

Summary and Highlights of the International Conference on Ecohydrology of High Mountain Areas

24-28 MARCH, 1996, KATHMANDU, NEPAL

The International Conference on Ecohydrology of High Mountain Areas was organised by UNESCO's International Hydrological Programme (IHP) and the Programme on Man and Biosphere (MAB), the Department of Hydrology and Meteorology of His Majesty's Government of Nepal (HMG/N), the International Centre for Integrated Mountain Development (ICIMOD), and the German National Committee for the International Hydrological Programme (IHP) of UNESCO and the Operational Hydrology Programme of WMO in cooperation with the World Meteorological Organization (WMO), from 24 to 28 March, 1996 in Kathmandu. Other co-sponsors of the conference were the National IHP Committee of Nepal, the National IHP Committee of Slovakia, the Steering Committee of the IHP FRIEND Project, the International Association of Hydrological Sciences (IAHS), and the IGBP/BAHC.

The main objectives of this conference were to discuss principal issues concerning the ecohydrology of high mountain areas and to help specify the needs and relevant components for regional studies. The aim of the Conference was to facilitate the exchange of scientific knowledge by bringing together scientists involved in the study of the ecohydrology of high mountain areas with a special emphasis on regional aspects.

The theme of this conference covered broadly all the relevant water-related problems of the most complex high mountain ecosystems and this was expected to encourage contributions from a wide range of specialists. The issues included:

- regional issues on high mountain ecohydrology;
- network design, instrumentation, data collection and processing methodology, and modelling;
- atmospheric, hydrologic, and ecological interactions;
- role of permafrost, glaciers, and snow covers;
- dynamics and hazards of erosion and sedimentation, ecosystems of high mountain areas, and landscape processes; and
- water quality and limnological issues.

Altogether 110 abstracts of papers were received for oral and poster presentations. All of them were published in the pre-conference Extended Abstract Volume and distributed at the time of the conference.

The conference was attended by 125 scientists from all over the World. The list of participants is given in Annex I. Of the 110 abstracts submitted prior to the Conference, 58 papers were presented, followed by oral presentation of 29

posters during the conference. In addition to these, four new posters and abstracts were presented in the conference hall. All the sessions were held in plenary. Brief summaries and highlights of the various sessions follow.

Inaugural Session - 24 March 1996

Mr. Kiran Shankar Yogacharya, Director General, Department of Hydrology and Meteorology and Chairman, Local Organizing Committee (LOC), in his welcome address, noted the growing concerns related to the scarcity of water due to the increasing demand for water and environmental degradation throughout the world. He highlighted the fact that, unless water resources were better managed, they could become a burden on economic growth and a potential danger to human health and environment. He said that there were several questions related to hydrological problems with respect to the natural ecosystems as well as those related to ecological problems caused by human interventions that disturb the natural hydrological cycle and which need to be answered from an ecohydrological perspective. He hoped that the outputs of this conference, participated in by leading scientists and specialists, would help planners and policy-makers to formulate eco-friendly management strategies for properly harnessing and developing water resources.

Prof. Andreas Herrmann, Chairman, International Organizing and Scientific Committee (IOSC), gave a brief background introduction to the conference. He pointed out that the idea for the conference originated at the International Conference on High Mountain Hydrology, held jointly with the meeting of the Steering Committee of the IHP FRIEND Project for Western and Northern Europe in 1994 in Slovakia, and that this conference was a contribution to UNESCO's IHP-IV project H-5-6, Mountain Hydrology. He also pointed out that the interdisciplinary orientation of the ecohydrology of high mountain areas called for the incorporation of part of the topic into the IHP-V project 2.4, i.e., Comprehensive Assessment of Surficial Ecohydrological Processes. He added that the effort to launch a regional FRIEND project, starting with the first meeting of a Regional Working Group in 1989 at ICIMOD in Kathmandu under the auspices of UNESCO's Regional Office in Delhi and supported by ICIMOD, was another background feature to the organization of this conference in Kathmandu. He said that the main objective of the conference was not only to undertake an assessment of water resources but also to extend our knowledge on ecohydrological processes relevant for high mountain areas. He also added that the conference was sponsored by UNESCO's International Hydrological Programme (IHP) and the Man and Biosphere Programme (MAB), WMO, the German IHP/OHP Committee, and the International Association of Hydrological Sciences (IAHS). Professor Hermann expressed his appreciation of the contribution made by the Department of Hydrology and Meteorology, HMG/N, and by ICIMOD in organizing the Conference. He was also appreciative of the cooperation of the distinguished members of the International Organizing and Scientific Committee from 20 countries and four international organizations. He stated that the cooperation of and collaboration with the local organizing

committee was also extremely effective. He thanked Mr. Kiran Shankar Yogacharya, Director General of DHM and Chairman, LOC, Mr. Adarsha Pokhrel, Secretary General, LOC, and Deputy Director General, DHM, and Prof. S.R. Chalise of ICIMOD for their full support and assistance in making the conference successful.

Prof. H. Lang, from ETH Zurich, Switzerland, then delivered the keynote speech. In his speech Professor Lang highlighted the concept of ecohydrology and the implications of high mountain areas in the areal distribution of water resources in the continents (for full text see Section 1). He emphasised that most of the earth's mountain region are extraordinarily rich in water resources and high mountain areas are providing a reliable water supply for a greater proportion of society. He pointed out that, in spite of the significant role of mountains in providing water resources, our scientific knowledge about mountain hydrology is still poor. He further added that extremely difficult terrain and greater spatial variability and complexity are major problems in understanding mountain hydrology. Although the development of hydropower and irrigation schemes in some high mountain areas has promoted hydrological networks and investigations, the information and knowledge on hydrology of mountain regions are incomplete and fragmentary. Again, high energy turnover in generation of atmospheric precipitation and in evaporative processes at the land surface in high mountain areas have consequences not only for hydrological investigation and water resource assessments but also for the accuracy in simulation and modelling of the general circulation of climate globally. He said that a high mountain Global Energy and Water Cycle Experiment (GEWEX) is still not in concrete performance; the Himalayan Experiment (HIMEX) is in discussion and a Mesoscale Alpine Programme (MAP) in the European Alps is in the concrete planning phase. He added that a strong international initiative for investigative research had been set up by the IGBP/ICSU core project 'Biospheric Aspects of the Hydrological Cycle (BAHC)' with its workshop on Climate-Hydrological-Ecosystems interrelation in Mountainous Regions (CHESMO). He further added that the First CHESMO seminar held in 1993 in St. Moritz recommended the need for research activities on i) modelling the interrelations between climate, hydrology, and ecosystem as well as the effect of climate change and other impacts on natural resources on different spatial and temporal scales; ii) development and improvement in measurement techniques for the harsh, extreme conditions in the mountains; iii) use of remote sensing; iv) long-term operation of a few, carefully selected, multidisciplinary experimental research basins; v) assessment of human impact on natural resources; and vi) integrative and multidisciplinary research activities. He pointed out that, in order to reduce the gaps in our knowledge of ecohydrological processes and water resources in high mountain areas, careful design and coordination on a large and small scale will be necessary. Considering the paucity of knowledge on precipitation at high elevations, he suggested an integrated approach for future research. He emphasised that, in combination with the larger-scale projects and with the advanced development of physically-based models, and, last but not least, with a minimum density of monitoring and observation sites, our understanding of the ecohydrology of high mountain areas would continue to progress.

Mr. Egbert Pelinck, Director General, ICIMOD, highlighted the need for a better understanding of ecohydrological processes for sustainable use of water resources in the context of the Hindu Kush-Himalayas. He pointed out four important aspects that needed to be taken stock of for an understanding of ecohydrological processes: (i) the controlling role of nature independently of man in hydrological processes; (ii) the impact of human interference in upstream areas and short-and medium-term water flow conditions in downstream areas; (iii) the medium-and long-term impact of climate change on water availability; and (iv) the sustainable use of water. He added that, as the problems were complex and the search for their solutions was beyond the capacity of individual nations, it was imperative that the basic scientific issues should be addressed in an environment conducive to exchange of information and experiences. He thanked HMG/N, Ministry of Water Resources, UNESCO, WMO, and the German IHP/OHP Committee for their strong professional, institutional, and financial support to the meeting. He also extended a warm welcome to all the distinguished scientists on behalf of ICIMOD and on his own personal behalf.

Mr. L.A. Mandalia, from UNESCO, conveyed greetings from the Director General of UNESCO, Professor Frederico Mayor, and highlighted the important role of high mountain areas in the understanding of complex natural processes. He added that mountain areas are very sensitive to changes in the environment and are good indicators of the changing scenario. He further added that an accurate prediction of global changes in response to increasing greenhouse gas concentration, or major changes in land use, and the elucidation of soil degradation on the regional and local scales would depend on a better understanding of the hydrological cycle and associated biogeochemical cycles in coupled hydrological/atmospheric models. He also pointed out that greater efforts were required to improve prediction capabilities and the interpretation of their regional consequences, especially in the mountain region where the predicted change is maximum. He pointed out that UNESCO's IHP and MAB programmes had tried to address these issues in high mountain areas and several study projects were undertaken that resulted in valuable improvements in scientific knowledge. He emphasised that this conference was further evidence of UNESCO's commitment to the issue of high mountain areas. He said that the UNESCO/WMO/ICSU International Conference on Hydrology, held in 1993, adopted a *PARIS STATEMENT on Hydrology* recommending the necessity of developing field and laboratory hydrological studies as well as experimental water balance studies aimed at improving the understanding of physical and biochemical processes on the landscape. He also added that the Intergovernmental Council of IHP at its 11th session had adopted a resolution to establish a UNESCO International Centre for Ecohydrological Research and Training and had designated the Valdai Experimental Centre of the State Hydrological Institute of the Federal Service of Russia for Hydrometeorological Monitoring.

Prof. Z.W. Kundzewicz, the WMO representative, on behalf of Professor Obasi, Secretary General of the World Meteorological Organization and Mr. Dieter

Kraemer, Director of WMO's Hydrology and Water Resources' Department, thanked the organisers for inviting WMO to co-sponsor the Conference. He said that WMO's mandate embraces promotion of operational hydrology and close linkages between meteorology and hydrology. He added that, although WMO did not deal with issues such as aquatic ecosystems and biodiversity of floodplains, it is aware of the increasing influence of ecological components in many water-related projects and decision-making. He said that WMO was carefully watching the increasing interest of the bio-science community in the data on quantity and quality of water which may or may not sustain the ecosystem. He emphasised that it was indispensable for bio-and eco-scientists to acquire a better understanding of the water-dependent biosphere and for hydrologists to strive towards a more complex comprehension of the water-dependent biosphere. He said that the hydrological and ecological processes in the mountains are poorly understood due to difficulty in access, sparse settlements, the harsh environment, and the need for a special design of heavy duty instruments. He also added that the problems of assessing mountain water resources were related to the boundaries between countries existing in many mountain regions and, sometimes the relations between countries on either side of the mountain frontiers were not very amicable and there was no willingness to cooperate (e.g., to exchange hydrological data). He also stated that, even if relations were good, data from neighbouring countries might be incompatible, as they might have been collected with different instruments and methodologies. He also stressed WMO's opinion that knowledge of the hydrological cycle is an indispensable component of sustainable development and added that, if the hydrological cycle was not monitored with appropriate spatial and temporal coverage, decision-makers and general public may not be informed of the problems until it is too late and the consequences were already severe. He emphasised the point that assessing and understanding mountain water resources on the global scale were imperative for sustainable development and managing fragile and vulnerable mountains ecosystems.

The Chief Guest, **Mr. Prithivi Raj Ligal**, Vice Chairman, National Panning Commission, Nepal, in his inaugural address, highlighted the processes of change in mountain ecosystems. He said that, due to large-scale deforestation and improper use of land, as a result of the increasing pressure of population and development activities, the flow behaviour of water and sediment had been changing and threatening the ecological equilibrium. He also emphasised the need to address these problems and hoped that the conference would contribute to formulating ways and means to solve them.

He also mentioned the call of the International Conference on Water and the Environment: 'Development Issues for the 21st Century', held in Dublin, Ireland, in January 1992, and stated that the Dublin conference had called for new approaches to the assessment, development, and management of fresh water resources and recognised water as an economic good.

Mr. Ligal also added that His Majesty's Government of Nepal attached great importance to the ecohydrology of high mountain areas and was willing to play a

significant role in ensuring environmentally-sound mountain ecosystems by working together with the global community. He also thanked the International and Local Organizing Committee for their untiring efforts in convening this Conference and UNESCO, the German IHP/OHP Committee, WMO, ICIMOD, and other organizations for their support.

Mr. Adarsha P. Pokhrel, Secretary General LOC, and Deputy Director General, Department of Hydrology and Meteorology, concluded the inaugural session with a vote of thanks.

Monday, 25 March: Morning Session

Theme - Regional Issues on High Mountain Ecohydrology

Co-chairpersons: P. Miklanek and B. A. Chandio

Eleven papers were presented on this theme dealing with ecohydrological aspects of the natural environment in different parts of the world. Seven presentations were based on the Hindu Kush-Himalayan region. The other four presentations were on the Peruvian Altiplano, Lake Baikal, Central Asia, and Central Europe. The authors presented the main ecohydrological issues in selected regions of the world.

Overviews of the ecohydrological and hydrological investigations in the Himalayas, and particularly in India (Bahadur), Nepal (Khanal et al.), Pakistan (Shah and Ahmad), and Bangladesh (Hossain) were presented by representatives of individual countries. The importance of areal precipitation distribution, glaciers, and snowmelt processes on river runoff was emphasised. There was an introduction to ecohydrological measures and the need for improvement in water resources' management.

A valuation method of ecohydrological conditions in high mountain areas, as indicated by different types of vegetation, was introduced with the example of the Lake Baikal case study (Khaustov et al.). The method allows the determination of the specific ionic flow from ungauged sites, knowing the area of specific types of vegetation and the total ionic flow from the area.

Other problems discussed during the session were the effects of altitude on ecohydrological processes (Peschke et al.), the effects of global warming on the streamflow of a high altitude river (Singh, P), and the anthropogenic river-runoff variations in mountainous areas of Central Asia (Semyonov). The suitability of geochemical and biological methods for evaluating ecohydrological conditions was also highlighted. The presentations were devoted to the neutron activation study of the natural waters in Tibet (Gu Wei-Zu et al.), study of the isotope composition and origin of water resources at Altiplano (Acosta et al., presented by Silar), and a biological assessment of water quality, effects of water use on aquatic environment, and using biological indices in water quality assessment (Moog et al.).

Results presented from different parts of the world highlighted the important role played by mountainous regions in the hydrological and ecohydrological conditions of much greater areas downstream. Improved monitoring and introduction of ecohydrological measures, as well as better management of resources (water, agriculture, forestry, etc), were considered essential for sustainable development of mountain areas.

Monday, 25 March: Afternoon Session

Theme: Network Design, Instrumentation, Data Collection and Processing, Methodology, Modelling

Co-chairpersons: V.M.Kotlyakov and Gu Wei-Zu

Under this theme, nine papers were presented. All of them dealt with network design, instrumentation, and data collection as well as processing, methodology, and modelling.

B.K. Gyawali (Nepal) presented his paper on the Integrated Pest Management approach as an alternative for safe pesticide use in Nepal. The paper dealt with the problem of pesticide use in Nepal and most of the insecticides used were broad spectrum and caused tremendous damage to human health and environment — including soil microbes and water biota. The target species were insect pests of agricultural crops in agroecosystems, but, in the food chain, other beneficial natural enemies were also victimised.

R.B. Singh (India) dealt with biogeohydrological data and GIS as decision-support systems for natural hazard management in the Himalayan watersheds. The presentation included the identification of key databases (geographical, glacial, hydrological, land use etc). Satellite data for specific purposes were considered necessary for compilation in a multidimensional database to support local projects. The hydrological information system should be considered as multidimensional (spatial, temporal, attribute) and GIS could be used as a decision support system for identifying, integrating, monitoring, and predicting natural hazards. The combination of type and casual processes was the basic condition for the classification of hazard issues and critical zones in a watershed.

S. Susanto (Indonesia) described the a water-yield model for the development of hydrological parameters of ungauged small watersheds in the mountainous terrain of the tropical monsoon region. A five-parameter water-yield model was used to study water yield from eight small watersheds in Central Java and prediction equations were derived for each model parameter. By using these calculated parameters, simulations of runoff in these watersheds were made. This method could be used on watersheds smaller than 3,500 ha. Further details on the proposed model were provided during discussions.

A. Lundberg (Sweden) gave details about modelling aerodynamic resistance during snow conditions while evaporation of intercepted snow takes place. Data were collected during the winters from 1983-1985 from the Highland Region of

Scotland. The transmission from solid to liquid phase was very important when dealing with evaporation of intercepted snow and no existing method could be applied directly. The comparison of intercepted snow evaporation calculated by the water balance method and the combination method using different aerodynamic resistances showed that evaporation of dry intercepted snow, calculated by the combination method, provided a much larger aerodynamic resistance (about 10 times) than when rain aerodynamic resistance was used. During the discussions, further details of the method used were provided.

A.B. Shmakin from Russia (Shmakin et al.) presented a combined parameterisation of orography-induced precipitation and runoff for regional and hydroclimatic studies. A model was developed for regional estimates of heat/water balance components and investigations of the relief influence on to the heat/water exchanges at the land surface. It included procedures of calculation for evaluation of orographic precipitation, soil hydrology, evapotranspiration, runoff formation, redistribution, and so on. The commonly-available data sets of the land-cover parameters and climatic parameters, with a resolution of $1^{\circ} \times 1^{\circ}$ and one month, were used; the authors also created some new data sets (relief dissection, runoff directions, etc.). The model was used for the Ganges- Brahmaputra basin. In spite of rough spatial and temporal resolution, a good general distribution of heat/water balance was obtained; the total runoff from the Ganges-Brahmaputra basin was modelled with an accuracy of three per cent in summer and 70 per cent in winter (the latter with low absolute values) as compared to the measurements.

Z.W. Kundzewicz (WMO) presented an overview of the problems of high mountainous hydrology (Kundzewicz and Kraemer). He said that the observation network in mountain regions should be denser than in other areas. Remote sensing, which offers considerable potential for studying the hydrology of mountainous areas, was emphasised. Creation of a systematic data collection network for measuring precipitation in mountainous areas was considered an urgent requirement.

M. Rahim (Afghanistan) gave a description of the geography of Afghanistan and presented an assessment of the hydrological and hydrometric studies carried out from 1979 to the early 90s.

B. Sevruc (Switzerland), in his presentation, raised the problem of error sources in the assessment of precipitation - altitude relationship. He pointed out that there were two main groups of errors. The first one was the systematic measurement error induced by wind, wetting, evaporation, and snow blowing. The second group of errors arose from the insufficient consideration, in a given network, of both the effects of topography on precipitation distribution, particularly the windward and leeward slopes, and redistribution processes of precipitation by wind over the mountainous ridges. The report dealt with the precipitation altitude relationship in the Swiss Alps. The results showed that the accuracy of precipitation maps in the mountains depends on the correct assessment of precipitation - altitude relationships.

R.C. Johnson from the UK (Johnson and Collins), in his presentation, discussed the development of a methodology for classifying sediments in Himalayan rivers, including the full range of sources and methods of transportation, and providing an essential information source for future projects to quantify the sediment loads of the rivers. He also elaborated on a GIS framework which was being developed on the basis of two of the river basins under study, the Upper Ganges in Northwestern India and the Trisuli in Central Nepal.

The main point of the general discussions was that it was very difficult and nearly impossible to generate an adequate network in mountainous regions for measuring precipitation. That was the reason why methods needed to be developed to calculate precipitation value and the use of remote sensing.

Tuesday, 26 March

Two field trips, one to Nakhu *Khola* and another to Jhikhu *Khola*, were organised. Nineteen participants visited Nakhu *Khola* and 48 participants visited Jhikhu *Khola*. A reception/dinner was hosted by the Director General of ICIMOD at Hotel Yak and Yeti at 1830 hours.

Wednesday, 27 March: Morning Session

Theme: Atmospheric, Hydrological and Ecological Interactions

Co-chairpersons: J. Bahadur and H. Fushimi

Twelve papers were presented in this session by scientists from New Zealand, the UK, Slovakia, Nepal, Russia, Germany, and Switzerland. The topics covered were biodiversity, chemistry and structure in stream (Ormerod et al.) and the hydrochemical characteristics of the head water systems of Nepal (Jenkins et al.); Runoff and water chemistry in the landscape ecology of a Swiss Alpine catchment (Doebeli); stream water and acidification (Collins et al.); diatom communities in Himalayan streams (Juttner et al); estimation of hydrological balance components and estimation of mean evaporation patterns with respect to elevation (Miklanek); transpiration as the main bio-aspect in the hydrological cycle (Molnar et al); water balance parameters with respect to environmental problems in Kathmandu Valley (Upadhaya et al); peculiarities of radiation balance on slopes (Vuglinsky), spatial a variation on the daily evaporation rates of a high Alpine valley (Jong and Erzenzinger); spatial distributed model approaches to hydrologic processes and river flow from mountain regions (Baltensweiler et al), and rainfall - runoff data and modelling for the Likhu *Khola* catchment of Nepal (Boorman et al).

The salient features of the findings of various investigators were as follow.

- Pronounced changes were found in taxon richness, community composition, chemistry and habitat structure, and the functional attributes of the

Nepalese rivers. Variations were observed in the chemistry and biology in different regions, and further work is needed to understand the interactions between the natural and anthropogenic factors influencing these streams.

- The chemistry in mid-high Himalayan mountain streams is well buffered with a pH range of 7.0 to 8.5. A number of sites, within the pH 5.5-6.5 range, may be sensitive to acidification. Close links were reported between the stream invertebrates and chemistry. Land-use changes could have biological consequences and needed further investigation.
- The glacio-nival regime of the Swiss Lammerew-Dala (6km²) basin and lake at an elevation of 2,350masl elevation showed an average suspended sediment concentration of 0.78, 0.51, and 0.07g/l per day under snowmelt, fair weather with rain by night, and fair weather without rain, respectively.
- Investigations under the land use, soil conservation, and water resources' projects of the UK demonstrated a constant pH throughout the year in the stream water from a relatively pristine forested catchment in contrast to agricultural catchments. Both forested and cultivated catchments in the middle hills of Nepal were susceptible to episodic acidification.
- Diatoms (Siliceous algae) were useful ecological indicators for hill streams. Significant variations were observed in the percentage of the total species recorded between different habitats at each site for investigations on biodiversity.
- The calculated value of monthly totals of potential evapotranspiration from 10 sites for 25 years, ranging in the elevation from 115 to 2635 masl, were compared with those modelled demonstrating usefulness of model equations.
- Direct measurements of evapotranspiration carried out at experimental and research stations were presented from Slovakia.
- Water balance parameters with respect to environmental problems (land subsidence, reduction in dry weather flow and fall in water quality) for Kathmandu Valley were examined and discussed with emphasis on the role of groundwater resources.
- The radiation balance changes on slopes depending on steepness and exposure. Errors in the normal annual evaporation from mountain basins (without taking into account the above factors) attain +37 per cent on northern slopes (steepness 20°) and - 11 per cent for the basin on the southern slopes (steepness 25°).
- The spatial variation of daily evaporation rates from 12 sites in a high Alpine Valley in the Eastern Swiss Alps (elevation range 1600-2800m), with varying agroclimatic conditions and aspects and gradients, was estimated. A Digital Terrain Model (DTM), with a grid mesh of 25x25m and 10x10m, was used to calculate the daily potential radiation using GIS and satellite images. The highest evaporation rates were found on the Valley floor in the windiest regions. Detailed geomorphological maps formed the basis of the parameterisation of hydrological responses.
- Sub-basins (size ranging from three to 1,703sq.km.) from the northeastern part of the Swiss Rhine basin (elevation range 400m to 2,500masl) were selected for spatially distributed modelling. The structure of the model

component for snow accumulation and melt, interception, soil water, storage and uptake, evapotranspiration, runoff generation, and flow routing including various time-dependent parameters was described.

- Analyses of rainfall and runoff data from five catchments of the Likhu *Khola* in the middle hills of Nepal showed substantial losses of water from catchments and some of the lost water is stored in the catchment on the flooded terraces and return slowly to the river channel.

Wednesday, 27 March: Morning Poster Session

Theme: Atmospheric, Hydrological, and Ecological Interactions

Co-chairpersons: H. Heuberger and I. Seversky

Oral presentation of thirteen posters took place during this session.

Wednesday, 27 March: Afternoon Paper Session

Theme: Atmospheric, Hydrological, and Ecological Interactions

Co-chairpersons: H. Lang and M.M. Hossain

A total of eleven papers was presented during this session. The topics ranged from the principles of hydrological regionalisation (Joanna) to distribution of snow cover (Seversky, and Grabs et al.), the contribution of snow- and glacier melt runoff modelling (Hottelet et al., Buchtele et al., Parida and Ujihashi), the recent changes in glacial phenomena (Kotlyakov et al. and Fushimi), hydrological analysis of agrarian watersheds (Rai), and the hazards of erosion and water resources (Malik et al.).

In the evening, the participants attended a cultural programme in Bhaktapur which was hosted by the LOC.

Thursday, 28 March: Morning Session

Theme: Dynamics and Hazards of Erosion and Sedimentation, Ecosystem of High Mountain Areas, Landscape Processes.

Co-chairperson: Z. W. Kundzewicz and R. Kattelmann

Nine papers were presented on a variety of topics as diverse as the title of the session would allow. Schreier and colleagues presented a paper which described nutrient transport in relation to water and sediment movement in the Middle Hills of Nepal. A geotechnical analysis of cliff stability in Bangladesh was presented by Rahman. Leber and Haeusler described recent trends in the climate of Southern Tibet. The Langtang *Khola* catchment of Central Nepal was described in terms of glacial geomorphology by Heuberger and Ibetsberger and soil development by Baeumler and Zech. Erosion hazards in different parts of India were discussed in the papers presented by Singh (Chamoli District, U.P.) and Anbalagan (Kumaun Himalayas). A natural hazard presented by an immense glacial lake in the Rowaling Valley of Nepal was described by Yamada and

colleagues. Becker closed the session with a discussion of the urgent need for integrated studies of biophysical processes in mountain areas on the catchment scale, in addition to plot and slope scales.

Thursday, 28 March: Morning: Poster Session

Theme: Dynamics and Hazards of Erosion and Sedimentation, Ecosystem of High Mountain Areas, Landscape Processes.

Co-chairperson: A. Becker and R. B. Singh

Six posters were orally presented during this session (Mahamood, Joshi and Negi, Panday and Singh, Dongol and Lacoul, Kattelmann and Watanabe, and Bhusal). In addition to these, four posters were presented in the hall (Sharma, Alwis, Baast, and Fundinger et al.).

Thursday, 28 March: Afternoon: Paper Session

Theme: Dynamics and Hazards of Erosion and Sedimentation, Ecosystem of High Mountain Areas, Landscape Processes.

Co-chairperson: A. Becker and R. B. Singh

Six papers were presented during this session. The various issues related to modelling land-atmospheric interactions were discussed by Avisar. Sediment transport in glacier-fed rivers in the Karakoram was discussed by D. Collins. An introduction to Hydrological Aspects of the Sierra Nevada Ecosystems' Project was presented by Kattelmann. Schulze described the techniques for mapping hydrological and ecological interactions. The water resources and ecohydrology of the Himalayas were discussed by Sahu. Bahadur (Mendiratta et al.) discussed the use of GCM (T80) for medium-range prediction of winter precipitation.

On the basis of session deliberations, the following points emerged.

1. A synthesis of hydrological aspects, landscape, and ecology is essential for understanding the dynamics and hazards of erosion and sedimentation.
2. It is necessary to monitor meteorological attributes in order to understand the sedimentation processes.
3. The study of hydrological-aerodynamics' interaction requires various simulation exercises. In the Himalayas, GCM is doing reasonably well, but for the meso-level, variability does not respond to GCM properly.
4. In the Himalayan-Karakoram Region, glacier-fed rivers contribute significantly to sediment transport. The roles of headwater and high mountain areas are vital.
5. Mixed forest/meadow plantations form an important aspect of ecosystem regeneration.
6. Meso-level mapping is an integral part of hydrometeorological mapping. This should include various hydrological and meteorological indicators — including minimum and maximum temperature, landslides, mean annual

rainfall and streamflow, water resources utilised, altitude, aspects, slope, radiation sky conditions, influence on topographic shading, cloud conditions in different seasons, human dimensions, and so on.

7. Agroclimatic zonation mapping can be taken as a criterion for monitoring in Himalayan countries. Regional cooperation is needed for an improved understanding of natural processes. Improvements should be made in expanding the hydrometeorological network in mountainous areas.

Thursday, 28 March: Concluding Session

Chairperson: Kiran Shankar Yogacharya

After four days of paper presentations on various themes related to ecohydrology, the International Conference on Ecohydrology of High Mountain Areas concluded on the 28 March, 1996. Mr. Kiran Shankar Yogacharya, Chairman of LOC, chaired the concluding session. Dr. A. Herrmann gave a technical summary of the proceedings of the conference.

On behalf of the International Organizing and Scientific Committee, **Dr. Herrmann** thanked the participants -- scientists, professors, and technocrats -- for their overwhelming response to the announcement of the conference. However, only a limited number of proposals could be realised. He stated that one glance at the list of participating countries -- 23 including UNESCO and WMO -- showed that an equal number of countries from the HKH region and Europe made presentations. He noted the good representation from Nepal, India, and Germany and regretted the absence of representatives from the Andes, although abstracts were submitted. In the selection of topics over the four days, he said that the theme of ecohydrology was well represented. The field visits gave a good idea of the amount of work being carried out in hydrology in Nepal. Also, all the sessions were very informative in terms of the extent of research being carried out.

He said that all the papers would be published, including the posters. The proceedings would be published under the aegis of UNESCO. Furthermore, on behalf of the scientific community, he thanked the organisers for the wonderful place and venue and also for the technical contribution. He also extended his thanks for the cultural programme at Bhaktapur and all the heritage sites around.

Dr. R.B. Singh, India, expressed gratitude for the opportunity to participate in the conference on behalf of the South Asian participants. According to him, this was the first real interdisciplinary seminar dealing with different types and ranges of issues from the national, sub-regional, and regional levels. He noted that the seminar also brought to the forefront the role of water management in peaceful coexistence within the region. He also felt the posters were of a high standard. He thanked the organisers and hoped to attend another such conference soon, as he considered such interaction essential for improved understanding of ecohydrology.

Next, **Dr. Carmen de Jong**, on behalf of all participants, expressed gratitude for being invited to present papers. She noted that the wide range of topics on and problems of ecohydrology presented from different countries was very informative.

She opined, however, that they were only beginning to touch upon solutions. She also emphasised the fact that, in addition to the climatic changes, the end uses of resources also needed to be tackled. She hoped that everyone would return to their countries with fresh ideas on and renewed vigour for working in the field of ecohydrology. She thanked all concerned for the opportunity and also presented a guide book, which could be used for training, to Prof Chalise, hoping that next time the topics would be more specific.

Mr. A.P. Pokhrel, DDG DHM and Secretary General of LOC, thanked all the participants for their active participation.

Thereafter, the Kathmandu Declaration on Ecohydrology was proposed and after a short discussion passed with 10 recommendations. The full text of the Kathmandu Declaration is given below (from Annex 3)

In his concluding address, **Mr. K.S. Yogacharya** said that efforts had been made to accommodate as many participants as possible. He expressed satisfaction that the conference covered all the five themes and said that research problems discussed there could be applied to other areas facing similar problems. Thanking all the chairs and distinguished delegates for successfully conducting the technical sessions, he said that the organizers had stretched their limited resources to provide the correct working atmosphere for all the participants. He extended special thanks to Dr. A. Herrmann for his ceaseless energy in making the conference a success and to Mr. Egbert Pelinck, Director General, ICIMOD, for his excellent support.

He concluded by saying that the conference had also focussed on the HKH-related aspects of ecohydrology and he hoped that it would facilitate data sharing and interdisciplinary analysis.

The Kathmandu Declaration

Mountain regions, in general, and the Hindu Kush-Himalayas (HKH), in particular, are areas of great physical and cultural diversity where rapid environmental changes are often coupled with severe socioeconomic consequences. The heterogeneity of the mountain region provides us with a rich opportunity for comparing patterns and processes ranging from those in the high mountains to those in the flat alluvial plains.

The United Nations Conference on Environment and Development (UNCED) decided to include in Agenda 21 a Chapter 13 on 'Managing Fragile Ecosystems: Sustainable Mountain Development' with the following two programme areas:

- a) generating and strengthening knowledge about the ecology and sustainable development of mountain ecosystems and
- b) promoting integrated watershed development and alternative livelihood opportunities.

The International Conference on Ecohydrology of High Mountain Areas, held in March 1996 in Kathmandu, Nepal, is considered to be a contribution towards fulfilling this agenda. It has been an important international joint initiative of UNESCO, ICIMOD, the German IHP/OHP, WMO, and DHM for understanding, monitoring, and managing issues related to high mountain areas. The Conference attracted substantial attention from the scientific community and decision-makers at global level, in general, and from the South Asian Region in particular. The papers presented covered wide ranging scientific investigations and empirical studies from different mountainous areas of the world. The scientists highlighted regional issues in ecohydrology such as data collection and information systems; atmospheric, hydrologic, and ecological interactions; and water-induced hazards of erosion, sedimentation, and landscape processes. The following recommendations emerged during deliberations.

1. It is necessary to promote cooperation at both regional and global levels by making a state-of-the-art inventory of existing knowledge, information, and data and making it accessible to researchers willing to undertake scientific investigations and studies.
2. It has been realised that ecohydrology is a science integrating various aspects of the hydrosphere with the atmosphere, geosphere, biosphere, and various anthropogenic activities.
3. It has been recognised that various studies on mountain areas are being carried out in isolation and these need to be synthesised in order to understand the hydrological Mountain Experiment on the lines of Apex and ecological processes on macro-, meso- and micro-scales.
4. It is recommended that collaborative studies of the hydrological and ecological processes be undertaken along meteorological altitudinal gradients, taking into account the areal distribution of their parameters in mountainous catchments.
5. It is necessary to establish regional monitoring systems, including remote sensing, for short- and long-term studies to improve our understanding of ecohydrological processes.
6. Efforts need to be made for integrated and user-oriented research and action programmes for mountain watersheds, taking into account the sustainable livelihood of mountain communities. Concerned countries and institutions are urged to prioritise these activities and allocate adequate funds.
7. It is highly recommended that the ecohydrology of high mountain areas is incorporated into the IHP-V UNESCO programme.
8. It is necessary to encourage and continue the exchange of scientific knowledge through international conferences and workshops.
9. It is proposed that the next International Conference on Hydrological Processes in Mountainous Catchments Affected by Man and Climate Change be held in 1998/1999 in Switzerland (subject to formal invitation from the host country).
10. It is proposed that linkages be established with the recently launched HKH FRIEND project for promotion of regional data collection, monitoring, and analysis.