collection and evaluation of precipitation data at GPCC;

(b) Collection and evaluation of runoff data and digitisation of catchment area boundaries at GRDC;

(c) Regional studies started by Winnegge at GRDC for the Niger catchment area and performed by Helbig and Lüllwitz (1995) for a part of Germany.

4. Further implementation

Phase I

(a) Installation of river basin data base of Oki;

(b) Compilation of data on snow cover, depth and liquid water equivalent for large river basins;

(c) Derivation of time series of monthly area-mean precipitation and mean snow depth (liquid water equivalent) for large river basins;

(d) Compilation of a set of discharge data for corresponding rivers and periods;

(e) Comparison and discussion of the time series.

Phase II

(f) Analysis and interpretation of the differences.

5. Organisations involved

GPCC and GRDC in Phase I

GPCC, GRDC and other (also national institutions) in Phase II

6. Tentative time schedule

(a) 1997 - 1998 for Phase I

(b) 1998 - 1999 for Phase II

7. Comments

Linked to projects A5, B3 and B6.

ACTIVITY AREA C

APPLICATION OF CLIMATE INFORMATION IN THE PLANNING, DESIGN AND OPERATION OF WATER-RESOURCE SYSTEMS

Water-resource projects can sometimes be planned, designed and operated purely on the basis of hydrological data. When such data are not sufficient, use must be made of other data, particularly climatological data. Even when a reasonable to good set of hydrological data is available, the use of climatological data can greatly improve the planning and design. In many cases the only local data are climatological and these must be used to derive estimates of hydrological and water-resource parameters for the localities concerned.

Long-range weather outlooks for periods of one to three months hold great potential for the improved management of water resources through their use in deriving predictions of future water supply and demand. The current uncertainty in these predictions means that a probabilistic approach needs to be taken.

There is a need for studies and guidance as to what climate information can be used and how in the planning, design and operation of water-resource systems. Future improvements in long-range climate predictions should be followed with a view to their being used to enhance water-resource management practice.

Project C.1 Application of Climatological Data and Methods to Water-Resource Projects

1. Background

The planning, design and operation of many water-resource projects is based in large part on the analysis of climatological data. Current practice already demonstrates the value of this approach and can provide the basis for the development of guidance on the subject.

2. Output

Guidance on the application of climatological data and methods to water-resource projects.

3. Past activities

Literature search and review led to a CHy Rapporteur's report "Climatological data and climate information for water resources projects" by H.J. Liebscher published as a WMO Technical Document (WMO/TD-No. 585, 1993). Report in related area was also prepared by a CCl Rapporteur, Ke-Rang Li (see paragraph 2.6.1 of the present report).

4. Further implementation

Project terminated at present.

5. Organizations/bodies involved

WMO through the CHy and CCl Rapporteurs.

6. Tentative time schedule

Project terminated at present.

Project C.2 Application of Climate Information for Water Projects in the Sahel

1. Background

Nowhere has the impact of climate variability been more evident in recent years than in the Sahel. The central actor in all considerations of the droughts and desertification is the shortage and unreliability of water supplies. Of all regions, therefore, the Sahel is one where all available information should be used to ensure the best designed and most efficiently operated water projects. This includes the use of climate information in the planning, design and operation of such projects.

2. Output

(a) Guidance on the use of climate information in conjunction with hydrological data for the design and operation of water projects, in particular where such information and data are scarce;

(b) Contributions to studies of the impact on water systems of climate variability in the Sahel;

(c) Assistance in the practical application of climate information for water projects in the Sahel.

3. Past activities

(a) Report on the derivation of design floods for small basins in the Sahel was prepared by WMO in 1984 with the support of the United Nations Sahelian Office (UNSO);

(b) A mission visited Niger in 1985 and prepared a report entitled "Application of Climate Information and Hydrological Forecasts for the Sahel";

(c) A technical meeting on hydrological design criteria for use in the Sahel was held in Dakar in 1986 with the support of WMO, the Committee Inter-African d'Etudes Hydrauliques (CIEH) and UNSO;

(d) Report by J. Sircoulon entitled "Impact possible des changements climatiques a venir sur les ressources en eau des régions arides et semi-arides" was published as report WCAP-12, WMO/TD No. 380, June 1990.

4. Further Implementation

Project inactive at present.

5. Organizations/bodies involved

WMO, with the participation of the countries of the Sahelian region and in collaboration with UNSO, CIEH and the AGRHYMET Centre and with the financial support of UNDP and other donors.

6. Tentative time schedule

Project inactive at present.

Project C.3 Application of Climate Information to Irrigation Water Supply Assessments in Africa using a Digital Geographic Information System Data Base

1. Background

A digital geographic information system (GIS) data base for Africa has been prepared by FAO with UNEP funding in connection with a desertification study. Twenty-three maps have been digitized and processed at a scale of 1 to 5 million including political boundaries, soils (FAO soil map), geology (UNESCO map), watersheds, annual rainfall, river systems and physiography. Because of FAO's emphasis on Africa and the need for consistent information on water and irrigation potential, the Africa GIS is being used as a basis for developing a methodology for water supply assessment on a regional and continent-wide basis.

2. Output

Climate information (precipitation for different periods, temperature, evapotranspiration) combined with elementary water balance principles is used to develop an assessment of water Supply for irrigation systems in Africa. More detailed assessments are being prepared for selected basins, first in the IGAD countries.

3. Past activities

The basic methodology was developed and a map showing the potential for irrigation in Africa on a scale 1:5 million was published in 1987. The publication is available on request from the Land and Water Division, FAO, Rome. The digitized version of the FAO/UNESCO Soil Map of the World at 1:5 million scale is now available. The data, in geographic projection, is in ARC/INFO EXPORT format, arranged in seven continental areas and contained on 63 diskettes. The use of the spatial data set requires access to GIS software which can read the ARC/INFO EXPORT format.

A customized GIS was developed for part of the Nile Basin. It supports analyses to estimate hydrological model parameter type information, including gridded flow path connectivity, drainage basin area definition for forecast locations and physical variables such as elevation, slope and length. The GIS utilizes vector and gridded raster formats. The raw data files were manually digitized from 1:2 million scale topographic maps produced by the US Defense Mapping Agency. A commercial GIS program (ARC/INFO) was used to digitize the basic GIS data sets which included streams, elevation contours, political boundaries, city names, and basin boundaries. The GIS is efficient and well designed for specific outputs, but it is not necessarily designed as a generalized GIS for any project.

4. Further Implementation

A new methodology to be used in this project for collection of data has been tentatively developed and is currently in a pilot test phase.

A study has been made on a larger scale (1:1 million) for selected IGAD countries (Nile Basin). A more sophisticated water balance model was used.

A GIS for the Nile basin is available, but at such a level of detail that it will be expensive to replicate. A new methodology has been developed at a lower cost and was successfully applied to the Niger basin. It allows the generation of information on surface waters at any point in the catchment. Technical information on this project carried out by FAO and UNESCO with the University of Texas at Austin is available at:

http://www.cc.utexas.edu/prof/maidment/gishydro/africa/africa.htm

5. Organizations/bodies involved

The Water Service in the FAO Land and Water Division has performed the work with the co-operation of countries in the Nile Basin belonging to IGAD. The Nile-GIS study was carried out by FAO and UNESCO with the University of Texas at Austin.

6. Tentative time schedule

Work completed.

Project C.5 Re-analysis of Hydrological Observations in the Czech Republic

1. Background

Hydrological and related climatological data have been collected and stored in Czechoslovakia for many decades. They have been analyzed as a basis for evaluating the country's water resources and for other purposes. From time to time such evaluations are revised to take account of new data that have become available and/or amendments to national water policy. Recent developments in our understanding of climate, its variability and its impact on available water resources may lead to new approaches in the assessment of water resources and call for a re-analysis of existing hydrological records.

2. Output

(a) Review of international guidance in the field, in particular in association with Projects A.2 and D.1, and their pilot application within the framework of national activities;

(b) Re-analysis of certain hydrological and climatological observations;

(c) Proposals for further development and future application of methodologies at national and international levels.

3. Past activities

On the basis of a pilot study which was finalized in 1988, the work continued on the selection and application of suitable methodologies for evaluating hydrometeorological data and information for each of the following parts of the project:

(a) Analysis of long-term hydrometeorological series:

A technique for analysis of homogeneity of the series of hydrological and climatological observations was developed with the aim of identifying and assessing changes in time. The study included preparation of relevant software for consequent application in detecting changes in long series of observations;

(b) Re-analysis of hydrometeorological characteristics: (part completed)

A new method was developed for evaluating the basic hydrological characteristics and hydrological design parameters in a system of sites of a river network. It was subsequently applied for the estimation of hydrological parameters at ungauged sites in the Elbe River basin. The report of the study: "Hydrological Design Data Estimation Techniques" has been published in the WCASP series of reports (WCASP-26, WMO/TD-No. 554);

(c) Changes in water balance:

Various techniques for water-balance studies were verified and the work continued on the preparation of input data and information. Methods for estimation of areal precipitation - the principal input element of the balance studies - were verified and modified and the relevant monthly water balance model was developed;

(d) Report entitled "Hydrological Characteristics of Selected Water Measuring Stations of the Czech Republic" (available in Czech only).

4. Further implementation

Project completed.

5. Organizations/bodies involved

The Czech Hydrometeorological Institute, Prague.

6. Tentative time schedule

Project completed.

Project C.6 Teleconnection of the El Niño Phenomenon with Extreme Hydrological Events in South America

1. Background

The meteorological anomalies, in particular those relating to precipitation, which are associated with the El Niño phenomenon affect the hydrological regime in those regions of South America situated on the western side of the continent.

It is also felt that these anomalies may be at the origin of droughts and floods affecting the eastern side at distances of 2000 kilometres and more.

A better understanding of the situation, besides being of considerable scientific value, would lead to the very practical application of improving hydrological predictions for the sub-regions concerned.

2. Output

(a) Collection of information on hydrological aspect of El Niño Phenomenon;

(b) Reporting on the results of the study.

3. Past activities

A survey was initiated in 1989 among WMO Member countries of Regional Association III (South America). The survey sought information on hydrological aspects of the El Niño phenomenon, geared to the establishment of a common methodological base that would allow the evaluation of the hydrological impacts of the phenomenon, with the aim of forecasting and mitigating its negative effects such as floods and droughts. The information collected was analyzed and a report prepared. Another survey was initiated in 1996 and a preliminary draft report was submitted to a meeting of the RA III Working Group of Hydrology in Caracas in April 1997.

4. Further implementation

Preparation of a final report by the RA III WGH rapporteur. Proposals are being put to RA III for the implementation of a truly regional project, possibility with external funding.

A Pan-American Climate Study (PACS) is being established under the U.S. Global Change Program which will link land and ocean studies in North and South America with GCIP and predictions for use in water resources management.

Work is also being undertaken at the University of California, Los Angeles, under the direction of J. Dracup, and at the Centre for Study of Hydroclimatology in the Pacific Rim. This is linked with work at the Centre for Catchment Hydrology at the University of Melbourne, under the direction of T. McMahon.

5. Organizations/bodies involved

WMO through the RA III Working Group on Hydrology.

6. Tentative time schedule

1997 - report of a rapporteur of the RA III Working Group on Hydrology.

7. Comments

Liaison with Project C.9 and D.1.

Project C.7 Development of Improved Climatic Scenarios for Water-Resource Assessment

1. Background

Perhaps the single most significant of all the effects of global climate change is the effect on the availability of water. Water-resources managers need to have methods for assessing the sensitivity of the systems they manage to changes in climate, CO_2 concentrations, and sea level. Also of importance is the need for methods of evaluating the risk or uncertainty associated with such assessments. Many of the existing predictive tools (watershed models) are not sufficiently focused on the water and energy balance issues to provide the necessary answers. Virtually all techniques of hydrological analysis are based on the assumption of a stationary or unchanging climate. Present means of generating the meteorological forcing functions for hydrological models under assumptions of climatic change use simple adjustments to current climatic conditions. It is planned to develop methods which make full use of information from general circulation models (GCMs) and observational data to drive hydrological models.

2. Output

Transferrable methods for translating generalized, synoptic-scale climate model outputs into a hydrologically-relevant stream.

3. Past activities

Progress has been made on the development of transferable methods for producing improved, hydrologically-relevant climatic scenarios from GCM output. Four distinct approaches have been devised: (1) a weather-pattern based stochastic temperature and precipitation model; (2) a regression-based model relating precipitation (snowpack accumulation) with atmospheric circulation; (3) a nested model approach; and (4) a canonical correlation based model relating regional streamflow with patterns of atmospheric circulation. A report has been prepared and is currently under review.

4. Further implementation

Upon completion of review, and subsequent revision, the document will be submitted for publication as a WCP-Water report by WMO.

5. Organizations/bodies involved

National agencies with international coordination by WMO, with contributions from UNESCO, IIASA and IAHS. USGS is currently undertaking such studies as part of the US Global Change Research Program.

6. Tentative time schedule

The project will be completed upon submission of the report to WMO, anticipated to be by December, 1997.

7. Comments

Liaison with Projects B.1 and D.1.

Project C.8 Verification of Probabilistic Streamflow Forecasts

1. Background

Forecasts of future streamflow events are beginning to be made in terms of estimated conditional distributions of the events. These forecasts are most useful for the distant future where there is usually much uncertainty. Long-term forecasts of seasonal snowmelt runoff have been made since the 1930's using regression models. Since the mid 1970's, conceptual hydrological models have been used together with historical climatological data to make "Extended Streamflow Predictions", not only of the seasonal snowmelt runoff volume, but specific attributes such as maximum or minimum stages, durations of events, etc. Their application to low flow and reservoir inflow forecasting during droughts has emerged during the last 10 years.

This study will investigate how to judge the performance of these techniques. Are probabilistic forecasts from conceptual models likely to be biased? Is there actually more uncertainty than these models indicate? How well do these models perform as compared to simpler statistical methods? If conceptual models lead to biased probabilistic forecasts, can the biases be corrected while preserving the skill without introducing bias in the resulting probabilistic forecasts?

The proposed approach is to formulate a conceptual statistical framework which allows verification statistics to be defined and their distributions to be estimated by simulating forecasts during the historical period. These statistics would be used to address the questions raised above.

2. Output

Report on the subject of the project.

3. Past activities

This project evolved from activities being undertaken in conjunction with WCP-Water Project C.4.

As of the end of March 1997, a one-month operational demonstration of an Advanced hydrological Prediction System for the Des Moines River Basin, Iowa (USA) was completed. The demonstration provided probabilistic streamflow forecasts for each of 21 forecast stations within the basin. The forecast products included the spatial display of probabilistic information using geographic information system capabilities.

4. Further implementation

The United States National Weather Service is now preparing a report regarding the demonstration. This could be used as the report for C.8.

5. Organizations/bodies involved

US National Weather Service in cooperation with other water-related organizations in the USA.

6. Tentative time schedule

Report should be available in 1997.

Project C.9 The impact of the El Niño southern oscillation phenomenon on the hydrology of the South West Pacific

1. Background

The variability of precipitation in many countries in the South West Pacific has been shown to be associated with phases of the El Niño-Southern Oscillation (ENSO) Index. Project A.2 has identified deficiencies in the availability of good quality long-term hydrological records for the South West Pacific. However, it is expected that the amount and distribution of long-term rainfall records will provide a better indication of hydrological trends. As part of Project A.2, it is proposed to apply the computer program for trend detection to long-term time series precipitation data. These long-term precipitation time series will also provide an opportunity to analyse the impact of ENSO on the hydrology of the South West Pacific. Particular emphasis will be placed on the occurrence and frequency of extreme hydrological events (floods and droughts) and the relative phase of the ENSO phenomenon.

2. Output

(a) Analysis of trends in precipitation data for the South West Pacific and comparison of this with available streamflow data;

(b) Maps of variability of precipitation and streamflow data and trends for the South West Pacific;

(c) Relationships between variations in the ENSO Index and variability of precipitation and streamflow;

(d) Methodologies aimed at providing a forecast of future hydrological conditions.

3. Past activities

There has been considerable research into the relationship between ENSO and the climate of some of the individual countries within the South West Pacific. However, there have been no studies aimed at evaluating the overall impact and interrelationships. The analysis of streamflow data within Project A.2 is seen as an initial step for this project.

Relevant activities have been undertaken within the Pacific Rim Study coordinated by the University of California, Davis.

4. Further implementation

The rapporteur for the Regional Association V (South West Pacific) Working Group on Hydrology who is responsible for WCP-Water in his report will emphasize this topic as one of importance for future work by RA V.

5. Organizations/bodies involved

WMO through the RA V Working Group on Hydrology.

6. Tentative time schedule

Report on WCP-Water to RA V session in 1998.

7. Comments

Liaison with Projects A.2 and C.6.

ACTIVITY AREA D

STUDIES OF THE INFLUENCE OF CLIMATE CHANGE AND VARIATION ON WATER RESOURCES

The projects under this activity field are divided into groups each prompted by a major observation about climate's impact on water resources.

Perhaps the most important outcome of any study in this area is a statement of the effect on water-resource decision variables of changes in climate inputs, whether actual, predicted or presented only as possible future scenarios. This activity therefore includes all sensitivity analyses, whether on hydrological variables or on water-resource decision variables (e.g. Project D.1).

The second class of projects is inspired by the recognition that climate is in continual motion. Movements which occur over a time scale of, say, 30 to 80 years are of particular importance as these are the planning horizons for current human activity in water-resource projects. Movements which occur over a 10-30 year time scale are important in that this is often the order of duration of our data base on which the scheme is designed. Within this time scale we conventionally ignore the possibility that part of the variation is due to movement and we tend to assign the total variability to the single cause of local fluctuation about a locally stable average value.

The final premise on which the projects in this activity field are founded is the idea that there is a distinction between hydrological variables (e.g. aquifer level, runoff volume, flood frequency distribution), and water-resource decision variables (e.g. reservoir volume, hundred year flood, crop water use). In some cases the difference is slight, but in general it can be stated that hydrological variables are directly measured or derived from measurements with little intervention. Water-resource decision variables tend to be derived quantities somewhat remote from the basic measurements. Thus it is often the case that the relationship is sufficiently obscured so that one cannot directly and simply estimate the effect of an alteration in the governing hydrological variables on the derived water-resource variable.

The question of establishing appropriate scenarios for climate change and variation to be expected within the planning period of important water-resource projects is covered under Activity Area B.

Project D.1 Sensitivity of Water-Resource Systems to Climate Variability and Change

1. Background

Hydrologists, water-resource planners and managers are increasingly alerted to the differences in the properties of climate and hydrological quantities as measured over different time periods. This realization, and the need to take action, exist independently of whether the differences are the product of sampling variability or intrinsic non-stationarity due to climate change. The problem is especially acute in arid and semi-arid regions where variability, for example in annual runoff, is already high so that stable water-resource schemes to compensate for the uncertainty and shortages of supplies are most vital. This project addresses directly the responsibility passed by the Villach Conference in 1985 to the scientific community to reduce the uncertainty in forecasting the impact of greenhouse gas induced change and in framing policies to meet the impact.

2. Output

(a) The enhancement of our understanding of the origin of interannual and seasonal variability and the persistence properties of salient hydrological variables;

(b) An increase in our appreciation of the performance of different hydrological modelling techniques in replicating the response to climate inputs;

(c) Estimates of the sensitivity of hydrological and water-resource qualitative and quantitative outputs due to possible changes in climate inputs using scenarios within the limits of climatological studies;

(d) Policy implications of climate change to water-resource management and planning.

3. Past activities

(a) International Symposium on the Influence of Climate Changes and Climatic Variability on the Hydrologic Regime and Water-Resources, Vancouver, August 1987, organized by IAHS with sponsorship of WMO and UNESCO. Proceedings: IAHS Publ. No. 168, 1987;

(b) Norwich meeting which reviewed procedures for developing scenarios and made future research recommendations across a broad spectrum of interest including Project D.1. Water Resources and Climate Change: Sensitivity of Water-Resource Systems to Climate Change and Variability - Report of a workshop held in Norwich, UK (March 1987), WMO/ESCAP Report No. 4, 1988;

(c) Convening by WMO of the Conference on Climate and Water (Helsinki, September 1989) - proceedings published in 1989 and report in 1990.

(d) The FRIEND project (IHP-V Project 1.1) on Western and Central Africa (FRIEND/AOC) includes a research theme related to: "the impact of climatic and anthropogenic variability on hydrological regimes", which started in October 1994. In the framework of this project, a workshop was organized in Cotonou (14 December 1995) which presented and discusses the initial results of the research activities, in particular those related to climatic variability and its impact on hydrological regimes; the proceedings will be published in the IHP series "Technical Documents in Hydrology".

(e) Publication of book "Water Resources Management in the Face of Climate/Hydrologic Uncertainties" by Z. Kaczmarek et al. (Editors). IIASA and Kluwer Academic Publishers, 1996.

4. Further implementation

UNESCO, WMO and IAHS are sponsoring an international conference on "Water Resources Variability in Africa during the XXth Century" to be held in Abidjan, Côte d'Ivoire from 16-19 November 1998.

Under IHP-V Theme 5: Integrated Water Resources Management in Arid and Semi-Arid Zones, Project 5.4 will develop methodologies to cope with water scarcity and negative effects of the hydrological cycle and develop public awareness. Several technical reports and popularized documents will be prepared and published in the IHP's series; a campaign of public awareness will be organized.

5. Organizations/bodies involved

Research at national level.
WMO at international level, with contributions from UNESCO and IAHS.

6. Tentative time schedule

Continuing long-term activity.

7. Comments

Closely linked with Projects B.1and D.5. Future contacts with ICOLD, ICID, IWRA, IWSA with respect to policy response.

Project D.3 Study of the Impact of Climatic Variability and Change on the Occurrence of Droughts

1. Background

There is a need to provide hydrologists with advice on how to make better use of climatological information so as to improve understanding of the occurrence of hydrological droughts and associated climate events. The aim is to improve related risk assessment, planning and management for the prevention and mitigation of the consequences of the natural hazards concerned.

2. Anticipated output

(a) Promotion of national studies;
(b) Publication of a technical report.

3. Past activities

The FRIEND project (IHP-V Project 1.1) on Western and Central Africa (FRIEND/AOC) includes a research theme related to: "the impact of climatic and anthropogenic variability on hydrological regimes", which started in October 1994. In the framework of this project, a workshop was organized in Cotonou (14 December 1995) which presented and discussed the initial resulty Of the research activities, in particular those related to climatic variability and its impact on hydrological regimes; the proceedings will be published in the IHP series "Technical Documents in Hydrology".

4. Further implementation

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Under IHP-V Theme 5: Integrated Water Resources Management in Arid and Semi-Arid Zones", project 5.4 will develop methodologies to cope with water scarcity and negative effects on the hydrological cycle and develop public awareness. Several technical reports and popularized documents will be prepared and published in the IHP series; a campaign of public awareness will be organized.

5. Organizations/bodies involved

UNESCO in cooperation with WMO and IAHS.

6. Time schedule

Publication of the proceedings of the Abidjan Conference mentioned above, in 1998. Publication of the report by UNESCO within IHP-V Theme 5 (1998-1999).

7. Comments

Liaison with Projects D.2 and D.4.

Project D.4 Study of the Impact of Climate Variability and Change on the Occurrence of Floods in Urban Areas

1. Background

Current design practice for urban drainage systems takes no account of possible climate change due to the effects on climate of the urban area. There is evidence of changes in rainfall rates and the incidence of heavy rainstorms which can cause more severe flood problems than hitherto.

2. Output

Improved awareness amongst urban designers of possible greater vulnerability of current drainage systems to floods and the development of design modifications to overcome the hazard.

3. Past activities

The International Hydrological Programme of UNESCO carried out, under its Fourth Phase (IHP-IV) lasting from 1990 to 1995, the Project M-3-3 Integrated Water Management in Urban Areas. The Netherlands/German IHP National Committees lent special support to his project. A number of activities and events were organized and/or sponsored resulting in various publications such as Hydropolis: The Role of Water in Urban Planning. Proceedings of the International UNESCO-IHP Workshop, Wageningen, The Netherlands and Emscher Region, Germany, 29 March-2 April 1993, Backhuys Publishers, Leiden, 1995; and Integrated Water Management in Urban Areas - Searching for New, Realistic Approaches with Respect to the Developing World, Proceedings of the International Symposium held in Lund, Sweden, September 1995, Transtec Publications, 1996. The Proceedings of the Workshop on Integrated Water Resources in Urban and Surrounding Areas held in Gelsenkirchen, Germany, 1994 are being prepared for publication. An attractively illustrated wide-circulation publication, Tropical Cities: Management of their Water, targeted at the concerned but non-specialized audience, such as decision-makers and the well informed layman, was published in 1993.

4. Further implementation

The Fifth Phase of the IHP (1996-2001) has adopted as one of its major themes Theme 7 Integrated Urban Water Management, not only as follow-up to the IHP-IV project referred to above, but as a part of expanded and more intense effort to develop further an integrated approach to urban water management. Three projects are underway:

Project 7.1: Non-structural flood control measures to balance risk-cost-benefit in flood control management in urban areas.

Project 7.2: Surface and groundwater management in the urban environment.

Project 7.3: Integrated urban drainage modelling in different climates: tropical, arid and semi-arid, and cold.

All three projects hold relevance to WCP-Water Project D.4. However, IHP-V projects 7.1 and 7.3 are more directly related.

5. Organizations/bodies involved

UNESCO/IHP with cooperation partners, notably numerous IHP National Committees and the International Research and Training Centre on Urban Drainage (IRTCUD) and its regional sub-centres. Other cooperating partners include, depending on the project, intergovernmental organizations such as WMO, WHO, ACSAD (The Arab Centre for the Studies of Arid and Dry Zones) and NGO's such as IAH, IAHS and IAHR.

6. Tentative time schedule

IHP-V has a detailed plan for 1996-2001, but the actual timetable of specific activities depends on many factors, including the approach adopted by the working groups of the respective projects, support and resources secured and other developments in the national and international scene. Some tasks under way include holding a symposium on Water, the City and Urban Planning (Paris, April 1997) in cooperation with France's Water Academy and the French IHP National Committee, the organization of an International Workshop on Non-structural Flood Control in Urban Areas (Sao Paulo, April 1998), and the preparatory work for an international symposium on integrated urban water management in urban areas to be held in 1999. A proposal for the development of a decision support system for urban flood management has been prepared and funding is being sought. Links are being established with the transdisciplinary coastal Mediterranean cities project launched under UNESCO's Coastal Zones and Small Islands Initiative in order to undertake some joint actions. The IRTCUD sub-centre for tropical climates is functioning in Sao Paulo, Brazil; plans are underway to have the IRTCUD sub-centre for cold climate operating shortly in Oslo with Norwegian support; and the feasibility for an IRTCUD sub-centre for arid zones in the Arab region is being studied.

7. Comments

Liaison with the WMO activities in urban climatology.

Project D.5 Testing the Transferability of Hydrological Simulation Models

1. Background

Remarkable progress has been achieved during the past period in the better understanding of problems related to the use of mathematical models of river basins for investigating changes in the hydrological regime due to climate variations (or changes) and/or other causes, such as land-use changes. Following this, consideration has turned to the usefulness, indeed the necessity, of testing more carefully the transferability of catchment models from gauged to ungauged basins or from given to changed conditions (climate or land-use changes, etc.), which is a prerequisite for the application of these models in studies of the effects of various changes in the physical conditions in a basin on its hydrological regime.

Moreover, it is felt that intensified activities in the development of hydrological models which meet the demands of physical soundness, geographic, climate and land-use transferability are most desirable and could contribute greatly to better solutions of the problems being considered within its activity area.

Long-term activities involving the testing of hydrological simulation models should continue. It is recognized that the testing of model transferability will require considerable research effort and that, even if specific activities would be initiated immediately, it would take some time before results could be obtained which would contribute directly to the objectives of the WCP and the Operational Hydrology Programme of WMO. Because of this, the recommendation for the above project should not be constructed as a recommendation to terminate studies of climate-impact assessment along the lines already pursued.

2. Output

Guidance and practical experience on the transferability of hydrological simulation models.

3. Past activities

(a) Publication by WMO in 1985 of WCP Report No. 98 - Sensitivity of Water Resource Systems to Climate Variability;

(b) Publications by the Danish Hydraulic Institute:

Danish Hydraulic Institute (1993): Validation of Hydrological Models, Phase II.
Refsgaard, J.C. (1993): Model and Data Requirements for Simulation of Runoff and Land Surface Processes in Relation to Global Circulation Models. Presented at the NATO Advance Research Workshop on Global Environmental Change and Land Surface Processes in Hydrology, Tucson, Arizona, 17-21 May 1993.

4. Further implementation

Further studies and testing of various hydrological models, for example under GEWEX. For example, the GHP model and data management strategy is concerned with, inter alia, the transferability between continental-scale experiments of land surface process models incorporated in mesoscale models and coupled or off-line hydrological models, including MOPEX where the parameterization of different models is tested in different basins and experiment areas.

5. Organizations/bodies involved

National studies with international co-ordination by WMO.

6. Tentative time schedule

Continuous.

7. Comments

Liaison with Project D.1.

Project D.6 Impact of CO_2 induced climate change on UK water resources

1. Background

The UK, in common with other countries, may be considerably affected by global warming caused by the increasing concentration of greenhouse gases in the atmosphere. The Institute of Hydrology has therefore developed a climate change impact research programme, with funding from several agencies. Specific objectives of the programme are:

(a) to investigate the sensitivity of different catchment types to changes in climate inputs (rainfall and potential evaporation) and changes in catchment land use following climate change, using physically-based models of river flow generation;

(b) to determine the implication of a number of climate change scenarios for river flow regimes and surface water resources in the UK;

(c) to develop procedures for including information on climate change in water resources planning and assessment.

2. Output

The basic data analysed during the course of the project are simulated daily and monthly flows, produced by applying conceptual rainfall-runoff models to time series of rainfall, temperature and potential evaporation data perturbed according to a number of equilibrium and transient climate change scenarios.

The studies have been published in reports to funding agencies and in the international refereed literature.

3. Past activities

Papers and reports have been published on potential changes in monthly flow regimes in different UK catchments, focusing on the effect of catchment characteristics on controlling the amount and type of change. A report has also been prepared reviewing the implications of climate change for the activities of the National Rivers Authority. Project results have been written up in a paper (Arnell, N.W. and Reynard, N.S. 1996, "The effects of climate change due to global warming on river flows in Great Britain" Journal of Hydrology 183, 397-424) and in a book (Arnell. N.W. 1996, "Global Warming, River Flows and Water Resources" Wiley: Chichester).

4. Further implementation

Project completed.

5. Organizations/bodies involved

Institute of Hydrology, Wallingford, U.K.

Project D.7 Assessment of Impact of Possible Climate Change and/or Sensitivity of Irrigation Systems including Storage of Irrigation Water in Reservoirs

1. Background

Several continents, Asia in particular, depend on irrigated agricultural production for feeding their population. Several preliminary studies were made by individual researchers and FAO on the possible impact of climate change on the availability of water for irrigated food production.

2. Output

An estimation of the degree of decrease of availability of water for irrigation, including the impact on storage reservoirs. Advice to be given to FAO member countries.

3. Past activities

Methodological studies have been undertaken as described under 1. above.

4. Further implementation

Project activity has been discontinued and no report was published.

5. Organizations/bodies involved

The Water Service in the FAO Land and Water Division, subcontractors, FAO Member countries, authorities involved in irrigation.

6. Tentative time schedule

Project discontinued.

Project D.8 Assessment of Climate Change Impact on Population Supporting Capacity of Land, Based on AEZ (Agro-Ecological Zones)

1. Background

FAO has developed a methodology to ascertain the population supporting capacity of land, using as input climatic, soil and crop production characteristics, spatially grouped by AEZ. This methodology has been used with data available in the FAO Geographic Information System (including the FAO-UNESCO soil map) and projections of the food production in the developing countries of the world have been published. Climate change would no doubt alter these projections considerably.

2. Output

Projections of the population supporting capacity of land with different scenarios of a climate changed by the greenhouse effect.

3. Past activities

FAO's AEZ methodology was used in a study to estimate changes in potential population supporting capacities in the Sahel countries due to southward shifts in the length of growing period. The study covers the 1960-1985 period.

Further, the following has been achieved:

(a) Upgrading the Kenya and Bangladesh national AEZ land resources databases, including complete update of the soil layers, climate layers (minimum and maximum temperatures, precipitation, solar radiation), land use, production systems, socio-economic databases, including sets of population projections, organized as multi-layered GIS databases at the scale of 1:1 000 000 for Kenya and 1:125 000 for Bangladesh;

(b) More detailed land resources inventories for three districts in Kenya, based on soil maps at the scale of 1:250 000;

(c) Refining the models of crop suitability assessment to:

- take into account CO_2 enrichment and its effects on the rate of photosynthesis and crop water use efficiency in the biomass calculation model, depending on the crop cycle length;
- better evaluate agroclimatic constraints and quantify soil moisture deficit at various stages of crop growth;
- enable artificial increments in temperature and precipitations under existing and evaluated CO_2 concentrations to test the sensibility of the AEZ models to climatic variations;
- enable inclusion of sustainability considerations in the formulation of the planning scenarios.

(d) Making land productivity runs under various climate change scenarios.

The project produced a technical report "Climate Change and Global Agricultural Potential: A case Study of Kenya", published in 1996 by IIASA.

4. Further implementation

Project completed.

5. Organizations/bodies involved

FAO Land and Water Division in association with UNEP, the Environmental Change Unit of Oxford University, IIASA, the Kenya Agricultural Research Institute and the Bangladesh Agricultural Research Council.

6. Tentative time schedule

Project completed.

Project D.9 Impact of Climate Change on Thermal and Ice Regime of Rivers and Lakes

1. Background

Due to the change of the climatological regime, the thermal and ice regimes of rivers and lakes may change as a consequence of changes in the hydrology regime due to climate change. A proper understanding of changes in the thermal and ice regime is also necessary for studies of water quality and of the impact on the aquatic environment. A study based on certain climate scenarios may help to derive some conclusions as regards the change in the thermal regime.

2. Output

(a) A methodology and generalized procedure for the assessment of changes in the thermal and ice regime of streams and lakes, including reservoirs;

(b) Case studies based on typical scenarios of the impact of climate change on thermal and ice regimes;

(c) Conclusions as to the order of magnitude of potential changes of water temperature, ice formation, duration of icy periods and ice thickness and on the general tendencies in these phenomena.

3. Past activities

Detailed studies of the thermal and ice regimes of major rivers and lakes have been implemented, but no account has been taken of potential climatic change.

4. Further implementation

(a) Compilation of a fact finding report on the status of methodologies available for the impact studies;

(b) Detailed plans for selected case studies to be implemented by methods selected on the basis of (a);

(c) Implementation of case studies;

(d) Workshop based mostly on the case studies;

(e) Final report on the conclusions related to the assessment of changes in thermal and ice regime.

5. Organizations involved

UNESCO and WMO in collaboration with interested national institutions, particularly for (c).

6. Tentative time schedule

Project suspended.

7. Comments

Liaison with Projects C.7 and D.1.

Project D.10 Impact of Climate Change on Suspended Sediment and Water Quality

1. Background

Any change in the hydrological regime may influence suspended sediment concentrations, the temperature of water and its hydrochemical and hydrological indices. A decrease in the minimum flow changes the dilution rate of pollutants and a change in flow velocity may influence sediment concentration. While some efforts have been successful in detecting changes in the water regime, far fewer references can be found to potential changes in sediment and water quality. Global warming may influence the thermal regime of rivers and lakes, which has an impact on aquatic life, including benthos and algae. A study based on certain climate scenarios may contribute to a better understanding of the potential influence on water quality.

2. Output

(a) A methodology and generalized procedure for the assessment of changes in the sediment and water quality regimes of streams and lakes;

(b) Case studies based on typical scenarios of the effect of climatic change on suspended sediment and water quality regimes;

(c) Conclusions as to the order of magnitude of potential changes in major parameters and as to general tendencies.

3. Past activities

Relatively little consideration has been given to these secondary effects of climate change. Some information can be found in the papers of the WMO RA VI Conference on Climate and Water (Helsinki,11-15 September 1989), particularly in the papers by M. Beran and M. Falkenmark. In addition, the IHP-IV project H-1.2 assisted the organization of the Fifth International Symposium on River Sedimentation (IRS), Karlsruhe, 6 to 10 April 1992. Some of the materials contributed to this Symposium could be considered as a contribution to this project. The Proceedings of the symposium were edited by P. Larsen and N. Elsenhauer and published by UNESCO in December 1992. This will be further developed into a UNESCO "Technical Document in Hydrology" in 1994.

The activities implemented in the framework of IHP-IV project H-1.2: "Study of erosion, river bed deformation and sediment transport in river basins as related to natural and man-made changes", included the organization of an international symposium in St. Petersburg (May 1994) and the preparation of a technical report including a representative selection of the papers presented at the symposium along with the contributions of the members of a working group established for project H-1.2.

4. Further implementation

The technical report for project H-1.2 will be published in the IHP series, "Technical Documents in Hydrology".

5. Organizations involved

UNESCO and WMO in collaboration with interested national institutions.

6. Tentative time schedule

1997 technical report.

7. Comments

Liaison with Project C.7.

Project D.11 Sensitivity of Water Resource Systems to Climate Change

1. Background

In many cases alternative management may be an efficient tool for coping with hydrological variability and for ensuring the necessary reliability of meeting various water demands. Because of their cumulative effects on both natural and man-made storage systems, any changes in climate and hydrological variables may be seriously magnified when they are transferred into changes of water demand and supply. Such changes might be reflected in the performance criteria of water-resource systems based on the operation and management of such systems. This project addresses directly the possible impact of climate and hydrological non-stationarity on the design and operation of water resource systems. A strong focus on reservoirs and water storage systems is evident in view of their importance in water resource management.

2. Output

(a) Methodology for evaluating possible consequences of climate change on reliability, resilience and robustness of water storage, delivery and supply;

(b) Methodology for estimating changes in water demand resulting from climate change;

(c) Policy suggestions in the face of uncertainty, linked with the estimation of future climate conditions of water resource system behaviour.

3. Past activity

A number of scientific papers have been published in connection with the possible impact of climatic change and storage systems. However, no systematic and comprehensive review of the problem is available.

4. Further implementation

Project completed.

5. Organization

IIASA's Water Resources project, in cooperation with interested national research institutions.

6. Tentative time schedule

Project completed.

7. Comments

This project has links with D.1.

Project D.12 Overview of methods for assessing the implications of climate change and variability for water resources management

1. Background

One of the most significant impacts of climate change, due to the increased concentration of greenhouse gases, is likely to be on river flows and groundwater, and hence on water resources. These changes may be felt over the next 20 or 30 years, which is well within the planning horizon for major water resources schemes.

There have been many individual studies into possible changes in water resources, and considerable experience is being accumulated in both potential impacts and appropriate methodologies. Little of this information or experience, however, is filtering through to operational water management agencies. There is therefore a need for an international project, coordinated by WMO, to ensure that water managers have access to the best possible data, results and methods. This project will both contribute to the IPCC studies and provide a means by which the recommendations of IPCC are disseminated to water managers.

2. Output

The overall objective of the project is to provide information on climate change and water resources in a form useful to water managers and policy makers. The specific outputs will be:

(a) A summary of methods for estimating the implications of climate change for river flows and groundwater recharge;

(b) A summary of methods for estimating the potential impact of changes in river flows, water quality and groundwater resources on the human and water use systems;

(c) The development of procedures for incorporating information on climate change in water resources planning and assessment;

(d) Illustration of methods and procedures with a number of case studies.

3. Past activities

Not applicable. Despite the importance of the topic the project has not been initiated.

4. Further implementation

There will be three components to the project:

(a) Nationally-funded and bilateral projects, examining specific aspects of climate change and water resources: many such projects are already under way or in preparation;

(b) Frequent workshops (possibly every year) to exchange results and experiences, and coordinate activities;

(c) A working group, established to encourage coordination and to produce a report giving advice to water managers and policy makers on how to allow for the effects of climate change in water resources planning and assessment. The report would be published and distributed through WMO.

5. Organisations/bodies involved

The project would need to be a joint effort between WMO, UNESCO, UNEP and IPCC, with significant input from other international, as well as national, agencies.

6. Tentative time schedule

Not decided.

7. Comments

The project is closely linked with the other projects in Activity Area D, and with Project C.7.

Project D.13 Climate Variation Impacts on Water Balance and Water Quality of Shallow Lakes

1. Background

The water balance and the water quality of shallow lakes are strongly influenced by meteorological factors. The meteorological parameters can effect the water quality of shallow lakes:

(a) directly (global radiation, temperature, wind), or

(b) indirectly (surface runoff, precipitation, evaporation, and other hydrological factors).

Shallow lakes have a high surface/volume ratio and so they are very sensitive to hydrometeorological changes. Moreover, in eutrophic shallow lakes, biological processes are not limited by nutrient deficiency, that is primary production is determined by meteorological parameters. Thus shallow eutrophic lakes are good subjects for the investigation of climatic variations on the hydrological regime and water quality of lakes.

Lake Balaton is a large shallow lake situated in West Hungary. Its surface area is about 600 km^2, catchment area is 6000 km^2 and the average depth of the lake is around 3 m. The western part of the lake is eutrophic and the eastern meso-trophic. Meteorological data have been collected regularly for over 100 years in this region. A long-term (over 70 years) time series of monthly water balance data and a shorter one (over 20 years) of water quality data exist for the lake. Consequently this lake is a good test area for the investigations mentioned below. The aim of the project is to prepare a case study for Lake Balaton by analyzing the effects of climatic variations on the water balance and water quality parameters.

2. Output

(a) Statistical parameters derived from the analysis of observed meteorological, hydrological and water quality data;

(b) Conclusions on correlation of the observed data;

(c) Impact of CO_2 increase on water quality of shallow lakes.

3. Past activities

(a) Data collection for Lake Balaton for the last 72 years (monthly average meteorological, water balance and water quality data);

(b) Selection of the parameters which are included in the analyses;

(c) Establishment of a uniform data base comprising meteorological, hydrological and water quality data for the period 1975-1992. Annual, half-year and monthly data were calculated;

(d) Statistical parameters have been derived from the observed data. The Wilcoxon test was used for the uniformity analysis;

(e) Linear trend analysis including a determination of trend significance;

(f) Attempts have been made to correlate the meteorological, hydrological and water quality parameters. The water quality time series were found to be short (1975-1992) and incomplete. The results for the trend analysis of hydrochemical data were summarized;

(g) Assessment of the data offered interesting information on meteorological and hydrological data. A review of the statistical characteristics of various water quality parameters has revealed regular changes along the longitudinal axis of Lake Balaton (trophity, concentration of organics, conductivity, dissolved salts, chloride, calcium, chlorophyll-a);

(h) Correlation analyses were confined to selected components and significant relationships were obtained. Regretfully, analyses failed to reveal a relationship with a correlation coefficient higher then 0.6. None of the meteorological data could be correlated with the chlorophyll-a data;

(i) A special model, MINEQUAL was used to analyze the effect of the increase of CO_2;

(j) The results on Lake Balaton were intercompared with another Hungarian lake (Velence) and with a reservoir (Csórrét). The study shows no characteristic changes in water quality due to climate change;

(k) A report on "the Effect of Climate Change on Water Quality Parameters" was published in Hungarian.

4. Further implementation

Project completed.

5. Organisation/bodies involved

Water Resources Research Centre (VITUKI) Budapest, Hungary.

6. Tentative time schedule

Project completed. A summary report is available as "VITUKI: Effect of Climate Change on Hydrological and Water Quality Parameters, OTKA 716/90, Budapest, VITUKI Publ. No 59, 1994 (in Hungarian).

ACTIVITY AREA E

IMPACT OF CLIMATE ON SOCIETY THROUGH WATER RESOURCES

The impact of climate on society through water resources can be considered on several levels.

One is a simple statement of the type of impact that a climate change or variation has on the population of a given region, either directly or through the projection of these water-regime changes into other areas of vital societal importance such as food, energy and health. It should be noted that the final impact might be positive or negative, not only as a function of the climate change or variation itself, but also as a consequence of the effect of the change in hydrological characteristics on societal interests. For example, flooding in moderation can be beneficial to some societies and reduced variability in streamflow could be detrimental.

A higher level involves the study of the adaptability of the given population to such impacts. For example, with regard to the impact of droughts and floods, two major hypotheses have been posed. The first states that persistent and adaptative societies, through their technological and social organization, lessen the impacts upon the resident population of frequent climate fluctuations or climate related events. The second hypothesis states that success in insulating a society from relatively frequent events of climate origin, where the society is becoming increasingly complex both socially and technically, will increase the vulnerability of such a society to natural (climate-related) as well as to social perturbations that occur much less frequently.

ACTIVITY AREA F

INFLUENCE OF MAN'S ACTIVITIES ON CLIMATE

There is much interest in both scientific and more general circles as to whether man's activities are influencing or will influence the climate. It is proposed that such an influence might be exerted through changes in the hydrological regime. If such a proposition is to be seriously studied, there is need for an improvement of the representation of the climate forcing functions in the modelling of the hydrological cycle under man's intervention. Results of such studies would help to separate man-made changes in the hydrological cycle from natural variability and would also help to reconstruct non-influenced conditions.

REPORTS PUBLISHED IN THE
WORLD CLIMATE APPLICATIONS PROGRAMME (WCAP)/
WORLD CLIMATE APPLICATIONS AND SERVICES PROGRAMME (WCASP)
SERIES

WCAP - 1 CLIMATE AND HUMAN HEALTH. Proceedings of the Symposium in Leningrad, 22-26 September 1986, Volume I

WCAP - 2 CLIMATE AND HUMAN HEALTH. Proceedings of the Symposium in Leningrad, 22-26 September 1986, Volume II

WCAP - 3 ANALYZING LONG TIME SERIES OF HYDROLOGICAL DATA WITH RESPECT TO CLIMATE VARIABILITY - Project Description *(out of print)*

WCAP - 4 WATER RESOURCES AND CLIMATIC CHANGE: SENSITIVITY OF WATER-RESOURCE SYSTEMS TO CLIMATE CHANGE AND VARIABILITY. Norwich, U.K., November 1987

WCAP - 5 FOURTH PLANNING MEETING ON WORLD CLIMATE PROGRAMME - WATER. Paris, 12-16 September 1988 *(out of print)*

WCAP - 6 CLIMATE APPLICATIONS: ON USER REQUIREMENTS AND NEED FOR DEVELOPMENT [Reports of the CCl rapporteurs on Users' Requirements and Publicity (F. Singleton) and New Approaches in Applications (D.W. Philips) to the tenth session of the Commission for Climatology, Lisbon, April 1989]

WCAP - 7 DROUGHT AND DESERTIFICATION. [Report of the CCl Rapporteur on Drought and Desertification in Warm Climates to the tenth session of the Commission for Climatology (Lisbon, April 1989) (L.J. Ogallo) and lectures presented at the training seminar in Muñoz, Philippines (14-24 November 1988) by N. Gbeckor-Kove] *(out of print)*

WCAP - 8 REPORT OF THE FIRST SESSION OF THE CCl WORKING GROUP ON CLIMATE AND URBAN AREAS INCLUDING BUILDING AND OTHER ASPECTS AND SOME RELATED PAPERS by Professors E. Jauregui and Shen Jianzhu, Members of the Working Group

WCAP - 9 REPORT OF THE EXPERT MEETING ON CLICOM CLIMATE APPLICATIONS (INCLUDING CARS), Geneva, 6-10 November 1989

WCAP - 10 URBAN DESIGN IN DIFFERENT CLIMATES by B. Givoni, University of California, U.S.A.

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WCAP - 14 EXTREMES AND DESIGN VALUES IN CLIMATOLOGY by Tibor Faragó, Hungarian Meteorological Service, Budapest, Hungary and Richard W. Katz, National Center for Atmospheric Research, Boulder, U.S.A.

WCAP - 15 BIBLIOGRAPHY OF URBAN CLIMATE, 1981-1988. Prepared by Prof. T.R. Oke, Atmospheric Science Programme, Department of Geography, University of British Columbia, Vancouver, B.C., Canada

WCAP - 16 REPORT OF THE WORKSHOP ON A CLICOM-HOMS INTERFACE, University of Reading, U.K., 6-15 March 1990)

Note: ***Following the change of the name of the World Climate Applications Programme (WCAP) to World Climate Applications and Services Programme (WCASP) by the Eleventh WMO Congress (May 1991), the subsequent reports in this series will be published as WCASP reports, the numbering being continued from No. 16 (the last "WCAP" report).***

WCASP - 17 A NONPARAMETRIC FRAMEWORK FOR LONG-RANGE STREAMFLOW FORECASTING by J.A. Smith, G.N. Day and M.D. Kane, Hydrologic Research Laboratory, National Weather Service, U.S.A.

WCASP - 18 REPORT OF THE FIRST SESSION OF THE ADVISORY COMMITTEE ON CLIMATE APPLICATIONS AND DATA (ACCAD), Geneva, 19-20 November 1991 (also appears as WCDMP-17) *(out of print)*

WCASP - 19 URBAN CLIMATOLOGY IN AFRICA (Special issue of the journal "African Urban Quarterly"), Yinka R. Adebayo, guest editor, August 1992 *(out of print)*

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WCASP - 28 DROUGHT AND DESERTIFICATION. Reports to the Eleventh session of the Commission for Climatology (Havana, February 1993) by Kerang Li and A. Makarau, CCl Rapporteurs on Drought *(out of print)*

WCASP - 29 SIXTH PLANNING MEETING ON WORLD CLIMATE PROGRAMME - WATER (Wallingford, 1-5 March 1993)

WCASP - 30 REPORT OF THE TECHNICAL CONFERENCE ON TROPICAL URBAN CLIMATES (TeCTUC) (Dhaka, Bangladesh, 28 March - 2 April 1993)

WCASP - 31 REPORT OF THE FIRST SESSION OF THE CCl WORKING GROUP ON OPERATIONAL USE OF CLIMATOLOGICAL KNOWLEDGE (Vacoas, Mauritius, 22-26 November 1994)

WCASP - 32 REPORT FROM THE MEETING OF EXPERTS ON CLIMATE INFORMATION & PREDICTION SERVICES, CLIPS (Melbourne, Australia, 28 to 31 March 1995) *(out of print)*

WCASP - 33 REPORT FROM THE MEETING OF EXPERTS ON CLIMATE, TOURISM AND HUMAN HEALTH (Topes de Collantes, Cuba, 22-29 January 1995)

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CLIMATE INFORMATION FOR THE APPLICATION OF SOLAR ENERGY / INFORMACIÓN CLIMATOLÓGICA PARA EL USO DE LA ENERGÍA SOLAR, prepared by/ preparado por/ Sandra Robles-Gil (Mexico), May 1997

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