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MOUNTAINS ECOSYSTEMS AND THEIR ROLE AS WATER SUPPLIERS
- Highland waters, a resource of global significance

Note by the Executive Secretary

I. INTRODUCTION

1. Decision VII/4, paragraph 14(a) , requests the Executive Secretary to compile, for consideration by the Conference of the Parties at its eighth meeting, information on mountain ecosystems and their role as water suppliers and examples of transferable technologies relevant to the implementation of the revised programme of work on inland water biodiversity also relevant to mountain ecosystems, and to ensure that this information is considered in the implementation of the programme of work on mountain biological diversity and taking into account, *inter alia*, the work of the Committee on Forestry of the Food and Agriculture Organization of the United Nations.

2. This document provides information to address this request. Information was gathered from a number of major sources in addition to a review of responses to notification 2005-14 which requested case studies on information on mountain ecosystems and their role as water suppliers and examples of transferable technologies relevant to the implementation of the revised programme of work on the biological diversity of inland water ecosystems.

II. BACKGROUND

3. There is no universally accepted definition of a mountain ecosystem. Mountains have different structures in different regions of the world. Mountains are characterized by their particular altitudes, gradient, topography, climate, vegetation and structure. Their ecological characteristics attract human activities and they are susceptible to natural and human induced hazards (Mountain Agenda 1997).

4. Mountains cover a large portion of the earth's surface. All of the world's rivers arise in "mountains" and they are therefore the major source of freshwater for lowland ecosystems and communities. Downstream countries often depend on mountain areas in upstream countries for much their water resources. For example, the Ganges River arises from the Himalaya, and provides water for domestic uses, agricultural and industrial needs to a population of about 400 million. The same role is fulfilled by the major Europeans rivers the Rhine, the Rhone, the Danube which all arise from the Alps (Bandyopadhyay et al. 1997).

5. Freshwater is becoming increasingly under stress through over-use, extraction and pollution from a multitude of terrestrial sources. Many areas are already experiencing severe water shortages. Mountains play a very important role in the hydrological process in all parts of the world. Their proper management as “water suppliers” is essential not only to the communities of people who inhabit them, but also to those who live downstream.

6. Chapter 13 of Agenda 21 (“Managing Fragile Ecosystems-Sustainable Mountains”) is a significant step for realizing the resource potential of mountains. This agenda indicates the necessity to promote and integrate watershed development approach giving due regard to local opportunities and their livelihoods. This includes the management and the conservation of freshwater. Governmental organizations, scientific researchers and NGO’s have shown an increased interest in sustainable management of mountains since UNCED in Rio and Agenda 21 (Mountain Agenda 1997).

7. This document analyses the role of mountains as suppliers of water. It examines the assessment of water resources, with a research agenda and recommendations for watershed management as an approach to addressing problems of mountain water resources.

III. HYDROLOGICAL CHARACTERISTICS

8. Mountains interact with the global atmospheric circulation and receive water in the form of mist (fog), snow and/or rain. After precipitation, some water is used directly within mountains or enters groundwater. But most forms “runoff” which is channelled through rivers of increasing size which may be either seasonal or perennial, sometimes after a brief period of storage as ice or snow, depending upon local climates. These rivers supply water to lowland areas and that water may be supplemented by water arising directly from precipitation in those areas. In this process, the role of groundwater, in both mountains and lowlands, should not be underestimated. Groundwater is particularly important in maintaining the availability of surface water, particularly stream flows, during periods of low precipitation.

9. Although, they provide the major part of the world’s freshwater resources, the hydrology of mountains is not thoroughly understood. Three of the important hydrological functions of mountain areas are:

> **Temporary storage:** in the form of groundwater, snow and ice that brings about a delay in runoff. Of these, snow-melt often contributes the largest volume of water on a seasonal basis to river flows in high altitude areas or at higher latitudes. Snow-melt is also an important source of ground water recharge;
>
> **Natural lakes and man-made storage reservoirs:** in mountain areas may be used for a number of purposes, especially for water supply, irrigation, power generation, and flood control. The runoff retained to reduce flooding downstream can be utilized later in the season; and
>
> **Potential energy:** water in rivers can be utilized to generate hydroelectricity.

10. Mountains generally experience increased rainfall principally from the enhanced precipitation that they engender due to the uplift and ascent of moist air over them. As moist air rises (over mountains), precipitation ensues. The relationship between precipitation and altitude varies considerably in different parts of the world, depending on the volume of moisture in the air and its temperature, the steepness of the ascent and several other factors such as time of year.

11. Mountains have a great impact on the distribution of the world’s climate zones, in terms of precipitation and other variables. On the micro-scale, mountains modify the climate with considerable economic impacts. In tropical humid mountain areas, local vegetation (land cover) also has an impact on the micro-climate. Particularly in forests areas moisture wets the forest canopy and alters the precipitation

and evaporation rates much more than short stature vegetation. When typically thin mountain soils are saturated, frozen or replaced by bare rock, overland flow (runoff) is enhanced. Vegetation type, area extent, and canopy density can affect hydrological interactions. How groundwater affects surface hydrology also varies according to gradient, geology, land cover and rainfall patterns. These factors, together with others such as aspect, exposure, the presence of peat and natural pipes, endow mountain regions with diversity in hydrological regimes and characteristics. This hydrological heterogeneity attracts humans to mountains in different ways and the impacts of humans also vary in terms of severity, location and impacts downstream.

Hydrological extremes

12. Typical conditions in mountain ranges are the variability of precipitation and stream flow. Floods outside normal ranges are hazardous to people and infrastructure when stream discharge exceeds the capacity of the channels and associated terrain, including groundwater, to convey the natural flow. Human interference with the physical attributes of water bodies and channels and land cover increase the intensity, frequency and impact of catastrophic flooding. These impacts are transferred downstream and can be even more significant in lowland areas which are highly populated, particularly on river floodplains.

13. Outbursts of glacial lakes (Bandyopadhyay et al. 1997, Watanabe et al. 1994) have recently gained attention as a serious hazard in some high mountain areas.

14. It has been widely held that reservoirs can mitigate the impacts of rare, large-magnitude, local flooding events and regulate downstream discharge. However, there is an increasing body of evidence that reservoirs, particularly on highly manage and fragmented rivers, can exacerbate flooding problems when the limits of storage are exceeded – particularly where their presence has given downstream communities a false sense of security against floods.

15. Droughts represent the other extreme of changes in the hydrological regime. Ecosystems and human are stressed by the relative lack of water. People benefit from water sources of the mountains and are often better placed than those on the plains during drought conditions. One role of groundwater in sustaining dry season flows, including during extreme droughts, is widely underestimated as are the impacts of its unsustainable use.

16. The altitudinal zonation of vegetation found in most mountain ranges can be modified dramatically by these extremes.

17. Most of the water resources infrastructure in mountains around the world was designed for conditions observed in this century (Bandyopadhyay et al. 1997). Irrespective of human induced climate change, they are mostly ill-designed to cope with longer-term natural climate cycles.

IV. THE ROLE OF MOUNTAINS AS WATER TOWERS

18. Mountains play an important role in providing water in dry periods. Bandyopadhyay et al. (1997) consider this could be the reason that indigenous peoples give a divine significance to mountains. Mountains are suppliers of water, energy, biodiversity and resources such as minerals, forest, agricultural products and recreation (Mountain Agenda 1997).

19. More than 50% of humans rely directly on freshwater provided from mountains. In 2050, 60% of the world's population in developing countries will meet water shortages. Mountains obviously have an important role in the supply freshwater to humans in both mountain areas and lowlands (Liniger et al. 1998). Globally, about 70% of agricultural activities depend on mountain water (Liniger et al. 1998). Rivers, which are generally born in and fed by mountains, are very important for humankind. A priority agenda of sustainable watershed management is particularly compelling as the conflict of uses of mountain water increases. Conflicts arise due to methods of accessing ecosystems services such as direct water extraction, forestry and mining and changing land use patterns.

20. For example, in La Paz, Bolivia, 1.4 million people depend on water supplies from glaciers above 4 900 m sea level, and dams in the Andes generate 75% of electricity power for the cities.

21. In the case of mountain forests, their role of conservation of water resources is well recognized (Liniger et al. 1998; Küchli 1997). Their capacity to clean water and to recycle precipitation is not yet well documented or established. Mountain forests also provide good buffers against excessive runoff which otherwise may cause catastrophic flooding downstream. Forests also conserve biodiversity; protect against natural hazards (avalanches, landslides; etc) and influence climate. It is therefore necessary to develop monitoring programs of natural resources and assessment of the impact of land use in upstream areas and lowlands to achieve meaningful sustainable management (Liniger et al. 1998; Liniger & Gichuki 1994).

V. TRANS-BOUNDARY CONSIDERATIONS

22. Many water resources supplied by water from mountains (lakes and in particular rivers) represent trans-boundary resources which require co-operation between two or more countries for their sustainable management.

23. International conflicts over water use and allocation are widespread with transboundary rivers but only reflect an international aspect of conflicts that exist equally between users within national boundaries. For example, there have been three agreements on water use in the Nile in 1906, 1929 and 1959. The last treaty is the most important. Sudan reduced its consumption to 70% to benefit Egypt where water issues are a powerful influence on the regional political agenda. Discharges from the Nile have been reduced to effectively zero as population demands increased. Water supplies from mountains are a significant source of historical and on-going political conflicts. For example, in 1995 the Arab-Israeli conflict, although starting as a political dispute, underlying the issue is essentially one of control of water resources: water suppliers of the Anti-Lebanon Mountains, Mont Hermon, the Golan Heights and the hills of the West Bank. Disputes are also commonplace at national level. For example, Mount of Kenya provides water services for 2 million people (60% of Ewaso Ng'iro population). In 1980, water flows in the Ewaso Ng'iro River on Mount Kenya generated conflicts between nomadic pastoralists and farmers, a conflict surged because increased irrigation in the highlands caused impacts in the use of water for pastoralists in lowlands. The 40% of the total population in lowlands depend on water use of upstream.

24. Further information on approaches to the management of trans-boundary river basins is available through the River Basin Initiative, which is a joint initiative between the Convention on Biological Diversity and the Ramsar Convention (**www.riverbasin.org**).

VI. MOUTAIN ECOSYSTEMS AND THE IMPACT OF HUMAN ACTIVITIES

25. Human activities cause several impacts on biodiversity of mountains. Agriculture and grazing in mountains cause land erosion and pesticides and fertilizers result in pollution. In addition, climate change poses serious long-term threats (Secretariat of the CBD 2003a; see also below).

26. Humans traditionally use freshwater for domestic supply and agriculture. During industrialization water is often regarded as a means to dispose of wastes and garbage. Water subsequently has often become so polluted that it becomes useless downstream and seriously undermines ecosystem services. Unsustainable agricultural intensification has also led to severe reductions in water availability and impacts on water quality through poor soil management and the inappropriate application of pesticides, herbicides and fertilizers. Only recently has serious attention been given to sustainable water resources management and in particular the need to sustain other ecosystem services provided by water. A major challenge over the next few decades will be to make more productive use of water in the face of increasing demands on its supply.

27. The conundrum with water is that it is globally available in large supply. 36 million km^3 exist in the world, equivalent to 7000 years of supply without replenishment. But its local availability and

distribution cause problems. Humans use water primarily from lakes, rivers and groundwater which represents only 0.01% of the total water availability in the world. Even that fraction is not evenly dispersed. Some regions have excess, many have shortfalls. Water supply and use is becoming an increasingly significant issue on the world development agenda in both developed and developing countries alike.

28. Reserves of water are available in the form of ice (e.g., Greenland and the poles). This represents about 99% of the world's freshwater but in terms of stream flows only about 10%. The majority of stream flow arises from mountains (of varying extent). The situation for the Himalaya region, feeding several large Asian rivers, is typical. Mountains need to be regarded as water towers more widely and a new, or more widespread, approach to their management adopted in the future (Bandyopadhyay 1995).

29. Human activity creates intense pressures on mountains. The attractions of mountains result more and more in population increases. Remoteness is no longer a safeguard for most mountains as humans encroach into all but the highest peaks. Pressures on the hydrological cycle modify the quantity and quality of water yielded and these changes, in turn, have impacts on other sectors. In mountain areas themselves soil erosion (causing siltation), pollution and acid rain are major problems. Interruptions to the water cycle become an increasingly evident problem downstream. Mining is a major problem in many mountain regions. Apart from the immediate effects of serious water pollution during mining operations, it causes other problems long after mining has stopped: removal vegetation, soil disturbance and leaching of wastes from tailings. In the past, post mining land rehabilitation through re-vegetation has produced a less ecologically complex state than existed pre-mining. However, overall the most significant impact on mountain waters is unsustainable land use. There is a serious hydrologic impact when forests are not regenerate and when conversion to other land uses is semi-permanent. Increase of infrastructure for industries and unsustainable tourism are added problems (Liniger et al. 1998).

30. Traditional agricultural activities by local and indigenous communities tend to be sustainable given low population densities including slash-and-burn (shifting) agriculture in heavily vegetated areas. However, they tend to become unsustainable as population pressures increase. The impact of unsustainable impacts on watersheds by indigenous and local communities is an increasing problem (Price 2004). Nevertheless, the role of local and indigenous communities in land management is significant and certainly any improved management approaches must consider their role as key stakeholders. Communities that inhabit mountains also have a better understanding of natural hazards and longer-term variations in climate etc. Such knowledge is often passed from generation to generation and incorporated into ongoing practices. The role of traditional knowledge in land management is a much neglected area (Mountain Agenda 1997).

31. Fragile ecosystems in mountains can respond rapidly to human activities. The restoration of the natural ecosystem following natural disasters or over-use can take a long time. For example: in 1930, following unsustainable land use on the Swiss Alps, a fertilizer experiment in the Schynige Platte generated new plants in 3 to 5 years but regeneration of the original plants is still ongoing. In this example, all the original species disappeared with a loss of 90% of the biodiversity (Mountain Agenda 1997).

32. Women have a significant social role in agricultural production and in sustaining the family. This role needs to be more fully recognized by society and governments. Policies are often gender discriminating, or gender blind. Often women do not have access to credit or participate effectively in the formulation of policies. The role of women across the board needs to be enhanced (Mountain Agenda 1997).

VII. IMPACT OF CLIMATE CHANGE ON WATER TOWERS

33. The relationships between climate change and biodiversity have been discussed at length under the Convention on Biological Diversity (for example, Secretariat of the CBD 2003a). Climate change and

its consequences in mountain ecosystems continue to be an active area of research (Becker and Bugmann 1996; Bandyopadhyay et al. 1997).

34. Mountains of the world are fragile ecosystems and climate changes influence in the quantity of freshwater, period of runoff from uplands to lowlands and the capacity to capture precipitation. Climate change produces changes in water temperatures, sea and river levels and changes in precipitation that cause associated impacts on vegetation and animals including those used directly by humans. Forests in mountains are also affected by increased atmospheric carbon dioxide that impacts on primary production of the biome but indications are that changes are slow and difficult to quantify. All these changes on biodiversity and land use will affect local communities and indigenous peoples, which depend on forests, biodiversity (medicinal plants and animals) and water supplies from mountains. All the highest mountains will be significantly affected by climate change and cultural practices and indigenous knowledge will be lost (Secretariat of the CBD 2003b).

35. If States implement adequate land use and reforestation programs, with the participation of local communities and indigenous peoples, net greenhouse gas emissions to the atmosphere can be reduced and the impacts of climate change on both local and downstream communities mitigated. Strategies must be complemented by sustainable conduct of industries and consumers for reducing atmospheric carbon dioxide and others pollutants.

VIII. MANAGEMENT FOR SUSTAINABLE WATER SUPPLIES

36. Efficiently managed mountain water supplies should be a global goal, which will ensure effective strategies for policies are developed on a river basin basis. France and Spain are rare examples of countries that have used river basins as the basic unit of analysis in water resources administration (Bandopadyay et al. 1997). Though hardly a panacea, a watershed approach to water problems can provide a valuable environmental education role as well as form the basis of rational management of water resources. As new water projects are considered in mountain areas, there is a wealth of experience available that can be used to improve project design and minimize adverse environmental effects.

37. Changing attitudes and practices with respect to development of water resources have been described in a policy paper of the World Bank in 1993. The new policy framework uses river basins as the planning unit, treats water as an economic good, encourages active public participation in project planning, recognizes water needs for maintenance of biodiversity and ecological processes, and attempts to establish a more holistic view of water resources administration. The water policy paper also endorses economic incentives for improving land management practices that could degrade water supplies and stream ecosystems.

38. Integrated river basin planning must also consider watershed disturbance as an important influence on water resources. Riparian protection can be a cost-efficient and ecologically effective means of stabilizing and restoring the health of aquatic systems. Improving water supply and sanitation for rural communities can have great benefits for human health and well being at relatively low cost.

39. Through taxes on delivered water and fees for new projects, funds could be generated to finance riparian restoration, pollution control, and rehabilitation of degraded watersheds. Such programmes could be the basis of employment for some mountain residents who would act as watershed stewards. Inclusion of people throughout a river basin in the water planning process can identify overlooked costs, suggest optimal solutions to allocation issues, and reduce the risk of future conflict (Mosley 1996).

40. Management approaches must be tailored to local conditions and setting. For example, the World Water Week in Stockholm, 21 – 27 August 2005, launched the report "From the Mountain to the Tap: How Land Use and Water Management can Work for the Rural Poor" this summarises research commissioned by the Tropical Forestry Research Programme of the United Kingdom Department for International Development. The potential implications of the results from this 4-year multi-country

collaboration in Costa Rica, South Africa, Tanzania, Grenada and India are immense as they contradict current tree-planting policies and environmental beliefs. Trees, if planted in water scarce environments, may reduce dry season flows and therefore worsen the living conditions of the poor. The research results point to the need for water managers and policy makers to base decisions on tree planting schemes on scientific evidence appropriate for the site. Unless there is urgent action, the looming water crisis will aggravate, and leave the most vulnerable – the rural and urban poor populations – ever more disadvantaged. More information about the Forestry Research Programme is available at www.frp.uk.com.

41. Some further technologies which are useful in the management of water supplies from mountains are included in the summary of case studies submitted (see section XIII).

42. Sustaining high quality stream flow requires sustainable development of mountain waters including the maintenance of both the physical and ecological processes. To have advantages of water in uplands, human activities must to respect the integrity of mountain watersheds. Maintaining and harnessing the benefits of the natural water systems of mountains requires an increase in our knowledge about aquatic systems in mountain areas and how to better manage them.

43. Fish are probably better known than most mountain aquatic biota due to their greater economic value. Resource exploitation that damages riparian and aquatic habitat is the principle cause of the noted declines in the distribution and abundance of native aquatic organisms, especially fish.

44. Water resource development by humans generally causes an impact on aquatic systems. Barriers and diversions cause impacts on biotic communities by modifying flow regimes, reducing water availability, converting running water habitats to reservoir environments, limiting sediment transport, changing temperatures, blocking migrations of biota and isolating populations (Bandyopadhyay et al. 1997). However, uplands areas tend to have fewer urban and industrial pollution sources compared to lowlands.

45. Human activity encourages pathogenic organisms derived from human and livestock wastes that enter drinking water supplies. Contamination of human drinking water supplies is a widespread human health concern. If water supplies have less degradation or pollution, their value for human uses downstream will increase.

46. Aquatic systems can be highly resilient but they need ecological processes to reassert themselves.

IX. INDIGENOUS AND LOCAL COMMUNITIES IN SUSTAINABLE WATER TOWERS MANAGEMENT

47. Although the areas in which many indigenous people and local communities live on mountains are rich in biodiversity and natural resources, many remain poor. Part of the cause of this is the exploitation of resources by others, without adequate participation of and benefit sharing with them. Lack of inclusion of local and indigenous participation in decision-making in mountain management is commonplace (Price 2004). Indigenous people and local communities must benefit from the economic advantages of mountain management and should participate in all the steps of development.

48. Poverty alleviation is a priority for developing States. However, policies often tend to be "conservationist" in mountain areas and marginalise mountain people. This is not a suitable mechanism for sustainable mountain management. If States continue to implement conservationist and economic policies without due regard to the livelihoods of mountain communities they will remain poor. Governments and the private sector often regard mountains as a source of economic resources. A contrary view is often held locally whereby these communities believe that mountains have a sacred spirit and they should not be disturbed. In the Andes, mountain people think that mountains are Gods (*Apus*) and they have a devotion to, and respect of them. This kind of belief has great influence on traditional activities and the conservation of biodiversity. It is important to maintain ethnic identities that contribute

to the conservation and sustainable use of biodiversity. Permitting their participation in natural resource's management is a vital key. Policy-makers also have to create mechanisms of conflict's resolution in mountains at boundaries to where indigenous and communities live (Butt and Price 2000).

49. Governmental economic projects rarely cover a full spectrum of livelihoods considerations. Scientific research in China determined that poverty could not be eliminated with economic programmes of increasing agricultural crops in poor mountain areas; also, Peru has several problems in applying management programmes for mountains in a context of two different production and development systems (Lynch and Maggio 2000).

50. Traditional knowledge has a fundamental role in the conservation and sustainable use of natural resources. Since immemorial times, indigenous people know how to preserve resources for present human needs and future generations and they have complex agricultural and silvicultural ancestral practices. Women play several prominent roles in biodiversity and traditional knowledge management (Lynch et al. 2000).

51. Local and indigenous people that live in mountains are better placed to control, manage and monitor watersheds than outsiders. However, they often experience expropriation of their lands, imposition of external policies and laws, and when these are gone, traditional knowledge is lost. Commercial breeders take advantage of traditional knowledge of local communities in mountains. One mechanism to help better appropriate intellectual rights is through the UPOV (*Union international pour la protection des obtentions vegetales)*. States should protect the intellectual rights of local communities, because they contribute to the conservation and sustainable use of mountains ecosystems. If their rights continue to be privatized, they will remain poor and poverty in turn will increase impacts on management of natural resources such as water and land (Lynch and Maggio 2000).

52. Of course, not all traditional knowledge supports environmental conservation and sustainable use. Traditional practices in South Asia can be based on discrimination against women and gender control of resources, which leads to adverse social, economic and environmental impacts. States must to work to create new legal mechanisms and policy programmes to address indigenous people and the conservation of invaluable knowledge (Lynch and Maggio 2000).

53. The International NGO Consultation on the Mountain Agenda (February, 1995, Lima, Peru) recommended States adopt integrated management of mountain ecosystems with a particular emphasis on mountain communities. NGOs recommended research programmes for documenting traditional knowledge, and educational programmes on water management for lowland communities, enforcement of local democracy and governance of mountain ecosystems, assessments of cultural and environmental impacts especially in tourism activities, and to invest in alternative livelihoods of local and indigenous peoples in mountains (Lynch and Maggio 2000).The European NGO consultation (July, 1996, Toulouse, France) remarked on the necessity to increase land management and assessments for viable development of mountain communities. In the same line, the meeting on the Sustainable Development of the Mountain areas of Asia (SUDEMA, December, 1994, Kathmandu) accorded importance to the identification of specific areas for an accelerated mountain development, to identify priority areas for investment in natural resource management, with full gender participation in decision-making, and the necessity to conserve traditional knowledge to achieve integrated mountain management.

54. Recommendations regarding traditional knowledge conservation and sovereign rights of States on plants genetic resources were established in the Convention for the Protection of Plant Genetic Resources. The *Leipzig Declaration* and the *Global Plan of Action* (FAO, June, 1996) refers to the role of local and indigenous people in the conservation of plant genetic resources and the need for their vital participation in management of these resources (Lynch and Maggio 2000).

55. The Declaration on the Rights of Indigenous Populations (OEA/Ser.K/XVI RECIDIN/doc.4/99) of the Organization of American States (OAS) remarks on the necessity of local control and sustainable use

of lands, water and other natural resources by local and indigenous populations to ensure local sustainable development and quality livelihoods. In addition, the declaration recognizes land rights and indigenous territories (Lynch and Maggio 2000).

X. ASSESSMENT OF MOUNTAIN WATER RESOURCES

> *"In the years to come, the health of these water towers will become even more critical as urbanization and the intensification of agriculture threatens to deplete and contaminate existing groundwater sources"* (Water Tower Summit, November 23-26, 2003, Banff, Alberta, Canada)

56. The basis rational management of water resources is the assessment of the quantity and quality of water available for use. Water resources assessment programmes usually have the following components: collection of hydrological data; collection of data about basins where the assessment is being made; and the application of scientific methods for using these data in the assessment (WMO 1996). These programmes include education, training, and research. Networks of field instruments must be deployed to collect hydrological data and they must be operated continuously to record the main variables. Monitoring programmes should be designed to address specific questions relevant to local water-resource development and impact avoidance or mitigation.

57. The Global Runoff Data Centre (GRDC) at Koblenz in Germany was established in 1988 by the WMO as a storehouse for such data. The GRDC, collects data from national institutions responsible for hydrology. More than 140 countries are included covering the discharge of more than 2900 of the major rivers of the world. In the future this will permit much more accurate assessments.

58. Precipitation is the major source of water supply on the globe's surface. A vital process in the large-scale distribution of water resources originates as precipitation in mountain ecosystems. Mountains regions serve as a most important water supply towers for the subtropical, middle and high latitudinal continental areas. Climate and hydrologic conditions in the high mountain areas have an important role in the supply of water. Monitoring and research in high mountain areas is therefore important in order to understand their climate and hydrologic and ecological variations.

59. The combination of access difficulties, extremes of climate and topography, the wide range in the magnitude of the variables to be measured, and uncertainties in the performance of the instruments and methods of observation, is a severe test of human ingenuity and persistence (WMO 1996). Images from satellites offer alternatives to some methods of measurement at the most remote sites, provided these images can be calibrated at accessible sites. The World Meteorological Organization's Guide to Hydrological Practices (WMO 1996) contains advice on appropriate instrumentation for mountains assembled over many years of experience of professional hydrologists.

60. The Guide to Hydrological Practices includes information for densities of instruments and networks appropriate to each physiographic region. But the densities of networks are currently insufficient at the global scale. Further studies of mountain regions conducted by the WMO, using results from 50 countries, have compared the actual densities of networks for the different variables with the minimum densities recommended in the Guide to Hydrological Practices (Bandyopadhyay et al. 1997). This study found that for most of the variables the actual network densities did not match the minimum recommended as the following table shows:

Region	% Mountainous area	% of water resources in mountains currently recorded
Africa	16	13
Asia	39	34
South America	23	8
North and Central America	21	10
South-west Pacific	26	0.3
Europe	22	8
World	22	10

61. Recently, scientific research has focused on hydrological knowledge and assessment in the world's mountains. There has been considerable progress in improving hydrological instrumentation leading to a better understanding of the physics, chemistry, and biology of the movement and storage of mountain waters.

62. Since the 1940s, remote-sensing data from aircraft and satellites have been conducted in the assessment of snow and ice cover for the estimation of surface runoff (Bandyopadhyay et al. 1997; Rango 1993). Information about the status of glaciers is available in volumes of the Satellite Image of Glaciers (Bandyopadhyay, et al. 1997; Williams and Feringo 1991), publications of the World Glacier Monitoring Service (Bandyopadhyay et al. 1997; Haberli and Herren 1991) and the World Atlas of Snow and Ice Resources (Bandyopadhyay et al. 1997; Kotlyakov 1996) provides archival information.

63. Significant environmental damage can occur through insufficient water resource assessment. Water resources planners must recognize limitations of short-term hydrologic data and associated inferences as well as consider potential extremes that are physically possible but have not yet been encountered during the short period of record. Evaluations must also include the current state of the aquatic system, potential degradation and pollution caused by water projects and independent changes in land use, and advantages for mitigation and restoration of the impacts of human activities.

64. Mountain water resources are generally exploited in an unplanned manner rather than safeguarded and developed in rational way. The consequences of this for mountain ecosystems are serious.

XI. RESEARCH AGENDAS

65. If States understand uniformly the importance of mountains as suppliers of water a clearer action agenda will emerge. Scientific researchers can elaborate the next steps to contribute to the understanding and interpretation of mountains ecosystems. In the case of precipitation, the vertical characteristics of mountains and their relationship to global atmospheric circulation are subjects yet to be adequately understood by scientists. The vertical characteristics of mountains have a great role in the generation of precipitation and its conservation in snow and ice that contributes seasonally to water flow in rivers.

66. Mountains also offer the option of the construction of artificial storage to provide water supplies in low flow periods. This can be an advantage for humans to control the flood of water, to benefit irrigation and to provide water for cities. The social and economic importance of distribution and conservation of water supplies from mountains is a key objective of governments. The best political strategy is to address management by local communities with participation of communities, and specially women, who work to provide drinking water for their families.

67. The scientific basis for sound water resources management is not yet thoroughly established. A detailed proposal for accelerated scientific research relating to fresh water has recently been proposed. Three broad questions were posed that integrate human needs with water resources (Naiman et al. 1995):

(a) What are the ecological effects of changes in the amount and water-borne materials along the hydrologic flow path, from precipitation falling on land to the ocean, under natural and altered conditions?

(b) What are the effects of human activities on freshwater ecosystems, and how do they influence the sustainability of inland aquatic resources?

(c) Are there key freshwater systems that can be used to evaluate and predict the effects of human influences at regional to continental scales?

68. NGOs have an important role to play in advocating policy and legislative changes sensitive to the need of local and indigenous communities. NGOs often correctly seek local control of water supplies for developments which include dams. This step is essential for an increase in economic development in poor zones. NGOs also have a role in seeking information from States, United Nations agencies and scientific institutions, on water management and water resources projects.

69. An ecosystem approach to mountain water management has to be realized from States to increase a high level of economic and social development. The ecosystem approach, a cornerstone of implementation of the Convention on Biological Diversity, is also consistent with the river basin or watershed basis for planning, development and management advocated by most experts, institutions and agencies.

XII. CONSERVATION OF HIGHLAND WATER RESOURCES

70. A variety of pronouncements regarding the water wealth of mountains have been made at high-level since the Mar del Plata Water Conference of 1977. Such declarations are a strong signal that water problems are gaining the attention of policy makers and that action is urgently required in many mountain ranges where demands on watersheds and water sources are accelerating. Having information about water resources allows decision-makers to explore the opportunity costs of additional water resources development. It essential to understand the trade offs between what is given up and gained through the supply of more water, and whether use is sustainable across all uses.

71. Given changing attitudes on the part of financial institutions, such as The World Bank, and water development agencies, such as the United States Bureau of Reclamation, there are brighter prospects for incorporation of environmental values in water resources administration. The adoption of holistic river basin planning by water management agencies should allow the more thorough evaluation of cumulative effects of resource development.

72. Designation of mountain catchments as water source protection areas could accomplish a variety of conservation and social goals. Institutional arrangements are needed to reinvest some portion of the benefits derived by water users back into the water source areas. Watershed management, restoration, and monitoring activities should provide employment opportunities and contribute to sustained livelihoods for mountain inhabitants.

XIII. CASE-STUDIES SUBMITTED AND EXAMPLES OF TRANSFERABLE TECHNOLOGIES

73. In response to decision VII/4, paragraph 14(a), the Executive Secretary issued notification 2005-014 which requested the submission of case studies and related information that demonstrate the role of mountain ecosystems as suppliers of water, including attention to technologies relating to the sustainable use of water that may be applicable to mountains and transferable for the benefit of other mountain ecosystems.

74. Eighteen case-studies were received. These are available at http://www.biodiv.org/doc/case-studies/

75. A summary of these case studies is provided in the annex. This also provides examples of transferable technologies that were identified. Further details on these are available from the case-studies at the aforementioned location.

XIV. BIBLIOGRAPHY

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Useful Web Sites:

Mountain agenda: http://www.mtnforum.org/resources/library/mtnag97a.htm. Ramsar Convention: www.ransar.org. World Wetlands Day 2004 – From Mountains to the Sea: http://www.ramsar.org/wwd/4/wwd2004_reports.htm. Global Water Partnership: http://www.gwpforum.org/servlet/PSP. River Basin Initiative: http://www.riverbasin.org/ev_en.php

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Annex

SUMMARY OF CASE-STUDIES AND SUBMISSIONS RECEIVED IN RESPONSE TO NOTIFICATION 2005-014

Country	Title	region/system in question	transferable technologies identified
Argentina	(1) Water quality in the area irrigated by the Mendoza River –m Argentina (2) The water delivery performance within the Chivilcoy Tertiary Unit, Mendoza (3) Snowmelt mathematical simulation with different climatic scenarios in the Tupungato River basin, Mendoza (4) Surface irrigation performance in the Mendoza River command area (5) Environmental conflicts in irrigated areas: impact assessment in the Tunuyán River basin, Mendoza	National, single basin studies	Water quality data collection; performance indicators quantifying water delivery; mathematical modelling of climate change scenarios for water resource availability; assessment tools for water use efficiency in agriculture; environment Impact Assessment
Australia	Case Study and Information on the role of Mountain Ecosystems as water suppliers and examples of transferable	Cross border management of a large multiple use alpine environment and	Alps liaison committee; afforestation; water reforms; environmental flows; standardized methods for assessing the ecological health of rivers, based on biological monitoring and habitat assessment; Toolbox of assessment techniques, models and protocols, including: • improvements to field sampling methods and protocols,

Country	Title	region/system in question	transferable technologies identified
	technologies relevant to the implementation of the Revised Programme of Work on Inland Water Biodiversity	sensitive alpine ecosystems	• implementing quality assurance and quality control procedures, • improving AusRivAS models and software interfaces, • investigating different analytical methods to allow better modelling of river health, • developing a physical and chemical assessment protocol, • developing and trialing a training and accreditation system, • investigating methods for assessing river health in arid and semi-arid rivers, • quantifying the impacts of temporal variability and errors on O:E scores and bands, and • inclusion of other biological monitoring methods using algae (diatoms), fish, and benthic respiration as indicators
Azerbaijan	The role of ecosystems of Azerbaijan – forests and wetlands – as water suppliers	General, national	Ramsar Convention provisions and guidelines; forest management plans; protection and rehabilitation of forests; measures for combating forest degradation; protected areas; integrated forest, rangeland and protected areas management; incentives to involve local communities; Integrated River Basin Plans – with stakeholder participation; management groups of stakeholders; monitoring and assessment of the efficiency of protection and restoration measures; integrated ecosystem approach; public awareness campaigns
Cameroon	Mount Cameroon biodiversity conservation	sub-national	Participatory strategy for sustainable use and conservation of forest resources; coalitions of local stakeholders; guidance on key principles; forest resource management models for participatory biodiversity conservation that focus on key forest resources of economic, social and ecological importance as entry points for community participation and empowerment in forest and land management Protected areas; Cameroon Mountains Conservation Foundation; Forest Zoning Plan; Sustainable methods of propagating and cultivating high priority species
Canada	(1) Lake O’Hara, Yoho National Park (2) South Saskatchewan River Basin	Sub-national	Long-term hydrological, chemical and biological measurements; physical water resources modelling - under the potential impact of climate change; modelling of socioeconomic impact scenarios
Chile	Water management issues of the Aconcagua watershed, Chile	Single large river basin	Design of watershed information systems; procedures for watershed management, water resources management, water allocation, water quality

Colombia	Information concerning environmental and institutional policy put forward by the páramo ecosystem management	National, high mountain regions	Protected areas; management plans; forestry conservation; stakeholder participation; restoration; conservation areas; reforestation; land cover assessments
Indonesia	Management of mountain ecosystem of Akarsari-Banten as water supply	sub-national, single mountain system	Integrated resources management; action plans; income and outcome regional budgets for implementation of action plans; participatory approaches
Philippines	(1) Maragang Watershed Development Project (2) Forestry Sector Project (3) Restoring Natural Forest Services of two important bird areas through community based rainforestation (4) Southern Philippines irrigation sector project – watershed management subcomponent	Watershed level	Reforestation; greenbelt areas to stabilize river and stream banks; soil conservation measures; plantation development as reforestation; watershed management framework; survey, mapping and planning; participatory approaches; policy frameworks; land management technologies; Information, education and communication; tree growing contests; community participation; guiding principles in management
Trinidad and Tobago (West Indies)	Case study on the role of mountain ecosystems as suppliers of water	National	Policy frameworks; water protection areas; watershed management; zoning for critical watershed areas; buffer zones; control of threats; maintenance of forestry; environment impact assessment; Wise Use Guidelines; water resources management strategy; Geographic Information Systems – for assessments

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