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DEVELOPMENT AND CLIMATE CHANGE IN NEPAL: FOCUS ON WATER RESOURCES AND HYDROPOWER

by

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FOREWORD

This document is an output from the OECD Development and Climate Change project, an activity jointly overseen by the EPOC Working Party on Global and Structural Policies (WPGSP), and the DAC Network on Environment and Development Co-operation (ENVIRONET). The overall objective of the project is to provide guidance on how to mainstream responses to climate change within economic development planning and assistance policies, with natural resource management as an overarching theme. Insights from the work are expected to have implications for the development assistance community in OECD countries, and national and regional planners in developing countries.

This document has been authored by Shardul Agrawala. It draws upon three primary consultant inputs commissioned for this project: “Nepal’s Hydropower Sector: Climate Change, GLOFs and Adaptation” by the Asian Disaster Preparedness Center (ADPC), Bangkok, Thailand (Vivian Raksakulthai); “Review of Development Plans, Strategies, Assistance Portfolios, and Select Projects Potentially Relevant to Climate Change in Nepal” by Maarten van Aalst of Utrecht University, The Netherlands; and “Analysis of GCM scenarios and Ranking of Principal Climate Impacts and Vulnerabilities in Nepal” by Stratus Consulting, Boulder, USA (Peter Larsen and Joel Smith). Valuable insights were also provided by experts, government officials, donor and NGO representatives at a consultative workshop organized in connection with this project in Kathmandu on March 5-6, 2003 by the Department of Hydrology and Meteorology of His Majesty’s Government of Nepal and the Asian Disaster Preparedness Center (ADPC). An additional contribution was solicited from John Reynolds of Reynolds GeoSciences, UK.

In addition to delegates from WPGSP and ENVIRONET, comments from Tom Jones, Jan Corfee-Morlot, Georg Caspary, and Remy Paris of the OECD Secretariat are gratefully acknowledged. Editorial inputs on an early draft were provided by Nipun Vats (Princeton University), and Martin Berg provided project assistance. ADPC would like to acknowledge the help and expertise provided by Adarsha Prokherel, Madan Lall Shreshtha, Arun Shreshtha, and other staff of the Department of Hydrology and Meteorology; John Reynolds of Reynolds GeoSciences; Sredhar Devkota and Ajoy Karki of the GTZ Small Hydropower Project; Tony Carvalho of USAID’s hydropower program; Tek Gurung of UNDP; and Krish Krishnan at International Resources Group. The Secretariat and Maarten van Aalst would like to acknowledge several members of the OECD DAC who provided valuable materials on country strategies as well as specific projects. Stratus Consulting would like to acknowledge inputs from Tom Wigley at the National Center for Atmospheric Research (NCAR).

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EXECUTIVE SUMMARY

This report presents the integrated case study for Nepal carried out under an OECD project on Development and Climate Change. The report is structured around a three-tier framework. First, recent climate trends and climate change scenarios for Nepal are assessed, and key sectoral impacts are identified and ranked along multiple indicators to establish priorities for adaptation. Second, donor portfolios in Nepal are analyzed to examine the proportion of donor activities affected by climate risks. A desk analysis of donor strategies and project documents as well as national plans is conducted to assess the degree of attention to climate change concerns in development planning and assistance. Third, an in-depth analysis is conducted for Nepal's water resources sector which was identified as most vulnerable to climate change. This part of the analysis also involved stakeholder consultation through an in-country workshop to identify key synergies and conflicts between climate change concerns and sectoral projects and plans.

Analysis of recent climatic trends reveals a significant warming trend in recent decades which has been even more pronounced at higher altitudes. Climate change scenarios for Nepal across multiple general circulation models meanwhile show considerable convergence on continued warming, with country averaged mean temperature increases of 1.2°C and 3°C projected by 2050 and 2100. Warming trends have already had significant impacts in the Nepal Himalayas – most significantly in terms of glacier retreat and significant increases in the size and volume of glacial lakes, making them more prone to Glacial Lake Outburst Flooding (GLOF). Continued glacier retreat can also reduce dry season flows fed by glacier melt, while there is moderate confidence across climate models that the monsoon might intensify under climate change. This contributes to enhanced variability of river flows. A subjective ranking of key impacts and vulnerabilities in Nepal identifies water resources and hydropower as being of the highest priority in terms of certainty, urgency, and severity of impact, as well as the importance of the resource being affected.

Nepal receives between 350-400 million dollars of Official Development Assistance (ODA) annually. Analysis of donor portfolios in Nepal using the OECD-World Bank Creditor Reporting System (CRS) database reveals that between 50-65% of development assistance (by aid amount) or 26-33% of donor projects (by number) are in sectors potentially affected by climate risks. However, these numbers are only indicative at best, given that any classification based on sectors suffers from over-simplification – the reader is referred to the main report for a more nuanced interpretation. Donor and government documents generally do not mention climate change explicitly, although some risks are being taken into account – albeit in a narrow engineering sense – as part of some development activities in Nepal.

The in-depth analysis of water resources in Nepal identifies two critical impacts of climate change – GLOFs and variability of river runoff – both of which pose significant impacts not only on hydropower, but also on rural livelihoods and agriculture. A preliminary discussion on prioritization of adaptation responses highlights potential for both synergies and conflict with development priorities. Micro-hydro, for example, serves multiple rural development objectives, and could also help diversify GLOF hazards. On the other hand, storage hydro might conflict with development and environmental objectives, but might be a potential adaptation response to increased variability in stream-flow and reduced dry season flows which are anticipated under climate change. Further, while addressing one impact of climate change (low flow), dams could potentially exacerbate vulnerability to another potential impact (GLOFs), as the breach of a dam following a GLOF might result in a second flooding event. Finally, the in-depth analysis also

highlights a trans-boundary or regional dimension to certain impacts, highlighting the need for regional co-ordinated strategies to cope with such impacts of climate change.

LIST OF ACCRONYMS

ADB	Asian Development Bank
CAS	World Bank Country Assistance Strategy
COP	Conference of the Parties
CRS	Creditor Reporting System of the OECD /World Bank
DANIDA	Danish International Development Assistance
DFID	Department for International Development
DHM	Department of Hydrology and Meteorology
EIA	Environmental Impact Analysis
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GLOF	Glacial Lake Outburst Flood
HMG	His Majesty's Government of Nepal
ICIMOD	International Center for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
MOPE	Ministry of Population and Environment
MTEF	Medium Term Expenditure Framework
NARMSAP	Natural Resource Management Sector Assistance Programme
NEA	National Electricity Authority
NPC	National Planning Committee
NSSD	National Strategy for Sustainable Development
SDAN	Sustainable Development Agenda for Nepal
SEA	Sectoral Environment Assessment
UN	United Nations
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention to combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	The United States Agency for International Development
USCSP	United States Country Studies Program
WSSD	World Summit on Sustainable Development
VDC	Village Development Committee

1. Introduction

This report presents the integrated case study for Nepal for the OECD Development and Climate Change Project, an activity jointly overseen by the Working Party on Global and Structural Policies (WPGSP), and the Network on Environment and Development Co-operation. The overall objective of the project is to provide guidance on how to mainstream responses to climate change within economic development planning and assistance policies, with natural resource management as an overarching theme. The Nepal case study was conducted in parallel with six other country case studies in Latin America, Africa, and Asia and the South Pacific region.

Each case study is based upon a three-tiered framework for analysis (Agrawala and Berg 2002):

1. Review of climate trends and scenarios at the country level based upon an examination of results from seventeen recent general circulation models, as well as empirical observations and results published as part of national communications, country studies, and scientific literature. These projections are then used in conjunction with knowledge of socio-economic and sectoral variables to rank key sectoral and regional impacts on the basis of a number of parameters. The goal of this tier is to present a framework to establish priorities for adaptation.

2. Review of economic, environmental, and social plans and projects of both the government and international donors that bear upon the sectors and regions identified as being particularly vulnerable to climate change. The purpose of this analysis is to assess the degree of exposure of current development activities and projects to climate risks, as well as the degree of current attention by the government and donors to incorporating such risks in their planning.

3. In-depth analyses at a thematic, sectoral, regional or project level on how to incorporate climate responses within economic development plans and projects, again with a particular focus on natural resource management. In the case of Nepal this in-depth research was conducted in close consultation with government officials, experts and in-country donor representatives. Subsequent to the scoping research a consultative workshop was organized jointly with the Department of Hydrology and Metereology in Kathmandu on March 5-6, 2003[1]. The workshop was attended by the Minister of Water Resources, representatives from the National Planning Commission as well as relevant government agencies, academia, donors, NGOs, and the media. As part of this workshop the participants collectively identified principal climate change impacts and vulnerabilities, and used the Adaptation Decision Matrix to rank adaptation responses along several criteria including effectiveness, cost, as well as synergies or conflicts with other environmental or development priorities.

2. Country background

Nepal is a land-locked country located in South Asia between India and China. It contains 8 of the 10 highest mountain peaks in the world, including Mount Everest (at 8848 m), although some of its low lying areas are only about 80 m meters above sea level (Figure 1). There is therefore extreme spatial climate variation in Nepal – from a tropical to artic climate within a span of only about 200 kilometers (the size of

1 Consultative Workshop on Climate Change Impacts and Adaptation Options in Nepal’s Hydropower Sector with a focus on Hydrological Regime, Kathmandu, March 5-6 2003 (Appendix A).

an average grid box in a climate model). Nepal is divided into five geographic regions: Terai plan, Siwalik hills, Middle Mountains, High Mountains (consisting of the Main Himalayas and the Inner Himalayan Valleys), and the High Himalayas (Table 1).

Figure 1. Geographical location and topography of Nepal

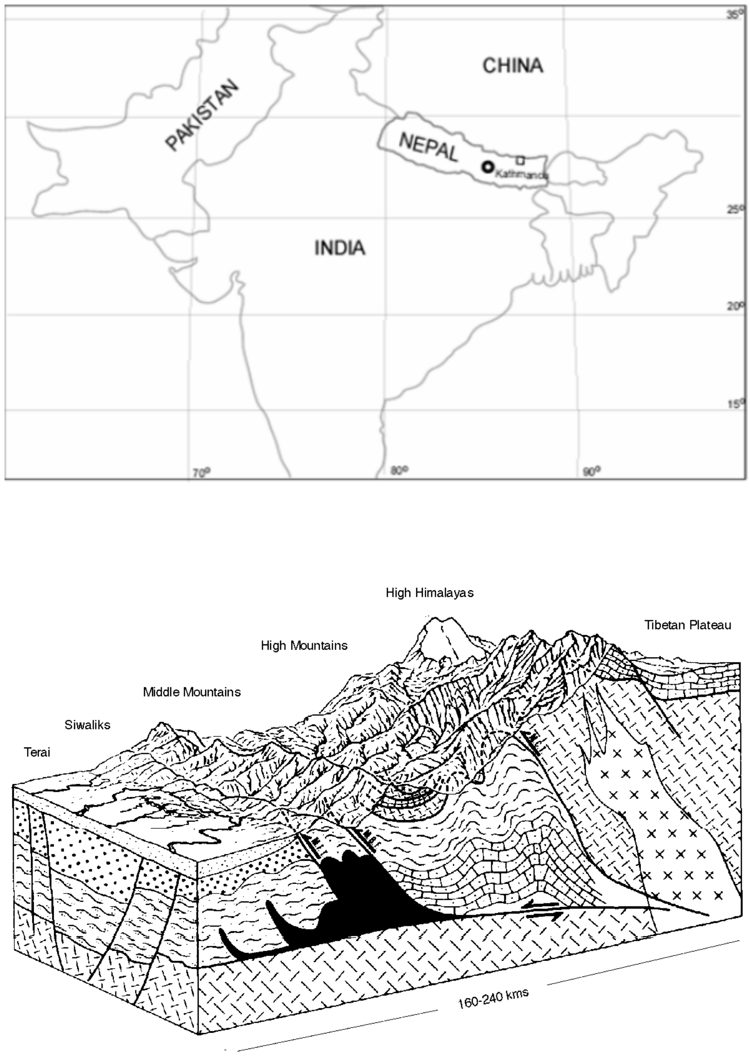


Table 1. **Geographic regions of Nepal**

Region	Geology and soil	Elevation (masl)	Climate	Average Temp.
Terai	Gently sloping, recently deposited alluvium	200	Humid tropical	> 25^{O}C
Siwaliks	Testing mudstone, siltstone, sandstone. Steep slopes and weakly consolidated bedrock. Tends to promote surface erosion despite thick vegetation	200-1500	Moist subtropical	25^{O}C
Middle Mountains	Phyllite, schists, quartzite, granite, limestone. Stony and course textured soil. Conifer forests commonly found associated with quartzite	1000-2500	Temperate	20^{O}C
High Mountains	Phyllite, schists, quartzite. Soil is generally shallow and resistant to weathering	2200-4000	Cool to sub-alpine	10-15^{O}C
High Himalayas	Limestone and shale. Physical weathering predominates, stony soils	> 4000	Alpine to arctic	< 0 to 5^{O}C

Source: CST Nepal 1997

Nepal has a population of 23 million. Compared to other Asian countries such as India or Bangladesh, it has a relatively low population density. However, the population is overwhelmingly rural, with only 12% living in urban areas (World Bank, 2002). Consequently, rural population density is relatively high at 686 people per square kilometer, a figure that exceeds that for most low income countries (World Bank, 2002). Additionally, nearly 100,000 Bhutanese refugees are located in seven United Nations refugee camps throughout the country (CIA, 2002).

Despite its natural beauty and enormous potential for hydropower and tourism, Nepal is one of the poorest countries in the world, with 82.5% of the population living below the international poverty line of $2 per day (World Bank 2003). A Gini coefficient[2] of 0.37 indicates that income distribution is somewhat uneven. In fact, some 38% of the population survives on less than US$1 per day. The wealthiest 20% of the population claims nearly 45% of total annual national income, while the poorest 20% can claim only 7.6%. Aggregate funding from various international agencies constitutes approximately 45% of Nepal's entire government expenditure (World Bank, 2002).

Nepal's economy is overwhelmingly dependent on agriculture. Approximately 40% of the country's GDP came from agriculture in 2000, down from 52% in 1990. Agriculture also provides a livelihood to nearly 81% of the labor force. In addition, because Nepal is a major tourist destination, a significant fraction of foreign earned income is dependent on the country's natural resources. Tourism receipts in 2000 amounted to 15% of exports. A heavy reliance on tourism and agriculture makes Nepal's economy very sensitive to climate variability (World Bank, 2002).

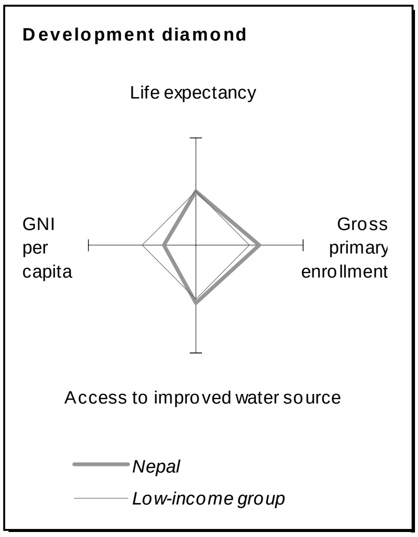
It is difficult to determine Nepal's potential to adapt to climate change, but several key statistics many give some insight as to the state of its infrastructure and social and human capital. While only 31% of Nepal's 13,223 km of highway are paved (World Bank, 2002), this percentage is almost twice that for other low income countries. The relationship between paved highways (or development more generally) and vulnerability is not clear. While a greater number of roads or a greater percentage of paved roads might imply a higher level of development, and *ceteris parebis* a higher coping capacity, it might also imply increased social exposure to climate hazards. For example, development of highways along river valleys in

2 The Gini coefficient is a number between zero and one that measures the degree of inequality in the distribution of income in a given society. The coefficient would register zero inequality for a society in which each member received exactly the same income and it would register a coefficient of one (maximum inequality) if one member got all the income and the rest got nothing.

particular might encourage settlements in regions that are most vulnerable to flooding from extreme precipitation or glacial lake outbursts.

Nepal's electricity infrastructure is heavily reliant on hydroelectric power: nearly 91% of the nation's power comes from this source. Hydroelectric plants are highly dependent on predictable runoff patterns. Therefore, increased climate variability, which can affect frequency and intensity of flooding and droughts, could affect Nepal severely. Also, according to the World Bank (2002), there were only three personal computers and 11 telephone main lines per 1,000 people in Nepal in 2000, lower than the average for countries of similar income. Nepal has a literacy rate of 58% (World Bank, 2002), suggesting relatively low levels of education and limited technical capabilities. A gross secondary school enrolment rate of 47% compares favorably with other low income countries. However, gross tertiary enrolment of only 3% is well below low income country averages. And, of this 3%, only 13% study sciences and engineering (World Bank, 2002). These figures suggest a relatively limited technical capacity which might make it difficult for Nepal to design and implement measures to adapt effectively to climate change. Figure 2 provides an indication of how Nepal compares to other low income countries in terms of four key indices of development.

Figure 2. Development diamond for Nepal



Source: World Bank, 2002

3. Climate change: trends, scenarios, and key vulnerabilities

The climate in Nepal varies from the tropical to the arctic within the 200 km span from south to north. Much of Nepal falls within the monsoon region, with regional climate variations largely being a function of elevation. National mean temperatures hover around 15 °C, and increase from north to south with the exception of mountain valleys. Average rainfall is 1,500 mm, with rainfall increasing from west to east. The northwest corner has the least rainfall, situated as it is in the rain shadow of the Himalayas. Rainfall also varies by altitude; areas over 3,000 m experience a lot of drizzle, while heavy downpours are common below 2,000 m (USCSP 1997). Although annual rainfall is abundant, its distribution is of great concern: flooding is frequent in the monsoon season during the summer, while droughts are not uncommon in certain regions in other parts of the year.

3.1 Climate trends

Temperature observations in Nepal from 1977-1994 show a general warming trend (Shreshtha et al. 1999), as shown in Figure 3. The temperature differences are most pronounced during the dry winter season, and least during the height of the monsoon. There is also significantly greater warming at higher elevations in the northern part of the country than at lower elevations in the south. This finding is reinforced by observations by Liu and Chen (2000) on the other side of the Himalayas on the Tibetan Plateau (Figure 4). Significant glacier retreat as well as significant areal expansion of several glacial lakes has also been documented in recent decades, with an extremely high likelihood that such impacts are linked to rising temperatures.

Figure 3. Pattern of temperature increase in Nepal 1977-1994 °C/year (Shrestha et. al. 1999

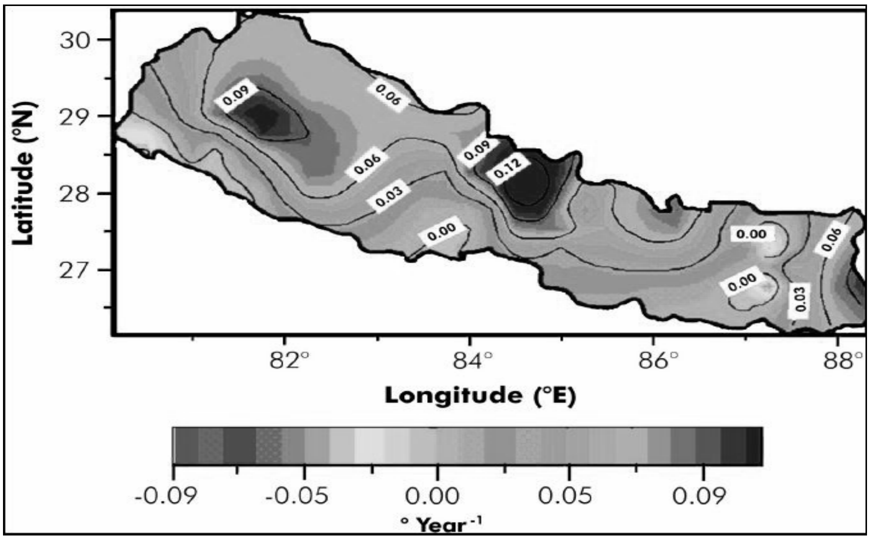
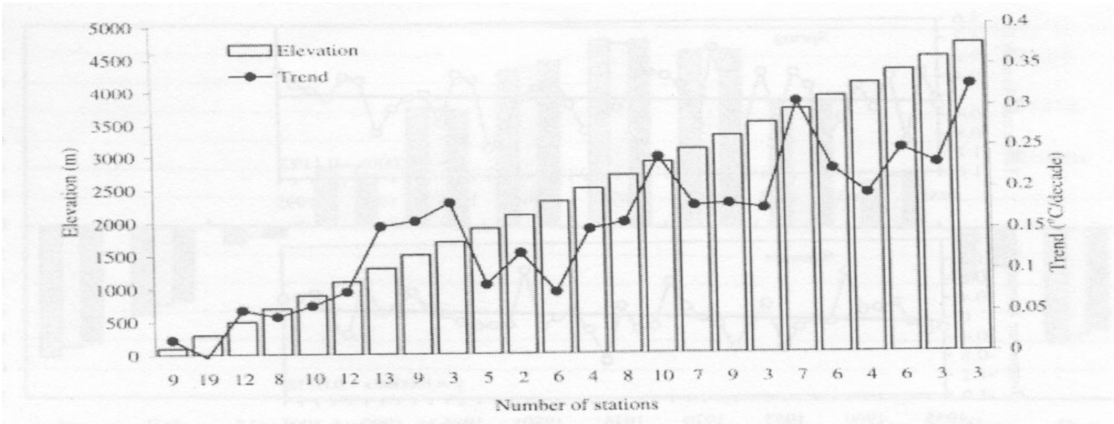


Figure 4. Temperature increase (per decade) as a function of elevation on the Tibetan Plateau (Liu and Chen 2000)



There are no definitive trends in aggregate precipitation, although there is some evidence of more intense precipitation events. A somewhat clearer picture emerges in stream flow patterns in certain rivers where there has been an increase in the number of flood days. Some rivers are also exhibiting a trend towards a reduction in dependable flows in the dry season, which has implications both for water supply and energy generation (Shakya 2003). Glacier retreat also contributes significantly to streamflow variability in the spring and summer, while glacial lake outbursts which are becoming more likely with rising temperatures, are an additional source of flooding risk.

3.2 Climate projections

Changes in area averaged temperature and precipitation over Nepal were assessed based upon over a dozen recent general circulation models (GCMs) using a new version of MAGICC/SCENGEN (Wigley and McGinnis, draft). MAGICC/SCENGEN is briefly described in Box 1. First, results for Nepal from 17 GCMs developed since 1995 were examined. Next, 7 of the 17 models which best simulate current climate over Nepal were selected. The models were run with the IPCC B2 SRES scenario (Nakicenovic and Swart 2000)[3]. The spread in temperature and precipitation projections of these 7 GCMs for various years in the future provides an estimate of the degree of agreement across various models for particular projections. More consistent projections across various models will tend to have lower scores for the standard deviation relative to the mean.

3 The B2 scenario assumes a world of moderate population growth and intermediate level of economic development and technological change. SCENGEN estimates a mean global temperature increase of 0.8 °C by 2030, 1.2 °C by 2050, and 2 °C by 2100 for the B2 scenario.

Box 1. A brief description of MAGICC/SCENGEN

MAGICC/SCENGEN is a coupled gas-cycle/climate model (MAGICC) that drives a spatial climate-change scenario generator (SCENGEN). MAGICC is a Simple Climate Model that computes the mean global surface air temperature and sea-level rise for particular emissions scenarios for greenhouse gases and sulphur dioxide (Raper et al., 1996). MAGICC has been the primary model used by IPCC to produce projections of future global-mean temperature and sea level rise (see Houghton et al., 2001). SCENGEN is a database that contains the results of a large number of GCM experiments. SCENGEN constructs a range of geographically-explicit climate change scenarios for the world by exploiting the results from MAGICC and a set of GCM experiments, and combining these with observed global and regional climate data sets. SCENGEN uses the scaling method of Santer et al. (1990) to produce spatial pattern of change from an extensive data base of atmosphere ocean GCM – AOGCM (atmosphere ocean general circulation models) data. Spatial patterns are “normalized” and expressed as changes per 1°C change in global-mean temperature. The greenhouse-gas and aerosol components are appropriately weighted, added, and scaled up to the actual global-mean temperature. The user can select from a number of different AOGCMs for the greenhouse-gas component. For the aerosol component there is currently only a single set of model results. This approach assumes that regional patterns of climate change will be consistent at varying levels of atmospheric greenhouse gas concentrations. The MAGICC component employs IPCC Third Assessment Report (TAR) science (Houghton et al., 2001). The SCENGEN component allows users to investigate only changes in the mean climate state in response to external forcing. It relies mainly on climate models run in the latter half of the 1990s.

Source: National Communications Support Program Workbook

The results of the MAGICC/SCENGEN analysis for Nepal are shown in Table 2. There is a significant and consistent increase in temperatures projected for Nepal for the years 2030, 2050 and 2100 across the various climate models. Increases in temperatures are somewhat larger for the winter months than the summer months. Climate models also project an overall increase in annual precipitation. However, given the high standard deviation the results for annual precipitation should be interpreted with caution. Even more speculative is the slight increase in winter precipitation. The signal however is somewhat more pronounced for the increase in precipitation during the summer monsoon months (June, July and August). This is because models estimate that air over land will warm more than air over oceans, leading to an amplification of the summer low pressure system that is responsible for the monsoon. These results are broadly consistent, though more pronounced than the Country Study for Nepal that was based on outputs from four older generation GCMs, only two of which simulated the summer monsoon and its intensification under the carbon dioxide doubling (Yogacharya and Shreshtha 1997).

Table 2. GCM estimates of temperature and precipitation changes for Nepal

	Temperature change (°C) mean (standard deviation)			Precipitation change (%) mean (standard deviation)		
Year	**Annual**	**DJF[4]**	**JJA[5]**	**Annual**	**DJF**	**JJA**
Baseline average				*1433 mm*	*73 mm*	*894 mm*
2030	1.2 (0.27)	1.3 (0.40)	1.1 (0.20)	5.0 (3.85)	0.8 (9.95)	9.1 (7.11)
2050	1.7 (0.39)	1.8 (0.58)	1.6 (0.29)	7.3 (5.56)	1.2 (14.37)	13.1 (10.28)
2100	3.0 (0.67)	3.2 (1.00)	2.9 (0.51)	12.6 (9.67)	2.1 (25.02)	22.9 (17.89)

Thus based on this analysis there is reasonably high confidence that the warming trend already observed in recent decades will continue through the 21st century. There is also moderate confidence that the summer monsoon might intensify, thereby increasing the risk of flooding and landslides.

3.3 Ranking of impacts and vulnerabilities

The necessity of suitable responses to climate change not only relies on the degree of certainty associated with projections of various climate parameters (discussed in the previous section), but also in the significance of any resulting impacts from these changes on natural and social systems. Further, development planners often require a ranking of impacts, as opposed to a catalog that is typical in many climate assessments, in order to make decisions with regard to how much they should invest in planning or mainstreaming particular response measures. Towards this goal, this section provides a subjective but reasonably transparent ranking of climate change impacts and vulnerabilities for particular sectors in Nepal.

Vulnerability is a subjective concept that includes three dimensions: exposure, sensitivity, and adaptive capacity of the affected system (Smit et al. 2001). The sensitivity and adaptive capacity of the affected system in particular depend on a range of socio-economic characteristics of the system. Several measures of social well-being such as income and income inequality, nutritional status, access to lifelines such as insurance and social security, and so on can affect baseline vulnerability to a range of climatic risks. Other factors meanwhile might be risk specific – for example proportion of rainfed (as opposed to irrigated) agriculture might only be relevant for assessing vulnerability to drought. There are no universally accepted, objective means for “measuring” vulnerability. This section instead subjectively ranks biophysical vulnerability based on the following dimensions [6]:

- *Certainty of impact*. This factor uses our knowledge of climate change to assess the likelihood of impacts. Temperatures and sea levels are highly likely to rise and some impacts can be projected based on this. Changes in regional precipitation are less certain. We use the MAGICC/SCENGEN outputs to address relative certainty about changes in direction of mean precipitation. Changes in climate variability are uncertain. The Intergovernmental Panel on

4 December, January, February

5 June, July, August

6 A comprehensive vulnerability assessment would have necessitated collection/aggregation of a range of socio-economic variables at a sub-national scale, and was beyond the scope of this desk analysis.

Climate Change (Houghton et al., 2001) concluded that higher maximum and minimum temperatures are very likely, more intense precipitation is very likely over most areas, and that more intense droughts, increased cyclone wind speeds and precipitation are likely over some areas.

- *Timing*. When are impacts in a particular sector likely to become severe or critical? Based on available information, we considered whether impacts are likely to become so in the first or second half of this century.

- *Severity of impact*. How large could climate change impacts be? Essentially this factor considers the sensitivity of a sector to climate change. For the most part, we did not consider the ability of adaptation to cope with climate change impacts.

- *Importance of the sector*. Is the sector particularly critical in terms of its size of economy, cultural or other importance, or its potential to affect other sectors? This factor considers exposure of the sector to climate change, that is, how many people, property, or other valuable assets could be affected by climate change.

A score of high, medium, or low for each factor is then assigned for each assessed sector. In ranking the risks from climate change, the scoring for all four factors was considered, but the most weight was placed on the certainty of impact. Impacts that are most certain, most severe, and most likely to become severe in the first half of the 21st century are ranked the highest. The results of this analysis are summarized in Table 3 [7].

Table 3. Priority ranking of climate change impacts for Nepal

Resource/ranking	Certainty of impact	Timing of impact (urgency)	Severity of impact	Importance of resource
Water resources and Hydropower	**High**	**High**	**High**	**High**
Agriculture	Medium-low	Medium-low	Medium	High
Human health	Low	Medium	Uncertain	High
Ecosystems/Biodiversity	Low	Uncertain	Uncertain	Medium-high

Water resources and hydropower rank significantly higher than any other sector for several reasons. First, a number of impacts on water resources and hydropower are directly related to rising temperatures that have already been observed, and are projected (with high confidence) to increase further over the coming decades. This includes glacier retreat that in turn causes greater variability (and eventual reduction) in streamflow, and glacial lake outburst floods that pose significant risk to hydropower facilities, and also to other infrastructure and human settlements. GLOFs are not hypothetical, as such events have already had significant impacts in Nepal, the most significant being the near total destruction of the newly built Namche Bazaar hydropower facility in 1985. Other climate induced risks to water resources and hydropower facilities include: flooding, landslides, and sedimentation from more intense precipitation events (particularly during the monsoon), as well as greater unreliability of dry season flows that poses potentially serious risks to water and energy supplies in the lean season. The significance of water

7 This ranking is focussed primarily on biophysical risks and does not explicitly include a detailed analysis of socioeconomic and demographic factors that might mediate vulnerability, which was beyond the scope of this study. The ranking however is broadly consistent with views expressed by national climate and development experts at a consultative workshop organized in connection with this project.

resources to agriculture, and the significance of hydropower to the nations electricity supply (a 92% share) further justify the high ranking for water resources and hydropower.

The impacts of climate change on other sectors tend to be less direct and/or less immediate, and much more speculative – even though the sectors themselves are quite significant. Three sectors that fall in this cluster are agriculture, human health, and ecosystems/biodiversity. Agriculture is very important for the country because a large portion of its output and labor force are devoted to it. From the limited information available, it appears to have moderate sensitivity to climate change. Our judgment is that significant impacts may not be seen for many decades unless there are substantial flood impacts. The direct impacts of climate change on agriculture seem relatively low.

Human health is ranked below water resources and agriculture mainly because of the significant uncertainty about many impacts, although it is likely that climate change will present health risks to Nepal from increased exposure to floods and vector-borne illnesses. We do not know how significant the health effects could be. The health related effects of flooding could be apparent in the near term, but other health effects may not become apparent for many decades.

Finally, ecosystems/biodiversity are ranked last because little historical research has been conducted on the effects of species diversity. Nepal is not a center of endemism, yet its vegetation diversity makes biodiversity an important issue. We are uncertain how sensitive biodiversity will be to climate change or when impacts may be realized.

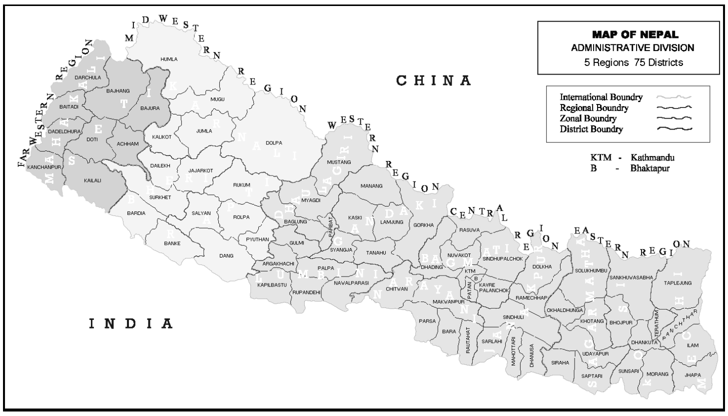
4. Attention to climate concerns in national planning

From a collection of small, independent states, Nepal was transformed into a monarchy in 1743 when the King of the principality of Gorkha, in resistance of incorporation into the British Empire, united all Nepalese territories under one flag (Shrestha 1998). In 1959, the first national general elections were held. However, the parliament was dissolved by royal decree the next year, and the monarchy's absolute power was not ended until 1990 when the multiparty system was instituted. Within the multiparty system, the royal family still maintains substantial influence in Nepal. In recent years Nepal has been in the midst of a Maoist insurgency which has severely hampered government activity and daily life during the past several years by calling for strikes. The last elections were scheduled for 13 November 2002, but were postponed indefinitely until the security situation stabilizes. This political instability dampened the tourism industry, which saw a precipitous decline, in addition to discouraging potential investors. Prospects for stability have improved significantly since the government and Maoists declared a ceasefire on 29 January 2003.

4.1 General overview of development planning in Nepal

Development planning in Nepal is under the responsibility of the National Planning Commission (NPC). The NPC releases annual plans and assesses resource needs, in addition to formulating 5-year plans for the country's general development strategy. Several other agencies are also involved with development, including the Ministry of Finance (MOF), which is responsible for mobilizing and coordinating foreign aid. Nepal is divided into five regional development regions: Eastern; Central; Western; Mid-Western; and Far Western.

Figure 5. Development regions and districts



Nepal's planned development began with the First Five Year Plan in 1956, which emphasized building the country's transport and communication infrastructure. This continued until the Fifth Five Year Plan (1975-1980), when a variety of issues were addressed, including energy were addressed. With 80% or more of the population dependent on agriculture, which is experiencing a fall in productivity with an increase of idle labor, planners are pushing to develop industry, services, and other sectors. However there has been concern that while infrastructure and external trade is a benefit to the country, a large majority of Nepal's population does not have its basic needs satisfied. This was finally addressed in the Eighth Plan (1992-1997) when the NPC targeted poverty alleviation and reducing regional inequality as two of the main goals (Mishra, 2000). In subsequent years the problems of drinking water, sanitation, health, housing, and primary education were addressed. The country is now in the last year of the ninth five-year plan, and the National Planning Commission recently adopted the Tenth Plan (2002-2007) on 17 December 2002. The total budget for the latest plan amounts to NPR 3.3 billion (USD 41.7 million). The primary goal for the next five years will be *poverty alleviation*, specifically to bring down poverty to below 30% of the population. At the beginning of the Ninth Plan this figure was 42%. HMG plans to alleviate poverty through programs in the following sectors: agriculture; tourism; communications; financial services and industry; electricity and fuels; strengthening social services; building rural infrastructure; and promoting good governance.

The budget estimates for His Majesty's Government (HMG) of Nepal for FY2002-03 were released in July, and showed that the Maoist insurgency is likely to have a significant dampening effect on development for some time to come. The economy is experiencing the lowest growth for a decade. The agriculture sector grew just 1.7%, down from 4.2% in 2001. Similarly, non-agriculture sectors grew only 0.2%, compared to 4.9% in the previous year. Tourism arrivals, a large source of foreign exchange for Nepal, saw numbers decline by over 44% due to security concerns. One of the only sectors to experience significant growth this past fiscal year were the utility sectors, including electricity, natural gas, and water. Together they reached almost 15% growth over last year, much of which may be attributed to the completion of the hydropower plants at Kali Gandaki A (144 MW) and Bhote Koshi (36 MW).

4.2 Attention to climate concerns in planning documents

The Tenth Plan, which has just been accepted (December 2002), has been developed as the country's PRSP. Even more than in the previous Ninth Plan, poverty reduction is the central focus of this new development strategy. The Development Plan is accompanied by a Medium Term Expenditure Framework (MTEF), which provides a prioritization of resources and ensures consistency of annual budgets with the 5-year Development Plan.

The current concept paper for the Tenth Plan acknowledges the important influence weather can have on overall economic performance:“The 10th Plan is being prepared and will be launched in a very difficult time/ GDP is projected to increase only by 2.5 percent in FY 2001/02, which is also the base year for the 10th Plan. The lower growth rate projection is mainly due to lower agricultural growth caused by bad weather conditions[8], domestic disturbances and lower external demand following the events of September 11.”

At the same time, this paragraph is the only place in the whole document where the development impacts of weather and climate are mentioned. While many of the proposed development activities may well reduce vulnerability to climate risks, explicit attention to these risks is lacking. Exploration of ways to reduce climate risks, or analysis of the risks themselves, is not included. The only activities dealing directly with climate risks in the activities matrix attached to the Tenth Plan are a couple of emergency management items in the urban development section (construction of emergency shelters and provision of housing for disaster-affected families). The overall Medium-Term Expenditure Framework (MTEF) does not discuss climate risks either. By itself, this lack of specific climate risk management items is no reason for concern. Ideally, climate risk management would be mainstreamed in many of the sectoral activities in the MTEF and the activities matrix (such as hydropower development and agriculture projects). However, effective mainstreaming requires explicit attention at the policy level. Such attention is not reflected in the Tenth Plan.

An analysis of the sectoral MTEF papers for some of Nepal’s vulnerable sectors underlines the impression that climate change is ignored, and climate risks in general tend to be neglected in the country’s development policy. For instance, the MTEF paper for the power sector does not recognize risks to hydropower plants due to the variability in runoff, floods (including GLOFS), and sedimentation. The MTEF paper for the health sector contains targets for vector-borne disease control and emergency preparedness and disaster management, but does not explicitly discuss natural hazards and climate risks. The MTEF paper for the road sector does not discuss flood and landslide risks, nor does the MTEF paper for water supply and sanitation discuss variability in rainfall, which may strongly affect the success of measures in this sector[9]. Similarly, the MTEF paper for the irrigation sector does not explicitly mention climate risks. However, its list of outputs includes mitigation of floods and erosion in cultivated areas, and water harvesting to provide year-round water supply for irrigation. Both measures would fit well in an adaptation strategy for Nepalese agriculture.

The MTEF paper for the agriculture sector pays some attention to climate-related risks. For instance, it mentions the criticality of the monsoon season for the sector. On the other hand, it lists the country’s “*agro-climatic potential*” as an opportunity. Moreover, a review of previous activities showed that outreach had been ineffective, mainly because it had been characterized by a top-down approach and a lack of orientation on small farmers’ problems, namely “*rain-fed and poor soils*”. Implicitly, this diagnosis identifies climate conditions as one of the challenges that poor farmers face, and that are currently lacking attention. The proposed solution “*major research funds to be used in need-based adaptive research*” seems unfocused, possibly a reflection of a lack of sufficient information on the importance of climate risks in the agriculture sector, and of a lack of awareness of options to reduce such risks. The document also proposes various other investments to improve the functioning of the agriculture sector that are likely to reduce vulnerability to climate-related risks.

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8 Anomalous weather, however, need not be linked to climate change.

9 The MTEF does propose simple solutions for sites where adequate and perennial water sources are lacking, including water-harvesting schemes and solar pumps. However, the real climate-related risks (what is “adequate” and how do you deal with a water source that is usually perennial but dries up during a period of drought) are not discussed.

4.3 Attention to climate concerns in environment focused plans and reports

Nepal has ratified the three Rio Conventions: the Framework Convention on Climate Change (UNFCCC), the Convention to Combat Desertification (UNCCD), and the Convention on Biodiversity (UNCBD). All conventions oblige their signatories to follow a stipulated reporting system.

Nepal's First Communication to the UNFCCC is currently in its final stages and expected to be submitted sometime in 2003, and is therefore not available for review. Nepal's most recent national report to the UNCD was prepared for the Fourth Conference of the Parties (COP-4) to the UNCD in 2000. The report does point to the need for integration of responses to the UNFCCC and UNCD, but few concrete steps are outlined. However, a number of desertification specific responses outlined in the report, for example, integrated watershed management, and community-based soil and water management are in fact no-regrets (or low regrets) measures for adaptation to climate risks.

With regard to the Convention on Biodiversity, Nepal's Biodiversity Strategy (2002) was prepared under the UNDP/GEF Biodiversity Conservation Project. It lists several climate related risks, including flooding and siltation, as threats to biodiversity conservation. However, the possibility that some of these risks [including both flooding and siltation] could be enhanced significantly under climate change is not discussed explicitly.

Nepal's Country Profile for the WSSD (2002)[10] discusses climate change only in the context of mitigation of greenhouse gas emissions; adaptation to climate change is not mentioned. However, the section on sustainable mountain development pays attention to indigenous systems of human adaptation to challenging geographic and climatic circumstances in mountainous areas. Furthermore, many elements of the proposed sustainable development policies (designed for current climatic circumstances) would also be no-regrets measures for adaptation to climate change.

Nepal's National Assessment Report for the World Summit on Sustainable Development (2002) recognizes the links between climatic circumstances and land degradation, erosion and landslides: "*in a nutshell, 'too much water' and 'too little water' is responsible for land degradation in different land uses in Nepal*." It also recognizes the increase in landslide risks due to the effects of paddy cultivation and livestock grazing in the hills and mountains. However, the fact that climate change might increase those risks is not discussed, and adaptation to climate change is not mentioned anywhere. Curiously, the only substantive discussion of risks due to climate change is featured in a paragraph on public awareness. The document mentions that FM radio stations should be used for this purpose: "*it will be important to increase awareness of the general public about the so far neglected messages (…) about emerging issues like climate change and its link with increased dangers from Glacial Lake Outburst Floods (GLOFs) and possible changes in monsoon patterns*". The 2001 Economic Commission for South Asia and the pacific (ESCAP) Nepal Country Paper (prepared for the Ministerial Conference on Infrastructure) meanwhile lists the facilitation of a rapid response to natural emergencies (such as floods or earthquakes) as an important role of infrastructure. Nevertheless, it pays little attention to the risk of extreme weather to the infrastructure itself, although it mentions that rural trails often become impassible during flooding. Since even current risks are not addressed, future risks due to climate change are also missing.

Nepal also has a National Strategy for Sustainable Development (NSSD) under the name of the Sustainable Development Agenda for Nepal (SDAN). The SDAN lists Nepal's continuing vulnerability to climate change, natural disasters and environmental degradation (in that order) among the constraints

10 These Country Profiles were published by the UN Commission on Sustainable Development on the occasion of the World Summit on Sustainable Development (Johannesburg, 2002). They cover Agenda 21, as well as other issues that have been addressed by the CSD since 1997, and are based on information updated from that contained in the national reports to the CSD, submitted annually by governments.

facing Nepal's Sustainable Development. It also contains a separate section on climate change, which lists the potentially serious consequences for infrastructure, agriculture, drinking water, irrigation, hydropower, and biodiversity, and mentions the risk of GLOFs. Climate change is not mentioned as a risk in the context of other sustainable development challenges, except in the case of biodiversity and natural disasters (increasing risk of GLOFs). Broader climate risks, including natural hazards such as floods and droughts, feature prominently, and concrete disaster mitigation measures are proposed (including the establishment of a national disaster preparedness and management agency, the creation of village-level early warning systems for floods, landslides or earthquakes, building decentralized emergency response capacity, enforcing design standards for buildings and infrastructure that take into account site-specific risks, investing in better weather and earthquake prediction systems, and, specifically for GLOFS, monitoring of the lakes and preparation of siphon materials). The discussion in SDAN therefore is consistent with the priority ranking of critical climate impacts listed in Section 3.3 of this report.

The sectoral reports for the SDAN do not mention climate change explicitly, except for the one that contains a specific section on protection of the atmosphere. While this section recognizes the vulnerability of Nepal and lists some expected impacts of global warming, it focuses primarily on mitigation and carbon sequestration. It recognizes the need to build capacity to minimize the adverse impacts of climate change, but offers no concrete measures. The report identifies a number of shortcomings in Nepal's approach to climate change: the delay of the National Communication to the UNFCCC, the lack of attention in national policy documents, the very low awareness among policy makers and the general public, and the low institutional capacity, also in international negotiations. In the context of climate change mitigation, the report points out that while the potential for CDM projects seems limited, many programs on alternative energy are being implemented without explicit linkage to climate change issues.

5. Attention to climate concerns in donor activities

Nepal receives large amounts of donor aid, of the order of US$ 350 million per year, or about 7% of GNI. The largest donors, in terms of overall investments, are Japan, the Asian Development Bank, and the World Bank (IDA). Figure 6 displays the distribution of this aid by development sector and by donor. Nepal receives large amounts of aid, both in absolute terms and in relation to GNI. Consequently, foreign aid also accounts for the lion share (70%[11]) of development investments in the country. Hence, while the overall development agenda is of course set by the government of Nepal, the donor agencies have quite a strong say in the strategic choices and ways of implementation of the vast majority of development investments.[12] The following sections highlight the possible extent of climate risks to development investments in Nepal, and examine to what extent current and future climate risks are factored in to development strategies and plans.[13,14] Analysis of selected donor project and planning documents is provided in Appendix C.

11 Donor review for 2002 Development Forum

12 A recent review of donor aid to Nepal, in the context of the preparations of the government's tenth National Development Plan, painted a rather bleak picture of the relationship between the government and the donor community. One of the reasons was the skepticism among donors about the government's performance and ownership of development projects. As a result, donors have taken a rather active role in planning and implementing development activities, to the extent that the national institutional capacity for development has eroded. At the same time, there has been a perception that donors have sometimes lost sight of local priorities and even seemed more interested in the quantity of aid resources delivered than in their quality and sustainability.

13 Given the large quantity of strategies and projects, the analysis is limited to a selection. This selection was made in three ways (i) a direct request to all OECD DAC members to submit documentation of relevant national and sectoral strategies, as well as individual projects (ii) a direct search for some of the most important documents (including for instance Nepal's national development plan/PRSP, submissions to the various UN conventions, country and sector strategies from multilateral donors like the World Bank and the ADB, and some of the larger projects in climate-sensitive sectors), and (iii) a pragmatic search (by availability) for further documentation that would be of interest to the analysis (mainly in development databases and on donors' external websites). Hence, the analysis is not

5.1 Donor activities affected by climate risks

The extent to which climate risks affect development activities in Nepal can be partially gauged by examining the sectoral composition of the total aid portfolio. Development activities in water resources, as well as sectors such as agriculture, and health could clearly be affected by climate change as well as current climate variability. At the other end of the spectrum, development activities relating to education, gender equality, and governance reform are much less directly affected by climatic circumstances.

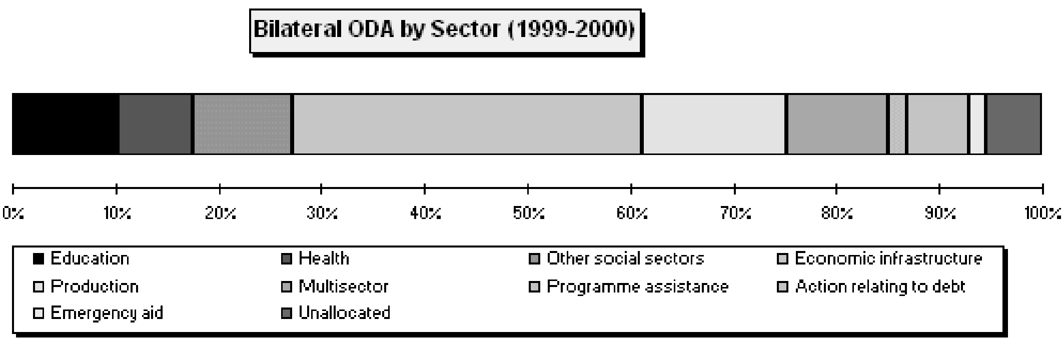
In principle, the sectoral selection should include all development activities that might be designed differently depending on whether or not climate risks are taken into account. Therefore, the label "affected by climate risks" has two dimensions. It includes projects that are at risk themselves, such as an investment that could be destroyed by flooding. But it also includes projects that affect the vulnerability of other natural or human systems. For instance, new roads might be fully weatherproof from an engineering standpoint (even for climatic conditions in the far future), but they might also trigger new settlements in high-risk areas, or it might have a negative effect on the resilience of the natural environment, thus exposing the area to increased climate risks. These considerations should be taken into account in project design and implementation. Hence, these projects are also affected by climate risks.

Figure 6. Development aid to Nepal (1998-2000)

Receipts	1998	1999	2000
Net ODA (USD million)	408	351	390
Bilateral share (gross ODA)	50%	54%	56%
Net ODA / GNI	8.2%	6.8%	7.2%
Net Private flows (USD million)	- 1	- 1	- 4

For reference	1998	1999	2000
Population (million)	22.9	23.4	23.9
GNI per capita (Atlas USD)	220	220	220

	Top Ten Donors of gross ODA (1999-2000 average)	(USD m)
1	JAPAN	98
2	AS. D B SPECIAL FUNDS	81
3	IDA	49
4	UNITED KINGDOM	25
5	DENMARK	24
6	GERMANY	22
7	UNITED STATES	16
8	SWITZERLAND	13
9	EC	12
10	UNDP	9



Source: Sources: OECD, World Bank

comprehensive, and its conclusions are not necessarily valid for a wider array of development strategies and activities. Nevertheless, the authors feel confident that this limited set allows an identification of some common patterns and questions that might be relevant for broader development planning.

14 The phrase "climate risk" or "climate-related risk" is used here for all risks that are related to climatic circumstances, including weather phenomena and climate variability on various timescales. In the case of Nepal, these risks include the effects of seasonal climate anomalies (like a dry winter or heavy monsoon), extreme weather events, floods and droughts, as well as trends therein due to climate change. "Current climate risks" refer to climate risks under current climatic conditions, and "future climate risks" to climate risks under future climatic conditions, including climate change.

Clearly, any screen for climate change risks that is based solely on sectors suffers from oversimplification. In reality, there is a wide spectrum of exposure to climate risks even within particular sectors. For instance, rain-fed agriculture projects might be much more vulnerable than projects in areas with reliable irrigation. At the same time, the irrigation systems themselves may also be at risk, further complicating the picture. Similarly, most education projects would hardly be affected by climatic circumstances, but school buildings in flood-prone might well be at risk. Without an in-depth examination of risks to individual projects, it is impossible to capture such differences. Hence, the sectoral classification only provides a rough first sense about the share of development activities that might be affected by climate risks.

To capture some of the uncertainty inherent in the sectoral classification, the share of development activities affected by climate change was calculated in two ways, a rather broad selection, and a more restrictive one. The first selection includes projects dealing with infectious diseases, water supply and sanitation, transport infrastructure, agriculture, forestry and fisheries, renewable energy and hydropower[15], tourism, urban and rural development, environmental protection, food security, and emergency assistance.[16] The second classification is more restricted. First of all, it excludes projects related to transport and storage. In many countries, these projects make up a relatively large share of the development portfolio, simply due to the large size of individual investments (contrary to investments in softer sectors such as environment, education and health). At the same time, infrastructure projects are usually designed on the basis of detailed engineering studies, which should include attention at least to current climate risks to the project.[17] Moreover, the second selection excludes food aid and emergency assistance projects. Except for disaster mitigation components (generally a very minor portion of emergency aid), these activities are generally responsive and planned at short notice. The treatment of risks is thus very different from well-planned projects intended to have long-term development benefits. Together, the first and the second selection give an indication of the range of the share of climate-affected development activities.

Box 2. Creditor Reporting System (CRS) Database

The Creditor Reporting System (CRS) comprises of data on individual aid activities on Official Development Assistance (ODA) and official aid (OA). The system has been in existence since 1967 and is sponsored and operated jointly by the OECD and the World Bank. A subset of the CRS consists of individual grant and loan commitments (from 6000 to 35000 transactions a year) submitted by DAC donors (23 members) on a regular basis. Reporters are asked to supply (in their national currency), detailed financial information on the commitment to the developing country such as: terms of repayment (for loans), tying status and sector allocation. The secretariat converts the amounts of the projects into US dollars using the annual average exchange rates.

In addition to the above two selections, the share of emergency-related activities was also calculated. This category includes emergency response and disaster mitigation projects, as well as flood control. The size of this selection gives an indication of the development efforts that are spent on dealing with natural hazards, including, often prominently, climate and weather related disasters.

The implications of this classification should not be overstated. If an activity falls in the "*climate-affected*" basket, which does not mean that it would always need to be redesigned in the light of climate

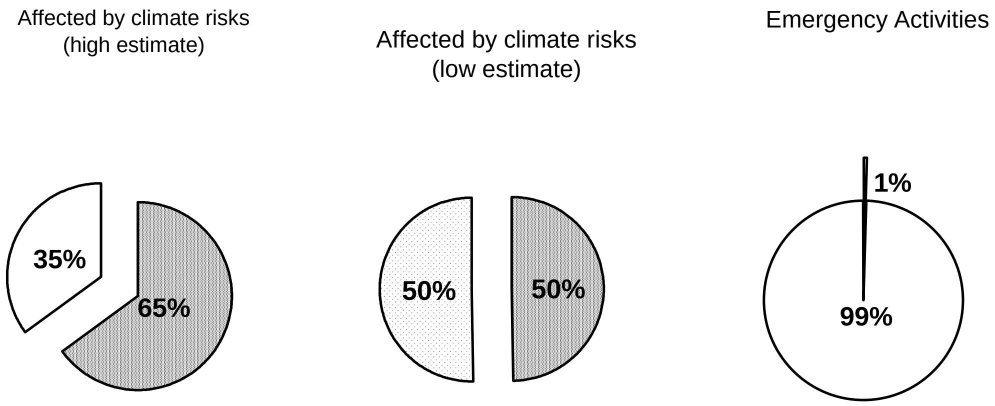
15 Traditional power plants are not included. Despite their long lifetime, these facilities are so localized (contrary to, e.g., roads and other transport infrastructure) that climate risks will generally be more limited. Due to the generally large investments involved in such plants, they could have a relatively large influence on the sample, not in proportion with the level of risk involved.

16 A complete list of purpose codes is included in the box on the methodology of the sectoral selections.

17 Note however, that they often lack attention to trends in climate records, and do not take into account indirect risks of infrastructure projects on the vulnerability of natural and human systems.

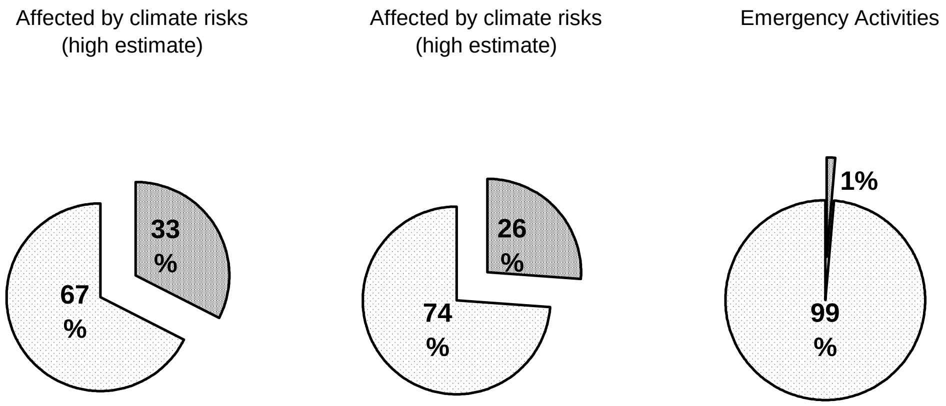
change, or even that one would be able to quantify the extent of current and future climate risks. Instead, the only implication is that climate risks could well be a factor to consider among many other factors to be taken into account in the design of development activities. In some cases, this factor could be marginal. In others, it may well be substantial. In any case, these activities would benefit from a consideration of these risks in their design phase. Hence, one would expect to see some attention being paid to them in project documents, and related sector strategies or parts of national development plans. Figures 7 and 8 show the results of these selections, for the three years 1998, 1999, and 2000[18], using the OECD/World Bank Credit Reporting System (CRS) database (Box 2).

Figure 7. Share of aid amounts committed to activities affected by climate risk and to emergency in Nepal (1998-2000)



18 The three-year sample is intended to even out year-to-year variability in donor commitments. At the time of writing, 2000 was the most recent year for which final CRS data were available. Note that coverage of the CRS is not yet complete: coverage ratios were 83% in 1998, 90% in 1999, and 95% in 2000. Coverage ratios of less than 100% mean that not all ODA/OA activities have been reported in the CRS. For example, data on technical co-operation are missing for Germany and Portugal (except since 1999), and partly missing for France and Japan. Some aid extending agencies of the United States prior to 1999 do not report their activities to the CRS. Greece, Luxembourg and New Zealand do not report to the CRS. Ireland has started to report in 2000. Data are complete on loans by the World Bank, the regional banks (the Inter-American Development Bank, the Asian Development Bank, the African Development Bank) and the International Fund for Agricultural Development. For the Commission of the European Communities, the data cover grant commitments by the European Development Fund, but are missing for grants financed from the Commission budget and loans by the European Investment Bank (EIB). For the United Nations, the data cover the United Nations Children's Fund (UNICEF) since 2000, and a significant proportion of aid activities of the United Nations Development Programme (UNDP) for 1999. No data are yet available on aid extended through other United Nations agencies. Note also that total aid commitments in the CRS are not directly comparable to the total ODA figures in Figure 5, which exclude most loans.

Figure 8. Share (by number) committed to activities affected by climate risk and to emergency activities in Nepal (1998-2000)



In monetary terms, between half and two-thirds of all development activities in Nepal could be affected by climate change. By number, the shares are somewhat lower; between a quarter and half of the activities would be affected.[19] Emergency projects make up about 1% of all activities. In addition to providing insight in the sensitivity of development activities in Nepal as a whole, the classification also gives a sense of the relative exposure of various donors[20]. These results are listed in Table 4 and 5 (again for the years 1998, 1999, and 2000).[21]

19 Note that the number of activities gives a less straightforward indication than the dollar amounts. First of all, activities are listed in the CRS in each year when a transfer of aid has occurred. Hence, when a donor disburses a particular project in three tranches, that project counts three times in the three-year sample. If the financing for a similar three-year project is transferred entirely in the first year, it only counts once. Secondly, the CRS contains a lot of non-activities, including items like "administrative costs of donors". Moreover, some bilateral donors list individual consultant assignments as separate development activities. In most cases, such transactions will fall outside of the "climate-affected" category. Hence, the share of climate-affected activities relative to the total number of activities (which is diluted by these non-items) is lower. On the other hand, the shares by total amount tend to be dominated by structural investments (which tend to be more costly than projects in sectors such as health, education, or environmental management).

20 Caveat: note that the CRS is not entirely complete; see footnote number 8*.

21 Note that in this selection, the role of large infrastructure projects is clearly visible. In Nepal, Japan tends to be a major donor in those sectors. Hence, it ranks much higher in the tables by amount than by number, and is absent from the table (by amount) of affected activities according to selection method 2 (which excludes transport and storage, as well as emergency projects).

Table 4. The relative shares of activities in the CRS database (1998-2000, by total disbursed aid amounts), for the top-five donors

Amounts of activities			Activities affected by climate risks (high estimate)			Activities affected by climate risks (low estimate)			Emergency activities		
Donor	million$	%	Donor	million$	%	Donor	million$	%	Donor	million$	%
Total	959	100%	Total	623	100%	Total	476	100%	Total	6	100%
Germany	195	20%	Germany	173	28%	Germany	166	35%	Japan	5	89%
AsDF	187	19%	AsDF	119	19%	AsDF	119	25%	Switzerland	0.5	9%
Japan	148	15%	Japan	76	12%	UK	67	14%	UNDP	0.05	1%
UK	89	9%	UK	72	12%	Denmark	49	10%	Germany	0.04	1%
IDA	72	8%	IDA	60	10%	Netherlands	13	3%	Belgium	0.03	1%

Table 5. The relative shares of activities in the CRS database (1998-2000, by total numbers of activities), for the top-five donors

Numbers of activities			Activities affected by climate risks (high estimate)			Activities affected by climate risks (low estimate)			Emergency activities		
Donor	Number	%	Donor	Number	%	Donor	Number	%	Donor	Number	%
Total	667	100%	Total	217	100%	Total	175	100%	Total	9	100%
Norway	118	18%	UK	35	16%	UK	27	15%	Switzerland	3	33%
UK	66	10%	Norway	23	11%	Norway	23	13%	Japan	2	22%
Germany	65	10%	Germany	20	9%	USA	15	9%	Belgium	2	22%
USA	51	8%	Switzerl.	19	9%	Germany	14	8%	UNDP	1	11%
Australia	45	7%	Canada	16	7%	Canada	14	8%	Germany	1	11%

Given the high share of development activities in Nepal that could be affected by climate risks, one would assume that these risks are reflected in development plans and a large share of development projects. The following sections will examine to which extent this is the case.

5.2 Attention to climate risks in donor strategies

The limited explicit attention to climate risks that is apparent in Nepal's own development strategies is also reflected in many of the major donors' strategies for the country, as can be seen in documents from multilateral agencies like the World Bank, UNDP and IFAD, as well as bilateral donors such as DFID and USAID. All of these strategies contain measures that will reduce Nepal's vulnerability in various, often indirect, ways. However, explicit attention to climate risks is lacking, and some opportunities for vulnerability reduction may well be missed. This section focuses primarily on donor strategies.

Several of these documents however do implicitly acknowledge the potentially large impacts of climatic factors on the success or failure of development investments. For instance, the World Bank's Economic Update for the 2002 Nepal Development Forum mentions that good rainfall has been one of the factors that contributed to the higher growth in the agriculture sector in recent years, putting climate on a par with increased use of fertilizer, private sector entry in the supply of inputs, better educated farmers, crop diversification, growth of agricultural credit, and improved infrastructure and irrigation. In addition, a relatively poor performance in agriculture is expected in the current year "following the untimely rainfall in September 2002". Nevertheless, when discussing priorities for the agriculture sector, the need to improve the resilience of the agriculture sector against adverse climatic conditions is ignored. A similar pattern arises in the ADB's Country Assistance Plan. Climate risks are also not explicitly mentioned in USAID's and DFID's country strategies for Nepal. USAID's Nepal Annual Report evaluates past performance and updates priorities for the coming years. The agency concentrates on hydropower development, health, and governance of natural resources. While these sectors are clearly sensitive to climate, the report contains no references to climate risks. Climate change is only mentioned in the context of the mitigation potential of hydropower development. DFID's Country Strategy Paper for Nepal (1998) presents a similar picture as the World Bank and ADB strategies: ample components that may well contribute to reducing Nepal's vulnerability, but no explicit attention to climate risks.

UNDP's Second Country Cooperation Framework (CCF 2002-2006) focuses on poverty reduction and sustainable development, but does not discuss the impacts of climate-related risks on those goals. However, a few crosscutting themes, including disaster mitigation, will be addressed in all projects and programmes of the CCF. This would mean that climate risk reduction ought to be mainstreamed in UNDP's activities in the coming years. No specific examples of such mainstreaming are offered in the CCF.

The IFAD Country Strategic Opportunities Paper (CSOP) addresses several aspects of vulnerability in the hill and mountain areas of Nepal, but pays little explicit attention to current climate-related risks, and entirely neglects climate change. However, it does bring up an interesting dimension of climate-related vulnerability in Nepal, particularly in relation to the hill and mountain areas. These areas are very poor, remote, and lack physical and social infrastructure. They became even more isolated and marginalized when they missed the "green revolution" because new agricultural technologies that helped to spark agricultural growth in other parts of the country were not suited for rain-fed agriculture in difficult mountain terrains and climates. In combination, these factors have contributed to a downward spiral of poverty and lack of empowerment, leading to a lack of benefits from investments at the national level, and thus to further poverty. Climate change could intensify such inequalities (but is not discussed in the CSOP).

An important point to note is that the lack of explicit mention of climate risks does not necessarily mean a lack of attention to climate change: several strategies mention the mitigation potential of Nepal's hydropower and forestry sector. No win-win options for combined adaptation and mitigation (for instance by afforestation) are discussed. An even more important point is that several donors and the government are in fact actively engaged in projects to reduce the risk of GLOFs over the past decade, as discussed in greater detail in the following section. Therefore, even if donors do not explicitly link GLOF risks to climate change per se, they are in fact actively engaged in devising adaptation responses to one of the most critical climate change related hazards for Nepal. This also highlights the limitation of using mention of "climate change" in project documents as a proxy measure to assess the significance the government or donors might attach to devising appropriate responses to some of the impacts associated with it.

6. Climate change, glacial lakes and hydropower

As alluded to in preceding sections, the most critical impacts of climate change in Nepal are related to its water resources and hydropower generation, stemming from glacier retreat, expansion of glacial lakes, and changes in seasonality and intensity of precipitation. These impacts include:

- Increased risk of Glacial Lake Outburst Flooding (GLOF)

- Increased run-off variability (as a result of glacier retreat, more intense precipitation during monsoon, and potentially decreased rainfall in the dry season)

- Increased sediment loading (and landslides) as a result of GLOFs, as well as intense rainfall events

- Increased evaporation losses from reservoirs as a result of rising temperatures

Increased sedimentation is in part linked to GLOFs, and so responses to GLOFs will partially alleviate this risk. Meanwhile, as regards evaporation losses due to rising temperatures, it is not yet clear how significant such losses might be relative to the volume of the reservoirs. Therefore, this discussion will focus on the first two impacts – GLOFs and increased run-off variability.

6.1 Glacial Lake Outburst Flooding (GLOFs)

One of the most tangible manifestations of climate change is the fact that many glaciers are melting. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that there is a high measure of confidence that in the coming decades many glaciers will retreat and smaller glaciers may disappear altogether. This has already been seen in the Alps, where a 1^{O}C increase in temperature has caused glaciers to shrink 40% in mass and 50% in volume since 1850 (IPCC, 2001). Analysis of local and regional records of glacier fluctuations in the Hindu-Kush-Himalayan (HKH) region during the same period shows that, while examples exist of both advance and retreat, the glaciers have mostly been retreating (Chalise, 1992). Glacial lake outburst floods (GLOFs) were first observed in Iceland and identified under the name *jokulhlaup*, Icelandic for “glacier leap”. Ives (1986:2) observes: “The catastrophic discharge of large volumes of water is characteristic of many mountain regions, and especially glaciated areas. Such discharges usually result from the collapse of unstable natural dams formed when stream channels are blocked by rockfall, landslide, debris flow, or ice and snow avalanches. Another cause is the outburst of lakes dammed by glacier ice or by glacier moraines…Depending upon the availability of loose material, the outbursts may be flood surges with a high sediment load, or actual debris flows.” Richardson and Reynolds (2000:31) further describe the phenomenon in the Himalayas: “As glaciers recede in response to climatic warming, the number and volume of potentially hazardous moraine-dammed lakes in the Himalayas is increasing. These lakes develop behind unstable ice-cored moraines, and have the potential to burst catastrophically, producing devastating Glacial Lake Outburst Floods (GLOFs). Discharge rates of 30,000 m^3s^{-1} and run-out distances in excess of 200 km have been recorded.”

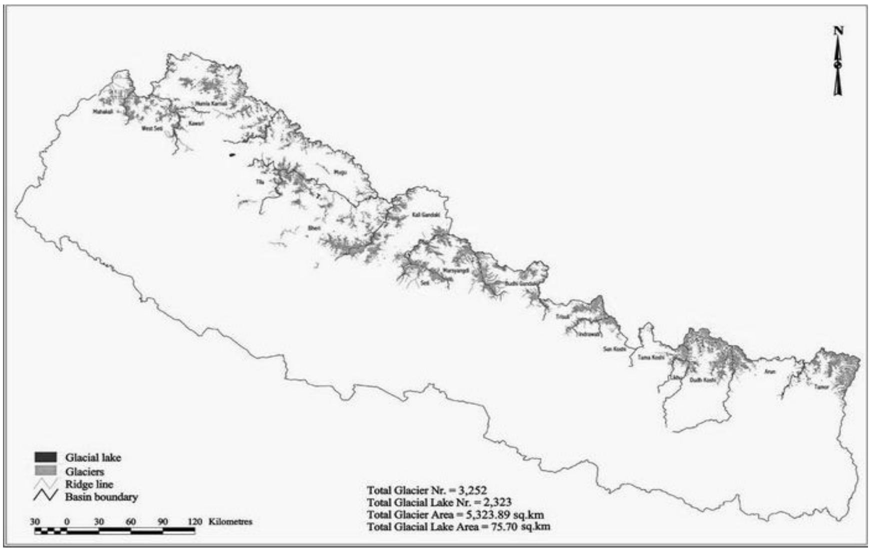
Glacial lakes can be ice-dammed or moraine dammed. Moraine dams are rocks and soil that have been pushed into a wall by the glacier. When the glacier retreats and a lake forms at the glacier tongue, the moraine holds the water back. GLOFs can also occur from lakes that form beneath the glacier or lakes on a glacier. Many glacial lakes drain periodically when the water reaches a certain level. This can be through a hole in the ice-cored dam, and the opening will become larger and larger, until suddenly the drainage accelerates to “flood” rate. In some locations, this is regulated with the seasons so that some lakes will self-drain once or several times each summer. With moraine-dammed lakes, when a GLOF occurs, too much of the moraine material will be washed away, so that the lake does not reform.

The most significant GLOF event in terms of recorded damages occurred in 1985. This GLOF caused a 10 to 15 meter high surge of water and debris to flood down the Bhote Koshi and Dudh Koshi Rivers for 90 kilometers. At its peak, 2,000 m^3/sec discharged, two to four times the magnitude of maximum monsoon flood levels. It destroyed the Namche Small Hydel Project, which was almost completed at the time and cost approximately NPR 45 million. An earlier GLOF in 1977 was recorded at Dudh Koshi. This event killed two or three people, destroyed bridges for 35 km downstream, and triggered many debris flows. Construction materials for a hotel that were kept 10 m above the river were swept away. The

Namche Hydel site sustained such damage that it was deemed unlikely to be salvageable for any reconstruction of the plant. Severe erosion destroyed the weir and headrace canal where water would flow into the plant. The flood plain was extensively widened. This damage was not the only damage that occurred that day on 4 August 1985. Damage occurred all along the length of the Langmoche Khola-Bhote Koshi-Dudh Koshi for a total of 90 km (Ives, 1986), including: 14 bridges, including new suspension bridges, were destroyed; at least 30 houses, likely the only property the families had; erosion, undercutting, and destabilization of long stretches of the main trail from the airstrip at Lukla to Mount Everest base camp; Prices increased by an average of 50% for staple supplies when the trail reopened; Cultivatable land and forest destroyed; Four or five deaths, but it could have been much higher had it occurred during peak trekking season; collapsed road sections, which the community repaired quickly, but it remained unsafe and caused accidents later.

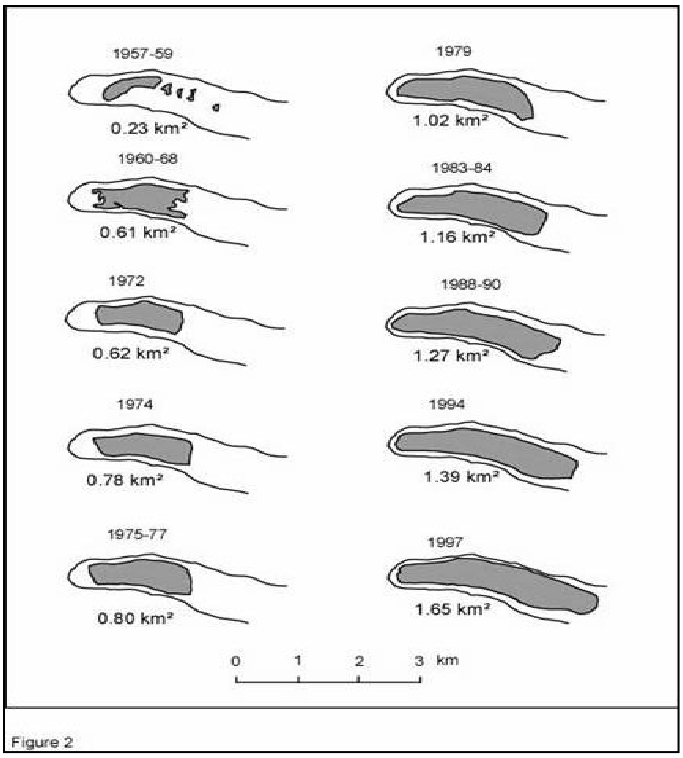
A joint United Nations Environment Programme (UNEP) / International Center for Integrated Mountain Development (ICIMOD) inventory glaciers and glacial lakes in Nepal in 2001 found over 3,252 glaciers, 2,323 glacial lakes, and 20 potential GLOF sites (Figure 9). While this only provides a picture of *static* risk, site based monitoring of specific glacial lakes has shown evidence for increasing lake volumes over time (see Figure 10 for one of the most significant lakes Tsho Rolpa). This trend in increase in lake volume correlates well with observed trends in high rates of temperature increase at high altitudes in the Himalayas, as previously discussed in Section 3.1. Taken together, the ensemble of evidence points to a potentially serious hazard that is closely tied to rising temperatures on account of climate change.

Figure 9. Glacial lakes and potential GLOF sites in Nepal



Source: ICMOD/UNEP 2002

Figure 10. Increase in area of the Tsho Rolpa Glacial Lake 1957-1997



Source: Department of Hydrology and Meteorology, Nepal

Many experts acknowledge that there is most definitely a retreat in glaciers, and glacial lakes have been growing (see figure above). With regard to a lake outburst, there are many trigger mechanisms, including earthquakes, spontaneous breakage of the moraine dam, and events such as the collapse of a large "hanging glacier" into the lake. However, climate change and higher temperatures are contributing to a very rapid increase in the volume of glacial lakes, which significantly increases the probability of catastrophic failure of lake walls as a result of these triggers. Richardson and Reynolds (2000) report that ice avalanches triggered more than half of all the recorded GLOFs in the Himalayas. Furthermore, all of the events occurred between the monsoon months of June and October when lake levels were at their highest. Therefore, increased intensity of monsoon precipitation which has been observed in recent years (and is consistent with climate change projections) could be an additional climate induced risk, in addition to rising temperatures that result in higher lake levels. Empirical evidence on the frequency of GLOF outbreaks seems to support this. Richardson and Reynolds (2000:36) note: "Historical records compiled by the authors of 33 Himalayan GLOFs indicate that the frequency of events appears to be increasing. It is also known that many existing lakes are growing in size as glaciers retreat and their moraine dams degrade. The potential for larger and more frequent floods is undoubtedly increasing."

The impact of the future GLOFs on hydropower will be proportional to the amount of water in the lake, slope of its path downstream, debris and sediment picked up, and proximity of the hydropower plant. In the high Himalaya, riverbanks are very steep and highly variable over short distances. It is likely that a GLOF would cause both vertical and lateral erosion. This would spark off further debris flows and landslides. The loss of the Namche hydropower plant in 1985 did indeed serve as a catalyst for the government and donors to begin to pay attention to GLOF risks in siting and construction decisions for hydropower facilities. For example, in developing the Arun-3 project funded by the World Bank, the threat of a GLOF was brought to the attention of donors during the later stages of decision-making. Donors were sufficiently concerned about the risk of a GLOF that an urgent meeting was called in Paris. After much debate, an investigative study was commissioned for up to half a million dollars. However, the study was never initiated because the Arun-3 project collapsed due to environmental and local community concerns, among varied other reasons.

6.2 Variability of river runoff

Two factors will contribute to increased variability of river runoff: glacier retreat; and changes in timing and intensity of precipitation. Runoff will initially increase as glaciers melt, then later decrease as deglaciation progresses. In addition, decreased winter snowfall means less precipitation would be stored on the glaciers, so this would in turn decrease the spring and summer runoff. Studies on climate variability in Southwest Asia show that decreased winter snowfall does indeed decrease the spring/summer runoff, and it has caused severe droughts in Iran and Pakistan in areas that depend on water from mountain sources (Subbiah, 2001). Winter runoff, on the other hand, would increase due to earlier snowmelt and a greater proportion of precipitation falling as rain.

As discussed above in the section on climate scenarios, precipitation projections show wetter monsoons (with moderate certainty) and drier low flow seasons (with lower certainty). Many of Nepal's rivers are fed by runoff from the over three thousand glaciers scattered throughout the country. These rivers feed the irrigation systems, power grain mills and electricity plants, and supply drinking water for villages for thousands of miles downstream. Some of the most prominent rivers in Nepal have average annual flows of 1,500 m^3/s, including the Koshi, Gandaki, and Karnali. The most severe projections for Nepal show that runoff could reduce by 14%. This would reduce the electricity generation of existing plants. This runoff decrease will affect Nepal's economically feasible hydropower potential; however, with only 1-2% of that potential currently developed, it will be quite some time before opportunities to expand the hydropower supply are constrained by climate change. This does not mean however that *existing facilities* might not be seriously affected by a combination of variable flows, flooding risks, as well as sedimentation brought down by intense rainfall of GLOF events.

Climate change has a number of implications for streamflow variability in Nepal. Shakya (2003) points out that 90% of debris volume in Nepal is transported by approximately 20% of rainfall. With the intense rainfall projected for the monsoon season, sedimentation is another factor that may shorten the operating life of a hydropower plant. There has also been an observed increasing trend in the number of flooding days. On the other hand, there might be significant declines in the dependability of dry season flows in certain rivers, which is quite critical for both water and energy supply. For example, for the Bagmati river, the long term 92.3% dependable flow, which is currently 21.1 m^3/sec, is projected to decline to 9.86 m^3/sec by 2030, and will be only 7.43 m^3/sec under CO_2 doubling (Shakya 2003). On the other hand, the intra-annual *variability* of stream flow is also projected to increase significantly. The current range of the Bagmati is 316.26 (from a low of 21.1 to a high 337.36). Under climate change this variability in flow will increase to 810.37 m^3/sec (from a low of 7.43 to a high of 817.8) – posing considerably more complexity for hydropower planners and engineers in maintaining electricity generation throughout the year.

While the numbers presented here are only illustrative, they do in fact point to changes in the characteristics in the level and variability of streamflow, as well as associated events such as flooding and precipitation risks, that might require adequate incorporation in water resource and hydropower planning, particularly because all except one of Nepal's existing hydropower facilities are of the "run of river" type, with no associated dams, which makes them more vulnerable to streamflow variability[22].

7. Analysis of adaptation options for GLOF risks and streamflow variability

A number of adaptation strategies are in fact available to cope with both GLOF risks as well as changes in streamflow variability. Some of these responses are already in varying stages of implementation within the context of development projects, although such responses tend to be more clustered on the mapping and (engineering based) reduction of GLOF risks, and far less so in the direction reduction in social vulnerability or to cope with enhanced streamflow variability.

7.1 Siting in non-threatened locations

This adaptation option reduces vulnerability of GLOF risks by moving proposed hydropower plants to alternative locations. This risk of a GLOF occurring is relevant to the construction of both small-scale hydropower and large-scale. The former because they are often located in close proximity to potential sites. The latter because of the danger of damage, clogging, and much faster rates of siltation than designs can cope with (Ives, 1986). It is also a concern for roads and communications that usually accompany the construction of a hydropower plant. Other major infrastructure is also threatened. A 1981 GLOF was estimated to have a peak discharge of 16,000 m^3/sec at the source, and it closed the China-Nepal Highway for one year, destroyed the Friendship Bridge, and modified the river for 30 km downstream.

Documents from the Namche Project that was destroyed in the 1985 GLOF event do not give evidence that any "special attention was paid to the possible occurrence of catastrophic geomorphic events, despite the fact that the project was being sited in one of the highest and most precipitous mountain regions in the world" (Ives, 1986: 18). However, after the Namche disaster in 1985, the Austrian Government relocated the plant and built it in another location. It has since been under continuous operation and the risk of GLOF is estimated to be low. However, in relocating hydropower plants, there is the question of whether the generating capacity is lowered, or if transmission costs increase. With the potentially reduced generating capacity, is it still possible to promote industrial and commercial growth at a rapid enough pace? Another concern is that, given the general uncertainty on GLOF risks at this time, investors and energy planners may be reluctant to relocate plants when it is only one of many factors in choosing a site. In discussions with hydropower officials, they stressed that assessments are conducted for a wide variety of risks as a matter of course in developing plants, and GLOFs are being considered more and more.

However, one of the main barriers in effectively incorporation of GLOF risks in project siting is reliable spatial mapping of which lakes are at risk of bursting[23]. This is not straightforward, however, since GLOFs can travel as far as 200 km or more. Catchment-wide analyses should be undertaken to determine the vulnerability downstream of hazardous glacial lakes. Furthermore, secondary damming resulting from the initial GLOF can pose just as great a risk to hydropower plants by forming large reservoirs, which may then burst themselves. In fact, the risk may be even greater, since the reservoirs are much closer to the

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22 Although, conversely, the absence of dams makes such installations safer in the event of glacial lake outbursts, as there would not be a secondary flooding event as a result of the breach of the dam. This also illustrates how suitable adaptation responses to one aspect of climate change impacts, might in fact exacerbate vulnerability to another aspect.

23 The UNEP/ICIMOD inventory of glacial lakes in Nepal and Bhutan is a step in this direction, but other experts observe that the database draws upon somewhat dated information.

plant[24]. An integrated risk management approach is therefore needed to supplement satellite based risk mapping of the lakes themselves.

7.2 Smaller hydropower plants

Hydropower in Nepal is divided into five categories:

- Micro – up to 100 kW
- Small – 101 kW to 10 MW
- Medium – 10 MW to 35 MW
- Large – greater than 35 MW

One adaptation response to GLOF risks is to promote the development of smaller plants would also spread the risk of a catastrophic flooding event and avoid damage to a huge plant with significant sunk costs. Micro-hydropower has the potential to fulfil a large amount of the rural demand for energy. Water wheels (*ghatta*) have already been used in Nepal for hundreds of years to process agricultural products. Nepal has 6,000 rivers and rivulets, with 25,000 traditional *ghatta* in use. Current micro-hydro plants range from 1 to 56 kW, and there are currently 924 units in the country, totalling approximately 10 MW. In addition, there is now a move to privatize hydropower plants with less than 10 MW capacity. For small and medium plants, the Ministry of Finance announced in the budget speech of 2001/02 that HMG will promote private investment in them as a "priority sector". This would encourage private development and increase the skills base of entrepreneurs and workers. Less bureaucracy should also be beneficial to the economic standing of plants. At the moment, a license must be obtained for any hydropower plant greater than 1000 kW.

The development of micro- and small hydro is already in line with Nepal's development priorities, and is being encouraged by both the government and donors. In other words, climate change might be one additional reason to promote a strategy that is already being implemented for reasons of economic development.

One issue is whether small hydropower or smaller scale plants would be sufficient to fuel industrial growth in Nepal. Further investigation is needed to determine this. On the other hand, one of Nepal's uppermost priorities is rural development, and small and micro-hydropower will play a much more important role in that regard. Electricity development can help to diversify the economy, and at the same time relieve some of the pressures – environmental degradation, deforestation, and shifting land-use patterns – that are pushing people to migrate out of the mountains. Micro plants are also normally in the control of the Village Development Committees (VDCs) or private investors, so there is a greater sense of ownership within the community. UNDP Nepal (2001b:17-18) recognizes the benefits of promoting micro-hydropower in achieving goals for rural development and forest conservation: "Rural settlements now face various environmental problems that aggravate poverty and internal migration…Protection and conservation of natural forests in such situations demands more attention to alternative energies like micro-hydro and solar energy. Changing the fuelwood consumption pattern in Humla means support[ing] the communities and the local government to identify the potential sites and installing alternative energy plants that can also lower the scope for diseases like acute respiratory infection (ARI) and blindness. The [District Forest Officer] in Humla encouraged [community based organizations] to install micro-hydro plants to

24 In 1998, the Macchu Picchu hydropower facility in Peru was inundated following a secondary dam burst, resulting in costs of over $200 million (Reynolds, personal communication).

reduce the consumption of pinewood. This helped not only in reducing the pressure on natural forest, but also in improving health, sanitation, indoor environment, and education."

There are however three key concerns with regard to smaller hydropower facilities: (i) cost per unit if energy; (ii) aggregate generation potential; (iii) and for the case of climate change, whether they are an adequate response to the spectrum of risks posed by climate change on hydropower resources in Nepal.

An analysis of the generation cost per kW for medium and large projects is 40% that of small plants, and only 25-33% that of micro-hydro (CETS, 1995). The costs of micro-hydro though have come down significantly since this study was published. Five of the plants have been privatized in the hopes of lightening the government's burden. Despite the greater cost of electricity generated in micro and small hydropower plants, several advantages should not be overlooked. The investment cost of small hydropower is lower, so development of the sector will likely proceed more quickly than when raising capital for a large project. The small hydropower plant is under the control of the district, and can be managed more efficiently. Local expertise and technology is more readily available than for large projects, which often call for foreign assistance. Also, it is not necessary to build dams or storage reservoirs for small plants, so there is less risk of environmental damage.

With regard to whether micro and small hydro facilities will suffice to meet Nepal's electricity demand, the current situation is that Nepal cannot currently absorb the electricity generated by mega-plants. Critics of large projects cite the danger in developing mega hydropower for the reason that India would be the sole export destination, leaving Nepal heavily dependent on one customer (Gyawali, 2001). However, it is important to note that Nepal is currently at only about 15% electrification, and significant increases in its electricity demands are likely in the coming decades as industries develop and as a significant portion of its population moves from biomass to electricity. It is not clear whether such future demands could be adequately met by small and micro-hydro alone, particularly given that at least some climate change impacts (such as increased streamflow variability, decreased low flow dependability, and increased sedimentation might diminish some of the existing hydropower potential).

Finally, while micro and small hydro offer a suitable diversification to GLOF risks, they might not be a good safeguard against variable and low flow situations that are anticipated under certain climate change scenarios. In fact, even the majority of large hydro-power facilities which are "run of river" would be vulnerable, since they do not have large reservoir dams to act as buffers. Thus, the possibility of dry season low-flows would actually argue for the need for *storage* hydro (dams), but which tend to be expensive and associated with other environmental risks that currently make them a low priority for many planners, donors, and environmentalists. The role of storage hydro might therefore be an example of a potential conflict between various development, environmental goals and climate responses, and the costs and benefits might need systematic investigation.

7.3 Reduction in GLOF risks

Another set of adaptation responses to GLOF hazards revolves around the physical reduction in the flooding risks of glacial lakes. Rana *et al* (2000) list several solutions, including:

- Draining the lake by siphon or pump
- Cutting a drainage channel for the lake to periodically drain
- Flood control measures downstream to mitigate the effects of the flood
- Developing a GLOF early warning system

An added benefit of GLOF mitigation measures is that the "methods of remediation can be harnessed to facilitate safe management of the water resource for hydro-electric power at a local scale (micro-hydro power) and for export (major hydro-electric power generation facilities)." (Reynolds and Richardson, 1999) During the consultative workshop on this issue in Kathmandu in March 2003, this notion received considerable support as a way to leverage the efforts from GLOF mitigation. In addition to hydropower, the siphoned water could also be used to supplement dry season flows, maintain adequate water levels in downstream ecosystems to protect valuable fish stocks, supply water for local usage, and even provide recreational facilities. However, the long-term economic feasibility of harnessing these waters may be limited. As one geologist at the Department of Water-Induced Disasters pointed out, these glacial lakes have been formed over several decades or more, and the rate of recharge may likely be less than the rate of draw down if used for other purposes. This would require more careful study into the possibilities of multi-benefit schemes.

GLOF mitigation measures however each have their own disadvantages. Pumping is expensive; because of the remote location at high altitudes, heavy infrastructure must be flown by helicopter to the site. Flood control measures are less desirable because Nepal's topography with steep gradients makes the flood behave unpredictably as it moves downstream, the flood can carry on for 200 km. Further, in effect, it is treating the symptoms rather than the cause, as it does not prevent a GLOF from happening in the first place. GLOF early warning systems tend to be expensive to set up and maintain, and only benefit populations downstream enough to have sufficient lead time.

These disadvantages notwithstanding, there is one instance in Nepal where such responses have in fact already been implemented in an integrated manner. The Tsho Rolpa glacial lake (Figure 8) project in one of the most significant examples of collaborative anticipatory planning by the government, donors, and experts in GLOF mitigation. Tsho Rolpa was estimated to store approximately 90-100 million m^3, a hazard that called for urgent attention. A 150-meter tall moraine dam held the lake, which if breached, could cause a GLOF event in which a third or more of the lake could flood downstream. The likelihood of a GLOF occurring at Tsho Rolpa, and the risks it posed to the 60MW Khimti hydro power plant that was under construction downstream, was sufficient to spur HMG to initiate a project in 1998, with the support of the Netherlands Development Agency (NEDA), to drain down the Tsho Rolpa glacial lake. This effort was led by the Department of Hydrology and Meteorology (DHM), with the technical assistance of Reynolds Geo-Sciences Co., Ltd. of Britain, supported by the UK Department for International Development (DFID). To mitigate this risk, an expert group recommended lowering the lake three meters by cutting an open channel in the moraine. In addition, a gate was constructed to allow water to be released as necessary. While the lake draining was in progress, an early warning system was simultaneously established in 19 villages downstream of the Rolwaling Khola on the Bhote/Tama Koshi River to give warning in the event of a Tsho Rolpa GLOF. Local villagers have been actively involved in the design of this system, and drills are carried out periodically. The World Bank provided a loan to construct the system. The four-year Tsho Rolpa project finished in December 2002, with a total cost of USD 2.98 million from The Netherlands and an additional USD 231,000 provided by HMG.

The goal of lowering the lake level was achieved by June 2002, which reduced the risk of a GLOF by 20%. The complete prevention of a GLOF at Tsho Rolpa necessitates further reducing the lake water, perhaps by as much as 17 meters. Expert groups are now undertaking further studies, but it is obvious that the cost of mitigating GLOF risks is substantial and time consuming. The cost, however, is much less than the potential damage that would be caused by an actual event in terms of lost lives, communities, development setbacks, and energy generation.

7.4 Incorporation of future reduced generation capacity in design

Hydropower generation already has several mechanisms in place to cope with streamflow fluctuations as a result of current seasonal as well as climate variability. For example, a plant may have three in-take channels and turbines to generate electricity during peak runoff season (monsoon). Then during the dry season, one or more in-take channels can be shut off. This allows the plant to generate electricity more efficiently and without incurring losses for excess capacity[25]. This option should be investigated to analyze the economic benefit of designing hydropower plants with the possibility of future lowered capacity, for example, in 25 years. The current design for small hydropower assumes an average lifespan of 50 years, with most investors expecting a return on their investment within 7 years[26]. When questioned about reduced runoff and electricity generation in coming decades, one hydropower expert replied that it would only affect his decision-making if there were greater certainty of significantly reduced runoff *and* if it occurs within 20-25 years. This highlights another constraint in medium to long term planning for climate change impacts, given the considerable uncertainties regarding both the magnitude and timing of many climate change impacts.

7.5 Integrated water resource and disaster management

The above measures are aimed at reducing the direct risks of climate change-induced GLOFs and runoff changes on the hydropower sector. A broader perspective on Nepal's development patterns incorporating migration, watershed management, flood management, and disaster preparedness will also help communities adapt to climate change. One of the most important indicators of vulnerability to climate change and disasters is poverty. This is the unfortunate situation for most Nepalis living in mountainous and hill regions. Only 2% of the land is suitable for cultivation, and it can support only 8% of the population (Tianchi and Behrens, 2002). Human activities to build settlements, cultivate steep slopes, gather fuelwood, and construct other infrastructure have led to severe land degradation. Deforestation is another problem in the mountain areas, leading to increased landslides—up to 12,000 per year—and floods. From 1979-1998, forested area decreased by one third.

With limited opportunities for safe and sustainable livelihoods in the mountains, population densities are growing within the river valleys where vulnerability to GLOFs increases. Migration in Nepal has been triggered through two main factors: population growth and decreased land productivity (Tianchi and Behrens, 2002). In fact, these two causes together have led to recent trends indicating that per capita food production may actually have fallen during recent years. Population growth means there are now more people exposed to GLOFs and other climate-related disasters, and this is compounded by the expansion of infrastructure and settlements into vulnerable areas. At the same time that communities are moving further into the hills, many more are migrating to the Terai, where almost 48% of the population now lives.

The poor land use practices in the mountains then take their toll on the progressively more crowded Terai region through increased floods. The environmental degradation and deforestation that prompted the migration from the highlands are now being observed in the Terai. Like many other developing countries, urban centers are also growing quickly. Over 10% of the population is now in urban areas, and this is growing by about 5% per year. In 2000, Kathmandu already experienced a water stress of approximately 60 million m^3 and a water scarcity of 40 million m^3. Ensuring adequate water resources for all of the country's various uses will become an increasingly urgent issue, especially to take into account climate change. According to the 25-Year Water Plan, Nepal aims to increase hydropower to 22,000 MW, expand irrigation to 90% of irrigable lands, and increase access for domestic water supplies to 100% of the population (Sharma, 2003). Current water availability is 215 km^3, but this is only 26 km^3 during the low

25 S. Devkota and A. Karki: personal communication.

26 S. Devkota: personal communication.

flow season. The amount of water needed to achieve the goals of the 25-Year Water Plan is 60 km^3 for hydropower and 28 km^3 for other uses.

A number of options can reduce vulnerability in all regions of Nepal to climate change and climate-related disasters. Non-structural measures are particularly attractive as they generally involve lower costs than engineering measures and would go a long way towards building capacity for disaster preparedness and water resource management. Such measures include: Developing and implementing land use/zoning policies; maintaining up to date hazard and vulnerability maps; training and capacity building for disaster and water resource management; working with the community to increase public awareness and develop early warning systems and evacuation plans; afforestation and reforestation programs (for reduction in flooding/landslide risk).

7.6 Energy supply and demand management

At its core, the various impacts of climate change (GLOFs, streamflow variability; reduced low flow dependability; increased sediment loads from floods and strong precipitation events) affect Nepal's hydroelectric potential. This is particularly significant, given that hydro contributes over 90% of Nepal's electricity generation. Among the adaptation options in the energy sector therefore are: alternate sources of energy supply, and better demand side management.

The potential non-hydro energy options for Nepal include: Fossil fuels (coal, petroleum, natural gas); Biogas and Agricultural residues; and Solar energy. Agricultural residues, solar and biogas have all made promising inroads into Nepal's energy consumption, but face constraints with regard to their overall potential. The efficiency of conversion is a major constraint for agricultural residues, while cost is the limiting factor for solar photovoltaics. Biogas has been considerably more successful and has the potential to meet one-third of current energy consumption. With regard to fossil energy, Nepal initiated plans to undertake petroleum exploration activities, supported by the World Bank and the International Development Agency. To date, no reserves of petroleum products have been found in the country and all petroleum is imported from India. The Ninth and Tenth Development Plans state that the policy in this regard is to reduce dependency on imports and instead promote indigenous sources. Natural gas has been found in Nepal, approximately 300 million cubic meters, and a model plant in Kathmandu Valley was installed in 1987. Over the past fifteen years, it has shown that natural gas could be used for domestic and industrial use in the Kathmandu Valley. The contribution of coal to Nepal's existing energy demand is quite small. There are 5.1 million tons of coal reserves estimated in Nepal, but the current production methods rely only on traditional tools. The advantage of fossil energy (relative to agricultural residues and biogas) is the greater potential for electricity generation (as opposed to direct energy end-use), given that electrification will be a primary vehicle for Nepal's development in the coming decades. The obvious drawback is that fossil energy (particularly coal) would contribute significantly to greenhouse emissions and climate change, in addition to other health related concerns. This highlights how a potential adaptation response to certain climate induced risks might actually be orthogonal to a greenhouse mitigation strategy. It is therefore all the more important for Nepal to maintain its current high share of hydropower in its electricity generation through suitable adaptation strategies that reduce vulnerability to climate induced risks, rather than a shift to fossil energy. In the case of Nepal this is consistent with current national priorities as representatives of the NPC and other government agencies have specifically stated their preference for hydropower as an indigenous source of energy.

Demand side management should also be an important tool in an energy adaptation strategy. Energy efficient lighting, water pumps, heaters, and cookers are now available in Nepal. Using compact fluorescent lightbulbs (CFLs) rather than incandescent bulbs would reduce by half the electricity for lighting requirements in the industrial, commercial, and residential sectors (Shresthacharya, 2002). One study projects that as much as 13%—5,876 GWh—of total electricity generated during the period 1996-

2010 could be avoided by using CFLs and energy efficient motors, from a technically feasible perspective. Economically, it would be possible to avoid 6.9% of electricity generated. Another benefit to promoting energy efficiency is the mitigation of greenhouse gas emissions. During the 14-year period, CO_2 emissions could decrease 97% from the business-as-usual emission scenario in the residential sector, 37% in the industrial sector, and 28% in the commercial sector (ARRPEEC, 1998). This would yield a 12.6% reduction in costs through demand side management, savings in electricity generation, and installed capacity. This adaptation option would indirectly reduce the risk of damages from a GLOF by the reducing the number of installations needed for electricity. This would mean either less plants existing or less capacity, meaning smaller plants, with reduced exposure to GLOF risk. It also leaves the energy system less vulnerable to climate change, in the event that future runoff changes reduce the capacity of plants to produce electricity. However, in general energy planners have tended to focus on the supply side issues of electricity generation, and not nearly enough on demand side management. Public awareness and incentives for incorporating energy efficiency is also low in Nepal. Finally, savings from energy efficient appliances are not easily predictable by the end users; this is due to distorted electricity prices and the lag times in recouping investment in the appliances

8. Towards prioritization of climate responses in the hydropower sector

An initial step towards prioritization and mainstreaming of responses to climate change in Nepal's hydropower sector was made as part of a consultative workshop on "Climate Change Impacts and Adaptation Options in Nepal's Hydropower Sector with a Focus on Hydrological Regime Changes including GLOF" that was held in Kathmandu, on March 5-6 2003 (Appendix A and B). The primary input to the workshop was a consultant report for the OECD Development and Climate Project produced by the Asian Disaster Preparedness Center (ADPC), and the workshop was organized in partnership with HMG's Department of Hydrology and Meteorology (DHM). As part of the workshop three breakout groups were established to engage government and donor representatives, as well as representatives from NGOs, the private sector, and academia in a discussion of the synergies and trade-offs between various adaptation options related to GLOF hazards, Hydropower, and Social Systems exposed to climate induced water hazards in Nepal.

This exercise was intended as a first step in a more systematic exploration of climate responses by the various stakeholders in Nepal. The results are therefore only illustrative, and briefly summarized below.

8.1 GLOF hazards

Response Option	Effectiveness	Cost	Implementation Barriers
Raising awareness	High	Low	Communication, what kind of media to use
Inventory and monitoring of glaciers and glacial lakes	High	Moderate	Lack of appropriate data, local capacity, funding
Vulnerability and risk assessment	Medium-High	Moderate	Lack of appropriate data, local capacity, funding
Research for multiple benefits of mitigation measures	High	Medium-High	Funds
Land use planning	Moderate	Moderate	Lack of coordination between agencies, with communities
Developing a national policy and action plan	Medium-High	High	Funds, political will
Mitigation and early warning systems, including drawing down water and storage for deglaciation	Medium-High	High	Funds, logistics, local capacity
Relocation of population	Uncertain	High	Social acceptance

An important point from the discussion on adaptation options for GLOF hazards, which is also relevant for other two issues, is that prioritization was difficult at this early stage. It is likely that several of the options would be implemented in tandem. For example, a risk assessment can only be undertaken once there is the knowledge of the locations and characteristics of the glacial lakes and/or glaciers in the process of developing supra-glacial lakes that may become risky. However, there will be positive feedback between each of the options such that the inventory would influence what the national policy and action plan should be, policies would influence land use planning, and so on. Furthermore, the range of options and their individual definitions can be refined, given more time and discussion between stakeholders. Implementation of action plans and inventories also depends on the modalities of the institutions involved, and their local capacity in terms of human, physical, and funding resources. The formulation of a national policy and an action plan should involve the adoption of political ownership and recognition by government agencies such as the National Planning Commission.

8.2 Hydropower

This group ranked the effectiveness and costs of each option from 1-10, with 1 meaning “most effective” or “least cost”, while 11 means “least effective” or “greatest cost”. Discussion on this issue stressed the importance of recognizing that GLOF risks should not pose excessive barriers to hydropower developments. Planners, donors, and investors should undertake risk assessments and work to understand how GLOFs and climate change can be managed. Some participants were concerned that the idea of climate change and GLOFs would lead some people to automatically rule out large hydropower plants. One advantage of large hydropower discussed during the consultative workshop is that reservoirs can provide dependable flows for electricity generation, supplement water supplies for domestic and agriculture uses during the dry season, and if properly designed, they may play a role in flood management. These possible benefits must be carefully weighed any against environmental impacts and the enhanced GLOF risks. Thorough risk assessments that closely examine climate-related hazards will provide a more accurate perspective of the costs and/or benefits of small versus large hydropower for a given site and need. The table above illustrates that, without information on a particular site's vulnerability, the preference is for smaller hydropower projects.

Option	Effectiveness	Cost
Lower risk site	2	1
Priority for high head schemes	3	2
Priority for run-of-river schemes	9	7
Watershed management	5	4
Reservoirs	10	9
Increased spillway design capacity	6	6
Multiple units within one plant	8	8
Develop hydropower from GLOF mitigation measures	11	11
Design structures with proper de-sanding/flushing system	4	5
Multiple projects to maintain generation capacity	7	10
Research	1	3

8.3 Social systems

The ultimate end-point of all climate induced water hazards in Nepal are the communities that are vulnerable to such impacts, primarily in mountain regions but also downstream in low-lying areas that suffer the consequences of flooding or reduced water/energy supply. In addition to the loss of life in flooding events such as GLOFs, it is the loss of livelihoods that is far more significant and long lasting. The washing away of a mountain bridge can often cut-off access to agricultural land or fuelwood, while landslides often render land unsuitable for cultivation. Yet, the primary emphasis of responses to water hazards and risks to hydropower generation have focused on engineering solutions such as better design of hydropower facilities or drainage of glacial lakes. Considerably less attention is paid to alternate measures to reduce the vulnerability of social systems to such impacts. Some of the response measures that could be undertaken this category were considered under the Social Systems breakout group.

Option	Effectiveness	Cost	Implementation Barriers
Early warning systems	High	High installation & cumulative maintenance; Low daily maintenance	Lack of awareness; political instability
Water storage for livelihoods	High	High dams and reservoirs; Low ponds	Lack of investment; implications for other environmental problems; lack of awareness
Planning new settlements in low risk areas	Very high	High	Lack of awareness; lack of adequate hazard mapping
Resettlement in low risk areas	High	High	Lack of awareness; lack of will to move
Non-agriculture employment	Low	High	Lack of education; lack of willingness; lack of non-agriculture opportunities
Develop drought-resistant cultivars	High	Low	Lack of information; high cost of new varieties

The above measures could be part of a broader agenda to mainstream climate change concerns in poverty reduction and rural development efforts. Elements of such an agenda - as identified in the Multi-Agency Report on Poverty and Climate Change (World Bank et al. 2003) - include: improving social networks to cope with climate related disasters; increasing the resilience of natural systems and their productivity in order to support the livelihoods of the poor; infrastructure solutions; boosting human capital through better education and awareness programs related to the potential impacts of climate change; and promoting safety net and risk spreading mechanisms to cope with climate risks.

9. Conclusions and further issues

9.1 Climate trends, scenarios and impacts

This integrated analysis reveals that the need for mainstreaming climate change responses in development planning and assistance is particularly acute for Nepal. Nestled in the Hindukush Himalayas Nepal is one of the poorest countries in the world, with the mountains and related water resources underpinning its economic and energy infrastructure. An observed warming trend over the past several decades is already having discernible and generally adverse impacts on both these key resources – many mountain glaciers are in a general state of retreat, and some are expected to disappear entirely in the coming decades. Glacier retreat and ice melt more generally are also significantly increasing the size and volume of several of Nepal's more than two thousand glacial lakes, making them more prone to glacial lake outburst flooding (GLOF).

Climate change scenarios across multiple general circulation models meanwhile show considerable convergence on continued warming, with country averaged mean temperature increases of 1.2°C and 3°C projected by 2050 and 2100. Continued glacier retreat can also reduce dry season flows fed by glacier melt, while there is moderate confidence across climate models that the monsoon might intensify under climate change. This contributes to enhanced variability of river flows. Potential intensification of monsoons combined with enhancement of GLOF risks also contributes to enhanced risk of flooding and landslides which can have serious a impact on mountain agriculture and rural livelihoods. A subjective ranking of key impacts and vulnerabilities in Nepal identifies water resources and hydropower as being of the highest priority in terms of certainty, urgency, and severity of impact, as well as the importance of the resource being affected.

9.2 Attention to climate change concerns in national planning

At the national level meanwhile Nepal has no specific policy documents dealing with climate change. Nepal's Tenth Development Plan, which has been developed as the country's PRSP, has poverty reduction as its central focus. Although the plan acknowledges the important influence weather can have on overall economic performance, explicit attention to climate risks is lacking. The Development Plan is accompanied by a Medium Term Expenditure Framework (MTEF), which provides a prioritization of resources and ensures consistency of annual budgets with the 5-year Development Plan. The sectoral MTEF papers for some of Nepal's vulnerable sectors lack consideration of climate change induced risks, for example the MTEF paper for the power sector does not recognize risks to hydropower plants due to the variability in runoff, floods (including GLOFs), and sedimentation. Nepal has yet to submit its first National Communication under the UN Framework Convention on Climate Change. Nepal's recent National Communication to the UN Convention on Biodiversity, to the UN Convention on Combating Desertification as well as its report to the World Summit on Sustainable Development (WSSD) make only marginal references to climate change.

9.3 Attention to climate change concerns in donor portfolios and projects

Nepal receives between US$ 350 and 400 million of development assistance annually. An analysis of donor projects in Nepal using the OECD/World Bank Creditor Reporting System (CRS) database reveals that roughly 50-65% (in terms of investment dollars) and 26-33% (in terms of number of projects) of donor portfolios in Nepal are potentially affected by climate risks. This includes both activities in sectors which may be impacted by climate change, as well as those development activities which may influence the vulnerability of natural or human systems to climate change. These numbers are only indicative, given that any classification based on sectors suffers from problems related to over-simplification. Nevertheless, such measures can serve as a crude barometer to assess the degree to which particular projects or development strategies may need to take climate change concerns into account.

Despite discernible impacts that can be related to climate change, Nepal has generally not received sufficient attention or funding from international efforts on adaptation to climate change. Meanwhile, on the development side, an analysis of donor country strategies and project documents reveals that such documents also do not mention climate change explicitly. Yet, field visits and consultation with government officials and donor representatives present a more nuanced picture[27]. Efforts are in fact underway to manage at least some of the risks, such as GLOFs, as part of their ongoing development projects and plans – albeit in a narrow engineering sense.

9.4 Climate change: water resources and hydropower

The most critical impacts of climate change in Nepal can be expected to be on its water resources, particularly glacial lakes, and its hydropower generation. Water supply infrastructure and facilities are at risk from increased flooding, landslides, sedimentation and more intense precipitation events (particularly during the monsoon) expected to result from climate change. Greater unreliability of dry season flows, in particular, poses potentially serious risks to water supplies in the lean season. Hydroelectric plants are highly dependent on predictable runoff patterns. Therefore, increased climate variability, which can affect frequency and intensity of flooding and droughts, could affect Nepal severely. GLOF and increased run-off variability threatens the potential for hydropower generation. GLOFs have already been associated with the loss of a newly built multi-million dollar hydropower facility in 1985, as well as significant loss of other infrastructure such as bridges, roads, livelihoods, and human life. Given that Nepal's electricity infrastructure heavily relies on hydro power - nearly 91% of the nation's power comes from this source - a reduced hydropower potential might imply that Nepal will have to seek for alternative sources of power generation, including from fossil fuel sources. In other words, failure to adapt to climate induced risks to hydropower might also be critical from the perspective of greenhouse mitigation. However, uncertainties in climate projections and lack of reliable hydrological records remain an important constraint for effective anticipatory planning.

9.5 Towards mainstreaming climate concerns in development planning: constraints and opportunities

Preliminary discussions with regard to prioritization of adaptation strategies and their mainstreaming with national stakeholders revealed that development priorities and climate responses can be complementary instead of orthogonal. For example, setting up micro-hydro generation facilities serves multiple development goals, including rural development and employment of women, in addition to serving as an effective diversification strategy for GLOF hazards. On the other hand, there are instances where climate risks and development paths might be on a collision course. For example, the construction of new roads, frequently in river valleys is encouraging settlements in precisely those areas that might be more vulnerable to flooding. Another critical issue for Nepal, where competing environmental and development priorities lead to conflicting priorities, is the case of storage hydropower. The growing demands for water and electricity, coupled with reduced dependability of low season flows under climate change would suggest the need for a greater role for storage hydro facilities as an adaptation response, as

27 This also highlights one limitation of "top-down" analyses of project documents for mention of climate change to infer the extent to which projects do in fact take into account climate change related concerns.

opposed to the conventional run-of-river schemes. Construction of dams, however, is currently not being encouraged, in large part due to other environmental risks posed by them. While addressing one impact of climate change (low flows), dams might in fact exacerbate societal vulnerability to another climate change impact (GLOFs), because the breach of a dam following a GLOF might result in a second flooding event. In such complex situations, it is not a case of binary choices, but of attempting to avoid premature closure of particular policy options. Sensible decision-making is needed on a case by case basis so that the implications (including from a climate perspective) of all choices can be suitably incorporated in final decision-making.

While there is evidence of significant collaboration between donors and the government, a key constraint is the capacity of host agencies and institutions – particularly the Department of Hydrology and Meteorology – to field simultaneous multiple and diverse requests from various donors. The amount, continuity, and scope of project funding remains a continuing concern. Further, donors point to a lack of co-ordination across various national government agencies, whereas government agencies point to a lack of co-ordination across donors. Funding in the hydropower sector has also traditionally been more readily available for infrastructure for risk reduction, as opposed to training and capacity building efforts that might contribute to vulnerability reduction. Further, generally only *current* risks are incorporated in project planning. The evidence is at best mixed as to whether plans and projects incorporate the *increase* in risks that are projected with a changing climate. This might be one area where climate change funds and projects could be used to complement existing development funding by focusing on training and capacity building, as well as longer term risk and vulnerability reduction.

Finally, there is also an important trans-boundary or regional dimension to both climate change impacts and responses. Many catastrophic GLOF events in Nepal, in fact originated in Tibet. Conversely, decisions about water resource management or hydropower generation in Nepal affect neighboring countries. Therefore, in addition to national discourses on linkages between climate change and development, such discussions might also be needed at a regional level to formulate co-ordinated strategies.

REFERENCES

Agrawala, S. and M. Berg, 2002, "Development and Climate Change Project: Concept Paper on Scope and Criteria for Case Study selection. COM/ENV/EPOC/DCD/DAC(2002)1/Final, OECD, Paris.

ARRPEEC, 1998. *Energy, Environment, and Climate Change Issues: Nepal*. Study by the Asian Regional Research Program in Energy, Environment, and Climate. Asian Institute of Technology, Bangkok

Barry, R.G., 1994. "Past and Potential Future Changes in Mountain Environments: A review," in M. Beniston, ed. *Mountain Environments in Changing Climates.* London: Routledge

Bhadra, B., 2002. "Hydro-Energy for National Development: Issues in Small and Medium Hydro Electricity Development" in S.K. Khatri and H. Uprety (eds) *Energy Policy: National and Regional Implications.* Nepal Foundation for Advanced Studies, Kathmandu

Boer, G.J., N.A. McFarlane, and M. Lazare. 1992. Greenhouse gas-induced climate change simulated with the CCC second-generation general circulation model. *Bulletin of the American Meteorological Society* 5:1045-1077.

CETS, 1995. *Sustainable Development of Small Hydropower in Nepal*. Centre for Economic and Technical Studies, Kathmandu

Chalise, S.R., 1994. "Mountain Environments and Climate Change in the Hindu Kush-Himalayas," in M. Beniston, ed. *Mountain Environments in Changing Climates*, London: Routledge

CIA. 2002. The World Factbook. http://www.odci.gov/cia/publications/factbook/print/np.html. Accessed January 6, 2003.

Country Study Team–Nepal, 1997. "Climate Change Vulnerability and Adaptation: Nepal Water Resources", prepared as part of the US Country Studies Program, Washington, DC

GRID-ARENDAL News. 2002. http://www.grida.no/inf/news/news02/news30.htm. Accessed December 30, 2002.

Gyawali, D., 2001. *Water in Nepal*. Kathmandu: Himal Books

ICIMOD and UNEP, 2002. *Inventory of Glaciers, Glacial Lakes, and Glacial Lake Outburst Floods Monitoring and Early Warning Systems the Hindu Kush – Himalayan Region: Nepal*. International Center for Integrated Mountain Development, Kathmandu

ICIMOD, 1996. *Climatic and Hydrological Atlas of Nepal.* International Center for Integrated Mountain Development, Kathmandu

IPCC, 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability Summary for Policymakers.* Intergovernmental Panel on Climate Change, Geneva

Ives, J.D., 1986. *Glacial Lake Outburst Floods and Risk Engineering in the Himalaya.* ICIMOD Occassional Paper No. 5. International Center for Integrated Mountain Development, Kathmandu

Liu, X. and B. Chen, 2000. “Climatic Warming in the Tibetan Plateau During Recent Decades,” in *International Journal of Climatology* **20**: 1729-1742.

Mishra, C., 2000. “Development Practice in Nepal: An overview” in K.B. Bhattachan and C. Mishra (eds) *Developmental Practices in Nepal*. Central Department of Sociology and Anthropology, Tribhuvan University, Kathmandu

Mool, P., S. Joshi, T. Yamada, T. Kadota, Y. Ageta, and V. Galay. 2003. ICIMOD, WECS, JICA-Nepal. http://www.rrcap.unep.org/glofnepal/guide/movie.html. Accessed January 19, 2003.

Rana, B., A.B. Shrestha, J.M. Reynolds, R. Aryal, A.P. Pokhrel, and K.P. Budhathoki, 2000. “Hazard assessment of the Tsho Rolpa Glacier Lake and ongoing remediation measures,” in *Journal of Nepal Geological Society*, 2000. Vol. 22, pp. 563-570.

Reynolds, J. and S. Richardson, 1999. “Geological Hazards: Glacial” in J. Ingleton (ed) *Natural Disaster Management: A presentation to commemorate the International Decade for Natural Disaster Reduction.* Leicester, UK:Tudor Rose

Reynolds, J.M., 1998. “High-altitude glacial lake hazard assessment and mitigation: a Himalayan perspective” in J.G. Maund and M. Eddleston (eds) *Geohazards in Engineering Geology.* Geological Society, London, Engineering Geology Special Publications, **15**, 25-34

Richardson, S. and J. Reynolds, 2000. “An overview of glacial hazards in the Himalayas,” in *Quaternary International* 65/66 (2000): 31-47

Shakya, N.M., 2003. “Hydrological Changes Assessment and Its Impact on Hydro Power Projects of Nepal” in draft proceedings of the *Consultative Workshop on Climate Change Impacts and Adaptation Options in Nepal’s Hydropower Sector with a Focus on Hydrological Regime Changes Including GLOF*, Department of Hydrology and Meteorology and Asian Disaster Preparedness Center, 5-6 March 2003, Kathmandu

Sharma, K.P., 2003. “Impact of Climate Change on Water Resources of Nepal” in draft proceedings of the *Consultative Workshop on Climate Change Impacts and Adaptation Options in Nepal’s Hydropower Sector with a Focus on Hydrological Regime Changes Including GLOF*, Department of Hydrology and Meteorology and Asian Disaster Preparedness Center, 5-6 March 2003, Kathmandu

Sharma, K.P., N.R. Adhikari, and R.G. Karbuja, 2002. *Vulnerability and Adaptation of Water Resources to Climate Changes in Nepal*. Interim report prepared for the UNFCCC Initial National Communication. Central Department of Hydrology and Meteorology, Tribhuvan University, Kathmandu

Shrestha, A.B., 2003. “Climate Change in Nepal” in draft proceedings of the *Consultative Workshop on Climate Change Impacts and Adaptation Options in Nepal’s Hydropower Sector with a Focus on Hydrological Regime Changes Including GLOF*, Department of Hydrology and Meteorology and Asian Disaster Preparedness Center, 5-6 March 2003, Kathmandu

Shrestha, A.B., C.P. Wake, J.E. Dibb, and P.A. Mayewski, 2000. “Precipitation Fluctuations in the Nepal Himalaya and Its Vicinity and Relationship with Some Large Scale Climatological Parameters” in *International Journal of Climatology,* (20) 317-327

Shrestha, A.B., C.P. Wake, P.A. Mayewski, and J.E. Dibb, 1999. "Maximum Temperature Trends in the Himalaya and its Vicinity: An Analysis Based on Temperature Records from Nepal for the Period 1971 – 94" in *Journal of Climate,* (12) 2775-2789

Shrestha, N.R., 1998. *In the Name of Development: A Reflection on Nepal.* Educational Enterprises (P), Ltd., Kathmandu

Shresthacharya, A., 2002. *Energy Economics in Nepal: Issues and Options*. Kathmandu: Udaya Books

Subbiah, 2001. *Climate Variability and Drought in Southwest Asia.* Asian Disaster Preparedness Center, Bangkok

Tianchi, L. and J. Behrens, 2002. *An Overview of Poverty, Vulnerability, and Disaster Management in Nepal*, paper prepared for under the Participatory Disaster Management Programme, ICIMOD, UNDP, and HMG/N, Kathmandu

UNDP, 2001a. *Rural Energy for Sustainable Development: Annual Report 2001*. Rural Energy Development Program, UNDP, Kathmandu

UNDP, 2001b. *Annual Report 2001: Towards a Sustainable Future*. UNDP, Kathmandu

UNEP, 2001. *Nepal: State of the Environment*. United Nations Environment Programme, Nairobi

UNEP/ICIMOD. 2002. www.unep.org/unep/eia/ein/grid/icimod/. Accessed December 30, 2002.

United Nations. 2002. United Nations Chronicle. http://www.un.org/pubs/chronicle/2002/issue3/0302p48_glacial_lakes_flood_threat.html. Accessed January 6, 2003.

World Bank, 2003. *World Development Report 2003: Sustainable Development in a Dynamic World.* New York: Oxford University Press

World Bank (ADB, AfDB, DFID, OECD and others), 2003: *Poverty and Climate Change: Reducing the Vulnerability of the Poor Through Adaptation*, 43pp.

World Bank. 2002. World Development Indicators. On CD Rom. World Bank, Washington, DC.

WRI. 2000. *World Resources: 2000-2001.* World Resources Institute, Washington, DC.

Yogacharya, K.S. and M.L. Shrestha. 1997. A Report on Climate Change Scenarios for Nepal. Prepared for the U.S. Country Studies Program by the Centre for Research Team, Kathmandu, Nepal.

Yogacharya, K.S. and R.B. Pradhan. 1997. A Report on Vulnerability and Adaptation Assessment of Climate Change Scenarios in Agricultural Production System in Nepal. Center for Agriculture Technology, Kathmandu, Nepal. February.

Yogacharya, K.S. and T.M. Gurung. 1997. Sector: Water Resources. Dynamic Systems (Ltd), Kathmandu, Nepal.

ANNEX. SOURCES FOR DEVELOPMENT PLANS AND PROJECTS

Statistics

CRS database, OECD/World Bank http://www.oecd.org/htm/M00005000/M00005347.htm

Documents of His Majesty's Government (HMG) of Nepal

Tenth Plan/PRSP

- concept paper (2002) http://www.ndf2002.gov.np/
- website http://npc.gov.np:8080/tenthplan/the_tenth_plan.htm

Medium Term Expenditure Framework (MTEF)

- Papers for MTEF (2002) http://www.ndf2002.gov.np/consult.html
- Final MTEF (2002) http://npc.gov.np:8080/prsp/mtef_prsp/index2.jsp

Donor Review for 2002 Development Forum (2002) http://www.ndf2002.gov.np/
National Planning Commission www.npc.gov.np

UN Conventions

UN Convention to Combat Desertification (UNCCD) www.unccd.int

- National Report (2000)

UN Convention on Biodiversity (UNCBD) www.biodiv.org

- Nepal Biodiversity Strategy (2002)
- National Report (1997)
- Second National Report (2001)

National Sustainable Development Strategy

- Sustainable Development Agenda for Nepal (2002) ***http://www.scdp.org.np/sdan/***

World Summit on Sustainable Development

- Country Profile (2002) ***http://www.scdp.org.np/wssd/***
- National Assessment Report (2002) ***http://www.scdp.org.np/wssd/nar/index.html***

UN Economic and Social Commission for Asia and the Pacific

- Nepal Country Paper (1996) http://www.unescap.org/tctd/gt/nepal.htm
- Update report (2001) ***www.unescap.org/tctd/gt/nepal2001.htm***

Donor reports

ADB www.adb.org

- Country Assistance Plan (2000)
- Melamchi water supply project, Report and Recommendation of the President (2000)
- Seventh Power Project, Project Completion Report (2001)
- Forestry Sector Program, Project Performance Audit Report (2001)
- Mini-hydropower project, Project Performance Audit Report(1998)

DANIDA

- Community forestry development sector programme (1999)
- Environment Sector Programme (1999)
- Natural Resource Management Sector Assistance Programme (1999)

DFID *www.dfid.gov.uk*

- Country Strategy Paper (1998)

IFAD

- Country Strategic Opportunities Paper (2000), report no. 1077-NP
- Western Upland Poverty Alleviation Project (Report and Recommendation of the President, 2001, environmental screening and scoping note)

ÖEZA (Austrian Development Cooperation)

- Small Hydro Project Evaluation Nepal & Bhutan, Final Report (2001)
- Namche Bazaar Small Hydropower Project, same report
- Makulu-Barun National Park Buffer Zone Development (Eco Himal),Project proposal (2002)
- Thame Valley Village Development (Eco Himal), Project Document, (2001)

UNDP www.undp.org.np

- Country Cooperation Framework (2002)
- Sustainable Community Development Programme (1999)
- Made in Nepal: Nepal’s Sustainable Community Development Programme. Capacity21 Approaches to Sustainability Country Study (2001)

UNEP www.unep.org

- UNEP/ICIMOD GLOF inventorization (2002) ***http://www.rrcap.unep.org/glofnepal/guide/movie.html***

USAID ***www.usaid.gov***

- Nepal Annual Report (2002)

World Bank ***www.worldbank.org***

- Country Assistance Strategy (1998)
- Country Assistance Strategy Progress Report (2002)
- Country Brief (2002)
- Economic Update (2002) ***http://www.ndf2002.gov.np/***.
- Power Development Project, Project information document (2002)
- Power Development Project – Sectoral Environmental Assessment (by HMG)
- The Policy Framework for Environmental Impact Assessment for projects under the Power Development Fund (1999)
- Proposed Power Sector Development Strategy (2001)
- Irrigation Sector Project, Project Appraisal Document (1997)
- Second Rural Water Supply Project, Project Information Document (2001)
- Road Maintenance and Development Project, Project Appraisal Document (1999)
- Rural Infrastructure Project, Project Appraisal Document (1999)

APPENDIX A

Consultative Workshop on Climate Change Impacts and Adaptation Options in Nepal's Hydropower Sector with a Focus on Hydrological Regime Changes including GLOF, Kathmandu, March 5-6 2003

Wednesday, 5 March 2003

09:00- 09:30	Registration
	Inaugural Session **Chief Guest:** ***Academician Dipak Gyawali,*** **Hon*****. Minister, MoWR*** **Chairperson:** ***Prof. Dr. Dayananda Bajracharya, VC, RONAST***
09:30	Arrival of Chief Guest
9:30- 9:35	Welcome Address: *Mr. Adarsha P. Pokhrel, DG, DHM*
9:35- 9:45	Welcome Address: *Dr. Shardul Agrawala, Environment Directorate, OECD*
9:45- 9:50	Introduction and Objectives of Workshop *Ms. Vivian Raksakulthai, ADPC*
9:50- 10:05	Inauguration and Inaugural Speech: *Academician Dipak Gyawali,* *Hon. Minister, MoWR*
10:05- 10:10	Chairperson's Remark
10:10- 10:15	Vote of Thanks: *Dr. Madan Lall Shrestha, DDG, DHM*
10:15- 10:45	Refreshments

	Session I **Chairperson:** ***Prof. Suresh R. Chalise*** **Rapporteur:** ***Mr. Om Ratna Bajracharya/Mr. Suresh Marahatta***
10:45- 11:05	Climate Change in Nepal *Dr. Arun Shreshtha, DHM*
11:05- 11:25	Impact of Climate Change on Water Resources of Nepal *Dr. Keshav P. Sharma, DHM*
11:25- 11:50	Climate Change and GLOF Risks *Mr. Pradeep Mool, ICIMOD*
11:50- 12:10	A Case Study of Tam Pokhari GLOF, 1998 *Mr. Shri Kamal Duibedi, DWIDP*
12:10- 12:30	Impact on Hydrology of Nepal due to Climate Change and its Impact on Hydropower Projects. *Dr. Narendra Shakya, IOE*
12:30- 13:00	Discussion
13:00- 13:45	Lunch
	Session II **Chairperson:** ***Dr. Janak L. Karmacharay, MD, NEA*** **Rapporteur:** ***Om Ratna Bajracharya/Saraju Baidya***
13:45- 14:00	Hydropower Development Plan *Devi Bahadur Thapa, NEA*
14:00- 14:20	Climate Change GLOF and Small Hydropower; Their Inter-linkages *Mr. Pushpa Chitrakar, GTZ*
14:20- 14:50	Adaptation for Nepal: Challenges and Opportunities *Prof. Bidur P. Upadhayay, CDHM, TU*
14:50- 15:05	Tea/Coffee break

15:05- 15:35	Discussion
15:35-16:00	Introduction to Adaptation Assessment Tool *Ms. Vivian Raksakulthai, ADPC*

Thursday, 6 March 2003

	Session III ***Chairperson:Dr. Binayak Bhadra, ICIMOD*** **Rapporteur:** ***Ms. Vivian Raksakulthai, ADPC***
09:00- 9:15	Introduction to Adaptation Assessment Tool *Ms. Vivian Raksakulthai, ADPC*
9:15- 9:30	Synthesis and Review of Day 1 *Dr. Shardul Agrawala,, OECD*
9:30- 10:00	Introduction and guidelines for Working Groups *Mr. Adarsha P. Pokhrel, DHM*
10:00- 11:15	Group Discussion (Tea/Coffee Served)
	Session IV ***Chairperson: Mr. Bikash Pandey, Winrock International*** **Rapporteur:** ***Ms. Vivian Raksakulthai, ADPC***
11:15- 12:00	Presentation by Groups and Discussion
	Concluding Session **Chairman:** ***Hon. Dr. Yuvraj Khatiwada, NPC*** **Rapporteur*:*** ***Dr. Arun B. Shrestha, DHM***
12:00- 12:30	• Recommendations by *Mr. Bikash Pandey* • Concluding Remarks by *Chairman*
12:30- 13:15	Lunch

APPENDIX B

LIST OF PARTICIPANTS

Consultative Workshop on Climate Change Impacts and Adaptation Options in Nepal's Hydropower Sector with a Focus on Hydrological Regime Changes including GLOF, Kathmandu, March 5-6 2003

Name	**Title/Affiliation**
Dipak Gyawali	Hon.Minister, MoWR
Yuvraj Khatiwada	Hon. Member, NPC
Adarsha P. Pokhrel	Director General, DHM
Madan L. Shrestha, Dr.	Deputy Director General, DHM
Keshav P. Sharma, Dr.	DHM
Purna B. Shrestha	Consultant, DHM
Arun B. Shrestha, Dr.	Hydrologist, DHM
Birbal Rana, Dr.	Meteorologist, DHM
Tony Carvalho	USAID
Puspa Chitrakar	Sen. Eng Adv., GTZ
Janak Lal Karmacharya, Dr.	MD, NEA
Devi Bahadur Thapa, Dr.	NEA
Bhoj Raj Regmi Director	NEA
Tek Gurung	UNDP
Bidur P. Upadyaya, Prof. Dr.	Head of Department, Tribhuvan University
Lochan P. Devkota	Assoc. Prof., Tribhuvan University
Khadga B. Thapa	Professor, Tribhuvan University
Deepak Kharal Forest	Economist, WECS
Binayak Bhadra, Dr.	DDG, ICIMOD
Mandira Shrestha	Water Res. Spec., ICIMOD
Pradeep K. Mool,	GIS Spec., ICIMOD
Kamal Risal	ICIMOD
Purushottam Kunwar	Under Secretary, MoPE
Narendra Shakya, Dr.	Institute of Engineering
Rabindra Bhattarai	Institute of Engineering
Bal Krishna Sapkota	Institute of Engineering
Lekh Man Singh, Dr.	DG, DoED
Dilli Bahadur Singh	DoED
Madan B. Basnet, Dr.	Director, AEPC
Vishwo B. Amatya	AEPC
Mahesh Banskota, Dr.	Director, IUCN
Bikas Pandey	Country Repr., Winrock
Manoj Ghimire	Kathmandu

Ajaya Dixit	NWCF
Shri Kamal Duibedi	DWIDP, Jawalakhel
Janak Lal Nayava, Dr.	Vice Chairman, SOHAM-Nepal
Jaya Pal Shrestha	Reg. Env. Special, Embassy of USA
Michael R. DeTar	Reg. Env. Officer, Embassy of USA
John Reynolds, Dr.	Director, Reynolds Geosciences
Vivian Rakshakulthai	ADPC
Shardul Agrawala, Dr.	Administrator, OECD
Ramesh Regmi	Meteorologist, DHM
Saraju Baidya	Meteoroligist, DHM
Suresh Marahatta	Secretary, SOHAM-Nepal
Om Ratna Bajracharya	Sen. Div., DHM
Keshav R. Sharma	DHM
Kumar Rajbhandari	Organizer
Usha Joshi	DHM, Organizer
Bharat Regmi	DHM, Organizer
Santosh Ram Joshi	Program Assistant, IUCN
Ajay Karki	GTZ Small Hydro Project
Krish Krishnan	International Resources Group

APPENDIX C

GCM Predictive Errors for Each SCENGEN Model for Nepal

These tables show the predictive error for annual precipitation levels for each SCENGEN model for each country. Each model is ranked by its error score, which was computed using the formula 100*[(MODEL MEAN BASELINE / OBSERVED) - 1.0]. Error scores closest to zero are optimal. For Nepal, the first seven models had significantly lower error scores than the remaining 10; therefore, the latter 10 were dropped from the analysis.

	Average[a] error	**Minimum error**	**Maximum error**
Models to be kept for estimation			
BMRCTR98	46%	24%	79%
ECH4TR98	49%	9%	113%
LMD_TR98	65%	55%	91%
ECH3TR95	67%	28%	158%
MRI_TR96	76%	15%	209%
W&M_TR95	92%	0%	227%
HAD3TR00	96%	2%	253%
Models to be dropped from estimation			
CSI2TR96	125%	4%	374%
CSM_TR98	125%	16%	292%
CERFTR98	153%	21%	340%
PCM_TR00	155%	13%	343%
IAP_TR97	187%	8%	421%
CCSRTR96	201%	87%	383%
HAD2TR95	225%	73%	589%
GFDLTR90	237%	36%	513%
GISSTR95	270%	111%	551%
CCC1TR99	325%	206%	475%

a. SCENGEN outputs data for 5×5 degree grids. To estimate for an entire country, a 10×10 degree area was used and the data output from the resulting four 5×5 grids were averaged. The maximum and minimum of these four 5×5 grids are also reported.

APPENDIX D

Analysis of Select Development Project and Strategy Documents

D.1 Projects dealing explicitly with climate related risks

D.1.1 UNEP/ICIMOD GLOF inventorization

This three-year study was a collaboration between UNEP and the International Center for Integrated Mountain Development (ICIMOD) in Katmandu. It concluded that as a conservative estimate, 20 glacial lakes in Nepal (and 24 in Bhutan) are at high risk of bursting their banks in the coming five years, causing the so-called Glacial Lake Outburst Floods (GLOFs). The rising GLOF risk is attributed to increased glacier melt related to global warming. Adaptation options include engineering works to reduce water levels in the lakes, and early warning systems to alert people in the region about impending floods.

D.1.2 Austrian Development Cooperation GLOFS research project

A research project funded by Austrian Development Cooperation also analyzed GLOF risks in Bhutan and Nepal. The research in Bhutan also included the design of mitigation measures, including the erection of protection walls for some of the houses downstream, the installation of an early warning system (at the study site, floods are estimated to take seven hours to reach the main populated areas), the introduction of a hazard zonation concept, as well as awareness raising.

D.2 Other development programs and projects

D.2.1 Sustainable community development program (UNDP, 1999)

The UNDP-supported Sustainable Community Development Program[28] (until 1999) focused at arrangements for local level development activities, but has no references to natural hazards. Nevertheless, its watershed management activities contribute to a reduction of landslides, flooding and erosion. The Program also contained an interesting pilot project, the so-called Eco-Village. A small village of sixteen households switched to biogas as energy source. While promoting renewable energy, the pilot also resulted in a higher forest cover in watershed areas, thus reducing the risks mentioned above and contributing to adaptation. A true overlap of mitigation and adaptation to climate change.

D.2.2. Rural Energy Development Programme (REDP/UNDP)

The UNDP supported Rural Energy Development Programme (REDP) completed its pilot phase in early 2002 demonstrating micro-hydro based rural energy systems in over 100 village development committees (VDCs) producing over 1.1 MW of electricity. REDP takes a holistic approach to natural resource management and capacity enhancement for sustainable development. Climate change was not mentioned in its original document but a retrospective calculation has estimated cumulative reduction of carbon emissions by 7,105 tonnes over a five year period.

D.2.3 Community forestry development sector program (DANIDA, 1999)

28 UNDP, 2001. Made in Nepal: Nepal's Sustainable Community Development Programme. Capacity21 Approaches to Sustainability Country Study.

DANIDA is involved in a five-year (1998-2003) Natural Resource Management Sector Assistance Programme (NARMSAP), a continuation of similar work under the World Bank Hill Community Forestry Project. By promoting community forestry development, the sector program contributes to poverty reduction, but also to adaptation to climate risks, as well as climate change mitigation (through carbon sequestration). Neither of these two aspects is explicitly considered in the component description. The description also lacks an analysis of climate risks to the program's implementation and objectives. However, given that the main program outputs are mainly institutional (the establishment of local Forest User Groups, which will manage the forests, and their support structures), direct climate risks are probably limited, and indirect effects on climate vulnerability are likely to be only positive.

D.2.4 Environment Sector Program (DANIDA, 1999)

In addition to the Natural Resource Management Sector Assistance Programme, DANIDA is also managing an Environment Sector Programme. Its main aims are the establishment of an institute for environmental management, cleaner production in industry, wastewater treatment in selected industrial areas, and institutional strengthening of environmental authorities. Such activities may have a slight positive impact on Nepal's climate vulnerability, but climate risks to the program are likely to be limited. In any case, they are not discussed in the program description.

D.2.5 Power development project[29] (World Bank)

The Nepal Power Development Project is about to be approved by the World Bank in February 2003. In line with the Bank's Power strategy and the government's revised Hydropower Development Policy, it aims to develop Nepal's hydropower potential, improve access to electricity in rural areas, and promote private participation in the power sector. Bilateral donors (USA, Germany, Norway) will provide technical support to prepare the investment pipeline, while the World Bank will take the lead in providing investment funding for private development of small- and medium-sized hydro plants. In addition, the Bank supports community-based village electrification through development of micro-hydro systems, as an extension of the successful UNDP Rural Energy Development Program. While the development of smaller hydropower plants and community-based management of those resources may well contribute to adaptation to climate change, this is no explicit objective. Climate change, or even current climate variability and natural hazards are not mentioned in the Project Information Document[30].

D.2.6 Power development project – sectoral environmental assessment (HMGN)

As part of the preparations for the Power Development Project, Nepal prepared a Sectoral Environmental Assessment (SEA) for the hydropower sector. In this case, SEA is used as an instrument to provide "upstream" screening of potential hydropower projects to be funded out of the Power Development Project's Power Development Fund. Beyond environmental impact studies, it looks at social aspects and risks caused by as well as risks to possible project components and sites. It supported a screening and ranking exercise by the Nepal Electricity Authority, which looked at a whole range of possible hydropower options, and ranked them with multiple criteria, in a process of open consultation with all stakeholders. While climate change as such is not explicitly mentioned, the selection and ranking process did include considerations of sedimentation, maintenance of adequate water quality, and glacial lake outburst floods. The SEA itself states that monitoring of relevant watersheds (above existing or proposed hydropower plants) and their appropriate management need to be incorporated in investments for power development, to reduce risks of erosion and sedimentation. Similarly, glacial lakes above existing or

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29 Project information document

30 On the other hand, the project does contain a component to strengthen maintenance and repair capacity, and allows for a certain percentage of failures to remain economically viable.

proposed hydropower sites should be monitored. While the strategy does not mention climate change as such, incorporating integral monitoring, risk evaluation and watershed management into investments in hydropower is a very strong example of adaptation to current and future climate risks. Interestingly, one of the projects selected in the screening process is a storage project, where water is stored during the monsoon season and released in the dry winter, thus augmenting the low flows through the system. This is another example of adaptation, in this case to current and possibly future precipitation variability.

The Policy Framework for Environmental Impact Assessment for projects under the Power Development Fund (Nepal, 1999) contains no specific attention to natural hazard risk management, and it lacks a discussion of potential climate risks to hydropower projects.

D.2.7 Power development strategy (World Bank)

The World Bank’s proposed Power Sector Development Strategy (World Bank, 2001) analyzes the key implementation constraints facing Nepal’s hydropower development, and proposes options for reform. In addition to institutional restructuring, the strategy proposes an active role for the government in promoting power trade with India and improving rural access to electricity. For the latter, Nepal should supplement existing institutional methods of delivering electricity to rural areas with innovative approaches, such as community based systems, presumably including micro-hydropower. One the other hand, the strategy points to the strong need for private investments in large-scale hydropower, but warns that “*Factors such as financing terms (and their implications for tariffs), the creditworthiness of buyers, cost of alternatives and environmental impacts must play an important role in deciding the location of sites and the number and magnitude of contracts to be awarded*.” Curiously, natural hazard risks to the plant and its environment are not considered in this list of factors. It could be that the strategy neglects these risks given that, ideally, the first screening of possible sites, as well as follow-up engineering studies, should include these considerations. In practice however, natural hazard risks do not appear on the radar screen of decision makers (except once a disaster occurs), and get less consideration than other factors that do appear in lists such as the one in this strategy. Interestingly, the list does include environmental impacts. If these impacts were to be defined broadly, and would include not only the risk of the hydropower plant to its environment but also vice-versa, natural hazards would automatically be considered in the context of the environmental impacts analysis (EIA). However, standard EIA guidelines seldom include such considerations. In the whole strategy, the word climate only appears as, “*climate for mobilizing private capital*”. [31] Climate change is not mentioned.

D.2.8 The Nepal irrigation sector project[32] (World Bank, 1997)

The Project Appraisal Document for the Nepal Irrigation Sector Project states: “Population pressure and the ad-hoc development of water resources have resulted in some adverse impacts on the country's ecological systems, for example... increased frequency of freak floods and droughts in many parts of the Terai.” While climate variability and change are not mentioned explicitly in the Appraisal Document, addressing issues like these clearly contributes to a reduction in vulnerability. Another example of the impact of seasonal weather extremes is the Sunsari Morang Irrigation system, which is targeted in one of the sub-projects. According to the Appraisal Document, this huge irrigation system has been plagued by sedimentation during the flood season since its inception. Given Nepal’s torrential and sediment-laden rivers, similar problems with sedimentation are one of the technical challenges for almost all irrigation systems.

31 There is a brief discussion about minimum flow requirements (for environmental reasons) in drought years. Drought as a risk factor to hydropower generation also features in several examples of hydropower development in other countries (including in Sri Lanka and New Zealand), but is not explicitly worked out in the strategy itself. Neither floods nor GLOFS are mentioned anywhere.

32 Project Appraisal Document (1997).

D.2.9 Second rural water supply project[33] (World Bank)

Again, the Project Information Document does not pay explicit attention to climate risks. However, the risk of landslides is mentioned as one of the environmental risks that can be avoided with appropriate project design, and the environmental section of the Project Information Document describes several guidelines for project implementation that would result in reduced vulnerability to climate risks, including watershed management, and promotion of integrated management of local water resources.

D.2.10 Road maintenance and development project (World Bank, 1999)

This project contains little discussion on natural hazards and climate risks, but the section on the analysis of alternative candidate roads shows that current climate risks, including risk related to extreme weather, floods, and landslides, were taken into account in the road design.[34] In addition, the Environmental Impact Analysis looked at impacts on land stability (slope stability hazards, erosion, drainage), and performed a full hazard rating along each road alignment. For critical areas, mitigative measures are included (such as appropriate drainage and bio-engineering). Climate change is not mentioned (studies were based solely on current conditions).

D.2.11 Rural infrastructure project (World Bank)

This project, which mainly aims to strengthen the local institutional capacity to improve rural roads, does not discuss climate-related risks. In the section on sustainability and risks, the two main issues are institutional sustainability and the maintenance and rehabilitation of the roads themselves. In the latter context, the role of floods and landslides, which might damage the roads, is not discussed. One of the reasons may be that the project objectives and key performance indicators for the physical investments are focusing mainly on the short term. For instance, one of the indicators is that the roads that are maintained or rehabilitated under the project will remain in operation for three (!) years after project completion. At such timescales, climate change is not a major factor. Current climate-related risks however ought to be considered. In fact, they are implicitly taken into account in another indicator, namely that the non-passability of roads is reduced to two months per year (presumably during the wet season).

D.2.12 Melamchi water supply project[35]

This large (US$ 464 million) project, co-financed by a number of donors, was designed over the course of several years in response to the ever-increasing demand for water in Katmandu Valley. Due to catchment deforestation, this area suffers from rapid runoff in the short wet season and water shortages in the dry season. In recent years, given a lack of runoff, users have resorted to extracting groundwater, which fails to be recharged naturally during the wet season. The project contains a diversion of water from the Melamchi river into the Katmandu valley, as well as social and environmental support, institutional reforms, and implementation support. Aside from the general considerations mentioned above, the report does not discuss climate risks. Climate change is not mentioned.

D.2.13 Seventh power project (ADB, 1988-1999)[36]

33 Project Information Document (2001)

34 The environmental screening of various alternative road locations included landslide hazard, slope failure risk, river bank erosion, and flood risk. In the final design, further refinement was undertaken with respect to geology (including landslide risk), topography (including flood risk) and land use (including degraded forests and bare land). Generally, roads would be constructed above valley flood levels, and above landslides on the lower slopes near rivers.

35 Report and recommendations of the President (2000)

36 Project Completion Report

This project was designed well before climate change featured prominently on the global agenda. However, it is interesting to assess to what extent completed projects in sectors currently vulnerable to climate risks have suffered from natural hazards during implementation. The Project Completion Report of this Seventh Power Project provides and interesting example. The project suffered from severe delays (three extensions were needed to complete the project). One of the factors responsible for this delay were heavy rains: *"Heavy monsoon rains in Nepal usually commence in June and end in September, flooding the plains and causing landslides and land erosion, disrupting daily life and transportation, and making it impossible for contractors to erect transmission and distribution lines (…) The impact of the monsoon on project implementation was not considered adequately when planning the construction works"*. Hence, climatic factors strongly influenced project performance, not just in terms of its long-term benefits, but already during implementation. Note that none of the current projects that were reviewed contain descriptions of monsoon rains similar to the one in this ex-post evaluation.

D.2.14 Forestry sector program, ADB[37]

While forestry activities could well contribute to both mitigation of and adaptation to climate change, climate change, nor climate risks, are mentioned in this audit report.

D.2.15 Mini-hydropower project (ADB 1981-1991)[38]

This is another example of a completed project where current climate-related risks had not been properly taken into account in project design. Overall, the project was deemed unsuccessful, based on a poor economic return and serious issues with respect to the future sustainability. Climate-related risks played a large role in this failure. First of all, the audit mentions that "*The consultant underestimated the extreme force of flash floods and the damage caused by landslides and huge boulders. The potential damage to weirs and intakes caused by floods was not fully appreciated. Many of the foundation and land stability problems would have been recognized and solutions engineered before construction, had a geologist and geotechnical engineer been included in the UNDP-financed consulting team*" The projects were indeed plagued by natural hazards. In one case, landslides redirected waters towards a plant's powerhouse, resulting in flood and the death of two employees. According to the audit "it is unclear to which the subproject's design with respect to the powerhouse may have contributed to the problem". In general, recurring post-flood repairs to weirs and intakes negatively affected electricity production output, as the repairs often required water diversions and curtailment of power supply. In one case, inadequate water flow forced operational shutdowns for more than two months each year and reduced generation for large parts of each day. These factors all contributed to the fact that four out of the six subprojects are not sustainable in their current operating mode without continued subsidy from the government. In addition, the audit notes: "*all projects remain highly vulnerable to seasonal floods, landslides, and other natural occurrences owing in part to a lack of robustness in design*." In the end, the audit draws rather negative conclusions about small-scale hydropower plants, and suggests that large-scale hydropower might be more cost-effective.

D.2.16 Namche Bazaar small hydropower project (Austrian Development Cooperation)[39]

The evaluation document evaluates two small hydropower projects and related development activities, one in Nepal and one in Bhutan. The project in Nepal was the Namche Bazaar small hydropower and rural electrification project, which included several subsequent components over about 25 years. A first

37 Project Performance Audit Report, 2001

38 Project Performance Audit Report, 1998

39 Small Hydropower projects final report (evaluation), 2001

hydropower plant was being built when it was hit by a GLOF in 1985. Subsequently, between 1988 and 1994, a new site was selected and a new plant constructed. After 1994, Austria supported further institutional development and training, so that a locally owned private organization could take over the management of the plant. The evaluation notes that the total investment costs were rather high, and that the project took much more time and management efforts than originally planned. Nevertheless, it was deemed a success. Austria's willingness to engage in intensive long-term efforts probably made the difference between this project and comparable, but less successful, hydropower projects by other donors. Besides the advantages of the electrification, the project has also brought benefits in terms of a reduction of the use of firewood, as planned. The evaluation mentions the extreme climatic circumstances in which the plant was built, and cites them as a continuing problem for the plant's buildings. No reference is made to climate change.

D.2.17 Makulu-Barun national park buffer zone development (Austrian Development Cooperation/Eco Himal)[40]

This rural development project for the buffer zone of the Makulu-Barun national park contains a variety of components, including education, health, natural resource management and biodiversity conservation, gender balance, and conflict mediation between various stakeholders. Current climate-related risks to the project are listed explicitly under "external factors": "*the high altitude mountain environment of the projects generally exposed to natural hazards like heavy rainfall in the monsoon season, long lasting droughts during winter time, and landslides*". No concrete measures are proposed to mitigate these risks. However, the project does promote soil protection and erosion control, measures which would reduce vulnerability to floods and droughts. Climate change is not mentioned.

D.2.18 Thame Valley village development (Austrian Development Cooperation/Eco Himal)[41]

This rural development project targets the Thame Valley, in the Everest Region. Due to its location away from the route to the Everest base camp, this valley attracts few tourists, and lags surrounding areas in development. An interesting example of vulnerability to climate-related risk: "*Eco Himal has built two bridges in the valley in 1997 and 1998. Both of them were designed according to traditional local conceptions. Unfortunately, they did not survive the unusually intensive monsoon in 1998. Therefore, it is essential to struggle for a long-lasting solution*". The project document mentions "*weather*" as an external factor, but does not discuss how to minimize those risks to the project and its development goals. However, it does pay attention to erosion and landslide risks. For instance, the project will relocate the Dumji House (centre for an important festival) in the light of high landslide risks in an erosion-prone area.

D.2.19 IFAD Western Uplands poverty alleviation project[42]

In line with IFAD's 2000 Country Strategic Opportunities Paper (see above) this project addresses the hills and mountains in the west of Nepal. Poverty in these areas is attributed firstly to "the extremely harsh terrain and climate", but also to, e.g., remoteness, lack of services, limited government presence, absence of donors, extremely limited savings and credit facilities, and poor links with markets due to the lack of infrastructure. While the project contains no measures that are explicitly aimed at reducing vulnerability to climate risks, it is almost certain to address various aspects of these regions' vulnerability by enhancing agricultural opportunities and natural resource management, and by establishing rural microfinance opportunities. More specific attention to climate risks, and particularly to possibly changing climatic

40 Project proposal, 2002

41 Project Document, 2001

42 Report and recommendation of the President (2001), Environmental Screening and Scoping Note (2001)

circumstances, might have helped to target, for instance, agricultural research activities. In addition, potentially substantial climate-related risks to physical investments are not discussed.

The Environmental Screening and Scoping Note discusses several climate related problems that could affect the project. Infrastructure construction could cause excess erosion during the rainy season, and small-scale irrigation could cause conflicts over water management and water allocations between villages, and increased breeding habitats for disease vectors. The additional impact of climate change on these considerations is not discussed.