Chapter 2

Water Resource Management in the HKH: An Overview

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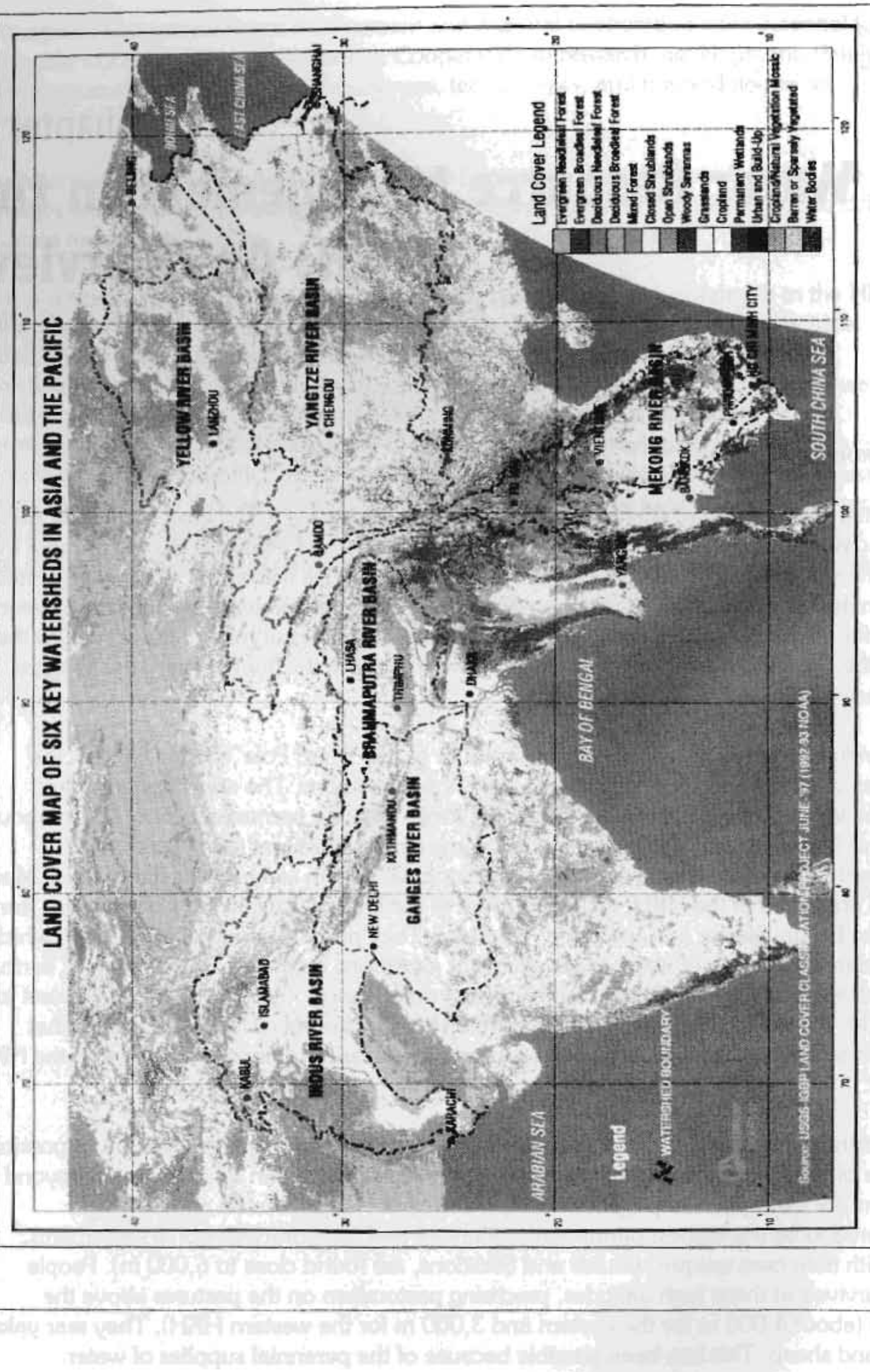
Background

Extending 3,500 km from Afghanistan in the west to Myanmar in the east, the Hindu Kush-Himalayas (HKH) are home to nearly 150 million people and influence the life of more than three times as many in the downstream basins and plains. As the largest storehouse of fresh water in the lower latitudes, these mountains and the Tibetan plateau are important water towers for nearly 500 million people.They are also the sources of mighty rivers such as the Indus, the Ganges, the Yarlung-Tsangpo, the Brahmaputra, the Nu-Salween, the Yangtze, the Yellow River, and the Mekong (Map 1).

The Hindu Kush-Himalayas are often referred to as the 'Third Pole' as they contain the largest mass of ice and snow outside the earth's polar regions. The areas under ice and snow are located at the highest elevations on earth, with the permanent snow line at about 5,000 m. The mountain peaks of the HKH reach almost 9,000 m; the highest Mt. Sagarmatha (Everest), also known as Chomolongma, has an elevation of 8,848 masl. Many glaciers are found in the HKH, including some of the longest outside the polar regions (for example, Batura glacier in Karakoram, Pakistan). They provide a unique situation in which vast, perennial sources of water are available at elevations higher than elsewhere on earth. The hydropower potential of the rivers and streams is enormous and one of the greatest in the world. Altitudes change very rapidly within short horizontal distances: a feature that provides advantages as well as posing problems for water resource management in the HKH (Fig. 1).

The fact that water can be found at such great heights has made human habitation possible at some of the highest elevations on earth.Human settlements can be found even beyond 4,000 m (for example, Khopagaon in Dolpa district of Nepal, located at 4,300 m, is considered to be the highest permanent settlement and temporary/seasonal settlements, each with their own unique cultures and traditions, are found close to 6,000 m). People have survived at these high altitudes, practising pastoralism on the pastures above the treeline (about 4,000 m for the eastern and 3,000 m for the western HKH). They rear yaks, goats, and sheep. This has been possible because of the perennial supplies of water.



Map 1: Major River Basins in the HKH
(Source: Myint and Hofer 1998)

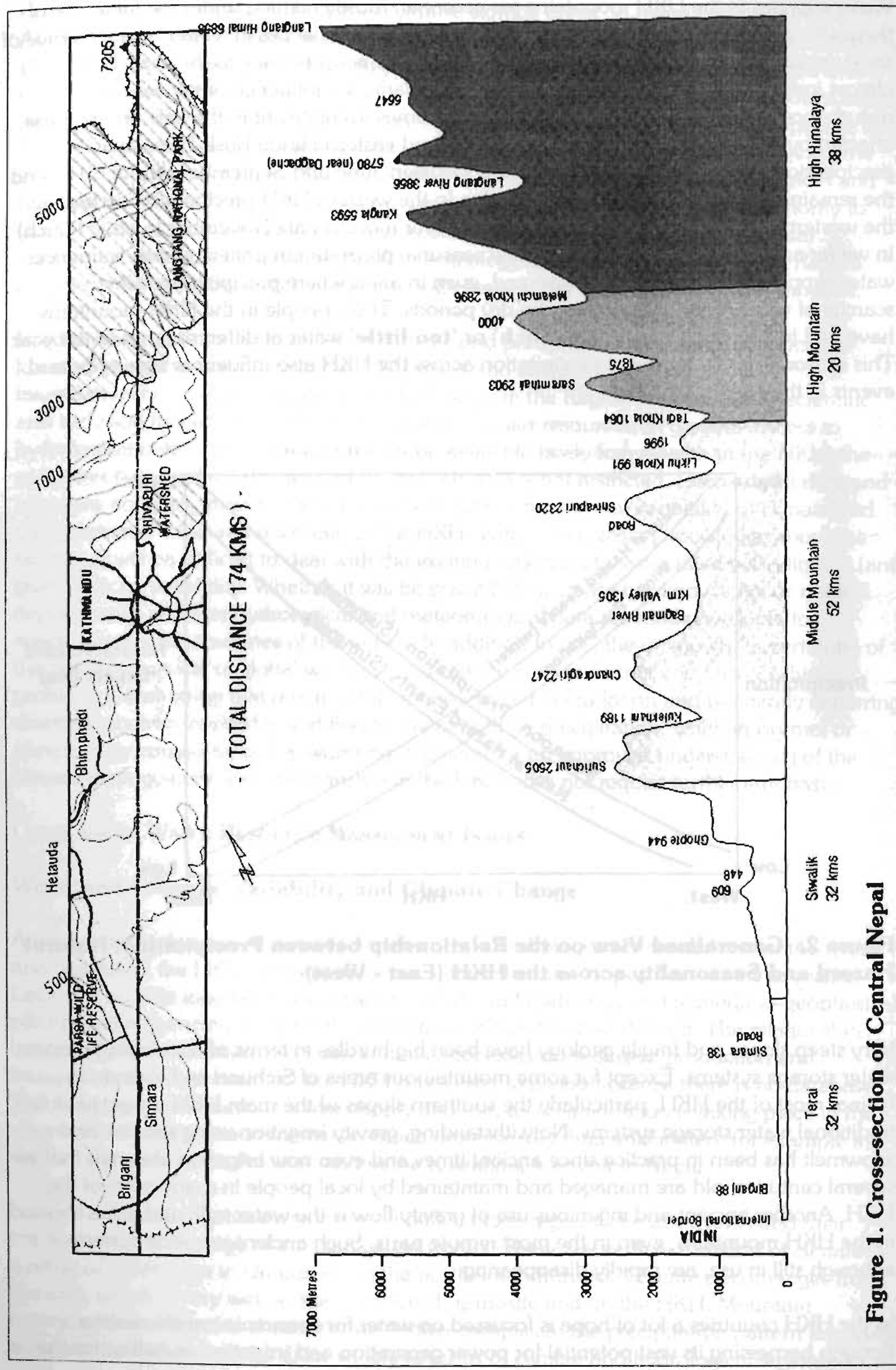


Figure 1. Cross-section of Central Nepal

Water supplies in the HKH mountains are seasonal, mostly coming under the influence of the south-west monsoon in summer and the western disturbances in winter. The influence of the summer monsoon is strong in the east and diminishes gradually to the west, being almost insignificant in the Karakoram region. Similarly, the influence of the western disturbances is predominant in the west and becomes insignificant in the east. In the areas affected by the monsoon, mostly in the central and eastern Hindu Kush-Himalayas, precipitation is confined to the four months between June and September (about 80%) and the remaining months are comparatively dry. In the western HKH precipitation caused by the western disturbances occurs mostly during four months (late November to early March) in winter and early spring. Such a marked seasonal precipitation pattern greatly influences water supplies from season to season and, even in areas where precipitation is intense, scarcity of water is common during the dry periods. Thus, people in the HKH mountains have had to cope with either **'too much'** or **'too little'** water at different times of the year. This seasonal characteristic of precipitation across the HKH also influences natural hazard events in the region (Fig. 2).

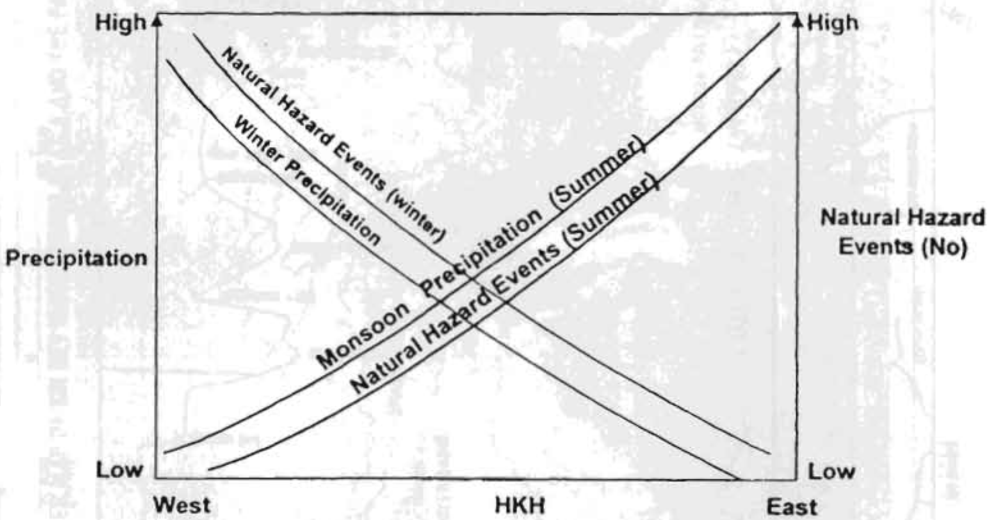


Figure 2: Generalised View on the Relationship between Precipitation, Natural Hazard and Seasonality across the HKH (East - West)

Very steep slopes and fragile geology have been big hurdles in terms of developing proper water storage systems. Except for some mountainous areas of Sichuan and Yunnan in China, most of the HKH, particularly the southern slopes of the main HKH range, have few traditional water storage systems. Notwithstanding, gravity irrigation using streams and snowmelt has been in practice since ancient times and even now irrigation channels that are several centuries' old are managed and maintained by local people in many parts of the HKH. Another ancient and ingenious use of gravity flow is the water mill, and these abound in the HKH mountains, even in the most remote parts. Such ancient irrigation systems, although still in use, are rapidly disappearing.

In the HKH countries a lot of hope is focussed on water for economic transformation through harnessing its vast potential for power generation and irrigation as well as for the control of floods by constructing multipurpose storage dams on mega and small scales. **According to the estimates available, the total theoretical power potential of the HKH countries (not including Afghanistan) is nearly 429,000 MW** (details and country breakdowns are given in Annex I of this paper). This is a substantial amount and naturally raises high hopes in the Region. Although mega projects for power, irrigation, and flood control were preferred in the past and are still priorities in many countries (e.g., the Three Gorges' project on the Yangtze River in China, Pancheswar/ Mahakali in India and Nepal, and Tehri in India), there is a growing and active campaign to shift the priority to 'small' projects. This campaign has arison out of concern about the environmental consequences of 'mega' projects, the fragile geology and active seismicity of the Region, and the costs of big projects that are normally beyond the means of the HKH countries.

In addition, the extreme variability of climatic and precipitation patterns, the paucity of knowledge on the hydrology of the HKH rivers and streams, and the complex interrelationships between ecology and hydrology in the Region impose serious scientific and technical limitations on the development of water resources. In general, access to hydrological data is restricted and not made available freely for research in the HKH; the exception being in Nepal where access to such data is not restricted. Even spatial data and maps are not easily available for researchers. Again, the normal variability of climate and precipitation is wide and uncertain in the HKH. Without increasing knowledge about the climate, it will be difficult to deal with the exciting 'uncertainty' associated with climatic (and precipitation) variability. Whether it will be possible to increase our knowledge or not will depend upon whether hydrological and meteorological data are made available to researchers by the countries of the region. In addition to this, the unknown 'uncertainty' of the possible impacts of global warming and climate change further complicates this problem. Considering that much of the environmental degradation and frequently occurring disasters, such as landslides and floods, are caused by precipitation, whether normal or abnormal or caused by global warming, the need for an improved understanding of the climate-ecology-hydrology relationship in the HKH does not require further emphasis.

Overview of Water Resource Management Issues

Water and Climatic Variability and Climate Change

A proper understanding of climatic variability and hydrological characteristics of the rivers and glaciers of the HKH is essential for translating the high 'hopes' for water into reality. Lack of a reliable long-term database on climate and hydrology and related bio-geophysical parameters influencing them for the mountains makes this task difficult. The relationship between human activities and hydroclimatic processes on sediment production and transport in the river basins of the HKH is not easy to assess because there is no database. This increases uncertainty in water supply and use, as sedimentation is taking place in the reservoirs of large dams in the region much more rapidly than anticipated; for example in the Tarbela reservoir in Pakistan and in the Kulekhani reservoir in Nepal.

Lack of a reliable database also makes it difficult to categorise climatic events and their impact on the hydrology of the Himalayan waters. There is a vertical zonation of climate as a result of differences in altitude along the north-south transect. Climate also changes from the east, which is very wet, to the west, which is mostly arid, in the HKH. Mountain topography and the rain-shadow effect further complicate the precipitation pattern and even adjacent watersheds can be differ widely in terms of climate and hydrological regimes. In addition to such diversity in climates caused by physical factors, there is also an inter-annual variability in precipitation and weather events. Hence, one can never ascertain whether any extreme weather event is a manifestation of normal climatic fluctuations or whether it is caused by abnormal conditions such as global warming and climate change.

The region has suffered major climate-induced disasters in recent years. Consecutive catastrophic monsoon floods occurred in Bangladesh during 1987 and 1988; there were floods in the Indus Basin in September 1992; a disaster was caused by floods and debris flows in south-central Nepal in July 1993; and there were floods along the Yangtze in 1995 and 1999. Relating these events to the impacts of climate change in any given pattern is difficult. It has been claimed that the Pakistan flood was caused by the changing strength and timing of summer monsoon incursions into the Trans-Himalayan region of the Karakoram. This was earlier considered to be an event that occurred every fifty years, although now it has been found to occur more frequently.

Systematic studies are yet to be carried out on seasonal snow cover in the HKH. However, snow and glacier studies have received a lot of attention in many countries of the region. Most of the studies indicate that glaciers are retreating. A serious implication of glacier retreat is the possible increase in Glacial Lake Outburst Flood (GLOF) events in the region. Mayewski and Jeschke (1979) have made local and regional syntheses of 112 records of such fluctuations in the HKH. Their study shows that the glaciers in this region have been in a general state of retreat since AD 1850. Reports of glacial retreat and accelerated ablation have also been given in Nepal. On the other hand, in the Karakoram and Kunlun mountains, both advancing and retreating glaciers have been reported.

It is difficult to determine the significance of these fluctuations in terms of global warming, although they indicate some kind of change in climatic pattern, and this has implications for managing and developing water resources in the region. Although a proper assessment of the potential impacts of global warming and climate change in the HKH region has yet to be made, it can be inferred from the Intergovernmental Panel on Climate Change (IPCC) Impact Assessment (Houghton *et al.* 1990) that, as a consequence of climate change, the HKH region will, in general, witness increased monsoon rainfall, increased precipitation, and shrinking of areas under snow and ice and permafrost (Chalise 1994). Obviously such events induced by climate change would have serious implications for food production; power generation; water supplies, particularly during the lean (dry) period; and on the frequency of natural hazards (floods and landslides) in the HKH.

Transboundary Nature of Major River Systems and Problems in Information/Data Exchange

Apart from the Yangtze, and the Yellow rivers, most of the major rivers of the HKH (the Indus, the Ganges, the Yarlung-Tsampo-Brahmaputra, the Nu-Salween, and the Mekong) originate in one country and traverse through other (one or more) countries before reaching the ocean. The catchment areas of these rivers, therefore, extend beyond the boundaries of one nation. Despite these realities dictated by nature, countries in the HKH do not share hydrological data as a rule. In many countries of the HKH, hydrological data and even spatial information and maps are classified and not available even for their own national researchers. There are, luckily, a few exceptions. There is an agreement between India and Pakistan on the Indus (its tributaries), data are exchanged between China and Bangladesh on the Brahmaputra, and hydrological data are openly available in Nepal. By not sharing hydrological data, the growth of knowledge on the hydrology of the region has been adversely affected and consequently the pace of development of water resources in the region. Sharing hydrological, climatological, and spatial data is a prerequisite for optimum use and management of regional waters in order to provide full benefits to the people from this rich resource. Some regional initiatives have been taken in this respect through the recently launched Hindu Kush-Himalayan Flow Regimes from International and Experimental and Network Data (HKH-FRIEND) project. HKH-FRIEND is a part of the global FRIEND project of UNESCO's International Hydrological Programme (ICIMOD/UNESCO-IHP 1999 a and b). The costs of the 'lost opportunities' in hydropower generation, in irrigation development, and in flood control are enormous, at both national and regional levels.

Regional Cooperation in Sustainable Development and Management of Water Resources

Regional cooperation in the development and management of water will help to realise full benefits from various water resource development projects at both national and regional levels. Except for India and China in a few cases, for most of the countries of the HKH, realisation of full benefits from their resources will entail cooperating and sharing with neighbours. This is particularly true for **'headwater countries'** like Afghanistan, Bhutan, and Nepal. Similarly, **'downstream countries'** like Bangladesh, India, and Pakistan, are dependent on their upstream neighbours for developing effective flood control and irrigation systems as well as for augmenting water supplies during lean periods. For the HKH countries, regional cooperation for optimum development and use of water resources is an imperative dictated by the geography of the region. Such cooperation alone can ensure that 'lost opportunities' are transformed into real benefits.

Ecohydrology of the Region and Water-induced Disasters

Because they are the most recently formed mountains on earth, the Hindu Kush- Himalayan ranges are tectonically active and hence inherently vulnerable to hazards. They are also exposed annually to intense, seasonal precipitation during the four months (June - September) of summer monsoon, particularly in the eastern areas. This acts as a trigger for natural hazards at different elevationss. If snow avalanches and glacial lake outburst floods predominate at very high elevations (>3,500 m), then landslides, debris flows, and flash floods are common in the middle mountains (500-3,500 m). Floods are the principal hazards in the lower valleys and plains. During extreme weather events, the consequences are disastrous. Hundreds of lives and billions of dollars' worth of property and investments in infrastructure are lost in the region every year. Landslides, debris flows, and floods also destroy scarce agricultural lands. In China, for example, landslides alone are estimated to cost US$ 15 billion and cause 150 deaths annually (Li Tianchi 1996), and in Nepal landslides and floods destroy important infrastructure worth US$ 2.5 million and about 400 deaths annually (Khanal 1996).

Despite climate and hydrology being the principal causes of and contributing factors to natural hazards in the HKH, they have received insufficient attention. Management of hazards and disasters in the HKH will not be possible without effective management of water (ICIMOD 1997), and this too has received insufficient attention.

Much of the discussion about environmental degradation in the HKH which started in the mid -70s focussed primarily on ecological concerns, particularly on deforestation caused by rapidly growing human and animal populations and the impacts on local and regional ecology and economics, particularly erosion and sedimentation. Since then, most research work, whether field-based or based on available data, has focussed on in quantifying the relative roles, impacts, and contributions of human and natural processes in causing environmental degradation in the region. However, the impact of climatic processes, particularly intense rainfall events of short duration, on the ecology and on environmental degradation has not received sufficient attention. A recent study demonstrates that human processes are more important for micro-basins, whereas natural processes predominate in macro-basins. It has also demonstrated that without a better understanding of the processes occurring on the meso-scale and the linkages between these processes on different scales, it will not be possible to ascertain the actual roles of human beings and Nature (Myint and Hofer 1998).

Pollution of water bodies, both surface and groundwater, is another problem that is growing rapidly, not only in urban areas (where it is mainly due to mismanagement of sewage and domestic and industrial wastes) but also in rural areas (where it is mainly due to indiscriminate and uncontrolled use of pesticides and chemical fertilizers) of the HKH. Although comprehensive studies are yet to be carried out, data from selected areas of the HKH show that deterioration in water quality is quite alarming, particularly in small rivers, streams, and shallow groundwater. This has serious implications for poor and marginalised people in both urban and rural areas, because they are dependent for water supplies on openly accessible water bodies such as rivers, streams, and shallow wells and springs.

Water for Mountain Households

The population of the HKH Region, which extends over an area of 3.4 million square kilometres across eight countries, from Afghanistan to Myanmar, is growing rapidly and with it the demand for water. The current population of nearly 150 million is expected to double within the next thirty-five years and hence the demand for water will increase tremendously within the next few decades, particularly because the pace of development is accelerating in all the countries of the region. Changes in life style, with greater consumption of water at individual household level alone, will create huge demands for fresh water in the region. Similarly, food production through increased use of high-yielding varieties of crops will mean additional and dependable supplies of water for irrigation; water supplies will have to be much greater than they are at present.

Recently the use of pumps (electric, or diesel) and PVC pipes for water supplies has increased in the rural mountains. Although this has reduced the drudgery of fetching water from long distances for women and children in some areas, most rural mountain communities are still left to their old methods of procuring water for domestic and agricultural needs. There are practically no data and information on water quality at local sources. It is an important challenge to combine modern methods and techniques with indigenous knowledge and traditional institutions for local water management: and such institutions are unfortunately disappearing (Agarwal and Narain 1997)

Human Capacity and Status of Research

Research skills and the state of research on water resource development and hydrology vary a great deal in the HKH countries.

So far, there is no institution established by the regional countries for research and training in water resource development. There are, nevertheless, institutions (particularly in India and China) that have been either sponsored by UNESCO or run by UNESCO-sponsored programmes for regional training and research on water resource development, hydrology, and related fields. The Water Resources' Development Training Centre in Roorkee, India, and the International Centre for Research and Training in Erosion and Sedimentation in Beijing, China, are among such institutions. A South Asian Association for Regional Cooperation (SAARC) Meteorological Research Centre, now located in Dhaka, Bangladesh, has begun functioning recently.

Sustainable development of water resources to the fullest extent possible depends not only on knowledge of engineering but also on an adequate understanding of the hydrological behaviour of water sources and its environmental consequences. Hydrology of water resources in any particular region is principally characterised by the climate and partially by local geology, topography, and land use (including agriculture and other economic activities affecting water). Unfortunately, as already stated, knowledge of hydrology of HKH water sources is limited, and most of the methods developed in entirely different climatic, geological, topographical, and land-use conditions of Europe and North America that are used in the HKH in the absence of reliable, regionally developed methods of hydrological analysis, assessment, and modelling are not entirely suitable.

In terms of scientific issues related to water resource development in the region, priority areas for research and training in the short term should include the following.

a) Management and optimum use of local water resources for and by the local people: water harvesting and water quality assessment at the local level
b) Development of appropriate methods and application of modern engineering and computer- based methods, technologies, and tools (including Remote Sensing and GIS) for hydrological regionalisation and assessment of and decision-making about water resources (big or small) for different uses (irrigation, hydropower, and so on)
c) Hydrometeorological database management
d) Management of water for disaster prevention and hill and slope stabilisation (for example, floods, GLOFS, landslides, and debris flow control and management).
e) Water laws and conflict resolution at local, national, and regional levels
f) Impact assessment of water resource development projects, particularly big and multipurpose projects
g) Glacier and snow cover monitoring (field-based as well as by using remote sensing/satellite data)

REGIONAL TRENDS

Water as 'Hope' for the Future

In some countries of the HKH, water has caught the imagination of the people as 'hope' for the future (Verghese 1990). It is seen as a national endowment that, through regional cooperation in water resource development for power, irrigation, and flood control, can do much to improve the standards of living and circumstances of the people of the HKH. However these expectations have been elusive. Such 'hopes' can be realised only if the countries concerned are willing to cooperate and take action. Some of the prevalent myths and expectations need to be reviewed and examined in the light of fresh evidence. For example, there is a widely held 'myth' that regular floods in Bangladesh are due to the Ganges overflow from India and Nepal. However, it has been shown that it is Meghalaya and not the Himalayan waters that are responsible for such floods (Hofer and Messerli 1997). A chain of high dams in the headwater regions of Nepal and India has been envisaged as a panacea to solve the problem of floods downstream and to provide water for irrigation and power during the lean (dry) period. Yet, considering the fragile and hazardous nature of environments in the headwater regions of Nepal and India, the 'new uncertainty' concerning the possible impacts of global warming and climate change, and the continuing uncertainty about the impact of people and nature on the quantity and quality of water flowing out of mountain watersheds, how realistic are these 'hopes'? This question should be examined on scientific and technical grounds. There are also differences in perception in the political circles of the regional countries about the way water resources should be developed and managed. Hence a lot of ground work has to be undertaken on scientific, technical, and socioeconomic aspects of regional waters before 'hopes' can really be translated into realities.

Water, Women and Basic Rights of the People

In all the countries of the HKH, governments are finding it difficult to meet the basic needs of the people; and this is an increasing concern. Basic needs include safe drinking water not only in urban areas but also in rural areas. Many international programmes, such as the International Decade for Drinking Water and the Dublin conference (1992), and the growing awareness of people about their basic right to have access to safe water have contributed to increased awareness at all levels and renewed commitment on the part of governments.

Many rural mountain households in the HKH do not have access to adequate supplies of safe water as yet. The use of polythene pipes and cement-lined storage systems, however, is increasing; and these new materials and systems have alleviated the problem of water scarcity and reduced the drudgery for women to some extent. However, much more needs to be done, particularly in terms of ensuring that women and children do not have to travel long distances for water in the rural mountains and hills of the HKH.

Water as an Economic Commodity

A key shift in the global perspective on water is to cease considering it as a free gift of nature but rather to consider it as an economic good or commodity. The 1992 Dublin Conference clearly enunciated this. Other international water programmes, including those of UNESCO, have emphasised this point recently. However, the perception of the average mountain dweller in the HKH is still traditional in this respect and water is still seen as a free gift of nature. With gradual incursion of the market economy, even in remote mountain areas, changes in this traditional perspective are becoming visible. Similarly, the possibilities of using water for power generation and using locally-generated power for economic activities or directly to produce high-value, off-season vegetables or cash crops have increased awareness about the economic value of water amongst local mountain communities. It is also true that, whereas, traditionally, conflicts about water among neighbours or neighbouring communities were related to survival issues, such as drinking and irrigation, more recently conflicts tend to be related to other uses such as hydropower generation and diversion of water from one watershed to another.

Integrated Development and Management of Water

The recent emphasis on sustainable economic development has encouraged thinking in terms of sustainable management of water on a holistic basis, taking into consideration its relationship with other natural resources as well as with other natural and human processes: processes that affect the quality and quantity of water in terms of long-term supply. People-oriented sustainable economic development has now become, more or less, a global aim and objective. This perspective has received due priority and consideration in all the countries of the HKH. This perspective was not there in the 1960s and 70s when governments did not hesitate to move people from project sites. Governments also failed to consider the impacts of such projects on the local ecology and on aquatic life (for example, the Bhakhra-Nangal in India, Tarbela and Mangla in Pakistan, Kaptai in Bangladesh, and the Koshi, Gandaki, and Kulekhani in Nepal). The Chakma problem in Bangladesh owes its origins to the construction of the Kaptai dam, and the Koshi Barrage in Nepal could not deliver the promised benefits as erosion problems were ignored. Yet, recently, the Arun Project in Nepal and the Tehri Project in India have been either abandoned or have had to face public and judicial trials on the grounds of their negative impacts on local communities, their cultures, and the local ecology and environment. In the contemporary world, there are also extreme cases in which older dams are being destroyed on ecological grounds (for example, dams on the Columbia River in Canada in order to save the salmon) and new giga projects and dams are being planned or constructed such as the Three Gorges' project in China (on the Yangtze) and the Tehri project in India; both of which are controversial.

Concerns should not only be limited to the development of water for power and/or irrigation, no matter how attractive economically, but it should also focus on development and management with a holistic and integrated approach. People-centred sustainable development of water resources that takes into consideration interlinkages with other resources, sectors, and processes (physical, biological, and human) within a basin is the most important priority.

The 'Big' versus 'Small' Debate

As elsewhere in the world, the 'big' versus 'small' debate is growing even about water resource development projects in the HKH. The main issues with regard to mega-scale projects and in favour of 'small' projects in the region are as follow.

- Impact on the lives and culture of the local people
- Environmental and ecological impacts of projects
- Absence of long-term hydrological and climatological data for planning and design
- Inadequate knowledge about the climate and hydrology of major basins in the HKH (particularly about extreme weather events, their rates of return, and their impacts on hydrology and sediment generation and transport)
- Uncertainty about the possible impacts of climate change
- Risks associated with the inherent seismicity of the region
- Inadequate knowledge about dam-induced seismicity related to mega projects
- Inadequate knowledge about the impacts of nature and people on mountain watersheds and on varying scales (macro, meso, and micro) and the impacts on the quantity and quality (physical as well as chemical) of out-flowing waters
- Lack of human capabilities, such as technical skills and financial resources, in the countries of the HKH (with the exception, perhaps, of China and India) for planning, designing, and implementing mega projects

- Related to the former—total dependency on external capital and technical know-how without taking long-term local and national interests and priorities into consideration and even discouraging local and national initiatives in this sector in future

'Small' projects, on the contrary are considered better than big ones as they can be planned and executed, both financially and technically, by the countries themselves without too much dependency on external factors. They are also considered to be more environmentally and ecologically friendly; less threatening to local people and their culture; less risk in terms of planning, designing, and managing with limited data; and more responsive to local and national interests and priorities.

Transboundary Water Issues

As mentioned earlier the main rivers in the region are transboundary in nature, as they originate in one country and traverse through one or more countries before they reach the ocean; with the exception of the Yangtze which lies entirely in China. Almost all the major rivers of the region (viz., the Indus, the Ganges, the Yarlung-Tsangpo-Brahmaputra, the Mekong, the Nu-Salween, and the Yangtze all originate in Tibet and pass through different countries before reaching the ocean. Hence, it is a practical necessity that, for realistic planning and to derive full benefit from such rivers. closer dialogue and collaboration on the use of such river waters should be established. The important transboundary issues related to river waters in the HKH are as follow.

1. Control of floods—including glacial lake outburst floods
2. Planning and management of large-scale water resource development projects (single or multipurpose) on transboundary or border rivers and sharing of water and benefits (mainly for irrigation, power, and flood-control)
3. Management of upland watersheds/sub watersheds of the major river basins from a longer-term perspective.
4. Large-scale collection and storage systems in headwater regions (countries) to ensure supplies during lean periods for both upstream and downstream areas within a country or even outside in a neighbouring country
5. Conservation and use of regional aquatic resources, particularly riverine aquatic resources, in consideration of the potential impacts of future development of water resources on their migration and survival

CONCLUSION

Water in the HKH also provides a unique opportunity for regional cooperation in which each partner will gain net benefits and no one will really be the loser. A lot of ground work at both political and technical levels is still needed to ensure that the full advantages of this opportunity provided by nature are realised.

There are clear indications that a crisis is building up in the HKH in the context of the sustainable management of water resources. The following are contributing to this crisis.

1. The rapidity with which the population is growing
2. The rapidly-changing consumption pattern with increasing demands for water and other natural resources
3. The breaking down or growing irrelevance of traditional social, economic, and technological systems and indigenous knowledge

4. The rapid depletion of the natural resource base through internal and external pressures
5. The inadequacy of knowledge about the natural processes that govern the natural environment
6. The uncertain but possible impacts of global warming and climate change

Already there is increasing evidence of glacier retreat and decrease in snow cover in many parts of the HKH. These could affect water supplies, particularly the low flows of even perennial rivers, during lean periods if such trends of rapid deglaciation continue.

If the crisis is to be averted, future research programmes will have to take into account these factors in order to develop the ability to respond to the challenges. Obviously it is a complex problem, and solutions are not going to be simple or easy to find. It is also clear that, irrespective of all the existing unknowns and uncertainties with regard to water resource development, massive investments are being made or will be made in the region in water resource development projects for power generation, irrigation flood control, and urban supply. Whether such investments will bring the returns estimated will depend on how reliable and adequate our knowledge is and how quickly we can develop knowledge on hydrological responses to 'normal' and 'abnormal' (due to global change) impacts of the climate in the HKH (Chalise 1998).

Another extremely important issue deserving the immediate attention of the governments of the HKH countries is reorientation of water policies. Without such reorientation the water supply problems of rural and marginalised mountain farmers will not be solved. The water needs of poverty-stricken people living at high altitudes are particularly critical as traditional sources of water are either insufficient to meet the present needs, even for drinking water, or have dried up and no longer yield water. Insufficient winter rains and an increase in the dry period, leading to drying up of local springs and small perennial streams, have been observed and experienced by mountain people in recent years throughout the HKH. Contrary to the popular belief that the drying of local springs and other water sources is linked to local deforestation, it appears that poor winter precipitation (rain or snow) is the principal cause of water scarcity in the hills and mountains of the HKH. This issue has not been studied systematically as yet.

The fundamental need is to provide water to the people in the hills and mountains who are totally dependent on rainwater or snow for water supplies for drinking or for other domestic and irrigation needs.So far, national water policies in the HKH countries have focussed on large-scale projects for power irrigation, flood control, and urban supplies, providing benefits mainly to the people living in urban or plain areas. The water supply problem in the mountains has already reached crisis proportions in many parts of the HKH. Thus scarcity of water adds to the already miserable economic circumstances and mass poverty that cause the constant outmigration of able-bodied men from mountain areas. There is an urgent need to avert such crises by introducing water harvesting, collection, and storage systems at the household and local community levels with people's participation.

A major policy shift is needed in water resource development in the HKH countries. It should take care of water supplies for mountain households. It has been already seen in China that a favourable policy promoting water harvesting and storage systems managed by the people at household level on a mass scale can transform the economy in poverty stricken areas within a very short time (Chalise *et al.* 1999). A similar approach would also benefit mountain people in other countries of the HKH. Guaranteeing domestic water supplies will lead to a sustainable improvement in the quality of life.

Table Annex I: Hydropower Potential in the Hindu Kush-Himalayas

Country	Total Hydropotential	Total Installed Capacity
Afghanistan	NA	292 MW (1)
Bangladesh	1500-2000 MW (2)	232 MW (1)
Bhutan	20,000 MW	342 MW (1)
China		
(a) Tibet : Yarlung-Tsangpo (Upper Brahmaputra)	110,000 MW (4)	NA
(b) China (whole country)	NA	30,100 MW (1)
India		
(a) Indus	19,998 MW (5)	2570 MW (5)
(b) Ganga	10,715 MW (5)	1,675 MW (5)
(c) Brahmaputra	34,920 MW (5)	288 MW (5)
(d) India (whole country)	84,000 MW (5) at 60% load factor	14% of total potential harnessed
Myanmar	108,000 MW (6)	267MW (1)
Nepal	83,280 MW (7)	235 MW (1)
Pakistan	40,000 MW (8)	2,897 MW (1)

Note: Total Installed Capacity (TIC) figures for all countries apart from India are for.. 1990. For India, the figures are for 1992.

Sources: (1) UN, 1992; (2) Shahjahan, 1983 as quoted in Bandyopadhyay and Gyawali, 1992; (3) RGB.PC (1991); (4) Guan and Chen 1981; (5) CWC 1992; (6) Burma 1983; (7) Gyawali 1989; (8) SHP 1991. Refer to Chalise *et al.* 1993

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