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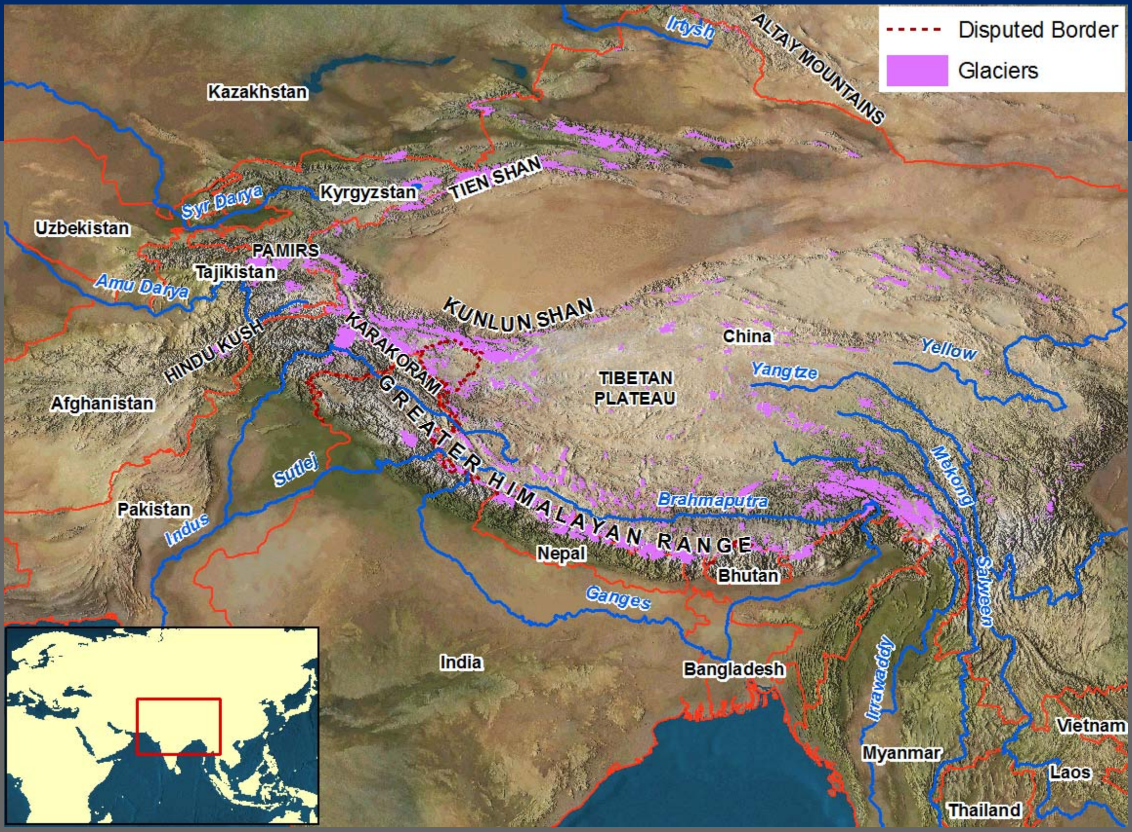
# CHANGING GLACIERS AND HYDROLOGY IN ASIA

## ADDRESSING VULNERABILITIES TO GLACIER MELT IMPACTS




**FINAL**

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Map credit: Brian Melchior

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Addressing Vulnerabilities to Glacier Melt Impacts

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Dr. Elizabeth L. Malone
Senior Research Scientist
Joint Global Change Research Institute
Battelle, Pacific Northwest Division

# ACRONYMS

| | |
|---|---|
| ABC | Atmospheric Brown Cloud |
| ADB | Asian Development Bank |
| ARC | Asian Research Center of Excellence on Climate Change and Development |
| ASEAN | Association of Southeast Asian Nations |
| AusAID | Australian Government Overseas Aid Program |
| Battelle | Battelle Memorial Institute |
| CAR | Central Asian Republics |
| CIDA | Canadian International Development Agency |
| DEM | Digital Elevation Model |
| ELA | Equilibrium Line Altitude |
| FUG | Forest User Group |
| CBO | Community-Based Organization |
| CGIAR | Consultative Group on International Agricultural Research |
| GCM | Global Circulation Model |
| GDA | Global Development Alliance |
| GIS | Geographic Information System |
| GLOF | Glacier Lake Outburst Flood |
| HKH | Himalaya-Karakoram-Hindu-Kush |
| ICESat | Ice, Cloud, and land Elevation Satellite |
| ICIMOD | International Center for Integrated Mountain Development |
| IDRC | International Development Research Centre |
| IEC | Information, Education, and Communication |
| IFPRI | International Food Policy Research Institute |
| IPCC | Intergovernmental Panel on Climate Change |
| LIA | Little Ice Age |
| MRC | Mekong River Commission |
| IWMI | International Water Management Institute |
| LDCs | Least Developed Countries |
| NAPA | National Adaptation Programmes of Action |

| | |
|---|---|
| NGO | Non-Governmental Organization |
| OFDA | Office of Foreign Disaster Assistance |
| PAI | Population Action International |
| REDD | Reducing Emissions from Deforestation and forest Degradation |
| RH/FP | Reproductive Health and Family Planning |
| RIMES | Regional Integrated Multi-Hazard Early Warning System |
| RDMA | Regional Development Mission Asia |
| SPOT5 | Satellite Pour l'Observation de la Terre |
| SRTM | Shuttle Radar Topography Mission |
| TERI | The Energy and Resources Institute |
| TMI | The Mountain Institute |
| TRG | Training Resources Group, Inc. |
| UN | United Nations |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USAID | United States Agency for International Development |
| USFS | United States Forest Service |
| WASH | Water, Sanitation and Hygiene |
| WGMS | World Glacier Monitoring Service |
| WHO | World Health Organization |
| Winrock | Winrock International Institute for Agricultural Development |
| WUA | Water User Association |
| WGMS | World Glacier Monitoring Service |
| WWF | World Wildlife Fund |

# EXECUTIVE SUMMARY

The United States Agency for International Development's (USAID's) Asia Bureau, with support from the Global Health Bureau, conducted a series of stakeholder and expert dialogues in 2009 with the Woodrow Wilson International Center for Scholars entitled "Asia's Future: Critical Thinking for a Changing Environment." The dialogues identified and explored issues that will shape conditions in Asia during the 21$^{st}$ century. One of the issues identified was climate change, and Asia's high-mountain glaciers were a focal point of discussions. The Asia Bureau realized a need to understand better the science and implications of glacier retreat and to assist Missions in planning and programming new funding that is targeted to address the impacts of glacier melt in the high mountains of Asia. USAID initiated a project, led and managed by CDM International, Inc., that undertook the following tasks:

- Review the science concerning glacier melt in Asia.
- Identify key glacier melt vulnerabilities in the Asia region.
- Identify organizations contributing to addressing glacier melt and its impacts in Asia.
- Develop strategic cross-sectoral responses to these vulnerabilities, including responses that provide multiple benefits.

The geographic focus of this study is on the region of "High Asia" (see the map on the cover), sometimes referred to as the Greater Himalayan region, and the countries whose river waters flow from High Asia. High Asia includes the Himalaya, Hindu Kush, Karakoram, Pamir, and Tien Shan mountain ranges, where current glacier coverage exists.

**The Scientific Perspective**

Although the world's glaciers have been retreating slowly since the Little Ice Age (approximately 1650 to 1850), recent climate warming has accelerated the rate of retreat. However, glacier systems at the highest elevations, 4000-7000 m – like those in High Asia – have not responded to recent climate warming in the same way as lower elevation glaciers, simply because higher-elevation glaciers currently remain below freezing during much of the year, even in the presence of a warmer climate.

Long-term, comprehensive data for the remote glacierized areas of the Himalaya do not exist, so rates of retreat are not known over the whole region. Field measurements are often, by necessity, limited to a few local measurements on easily accessible glaciers, typically at the lower elevations. More recently, measurements over larger areas are becoming available utilizing satellite remote sensing—but often lacking historical baselines. Historical glacier data from the Himalaya and adjacent mountain ranges are limited mostly to terminus location measurements. These are problematic because they only show that the ice at the terminus is melting faster than the rate at which ice is being supplied to that location by movement (dynamics) of ice from further upslope in the system. A glacier might gain total mass from one year to the next (from increasing amounts of snow arriving at the higher elevations), while the terminus, at the lowest elevation, retreats. Measuring the mass of glaciers and methods to monitor mass balance (melt subtracted from additions) vary, and are always complex and time-consuming; there are currently no such long-term records for the Himalaya.

Moreover, efforts to quantify the contribution of melting glacier ice to the regional hydrology are just beginning. Precipitation and basin runoff generally decrease from the east to west – a direct result of the summer monsoon's weakening. Also, glaciers in the west are a more important source of streamflow volume. However, the total runoff in the western mountains is considerably less than that in the east at all altitudes – as expected, given the relative aridity of the western mountains.

Glacier ice melt rate under any reasonable future warming scenario is relatively slow, and thus cannot, in itself, cause floods. Actual environmental hazards come in the form of two distinct types of glacier lake outburst floods (GLOFs). One type, a moraine-dammed outburst flood, occurs when large volumes of water build up behind the terminal moraine of a rapidly melting, retreating glacier and the moraine dam fails. The other, associated with advancing glaciers, occurs when the glacier tongue dams a river; an outburst flood may occur when the glacier subsequently retreats or breaks up.

Black carbon from widespread biomass burning in Asia poses a special type of threat, to glaciers and people. Generated indoors from cooking and heating, black carbon causes or exacerbates respiratory illnesses; released to the atmosphere, it is an air pollutant and contributes to regional climate change; deposited on glaciers, it accelerates melt rates.

Many of the glaciers in the Himalaya are indeed retreating, especially at the lower elevations in the eastern Himalaya. On the one hand, no region-wide evidence supports the claim that the glaciers of the Himalaya are retreating faster than any other location in the world. On the other hand, even if Himalayan glaciers may not be disappearing as fast as had been previously thought, the need for mitigation and adaptation remains. Glaciers and their melt rates are part of the hydrological system that also includes monsoons and other rainfall and snow, although the larger system changes are outside the scope of this report.

Glaciers of the Himalaya do provide a small amount of the runoff to the 1.5 billion people living downstream, perhaps the smallest amounts corresponding to the regions of the highest population: China, India and the Southeast Asia mainland. In the eastern Himalaya the contribution of melting glacier ice to the downstream river flow is most likely about 5% or less. But in the western Himalaya, and specifically the Indus Basin, the contribution of melting glacier ice to the rivers is thought to be considerably larger, perhaps one-third or more.

Accurate, comprehensive assessments of the future availability of water resources in the Himalaya region are not possible until the existing hydrologic regime of these mountains is better defined; and the current relationship among glaciers and other sources of streamflow is examined.

The scientific assessment thus shows a lack of scientific knowledge to answer questions about glacier melt and its impacts; this lack of knowledge is itself a vulnerability that USAID programs can address (see the first program concept below).

### The Vulnerability Perspective

A second perspective on vulnerabilities focuses on two assumptions that are underpinned by current knowledge: (1) human health and ecosystem impacts are likely to result from the changes in the hydrologic systems, of which glaciers are a component; and (2) current existing health, ecosystem, population, and pollution issues make communities more vulnerable to *any* changes in their water systems, whether too much water (floods), too little water (droughts and increasing aridity), or water at different times (earlier in the spring, for instance).

Therefore, vulnerabilities arise from current conditions that will be exacerbated by changes in glaciers and their associated river basins. Near-term vulnerabilities include GLOFs and the disappearance of some glaciers that people rely on for water; typically, these concerns focus on small communities at comparatively high altitudes. The upper Indus and Yarkand River Basins are examples of areas that are vulnerable in these ways. In the longer term, climate change and glacier melt will exacerbate water stress for hundreds of millions of people downstream from glaciers, for example, in the Ganges River Basin. Human health status is vulnerable to changes in water availability, including potential increases in diarrheal diseases and worsening nutrition as food and water supplies are affected. In addition, high rates of population growth constitute a vulnerability to water stress, as more people need water (including water for irrigation) and the concentration of pollution may increase. Threats to ecosystems come directly and indirectly from changes in the melt rates of glaciers and other associated changes in water systems, increasing biodiversity vulnerability. Finally, the existing potential for conflict will be increased as the water system changes where governance institutions have not achieved stable agreements to share cross-boundary water – for instance, in the Central Asian Republics. In the Indus River Basin, several vulnerabilities combine: the aridity of the area, a high dependence on glacier melt for river water, and poor existing water infrastructure.

### Existing Activities Related to Glacier Melt

Current programs, projects, and activities related to glacier melt and retreat in Asia have focused on glacier monitoring, although GLOF risks are receiving increased attention as key climate change hazards in High Asia, including the Himalayan, Karakoram, Pamir, Tien Shan and Hindu Kush mountains. Less attention has been paid to downstream implications of glacier melt and adaptation strategies. There is very little assessment of the factors underpinning risks from glacier melt that exacerbate vulnerability on the ground. For example, despite an active effort to find evidence of work relating glacier melt and health in Asia, none was found.

Although there is a dearth of scientific data and knowledge, research institutes are the most active in addressing glacier-related issues. Very few actual glacier-melt-related adaptation projects exist, and most of the projects tend to use large-scale, technological approaches.

## Potential for Cross-Sectoral, Multiple-Benefit Programs

In the spirit of Asia's Future dialogue, USAID wanted to:

- Address priority issues related to glacier melt and retreat in a cross-sectoral way designed to yield co-benefits in multiple sectors.
- Complement or fill gaps, considering activities already underway.
- Correspond with USAID's interests and mandate.

Although the speed and degree of glacier melt is uncertain, USAID recognizes the importance of addressing vulnerabilities, because even small changes in glacier melt will result in large impacts downstream from High Asia. With this in mind, program concepts and approaches have been developed that would address near-term vulnerabilities directly related to glacier melt and longer-term vulnerabilities to help build resilience in the face of future impacts. Each program approach has a specific focus, but each is designed to be cross-sectoral and to yield co-benefits across a range of issues. For instance, a focus on management of water resources should integrate governance, food security and nutrition, gender equality, regional cooperation, ecosystem resilience (e.g., sustainable forestry), education, and the potential to use local groups to promote good health practices and family planning. Because conditions and opportunities will differ widely from place to place, Missions can use these descriptions of program approaches as menu from which to choose, rather than as a cookbook of recipes to follow.

The first program concept, "Responding to the Challenge of a Lack of Information," addresses the need for collaborative and integrated scientific efforts to increase scientific knowledge and to engage in monitoring changes in glaciers. The two program approaches focus on (1) improving regional scientific cooperation of glacier, snowpack and water resources in High Asia; and (2) strengthening monitoring capacity for climate and water resources in High Asia.

The second program concept, "Responding to Vulnerabilities," addresses both near-term preparedness and longer-term resilience-building to existing vulnerabilities, including GLOFs and the disappearance of some glaciers; water stress and associated food and nutritional deficits; health issues, particularly population pressures and diarrheal diseases associated with poor water quality, as well as malnutrition; threats to ecosystems, particularly biodiversity; and potential governance and conflict implications of unstable water supply. The three program approaches focus on (1) improving the management of water resources, (2) conserving ecosystems, and (3) preparing high-mountain communities for direct impacts of glacier melt.

The third program concept, "Responding by Mitigation," addresses two different issues simultaneously, thus presenting combined opportunities for program integration and co-benefits. Black carbon and other aerosols likely change the regional climate and accelerate glacier melt when black carbon is deposited on reflective glacier surfaces. Therefore, reducing these emissions mitigates climate change and thus reduces vulnerability to glacier melt. In addition, reducing these emissions brings significant health improvements, particularly to women and children in households where cooking and heating are fueled by biomass, and to urban dwellers where multiple sources contribute to high levels of air pollution. The program approach thus focuses on reducing emissions of black carbon and other aerosols.

## Conclusions

The review of scientific information about glacier melt in High Asia revealed, first and foremost, a lack of data and information, a lack that hampers attempts to project likely impacts and take action to adapt to changed conditions. Known near-term impacts include the increasing potential for GLOFs and the disappearance of small glaciers, especially at lower latitudes. Understanding that glacier melt/retreat, although occurring at increasing rates, is not likely to produce widespread disastrous impacts in the next decade or two means that societies have time to build their resilience to changes in the amount of water available and when it arrives during the year. However, existing vulnerabilities in human health status, population pressure, degraded ecosystems and – especially – water stress make societies and ecosystems vulnerable to *any* changes in water availability as glacier melt accelerates in the coming decades.

As a result of this analysis, the program concepts developed in consultation with USAID addressed three different elements: the challenge of lack of information, vulnerabilities related to current societal and ecosystem conditions, and the need for mitigation, focusing on black carbon. These program concepts represent "no regrets" activities, meaning that they address critical needs no matter how the glaciers respond to climate change.

The multi-faceted analysis presented here leads to the following conclusions (listed in italics) about the characteristics of programs that are likely to be effective in addressing glacier melt and its impacts:

*As glacier melt is part of complex, region-wide hydrologic changes that are happening as a result of climate change, effective programs to address glacier melt will be cross-sectoral and will achieve co-benefits across sectors.*

Below are examples of benefits that can be part of co-benefit streams:

1. Improved health outcomes (from healthier ecosystems, reduced pollution, improved sanitation, more efficient water use);
2. Reduced fertility and easing of population pressures (by meeting family planning needs);
3. Strengthened governance institutions (through environmental, agricultural, and forestry management; development of national and local policies; establishment and empowerment of local resource user groups);
4. Improved regional cooperation (through scientific cooperation, shared monitoring and information programs, common educational outreach programs, community-based monitoring, strengthened cross-boundary institutions and treaties);
5. Protection of biodiversity and maintenance of ecosystem services (through improved water management and ecosystem management for health);
6. Better water management at all levels, from transboundary/multi-country all the way to use on farm fields and for household drinking water;

7. More efficient, climate-change-resilient food production (irrigation systems, on-farm management, harvest of food and fodder from forests and rangeland, and homestead vegetable gardens);

8. Creative, effective approaches to monitoring and managing climate-change-induced threats, starting with glacier lakes;

9. And effective disaster planning for both too much water (floods, GLOFs) and too little water (droughts).

*As climate change is a global and long-term issue, extending program timelines beyond 3-5 years and explicitly coordinating projects, especially across sectoral and geographic boundaries, should be considered.* One option is to link projects that could be completed in a decade-long sequence, in order to allow for periodic evaluation and course correction, institutionalization of best practices, and scale-up. Another option is to coordinate programs with other Missions and/or sectors, exploring mechanisms to share resources and management.

*A crucial role USAID can play is to link up partners in the government and private sector (both NGOs and for-profit organizations) to build capacity*, as many of the illustrative programs describe.

*USAID should take advantage of synergies by linking new initiatives, such as the Feed the Future initiative with its emphasis on food security and nutrition, to climate change impacts and vulnerabilities of glacier melt on water supply; such links will yield many "no regrets" programs.* As impacts of changing water supply, including glacier melt, unfold, resilience can be built through such varied strategies as diversifying diets, crops, and livelihoods; increasing productivity; and encouraging the adoption of improved water management systems such as drip irrigation, rainwater harvesting, and other water efficiency technologies.

*USAID's partnerships with forest user groups, water user associations, and other local organizations to address climate change (and other environmental) issues will strengthen governance capacity of civil society.* Such partnerships are essential parts of many illustrative programs described in Section 5.

*USAID should promote and support "south-to-south" scientific and technical exchanges such as the recently initiated Peru-Nepal exchange regarding glacier lake management*, involving governments as feasible. Intra-regional exchanges could focus on water and agricultural issues.

*In the midst of changing climate and uncertainties, greater emphasis on collecting local, indigenous knowledge of the environment and existing adaptive mechanisms may be critical for future long-term adaptation to changes in glaciers and climate.*

# SECTION I
# INTRODUCTION

## 1.1 NEW CHALLENGE FOR ASIA AND USAID MISSIONS

Glaciers are icons of Nature on a grand scale, on mountains that challenge humans physically and provide breathtaking scenery. Some are sacred landscapes, like the Gangotri Glacier at the headwaters of the Ganges River. Others are significant in different ways. For instance, the Siachen Glacier is at the border of India and Pakistan and a site of disputes and conflicts. The highest mountains in the world, including Mount Everest and K2, are home to thousands of glaciers, which are part of their majesty and mystique (see photo below).

**Mount Machapuchare in Nepal, revered as sacred to the god Shiva.** *Photo courtesy of Dan Miller*

To help plan future programs and initiatives, USAID's Asia and Global Health Bureaus, with the Woodrow Wilson International Center for Scholars, led a process called "Asia's Future: Critical Thinking for a Changing Environment" that identified a series of complex trends facing the Asia region over the next 10–15 years (Zbicz 2009). These trends range from increasing and unsustainable demand for natural resources, food insecurity, rapid and uneven population growth, urbanization, and climate change impacts, all of which may lead to threats to human health, and national and regional environmental security.

An outcome of this process was increased attention to glaciers of the Himalaya region and adjoining mountain ranges as a potentially important aspect of climate change in the region (see box below). Among these mountain ranges are the Himalaya, Karakoram, Pamir, Tien Shan, and Hindu Kush. Tens of thousands of glaciers in these mountain ranges – which in this report are collectively termed "High Asia" – are part of vital water lifelines to Asia's great rivers – the Yellow, Yangtze, Mekong, Salween, Indus, Ganges, Brahmaputra, Syr Darya and Amu Darya. Perhaps two billion of the world's people depend on these rivers for their water and food supply.

Climate change, as the world is experiencing it now and will experience in the future, has raised questions and concerns about how rising temperatures and changing climatic patterns will affect the glaciers of High Asia and, in turn, the water lifelines of the region. Changes in climate and their impacts on glaciers and regional hydrology are expected to have dramatic adverse effects on earth and human systems, with long-term implications for water, food, health (particularly maternal and child health), disaster survival and resilience, culture and traditions, energy security, migration and perhaps the political stability of the region.

Glaciers all over the world have been shrinking since the last ice age, and they experience melting every year (along with additions from annual precipitation). The increasing temperatures of climate change are speeding up the shrinking process – a concern usually captured in the terms "glacier melt" and "glacier retreat."

**Climate Change and Glacier Melt**

The impacts of climate change are likely to be numerous and wide-ranging, including sea level rise, temperature increases, changes in the timing of seasons, precipitation increases and decreases (depending upon regional conditions) – and the shrinkage and eventual disappearance of ice formations, including the Greenland Ice Sheet, the West Antarctica Ice Sheet, and the glaciers of the world. High Asia's glaciers, because they are generally at high elevations, will tend to disappear more slowly than glaciers in other parts of the world.

Although the focus of this report is glacier melt, this impact of glacier melt cannot be considered in isolation from the larger climate system changes. In particular, glaciers are part of a complex hydrologic system that includes monsoons and other rainfall, as well as snow and seasonal ice.

Changes in glacier melt amounts and patterns, along with other changes in high-altitude hydrology, will affect agricultural production across the region. Along with glacier melt changes, increased temperatures will reduce snow cover throughout the winter but especially in spring, and monsoon patterns will likely change as well. The natural environment, ecosystems with high biodiversity, and human populations that live in these watersheds may experience severe impacts. The livelihoods of up to a billion people in Asia could be affected through changing agriculture and land use. Fluctuations in water supply and availability may lead to increases in malnutrition and increased incidence of water-borne diseases, which can particularly affect infant and child mortality. These potential conditions raise the possibility of conflict over increasingly scarce and unpredictable resources across the region, as countries compete for land and transboundary river resources. Conflicts may first be expressed at the local level between and within communities.

Changes in the glaciers and the high-altitude hydrologic system of which they are part could potentially impact most Asian mainland countries in which USAID works. Through the commissioning of this project, USAID took a proactive approach to assessing the implications of glacier retreat and other high-altitude hydrologic changes. The Asia's Future process and the activities described in this report are the first steps in recognizing key vulnerabilities and strengthening the ability of countries and communities to mitigate and adapt to reduced water and food supplies, and changing land use patterns; and to help plan and prepare for natural disasters. Urbanization, population growth and distribution, and the potential for increased incidence of water-borne disease and infectious disease provide additional reasons for increased attention in both analysis and action. There is an increasing need for government effectiveness to mitigate threats and conflict through rule of law, public policy, regional and international collaborations, disaster preparedness, planning and response, and general development. Moreover, resilience of communities will depend on local adaptive responses, knowledge and information transfer, and capacity to engage with governments for public service provisions.

The Asia's Future process resulted in a better understanding within USAID of the need to address these issues, motivated by the projections of climate change impacts. USAID then initiated through this study an exploration of the potential impacts of glacier retreat in an integrated and cross-sectoral fashion, and developed program concepts and approaches designed to reduce societal vulnerabilities, adapt to the potential impacts of glacier melt, and prevent excess melting to the greatest extent possible.

The project assessed current scientific knowledge about climate change's impact on glaciers in Asia. In 2009, scientists had begun to challenge statements in the literature about the possibility that all Himalayan glaciers might disappear in the next 20-30 years. The science assessment confirms that the High Asian glaciers are not going to disappear in the next few decades – but demonstrates the reasons for concern and the great uncertainties stemming from a lack of knowledge about current melt rates and general conditions in the different climatic conditions of the eastern and western mountain ranges.

Although the pace of glacier retreat is slower than was thought at the time of the project's initiation, the phenomenon *is* occurring. A slower pace of change is good news: societies have more time to plan and act. This study also examined current and projected vulnerabilities in societies that will need to respond to changes as they learn more about the nature and timing of these changes. In responding to vulnerabilities, there are ample opportunities for "no regrets" strategies—activities that will increase well-being no matter what the future holds.

## 1.2 Scope of the Report

USAID recognizes the need to proactively address the implications of glacier melt, including the drivers of the process and the factors that may impede adaptation. This report provides approaches to vulnerabilities associated with glacier melt and ways to strengthen the ability of countries and their communities to adapt to potential reductions in water and food supplies, changing ecosystems and land-use patterns, and increasing disasters. To address this issue in a systematic, strategic way, the scope of work has defined four tasks:

1. Review the science concerning glacier melt in Asia
2. Identify key glacier melt vulnerabilities in the Asia region
3. Identify organizations contributing to addressing glacier melt and its impacts in Asia
4. Develop strategic cross-sectoral responses to these vulnerabilities that provide multiple benefits

This report summarizes the findings of the four tasks.

The geographic focus of this report is on the region of "High Asia" (see map on cover), sometimes referred to as the Greater Himalayan region; and the countries whose river waters flow from High Asia. High Asia includes the Himalaya, Hindu Kush, Karakoram, Pamir, and Tien Shan mountain ranges, where current glacier coverage exists; and all the countries of east, southeast, south, and central Asia are included.

The greater Himalaya is not a single climate region: the eastern Himalaya are separated from the Karakoram-Hindu Kush mountains by approximately 2,000 kilometers. These two areas, east and west, differ in climate, especially in sources and types of precipitation, and in glacier behavior/dynamics. Moreover, no sharp dividing line exists between east and west; rather, conditions change gradually across this geographic spectrum.

## 1.3 Objective of This Study

The goal of the study reported here is to provide approaches to glacier melt, within the context of climate change, based on state-of-the-art knowledge, to USAID Missions in three topic areas: (1) science related to glacier melt and high-altitude hydrology, (2) the impacts of changes near and far in space and time, and (3) the organizations and activities already addressing these issues. The key strategy is then to identify cross-sectoral approaches that will have multiple benefits for improving the safety, health and overall well-being of the region's populations.

## 1.4 Methodology

To carry out these tasks, the team concurrently developed a state-of-the-science report on glacier melt in High Asia and reviewed available information on organizations who are engaged in activities that address aspects of glacier melt in the region. In consultation with USAID, the team also constructed maps within a geographic information system (GIS) to visualize the existing vulnerabilities that either arise from glacier melt or that will impede adaptation to glacier melt impacts. The team, including USAID staff, then met to review these knowledge streams and to develop candidate program concepts and approaches that would address the issues associated with glacier melt within the context of USAID's mandate. Four team members discussed the candidate program concepts and approaches with USAID Missions and stakeholders in India, Nepal, Thailand, and the Central Asian Republics. Stakeholder organizations included government agencies, Non-Governmental Organizations (NGOs), research institutions, and multi-lateral banks. With all of these inputs, the team further developed the program concepts and approaches described in this document, emphasizing their cross-sectoral nature and the potential for co-benefits.

Team members' expertise and experience is wide-ranging. Team members have backgrounds in geography (snow physics), agronomy, sociology, forestry management, health, climate change, and development. The team collectively has decades of experience with USAID programs in Asia and elsewhere, in the fields of health, environment, agriculture, natural resource management, and disaster management programs. USAID team members were Heather D'Agnes, Mary Melnyk, Rochelle Rainey, and Kristina Yarrow. Project team members included Richard Armstrong (science assessment), Leona D'Agnes (health sector specialist), Jessica Ayres (survey of current activities), John Gavin (project manager), Scott Harding (disaster management sector specialist), Elizabeth Malone (technical lead), Ken McNamara (agriculture sector specialist), Brian Melchior (geographer and GIS specialist), Fred Rosensweig (activities manager), and George Taylor (ecosystems and biodiversity sector specialist).

## 1.5 Organization of the Report

The following provides details on the organization and content of the succeeding sections of this report:

- Section 2 establishes the state of the science about glacier melt/retreat in High Asia and the implications of that knowledge for climate change impacts, including current changes and threats as well as longer-term projections.
- Section 3, discusses the near-term and longer-term vulnerabilities of both societies and natural systems to changes in glaciers and the hydrologic system in the region, particularly as current vulnerabilities may be exacerbated by climate change impacts.
- Section 4 provides an overview of ongoing activities that address issues arising out of changes in glaciers and the hydrologic system (a database of these activities is in the Appendix).
- Considering scientific knowledge, vulnerabilities, and current activities, Section 5 presents program concepts and approaches—ways that USAID could approach these issues in a cross-sectoral manner to realize co-benefits in sectors such as health, natural resources, food security, and cross-boundary cooperation.
- Section 6 presents overall conclusions.

# SECTION 2
## GLACIERS AND HYDROLOGIC CHANGES/IMPACTS

The high mountains of Asia were a "white spot" in the Intergovernmental Panel on Climate Change's (IPCC's) 2007 Assessment Report—meaning that little to no data existed. Therefore, before developing programmatic approaches for addressing possible impacts of glacier melt, a summary of existing scientific knowledge was required. This section describes the state of knowledge about glacier melt in the heavily glaciated areas of the Himalayan region, including the various ways to measure glacier health, glacier dynamics, and current studies of the potential impacts of accelerated glacier melt.

The main conclusion of this assessment is that scientific studies and evidence are currently inadequate to assess how much melt is occurring across High Asia and what the rates of change are under various conditions. Different studies show the retreat of some glacier termini, loss of mass in some areas, and a few indications that excess melt (that is, more melting than accumulation) is not occurring in some areas. However, the data and studies in High Asia are not extensive enough to provide a general assessment or projections of impacts. The lack of data should not encourage complacency but presents a critical risk in effective preparations for adaptation to climate change.

### 2.1 BACKGROUND

Glacier retreat did not start with recent climate change, but with the more gradual climate warming since the Little Ice Age (LIA), which occurred from approximately 1650 to 1850 (Oerlemans 2005). Throughout the world, including the Himalaya, evidence left by glacier moraines shows the maximum extent of these glaciers during the LIA and quantifies the fact that glaciers have been retreating since this period in response to a warmer climate.

What is new is the clear evidence of the accelerated pace of that change in recent decades (Zemp et al. 2008). Many glaciers all over the world are retreating—but differences exist, most notably because of different elevations. Glacier systems at the highest elevations, 4,000-7,000 meters (m), have not responded to recent climate warming in the same way as glaciers that extend to lower elevations, simply because glaciers at higher elevations remain below freezing during much of the year, even in the presence of a warmer climate. Therefore, although glaciers are retreating both in the European Alps and in the Himalaya, one cannot always make direct comparisons and extrapolations from the well-studied lower elevation glaciers to the more poorly observed higher elevations of the Himalaya.

### 2.2 MEASUREMENTS OF GLACIER TERMINUS FLUCTUATIONS

Perhaps the simplest method to monitor mountain glacier change is by recording the annual location of the glacier terminus—the location at which the glacier extends furthest down valley. Abundant terminus histories are available from several regions of the world, Europe in particular. Comparative pictures show rapid retreat of some glaciers. But terminus measurements are misleading in the following ways:

- Field-based measurements in remote glaciated areas such as the Himalaya are often, by necessity, limited to a few measurements, typically from accessible glaciers at the lower elevations. Therefore, scientists know more about lower-lying glaciers than they do about the more abundant glaciers at higher altitudes.

- The location of a glacier's terminus is not a comprehensive assessment of total glacier condition or health. It is possible that a glacier with a retreating terminus may be gaining in total mass from one year to the next, due to increasing amounts of snow arriving at the higher elevations by precipitation, wind deposition and avalanching. Therefore, it should be understood that measurements showing short-term retreat only indicate that the recent climate does not support the extension, or even stability, of the lowermost elevation of a given glacier, and does not define the current conditions controlling the changes in volume over the entire glacier at all elevations. Certainly, however, when glaciers are observed to have been in retreat consistently over many decades, they are not in balance with the recent climate.

## 2.3 Measurements of Glacier Mass Balances

More direct and comprehensive methods have been developed to determine the year-to-year condition of a total glacier system through measurements of "mass balance." During the accumulation season (often, but not in all locations, the winter season), a glacier gains mass from accumulating snow. During the following summer melt season, some or all of that winter accumulation is lost to ablation, predominantly by melt, but perhaps by sublimation/evaporation as well as calving where a glacier enters a water body. The upper elevation zone where the glacier experiences an annual net gain in mass is called the accumulation area; the lower elevation zone where the glacier experiences a net mass loss is called the ablation area. The elevation contour at which these two zones meet is called the equilibrium line altitude (ELA) representing the point on the glacier where the annual net mass balance is zero (see Figure 2.1 at right). The difference between the accumulation and ablation for a given year describes the annual net mass balance, which corresponds to the change in total glacier volume and mass. If the annual net mass balance is zero, the glacier is neither growing nor shrinking. Methods to monitor mass balance vary but are always

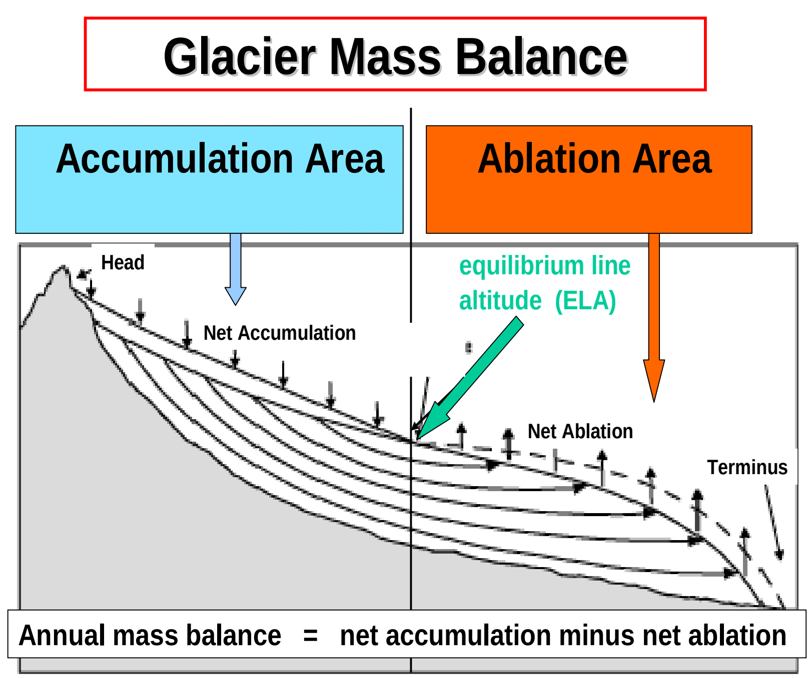


**Figure 2.1.** Glacier accumulation, and ablation areas and ELA.

complex and time consuming, so only a few dozen such records in the world exist that cover significant periods of time (decades). There are currently no such long-term records for the Himalaya (Kaser et al. 2006).

## 2.4 Glacier Dynamics

An understanding of the response of glaciers to climate change must include basic concepts of ice dynamics. Glaciers continually move, carrying mass downhill somewhat like a conveyor belt. If the combination of climate (principally precipitation and temperature) and ice dynamics (internal deformation of the ice and sliding at the base in response to the force of gravity) determines that the glacier is extending further down slope with time, this advance of the terminus will increase the glacier length and total area. Because glaciers move slowly, however, a significant time lag occurs between the changing climatic conditions and the resulting glacier advance or retreat. This response time may last several decades or longer for mountain glaciers, determined by complicated processes that control how fast the glacier moves—that is, how quickly a glacier transfers mass from the higher elevations of the accumulation zone to the lower elevations of the ablation zone. Therefore, year-to-year glacier terminus fluctuations may be a response to climatic events that occurred several decades or more in the past.

Response times for the majority of Himalayan glaciers are most likely decades to centuries, appropriate for glaciers whose movement results mainly from internal ice deformation (i.e. in contrast to surging or dramatic basal sliding[1] examples). Rough estimates of glacier response time can be based on size and slope. Large low-slope glaciers may have response times on the order of centuries. Length changes of such glaciers, especially if debris-covered, therefore cannot be used as indicators of recent (decadal) climate change. Such decadal changes are much better reflected by smaller/steeper glaciers. Response time scales have been described by Raper and Braithwaite (2009), Adhikari et al. (2009), McClung and Armstrong (1994) and Johannesson et al. (1989).

## 2.5 Controversy about Glacier Melt

In late 2009 and early 2010, a lively scientific debate opened up about accelerated glacier melt (as reported in the IPCC 2007 assessment and seemingly supported by a number of studies showing individual glaciers retreating) and the attribution to climate change. The debate served to highlight important issues regarding the extent and state of available information on glacier melt in general, and in Asia in particular.

In November 2009, the Indian Environment Minister released a commissioned report entitled "Himalayan Glaciers: A state of the art review of glacier studies, glacier retreat, and climate change" (Raina 2009). The report argues that it is impossible to make generalized statements claiming that all glaciers are retreating. At least part of the problem is a lack of data.

[1] Basal sliding refers to glacier movement resulting from the glacier sliding over the bedrock or ground beneath the ice, often involving a layer of meltwater, which acts as a lubricant – in contrast to movement resulting from the internal deformation of the glacier ice.

These and other reports and statements posed a challenge related to the 2007 IPCC Synthesis Report (IPCC 2007), which stated the following:

> "Glaciers in the Himalaya are receding faster than in any other part of the world and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps warming at the current rate. [Their] total area will likely shrink from the present 500,000 to 100,000 $km^2$ by the year 2035."

The IPCC AR4 cited data from non-peer-reviewed material from a 2005 World Wildlife Fund (WWF) report. In addition to the issue pointed out by Raina, analysts have also noted that original source material specified the year 2350, not 2035.

The IPCC has since responded by stating that "in drafting the paragraph in question, the clear and well-established standards of evidence, required by IPCC procedures, were not applied properly."[2] WWF has issued the statement that "[the original statement] was used in good faith but it is now clear that this was erroneous and should be disregarded." Both organizations nevertheless continue to support the claim that widespread mass losses in the Himalayan glaciers are likely in the 21st century.

One conclusion to be drawn from this controversy is that scientific knowledge lacks comprehensive data and information on glacier melt in the Himalayan region.

Another conclusion is emphasized by the IPCC (2007 Synthesis Report, page 49; 2010):

> "Climate change is expected to exacerbate current stresses on water resources from population growth and economic and land-use change, including urbanisation. On a regional scale, mountain snow pack, glaciers and small ice caps play a crucial role in freshwater availability. Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century, reducing water availability, hydropower potential, and changing seasonality of flows in regions supplied by meltwater from major mountain ranges (e.g. Hindu-Kush, Himalaya, Andes), where more than one-sixth of the world population currently lives."

## 2.6 What is Known

**The extent of glacier coverage and the main mountain ranges within the study area**

Although complete glacier inventories do not currently exist, there is general agreement on the area of the glaciers in High Asia. The total glacier coverage is estimated to exceed 110,000 $km^2$, with the number of identifiable glaciers exceeding about 50,000 (Dyurgerov and Meier 2005). The major concentrations of glaciers are spread across about 12 mountain ranges forming the headwaters of most all the major rivers in the Central, South and Southeast Asia mainland.

[2] IPCC Statement on Melting of the Himalayan Glaciers, January 20, 2010. www.ipcc.ch

The World Glacier Monitoring Service (WGMS) in "Global Glacier Changes: Facts and Figures" (Zemp et al. 2008) states that the total glacier coverage for the "greater Himalayan region" is 114,800 $km^2$, with 33,050 $km^2$ in the central Himalayan range.

The International Center for Integrated Mountain Development (ICIMOD), Kathmandu, reports that there are 35,110 $km^2$ within the central Himalayan region, including only the Himalayan, Karakoram and Hindu Kush mountain ranges, sometimes referred to as the HKH region, also defined as those mountain catchments feeding the Ganges, Brahmaputra and Indus River Basins.

**Glacier melt and retreat, and relation to precipitation and runoff**

Three phenomena are occurring in the region:

- Glacier melt is a normal warm season phenomenon at the lower elevations of virtually all glaciers. The amount of melt generally depends on elevation, aspect (exposure to the sun), and local climate of the glacier.

- Glacier retreat or shrinkage, typically measured directly by the amount of terminus retreat or by areal photography or satellite remote sensing, has been observed and mapped as described below.

- Glacier mass loss is also occurring, although these more complicated and scarce measurements cannot be the basis for generalized statements.

All of these phenomena are influenced by climate and specifically by differences in precipitation and runoff, which vary from the eastern part of the region to the west. Differences in total precipitation and runoff, as well as elevation-related variation, are observed.

Precipitation and basin runoff[3] generally decrease from the east to west as the summer monsoon weakens on its annual westward journey along the Himalayan range. In the east, the summer monsoon provides snow and ice for glaciers; in the west, westerly circulation and cyclonic storms contribute two-thirds of high-altitude snowfall during winter, with one-third resulting from summer precipitation mainly from monsoon circulation (Wake 1989). Hewitt and Young (1993) note that a very significant source of nourishment for many Himalayan glaciers is avalanche snow.

The variation in runoff depending on the elevation is also very different between east and west. While data from Nepal show the maximum runoff being generated at approximately 3,000 m with decreasing amounts at both lower and higher elevations (Alford 1992), data from regions further to the west indicate steadily increasing runoff up to a maximum at 5,000 m to 6,000 m (Hewitt and Young 1993). This means a gradual shift upwards in the altitude of the zone of maximum runoff from east to west. This high-altitude runoff would indicate that glaciers in the western Himalaya, Karakoram, and Hindu Kush mountain ranges are an increasingly important

[3] That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. See http://ga.water.usgs.gov/edu/runoff.html

source of streamflow volume. However, the total runoff in the western mountains is considerably less than that in the east at all altitudes—an expected condition given the relative aridity of the western mountains. Moreover, throughout the greater Himalaya, most available precipitation data come from lower elevation stations, generally below 2,000 m, and a very significant increase in precipitation can occur between those lower elevations and the accumulation zones of glaciers (Alford 1992).

**Rate of retreat and disappearance**

Estimated rates of terminus retreat, typically measured from the point of furthest down-valley extent of a glacier, vary from approximately 2 to 20% over the past 40 years (Kulkarni et al. 2007). ICIMOD reports that glaciers are retreating at rates of 10 m to 60 m per year and many small glaciers (<0.2 $km^2$) have already disappeared (Bajracharya et al. 2007). Upward shifts in the elevation of a terminus as great as 100 m have been recorded during the past 50 years and retreat rates of 30 m per year are common. These rates of retreat do not differ to any significant extent from retreat rates measured at other locations throughout the world.

In the eastern Himalaya, Kayastha and Harrison (2008) note that precipitation records for Kathmandu and the Langtang Valley, north of Kathmandu, show no significant trend for the period of record, up to about the year 2000. They therefore concluded that the rates of retreat in recent decades are mainly due to increased air temperature.

Although evidence in the eastern Himalaya shows increasing rates of retreat during recent decades, a contrasting picture often emerges from the western Himalaya, as noted above, where examples of decreasing rates of retreat are reported, such as those from observations on the Gangotri Glacier (Kumar et al. 2008) and other locations further to the west in the Karakoram[4] (Hewitt 2005). Temperature data from the Hindu Kush and Karakoram Mountains of the Upper Indus Basin show a variable pattern, but one that would support the stability, if not growth, of glaciers in the region. Since 1961, summer mean and minimum temperatures show a consistent decline while winter mean and maximum temperatures show significant increases, although still remaining well below the freezing level at the elevation of the glaciers (Fowler and Archer 2006). Decreases of approximately 20% in summer runoff of the Hunza and Shyok rivers are estimated to have resulted from the observed 1° C decrease in mean summer temperatures, a pattern consistent with the observed thickening and expansion of some Karakoram glaciers (Fowler and Archer 2006; Hewitt 2005).

Two relatively recent studies have evaluated glacier retreat in the Akshirak and Ala Archa mountain ranges of the Tien Shan. Khromova et al. (2003) used aerial photo mapping surveys from 1943 and 1977 with ASTER satellite imagery from 2001. They determined a small shrinkage of only a few percent between 1943 and 1977 in contrast to a major shrinkage of more than 20% between 1977 and 2001. The reasons presented for this large reduction in glacier area include increases in annual and summer temperatures, decreases in precipitation,

[4] The Gangotri glacier is in Uttarakhand, India, in a region bordering China; its meltwaters eventually flow into the Ganges River. The Karakoram Mountains span the borders of India, Pakistan, and China.

and a decrease in the summer/winter precipitation ratio – less snowfall at the higher elevations on the glaciers during summer results in a lower albedo (reflectivity) and higher melt rates. Another study in the same region by Aizen et al. (2006), using similar input data, found lesser amounts of glacier shrinkage over the later period of 1977 to 2003, 8.7% and 10.6% respectively for the Akshirak and Ala Archa mountains. A third study (Bolch 2007) determined that for the Northern Tien Shan (Kazakhstan/Kyrgyzstan) the average decrease in glacier extent was more than 32% between 1955 and 1999 in the valleys of Zailiyskiy and Kungey Alatau. In Central Asia in general, Kotlyakov and Severskiy (2009) report that during the period 1956 to 1990 glaciers receded by more than one-third and that the current rate of recession is thought to be approximately 0.6 - 0.8% per year.

Glaciers in the Muztag Ata and Konggur mountains of the eastern Pamir plateau in northwestern China, have been monitored by applying aerial photo stereo models (1962/1966) and Landsat TM (1990) and ETM+ (1999) images, which have been compared in order to detect areal and frontal changes through the past four decades (Shangguan et al. 2006). Glaciers in the Muztag Ata and Konggur mountains retreated 6.0 m per year between 1962/66 and 1990, increasing to 11.2 m per year between 1990 and 1999, with an overall glacier length reduction of 9.9% for the whole study period. The glacier area has decreased by 7.9%, mainly due to changes observed in the most recent period (1990-99), when the annual area loss almost tripled.

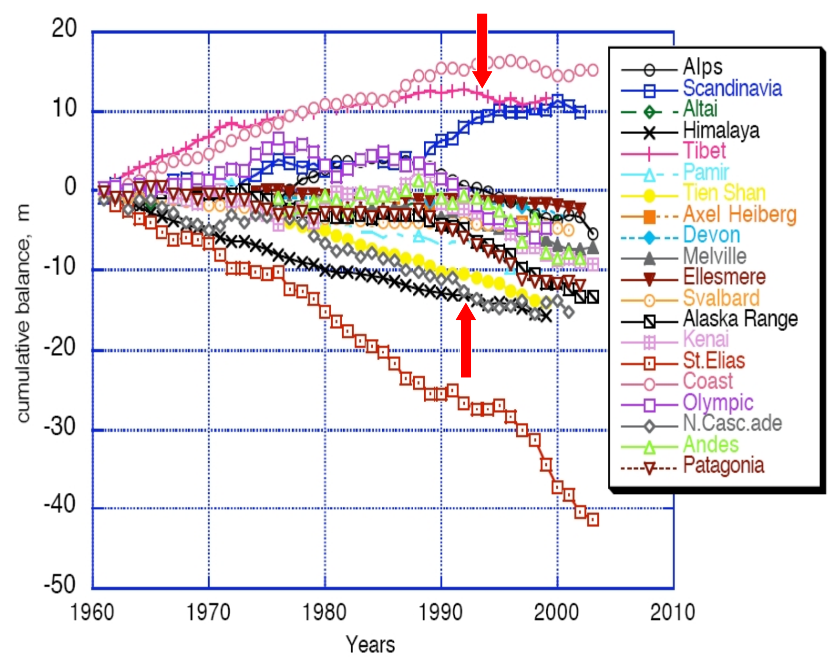


**Figure 2.2.** Cumulative mass balances (m) for selected glacier systems compiled from individual glacier time series. Dyurgerov and Meier (2005). Upper red arrow-"Tibet" region; lower red arrow-"Himalaya" region.

Yao et al. (2009) describe how the percentage of retreating glaciers within China has increased from about 50% of all glaciers during the period 1950-1970 to more than 90% since 1990. The least amount of retreat has occurred at the higher elevations of the Tibetan Plateau with increasing amounts of retreat toward the lower elevations of the southeast edge of the Plateau and the lower elevations of the Karakoram mountains. This general situation is reflected in Figure 2.2 (above), where the mass of the glaciers at the higher elevations of the "Tibet" region is shown to be decreasing at a slower rate than glacier mass in the more extensive "Himalaya" region, which includes glaciers found at much lower elevations.

In general, the rate of retreat and/or down-wasting depends on several factors, independent of dynamics. These include elevation, debris cover, ice thickness, and topographic slope and aspect; and not all investigators consider these variables when they report retreat rates. Clearly, the greatest retreat and or down-wasting is associated with those glaciers located at the lowest altitudes on gentle slopes, with thin ice near the terminus, and the thickness of debris-cover that enhances rather than retards melt. Smaller glaciers at the lowest elevations with a southerly aspect, and those "hanging glaciers" cut off from a substantial accumulation area, will be the first to disappear.

**Mass balance measurements**

As indicated in Section 2.3, mass balance measurements subtract the amount of melt (ablation) from the amount of accumulation. A negative result indicates that the glacier is shrinking, a positive result that it is growing. The unit of measurement is meters of water equivalent.

WGMS (Zemp et al. 2008) reports an average global annual ice loss of almost 0.75 m of water equivalent since 1997, twice as much as in the decade before (1988-1997) and three to four times as much as the time period 1978-1987. However, a key fact to note here is that virtually all of the glaciers in this global sample exist within an elevation range that is well below the average elevation of the Himalayan glaciers. For a review of mass balance monitoring of the past six decades, see the recent publications by Zemp et al. (2009) and Lemke and Ren (2007).

Mass balance records from Himalayan glaciers are extremely rare and of short duration (Zemp et al. 2009). Only records of ten or more years are relevant for climate and hydrological variability and trend studies, and only two glaciers barely meet this threshold. Most glaciers are also very small and located at low altitudes, and as such are not representative of all Himalaya glaciers. Data from the higher elevation Langtang and Chhota Shigri glaciers indicate consistently negative mass balance values, but the extent to which they can be considered regionally representative is not known. The glacier AX010 in Nepal has been predicted to disappear by the year 2060 if conditions represented by the period 1992-1996 remain unchanged (Kadota 1997). This could be considered a reasonable prediction, given that the size of this glacier is only 0.57 $km^2$. The uppermost altitude of AX010 is 5,360 m, while approximately 50% of the surface area of all Nepal glaciers exists at altitudes above 5,400 m, so AX010 can only be considered representative of the lower elevation glaciers (Alford et al. 2010).

On the Yala Glacier, in Nepal, at a higher elevation than the Langtang, Fujita et al. (2006) have constructed a 30-year mass balance history from ice cores and the inspection of crevasse layers. They determined that the mass balance on the Yala Glacier at 5,380 m shows a positive balance, about 0.2 to 0.8 m, during the period 1960 to 2000, tending towards zero in the mid-1990s. A limited amount of melt was observed at 5,380 m on the Yala, while no melt was observed in the same region at 7,200 m on the Dasuopu Glacier which is located on Mt. Xixabangma in China. No melt at this elevation would agree with the calculations by Alford et al. (2010) described below.

Individual glaciers can respond with great variability to a changing climate. Therefore, it is important to involve more regional-scale estimates in the analysis of Himalayan glacier mass balance. Berthier et al. (2007) compared elevation data from a 2000 Shuttle Radar Topography Mission (SRTM) with a 2004 digital elevation model (DEM) derived from SPOT5 (Satellite Pour l'Observation de la Terre) imagery in the Himachal Pradesh region of northwest India. Results indicated an average mass balance of - 0.7 to - 0.85 m per year of water equivalent over a total glacier area of 915 $km^2$, and representing an elevation range of 4,500 to 5,500 m.

Naz et al. (2008) calculated recent thickness changes on glaciers in the Upper Indus Basin of the Western Karakoram by subtracting SRTM elevation data from Ice, Cloud, and land Elevation Satellite (ICESat) data for the period 2004 to 2008. Preliminary results indicated the average thickness change over glaciers in the Hunza Valley to be approximately + 0.10 m/year in the ablation zone and approximately + 0.64 m/year in the accumulation zone, implying a recent mass balance regime that is positive.

Only one time-series set of mass balance measurements has ever been made in the Karakoram. Bhutiyani (1999) used the hydrological (water-balance) method to compute the mass balance of the Siachen Glacier in the Nubra Valley, eastern Karakoram range of the Himalaya, India – the largest glacier in the Himalaya (1,142 $km^2$) for the period 1986-1991. The average mass-balance was negative, the lowest being in 1990-91 (-1.08 m). A positive mass balance was calculated for 1988-89 (+ 0.35 m) and was attributed to comparatively heavy winter snowfall amounts and low temperatures during the ablation season. Significantly lower runoff was measured during this season. The most negative values of 1989-1990 and 1990-1991 are thought to be the result of comparatively dry winters and warm ablation periods, with monthly mean air temperatures 1.4 to 5.1°C higher at the beginning of the ablation season, June and July, than the mean of the five years.

**Projected extent (range and magnitude) of glacier melt in the next 15 to 20 years**

As discussed earlier, the 2007 IPCC statement about the possible disappearance of Himalayan glaciers by 2035 is not correct. No evidence was presented that Himalayan glaciers are receding faster than those in other parts of the world, as only rates of retreat for the Himalaya were presented. Also, a rough calculation would indicate that melt rates on the order of 20 times the current observed melt rate in the Himalaya would be required to remove all glaciers by 2035. The 2007 IPCC WG I authors of "Changes in Glaciers and Ice Caps" noted that "the glaciers of High-Mountain Asia have generally shrunk at varying rates and that several Karakoram glaciers are reported to have advanced and/or thickened" (Lemke and Ren 2007). The cumulative glacier mass balance data from the high mountains of Asia show values that are, in fact, approximately mid-way between the global extremes (see Figure 2.3 on the following page).

In one recent study involving prediction, Ren et al. (2007) applied three global circulation models (GCMs), with warming effects based on a high emissions scenario, for 2001–30, over the greater Himalayan region. Despite certain regional differences, all three GCMs indicated spatially averaged glacier thickness reductions of approximately 2 m for the 2001–30 period, but only for those areas located below 4,000 m.

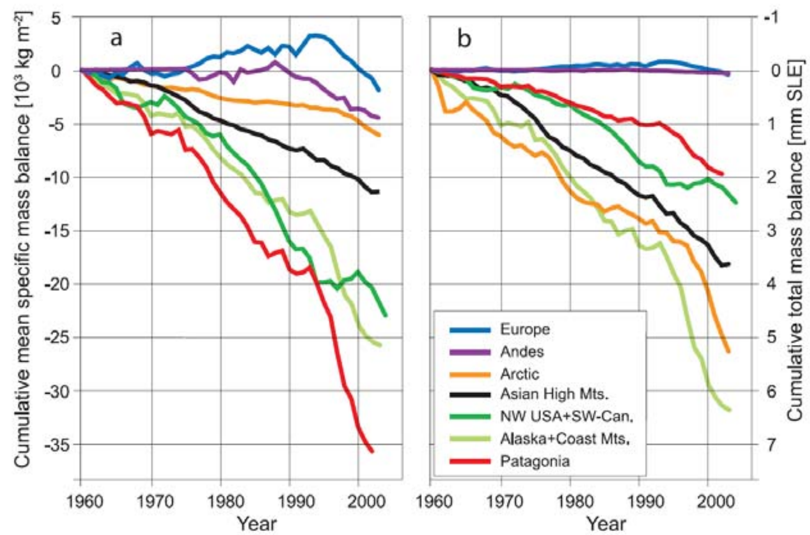


**Figure 2.3.** Cumulative glacier mass balance ($10^3$ kg $m^{-2}$) for selected glacier systems, (left panel) and cumulative contribution (mm) to sea level (right panel), Lemke and Ren (2007).

Rees and Collins (2006) have applied a temperature-index-based hydro-glaciological model in which glacier dimensions are allowed to decline with time to determine by how much and when climate warming will reduce Himalayan glacier dimensions and affect downstream river flows. Two hypothetical glaciers, of equal dimensions and initial geometries, were located within two hypothetical catchments representing the contrasting east and west climates of the Himalaya. The model was applied from a start date of 1990 continuing for 150 years with a uniform warming scenario of 0.06°C year $^{-1}$. Flows for these glaciated catchments attain peaks of 150% and 170% of initial flow at around 2050 and 2070 in the west and east respectively, before declining until the respective hypothetical glaciers disappear in 2086 and 2109. The general modeling approach is appropriate here but model inputs and glacier geometries are hypothetical. It is assumed that melt is uniform over the total glacier surface with no distinction between specific ablation and accumulation zones; therefore, the accuracy of results is uncertain.

In summary, where consistent results exist across various modeling efforts, they indicate little potential loss in total melt water available from glaciers over the next few decades. This is because increased temperatures could be compensated by increased precipitation falling as snow at the higher elevations, above approximately 5,000 m, as a possible result of a strengthened Indian monsoon (Sreelata 2006).

### The role of black carbon in accelerating glacier melt

Black carbon emissions originate from a variety of sources, including biomass burning, residential burning, transportation, and industry/power production; the relative amounts of each source differ from region to region (USAID-Asia 2010). Black carbon strongly absorbs solar radiation and is thought to be second only to carbon dioxide as a contributor to global excess radiative forcing (climate change) (Ramanathan and Carmichael 2008). Moreover, with other aerosols in atmospheric brown clouds (ABCs), black carbon contributes substantially to warming trends in the lower atmosphere of Asia (Ramanathan et al. 2007). Where black carbon accumulates over a snow or glacier surface, the impact on melt rate can be significant and can be quantified where amount and type of soot/black carbon are known. Kandlikar et al. (2009) point out that black carbon particles that fall on bright snow or ice surfaces may cause several extra months of warming each year. At this time very few in situ measurements are available, although appropriate measurements can be expected to increase in the future.[5]

A recent paper by Xu et al. (2009) describes measurements of black soot in ice cores from Tibetan glaciers and speculates on the melt rate impact. They show that the black soot content is sufficient to affect the surface reflectivity of the glaciers and that the black soot amount has increased rapidly since the 1990s, coincidentally with the accelerating glacier retreat and increasing industrial activity in South and East Asia. They suggest that a successful strategy to retain the fresh water benefits of Himalayan glaciers will need to reduce black soot emissions so as to restore more pristine high-reflectivity snow and ice surfaces. They noted that black carbon concentrations of 10 ng $g^{-1}$ significantly alter the albedo (reflectivity) of a snow layer. The visible albedo of fresh snow, about 0.90–0.97, is decreased by 0.01–0.04 by a black carbon amount of 10 ng $g^{-1}$, thus increasing absorption (1 minus albedo) of visible radiation by 10–100%, depending on the size and shape of snow crystals and whether the soot is incorporated within snow crystals or externally mixed (Hansen and Nazarenko 2004). The impact of the albedo change is magnified in the spring at the start of the melt season because it allows melt to begin earlier.

As an example of work beginning in this area, in November 2009, a French research team (IRD)[6] began work on Kongma La Glacier, a very small and debris-free glacier, in the Everest area, near the Khumbu Glacier, in collaboration with the Ev-K2-CNR project. This glacier, close to the EVk2 CNR Pyramid laboratory, will be used for studying the impact of aerosols and black carbon on glacier melting. This is part of a project (PAPRIKA) recently funded by the French National Research Foundation that starts officially in 2010 for three years.

### Impacts on water resources

While the mass balance measurements described above represent the measure of the health of a glacier and its ability to maintain its mass from one year to the next, the values, per se, do not reveal anything about the hydrology. If the mass balance is not changing, the health of the glacier is in balance. But this provides no direct quantitative information about how much glacier melt water is being contributed to the river system leaving the basin containing the glaciers.

[5] See 2009 AGU Annual Fall Meeting, Lau, W. et al. "Will Black Carbon Siphon Asia's Drinking Water Away?" - http://www.nasa.gov/topics/earth/features/carbon-pole-briefing.html and proceedings of the UNEP sponsored International Expert Workshop, "Emerging Issues in Climate Change: State of Tropospheric Temperature, Pollution, Snow, Melting Glaciers and Potential Impact on Monsoon in the Himalayas-Tibetan Plateau," December 28-29, 2009, New Delhi.

[6] Y. Arnaud, personal communication.

Previous assessments of the glacier melt impact on surface water supply have been primarily either highly qualitative or local in scale, or, in some cases, simply incorrect. For example, values reported in Singh and Bengtsson (2004) and Barnett et al. (2005) appear to be far too large. Barnett et al. (2005) stated that "There is little doubt that melting glaciers provide a key source of water for the Himalayan region in the summer months: as much as 70% of the summer flow in the Ganges and 50–60% of the flow in other major rivers." Little evidence supports such high values for the contribution of glacier ice melt to total river flow volume.

Rees and Collins (2006) believe that if all glaciers were to disappear, there would be a much greater impact on the water resources of the west than the east, with reduction in annual mean flow of about 33% in the west, but only about 4–18% in the east, compared to 1990 levels, because of the climatic differences between the drier western and monsoonal eastern ends of the region. They note that high discharge from glacier ice melt often dominates flow for considerable distances downstream, particularly where other sources of runoff are limited. They also speculate that, should Himalayan glaciers continue to retreat rapidly, water shortages might be widespread within a few decades.

A study by Alford et al. (2010) indicates that in Nepal the glacier contribution to sub-basin stream flow varies from approximately 20% in the Budhi Gandaki Basin to approximately 2% in the Likhu Khola Basin, averaging approximately 10% across nine basins. This discharge volume represents approximately 4% of the total mean annual estimated volume of 200,000 million cubic meters for the rivers flowing out of Nepal. Under current climate conditions, results indicated that the glaciers of Nepal experience no significant melt over approximately 50% of their surface area at any time of the year. This is in sharp contrast to lower elevation glaciers of the world that melt over their entire surface during the summer months, often resulting in significant mass loss.

For the upper Indus Basin, Immerzeel et al. (2009) found that glacier melt contributed substantially to streamflow – 32% in a reference situation, peaking in July (with snow melt providing 40% of the total with a peak in June, and rain comprising 28% with a peak in July). The removal of all glaciers, with an accompanying increase in the winter and summer temperatures of 4.8° C and 4.5° C respectively and precipitation increases of 19.7% and 15.7% (climate model scenario for 2071-2100) indicated summer maximum flow reduction of approximately 30% and reduction of total precipitation falling as snow from 60% to 48%. In these types of projections there is typically an increase in total precipitation, summer and winter, with melt from snow cover remaining about the same and peak discharge appearing approximately one month earlier than present conditions. Patterns of increased total precipitation and earlier snow melt can actually be beneficial for agriculture, as this pattern would provide more water for local irrigation and increased input to reservoirs when they are most empty at the beginning of the growing season.

Immerzeel et al. (2010) have recently applied their modeling approach across the greater Himalayan region and conclude that glacier melt water is extremely important in the Indus Basin and reasonably important for the Brahmaputra, but only plays a modest role for the Ganges, Yangtze, and Yellow rivers. Preliminary results indicate that the snow and glacier melt contribution, compared to total runoff generated below 2,000 m, is the following: Indus, 151%; Brahmaputra, 27%; Ganges, 10%; Yangtze, 8% and Yellow, 8%. This shows the much higher contribution of glacier melt to the Indus than to other rivers. This recent work of Immerzeel et al. represents an important step forward in understanding the regional hydrology of the greater Himalaya.

In Central Asia, Severskiy (2009) reports that glaciers lost volume at about 1% per year during the last 35-40 years of the 20th century. Such losses will result in significant changes in the hydrologic cycle as glacier runoff is responsible for 40-50% of discharge in the Tarim and Balkhash Basins (from Dolgushin and Osipova 1989, referenced in Kotlyakov and Severskiy 2009). For the whole Tien Shan, the annual and summer fractions of glacier runoff are approximately 20 and 35% respectively (Aizen et al. 2006).

In summary, a highly accurate assessment of the significance of snow and glacier melt in the overall Asian river hydrology remains largely unaccomplished. There is reasonable confidence in stating that the contribution of glacier ice melt to the downstream hydrology is small in the east, and not expected to change in the next few decades. Contribution is considerably larger in the west, but the total volume from glacier melt is still relatively small and there is no apparent reason to think that it would change significantly in the next few decades. Although the contribution from melting glacier ice to the hydrology of the lower reaches of mountain rivers is relatively small, melt water increases in significance as one moves upward in the basin towards the source of that melt water. However, societies that have adjusted to this current minimal volume of melt water from glaciers are not likely to be in for any great surprises over the next few decades.

### Known and/or projected environmental impacts of glacier melt

Because knowledge is incomplete about glacier melt and the rates of melt, impacts (except as indicated below) are uncertain. However, glacier melt is occurring and will result, along with other hydrological changes, in impacts that will be felt in the basins of rivers that originate in High Asia. These impacts may be too much water (floods), too little water (droughts/ increased aridity), or water at different times (more early in the growing season/less late in the growing season).

A misconception sometimes found in the popular literature expresses the concern that the rapid melting of glaciers alone will lead to catastrophic flooding downstream. This is physically impossible. Glacier ice melt rate under any reasonable warming scenario is relatively slow, and thus cannot, per se, cause floods. Environmental impacts come in the form of hazards associated with two distinct types of GLOFs. Interestingly, these types of floods can result from both retreating and advancing glaciers. The first type, a moraine-dammed outburst flood, occurs when large volumes of water build up behind the terminal moraine of a rapidly melting, retreating glacier and the moraine dam fails. For example, in 1985 a glacier lake, Dig Tsho in the Khumbu region of Nepal, burst and the flood waters completely destroyed a nearly completed hydro-electric power station at Thame, some 12 km below Dig Tsho. Thirty houses, many hectares of scarce agricultural land and 14 bridges were also destroyed (Ives 2006). However, only a small number of moraine-dammed lakes are actually dangerous at the present time.

Results from a 20-year study of the moraine-dammed glacier lake at the Imja Glacier in the Khumbu Himal, located a few kilometers south of Mt Everest and often characterized as one of the most dangerous in the Himalaya, show that it is relatively stable (Watanabe et al. 2009, Fujita et al. 2009). Efforts to identify which lakes are actually the most dangerous are currently underway (Bajracharya et al. 2007). Bajracharya and Mool (2009) report that during the past decade the overall area of moraine-dammed lakes has increased, although the number of lakes above the elevation of 3,500 m has decreased.

The other type of outburst flood, which is associated with advancing glaciers, occurs when a glacier tongue reaches the location where a tributary river or stream converges with the advancing glacier and is dammed by the advancing ice tongue. In this case an outburst flood may occur when the glacier subsequently retreats or breaks up. These glacier outburst floods are often referred to by the Icelandic name of "jökulhlaups" (Ives 1986).

Hewitt (2010) notes that in the Karakoram, there is a greater prevalence of ice-dammed lakes or jökulhlaups, formed by advancing glaciers (typically short-lived and unstable), in contrast to moraine-dammed lakes, which are more typical in the east and associated with greater rates of melt. The only types of damaging outburst floods reported from the upper Indus Basin in recent decades have included debris flows (conversion from water flood to debris flow). According to Hewitt (2010), regions where advancing glaciers may possibly soon impound rivers are the Shaksgam, upper Shyok, and Shimshal valleys. In 2009, satellite imagery revealed a sudden advance of the Chong Khumdan Glacier into the Shyok River. Previously, between 1926 and 1932, this glacier formed a series of large ice dams and at least four outburst floods were reported that resulted in a measurable rise in the river 1,100 km away at the Attock gauging station.

### Indirect health impacts of glacier melt

Scientific studies and other analyses that relate health impacts specifically to glacier melt are sparse to non-existent. For the broader issue of climate change impacts, there is a more robust literature linking climate change impacts to health. The influential journal, *The Lancet* (Costello et al., 2009), recently issued a commissioned report which reviews and summarizes the scientific projections of climate change (including glacier melt) and its impacts. The report discusses six ways that climate change and health are linked: changing patterns of disease and mortality, extreme events, food, water, shelter, and population. Of these, glacier melt links indirectly with patterns of disease, food, water, and population. The report concludes that three responses to the health risks from climate change are important: "First, policies must be adopted to reduce carbon emissions and to increase carbon biosequestration, and thereby slow down global warming and eventually stabilize temperatures. Second, action should be taken on the events linking climate change to disease. Third, appropriate public health systems should be put into place to deal with adverse outcomes" (Costello et al. 2009: 1693).

These concerns are mirrored in the IPCC's health chapter (Confalonieri et al. 2007), which highlights that projected trends in climate-change-related impacts will, with very high or high confidence, have negative impacts on nutrition and consequent disorders, deaths and injuries from natural disasters, the range of some infectious disease vectors, and the incidence of diarrheal diseases and cardio-respiratory morbidity and mortality.

## 2.7 Conclusions

Glaciers can be thought of as "time machines," storing water in one place over many decades – unlike rain, or even seasonal snow melt, that typically reaches the stream flow within days to months. This glacier storage acts like a large-volume water tank on the mountain side with new water coming in the top throughout much of the year, and some of the older water running out the bottom during the melt season. The annual balance question involves whether more runs out the bottom during melt than arrives during that year at the top – and, of course, it is the long term that is more important than the annual or short term – that is, the climate versus the weather.

Realistic, accurate and comprehensive assessments of the future availability of water resources in High Asia and the downstream areas in the context of glacier retreat are not possible until the existing hydrologic regime of the High Asian mountains is better defined, the current relationship between glaciers and streamflow is evaluated in quantitative terms, and the contribution from other sources of streamflow is examined. However, reasonable approximations of the impact of glacier retreat on water resources have been summarized in this section.

The glaciers of High Asia do provide a certain amount of the runoff to the people living downstream, perhaps the smallest amounts corresponding to the regions of the highest population: China, India and the Southeast Asian mainland. In the eastern Himalaya the contribution of melting glacier ice to the downstream river flow is most likely about 5% or less. In the western Himalaya, and specifically the Indus Basin, the contribution of melting glacier ice to the rivers is considerably larger. However, it is also thought that the glaciers in the western Himalaya are more in equilibrium with the current climate and may be retreating at a slower rate than those in the east, and in some cases advancing. Glacier melt water is estimated to comprise approximately 30% or more of the flow of the Indus River, with snow and ice together providing perhaps over two-thirds. The Indus River has perhaps the largest ratio of melt water to population of any river system anywhere in the world.

For the population relying on the water resources provided by the High Asian drainages, primary measures should involve well-planned management, conservation, and efficient use of the water people currently have available to them. Rapidly increasing consumption and the effective management of these existing resources should be of much greater concern than the relatively small changes that may occur in either the climate or hydrology in the coming decades.

Finally, although glaciers across High Asia may not be disappearing at as rapid a rate as had been previously thought, the need remains for mitigation and adaptation to the response of these glacier systems to climate change, as well as for development of accurate estimates of the potential impacts of melting glaciers, including the effects of black carbon on melt rates.

# SECTION 3
## THE STATE OF SOCIETIES: VULNERABILITIES AND RESILIENCE TO THE EFFECTS OF GLACIER CHANGES

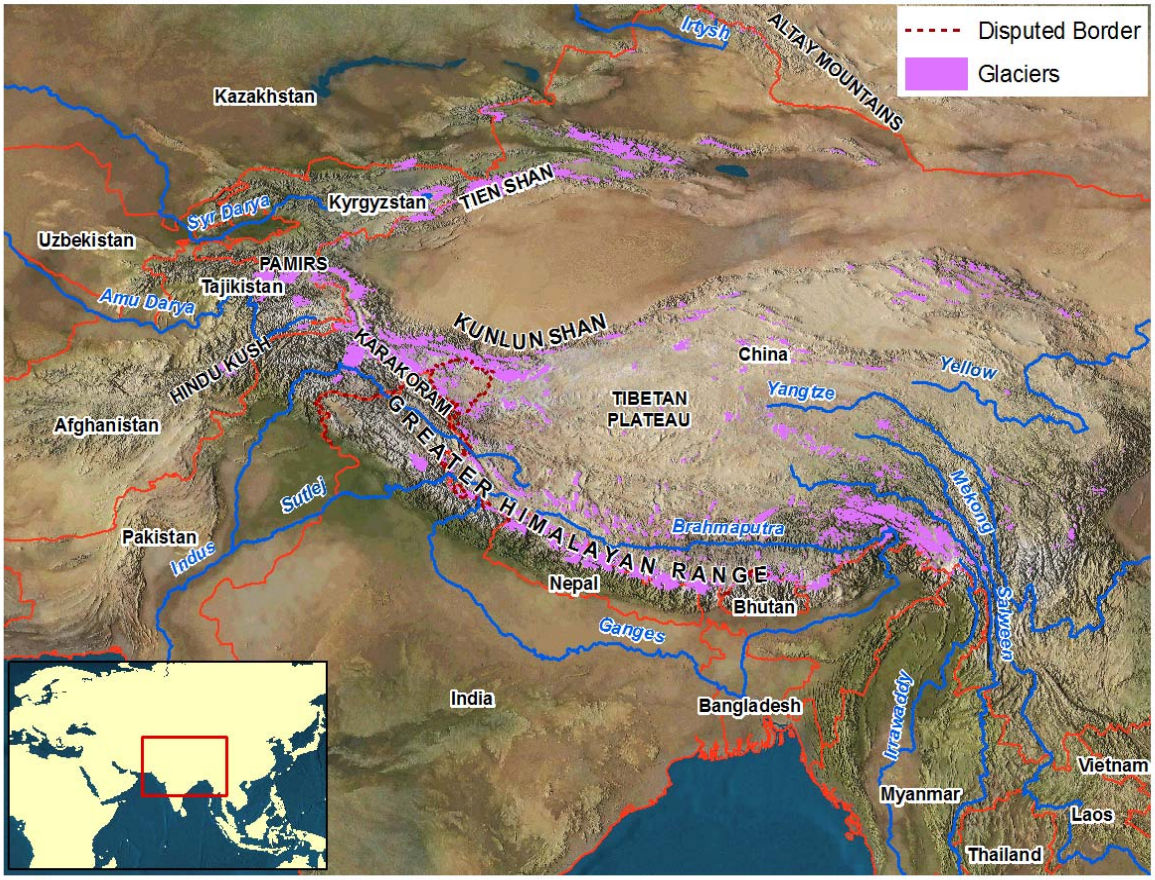


**Figure 3.1.** Map of the Himalaya region - countries and river basins. *Map credit: Brian Melchior*

The scientific report, as discussed in Section 2, demonstrated that current scientific knowledge does not provide definitive answers to questions about specific impacts on food security, water security, flood and drought risks, population displacements, and ecologically sensitive areas. We do not have, for most of the vast region of High Asia (reference Figure 3.1), accurate estimates of how much and how fast glaciers are receding, the effects of that process on river flow rates and generally on water supply, the interaction of glaciers disappearing and other hydrologic changes (such as monsoonal shifts), and what the results of all these changes will be for agricultural yields, irrigation and drinking water supply, health, and political stability.

However, we do know that the world, including this region, is warming; that there are direct, near-term threats, such as GLOFs; and that the longer-term impacts of glacier melt will be experienced through the water systems of the region, since the glaciers – along with monsoons and other rain plus snow – contribute to the water supply of the region. Thus, we can make the following assumptions:

- Human health and ecosystem impacts are likely to result from the environmental impacts of changes in the hydrologic systems, of which glaciers are a component. There may be too much water in the form of floods, which may overwhelm local water and sanitation systems and raise the risk of diarrheal and other diseases, ruin agricultural crops and infrastructure, destroy livelihoods, and increase health risks from standing water that may be breeding grounds for disease vectors. There may be too little water in the form of longer times between rains or increased aridity, which will result in less water available for drinking, sanitation, and food and hand washing – all raising health risks. Less water will be available for crops and ecosystems. Pollutant concentrations will be proportionately greater in less water. Scarcity of water also means that more time must be devoted to finding and carrying water. In addition, there may be changes in when water is plentiful, causing uncertainties about what to plant and when, resulting in likely decreases in crop yields.

- Current existing health, ecosystem, and pollution issues make communities more vulnerable to *any* changes in their water systems. Glacier melt and its water-related changes will likely exacerbate current vulnerabilities, such as demographic factors (population size and density, fertility rates, and population momentum), high burden of disease, degradation of ecosystems, and poor air quality. These current vulnerabilities will make communities less resilient to any glacier-melt-related shifts in hydrologic systems.

Based on these assumptions, the study team next identified societal and ecological vulnerabilities to potential impacts associated with glacier melt. For this task, the team first focused on the collection of geo-referenced data from the region, using the data sets most likely to provide substantive data for subsequent analysis (e.g., population distribution, river basin areas, primary agricultural products, and sensitive ecological areas or regions). Maps with overlays were prepared for identifying glacier melt vulnerabilities that overlap with USAID sectors (health, agriculture, environment, biodiversity, conflict/security, and water).

At a March 31-April 1, 2010, workshop, the project team, in consultation with USAID team members, drafted a set of issue areas and key vulnerabilities (described below) related to glacier melt in the larger context of high-altitude hydrology. Additional types of data to be mapped were then identified. All maps have been produced using GIS technology.

## 3.1 Near-Term Issues Resulting from Current Glacier Changes

The most visible near-term issue is the danger of GLOFs, which are described in Section 2. Another issue is the projected near-term retreat and disappearance of some glaciers that provide fresh water for nearby communities.

A comprehensive database of glacier lakes and the danger of GLOFs has not yet been compiled, although remote sensing has been used to examine glacier lakes. However, remote sensing is not necessarily an accurate way to determine whether or not a particular glacier lake presents an outburst flood danger. For instance, Byers (2009) reports on ground-based expeditions that have corrected several of the remote sensing results.

The more immediate glacier hazards and response needs in the Asia region involve communities and activities in the high mountains. Although these communities are often small and remote, only the Andean highlands rival High Asia in the numbers and diversity of settlements close to, and at direct risk from, glacier change. The most serious dangers are GLOFs and debris flows. The risk of GLOFs received particular attention in Bhutan, Nepal and Tibet, where more than 25 glacier lake outburst floods have been recorded since the 1930s, with especially destructive events in 1985, 1991 and 1994. Nepal has one of the highest numbers of glacier lakes in the region.

There is also a history of outburst floods from Karakoram glaciers involving much larger impoundments by short-lived, unstable ice dams that blocked tributaries of the upper Indus and Yarkand Rivers, causing outburst floods of exceptional size and destructiveness. The most urgent questions today involve three Karakoram valleys whose glaciers created ice dams and catastrophic outburst floods in the past and that are advancing right now (the Shaksgam, upper Shyok and Shimshal valleys) (Hewitt 2010). Both permanent and seasonal pastoral settlements are found within these remote high mountain valleys. Other devastating sources of danger to these oasis settlements include frequent mudslides and rock falls and seasonal flooding.

Although the numbers of people are small, impacts can be extensive; GLOFs destroy villages, agricultural lands, roads, bridges, hydropower, and trekking trails, as well as human lives and property. The destruction may be so complete that people who survive must move and begin to rebuild their lives in other places.

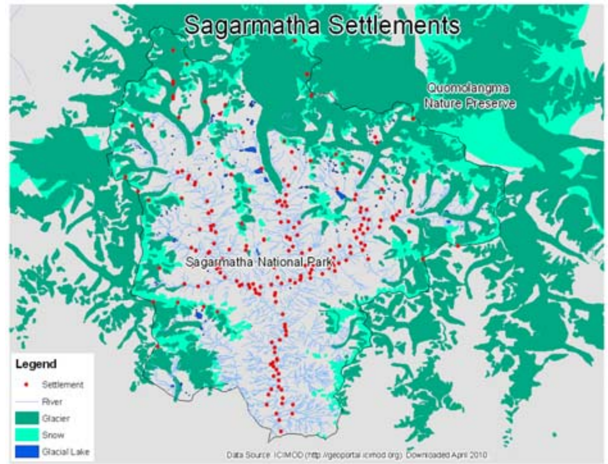


**Figure 3.2.** Settlements and glacier and snow coverage in Nepal's Sagarmatha area. *Data source: ICIMOD (http://dataportal.icimod.org) downloaded April 2010.*

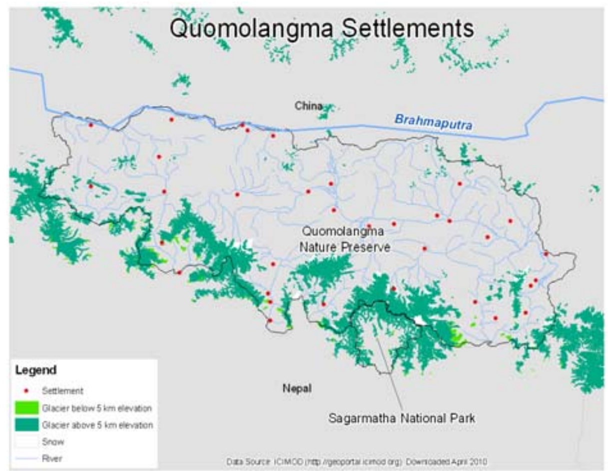


**Figure 3.3.** Settlements and glacier snow coverage in Nepal's Quomolangma area. *Data source: ICIMOD (http://dataportal.icimod.org) downloaded April 2010.*

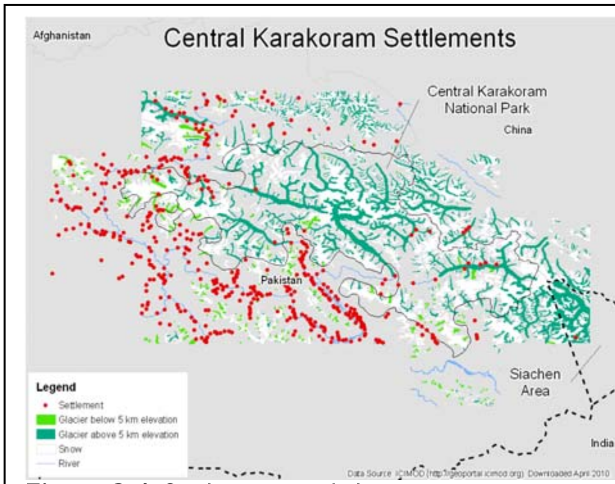


**Figure 3.4.** Settlements and glacier snow coverage in the central Karakoram area. *Data source: ICIMOD (http://dataportal.icimod.org) downloaded April 2010.*

Glaciers are also an important source of freshwater for people living in High Asia, typically small communities. Glacier retreat could thus cause long-term loss of natural fresh water storage. Also, lower elevation glaciers (below 5 kilometers) are especially vulnerable to retreat, especially if they are located on south-facing and/or relatively flat landscapes, and are covered with melt-enhancing debris or black carbon. Populations historically getting their water from these glaciers must begin to plan for large changes in water supply. Figures 3.2-3.4 (shown on previous page) show the proximity of human settlements to glaciers and glacier lakes in Nepal's Sagarmatha National Park, and the proximity of human settlements to low-lying glaciers in Nepal's Quomolangma and Karakoram regions.

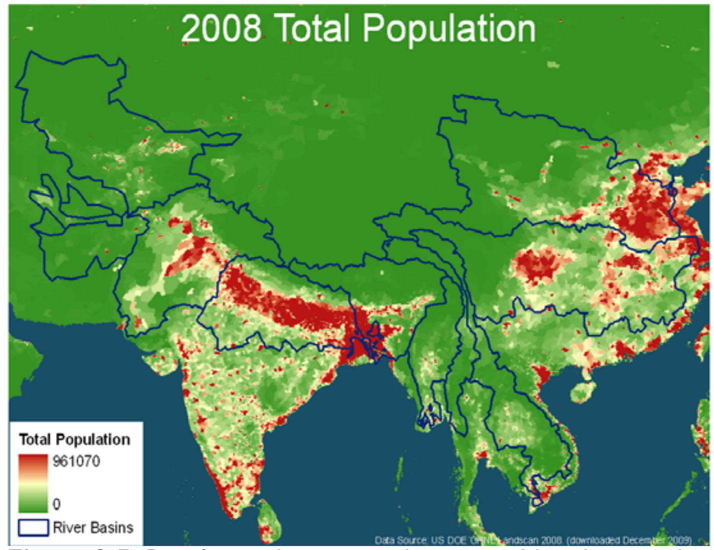


**Figure 3.5.** Population densities in the region. Map showing the total population count per pixel (2.5 minute resolution or roughly 5km x 5km pixel). See Figure 3.1 for country boundaries and basin names. A standard deviation stretch is used, meaning that classes are created around the mean based on the number of standard deviations (in this case, 2). The intention of this graphic, as well as any of the other graphics using a standard deviation color stretch, is merely to show magnitude, high (red) to low (green) of population. *Data source: US DOE ORNL Landscan 2008, downloaded December 2009.*

Therefore, as low-lying glaciers are at risk of forming glacier lakes that may be unstable and of retreating and disappearing, these lakes require monitoring and the nearby settlements require disaster preparedness.

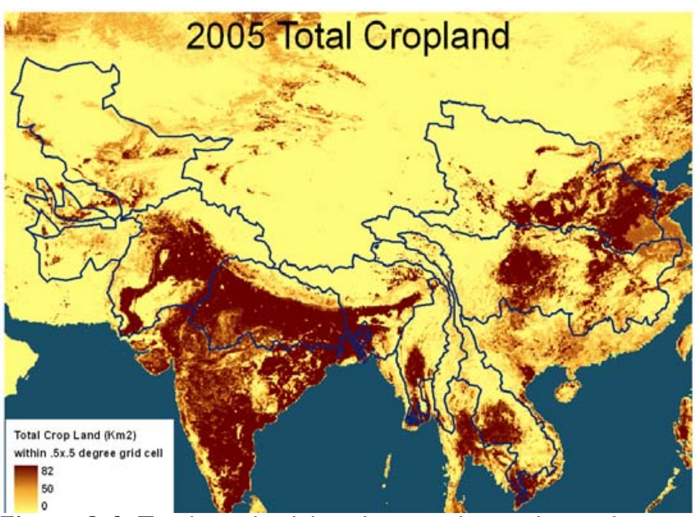


**Figure 3.6.** Total cropland, largely coinciding with population densities and partly with incidence of hunger, shows that many people are dependent on agricultural productivity and thus on a reliable water supply. See Figure 3.1 for country boundaries and basin names. *Data source: HYDE Netherlands Environmental Assessment Agency 2005.*

## 3.2 Existing Vulnerabilities to Water Stress

Dependence on glacier meltwater can take two forms. On the one hand, in the Indus River Basin, water from glacier melt constitutes a high percentage (approximately 30% or more) of the water supply from the river. On the other hand, the high population density in the Ganges River Basin means that dependence on the current water supply is high simply because of the number of people. Even small changes (glacier meltwater accounts for less than 10% of the river's water) – no matter what the nature of the change – may cause water stress and other hardships.

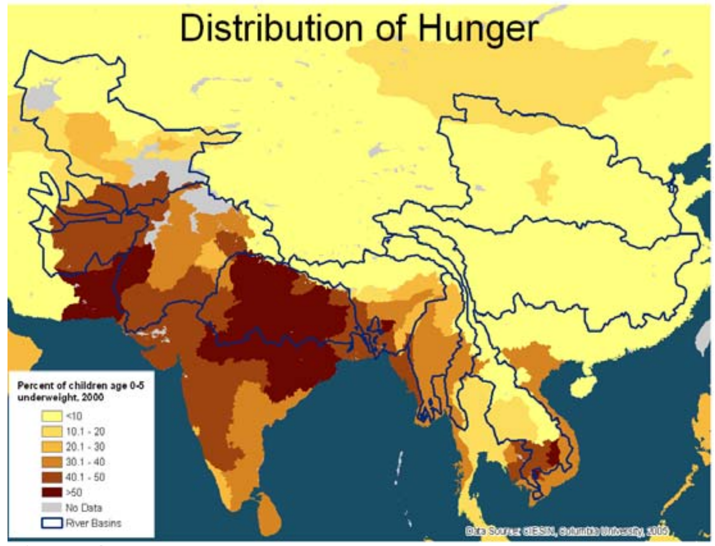


**Figure 3.7.** Hunger prevalence, which coincides with high population concentrations in India, Pakistan, and central Asia. See Figure 3.1 for country boundaries and basin names. *Data source: CIESIN, Columbia University 2005.*

Nearly 500 million people live within the Ganges and over 200 million within the Indus river basins (see Figure 3.5 on top right of previous page). These high populations and the large amount of land already dedicated to crops (see Figure 3.6 bottom left of previous page) are contributing to food insecurity in the region (see Figure 3.7 at right). Food insecurity will likely rise in the future, partially because of the high fertility rates and large cohorts of young people within these river basins (see Figures 3.8-3.10 below and on following page). In the central Indian states such as Uttar Pradesh and Bihar, as well as in most of Nepal, the total fertility rate is above 3.0. In Uttar Pradesh, the rate is higher than 3.8. The large numbers of women of child-bearing age means that population momentum would be difficult to slow in the near term. And the high fertility rates coincide with food-insecurity-related health impacts on children; many young children are already underweight and severely stunted (see Figure 3.11 at top of page 27). In most of central India, more than 20 percent of children have a height-for-age ratio below 2 standard deviations. These current vulnerabilities will likely worsen with increasing uncertainties related to water supply.

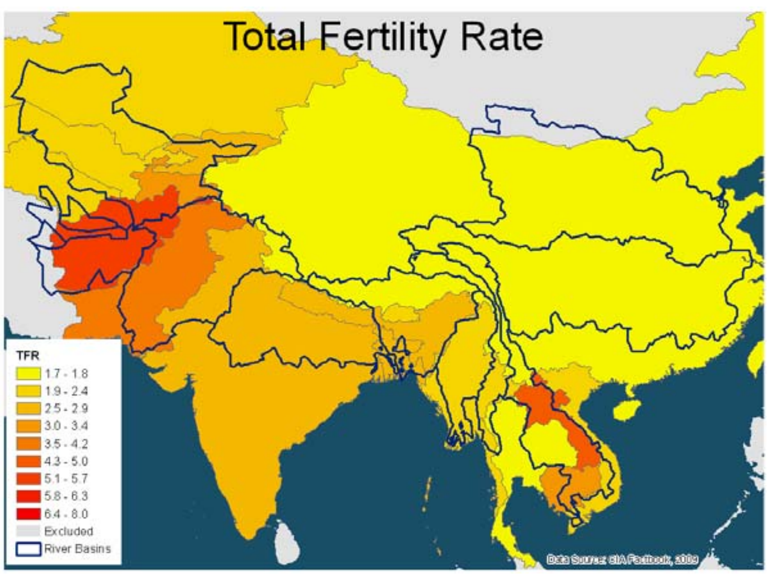


**Figure 3.8.** Fertility rates are high in Pakistan and Afghanistan where population densities are already high and hunger is a current problem. See Figure 3.1 for country boundaries and basin names. *Data source: CIA Factbook 2009.*

In the Indus and Ganges River Basins, the amount of irrigated land is higher than in any other river basin in Asia (Figure 3.12 at bottom of page 27). Both population growth and climate change will place significant stress on water resources in these areas and water stress is projected to rise in India and China (Figure 3.13 on page 28). Thresholds of water scarcity have been defined to describe the different levels of water stress and potential levels of need. In Figure 3.13, a water stress threshold has been defined as 1,000 $m^3$ per person per year; below this threshold, populations are defined as being under "water stress" conditions. This threshold serves as a warning sign to places expected to experience population growth, increases in future water demand for agriculture or industry, and vulnerability to potential impacts of climate change.

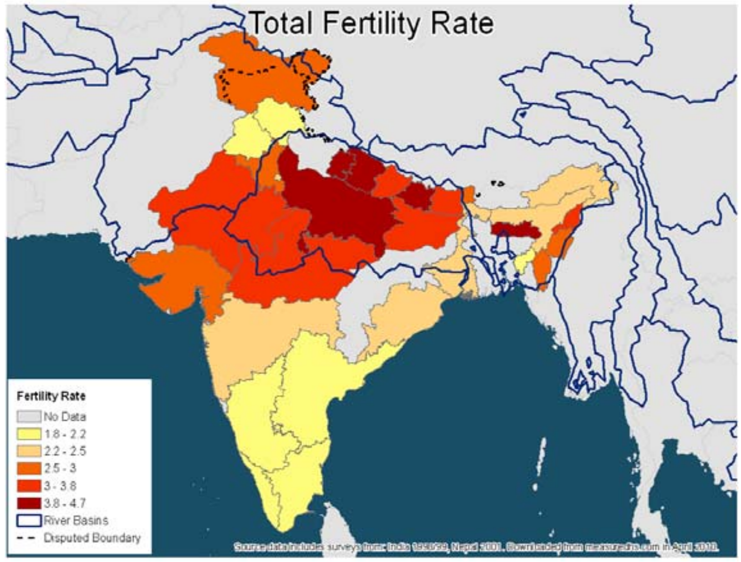


**Figure 3.9.** A closer look at the total fertility rate in South and Central Asia. See Figure 3.1 for country boundaries and basin names. *Data source: Includes surveys from India 1998-1999, Nepal 2001, downloaded from measuredhs.com April 2010.*

The three panels of Figure 3.13 show, from top to bottom, scenarios of water stress conditions in 2030 under climate change only, under population change only, and then with both climate change population changes. In the latter two scenarios, water stress conditions are projected to spread to Pakistan, India, and most countries of Southeast Asia. Under water-stressed conditions, irrigation will be less and less viable as time goes on—another threat to food security and health.

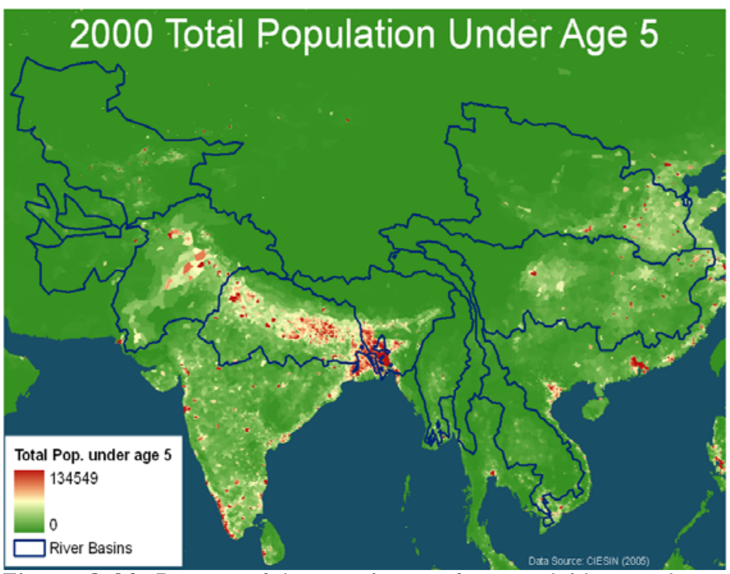


**Figure 3.10.** Density of the population of young children in the area. See Figure 3.1 for country boundaries and basin names. Map showing the total population count per pixel (2.5 minute resolution or roughly 5km x 5km pixel). A standard deviation stretch is used, meaning that classes are created around the mean based on the number of standard deviations (in this case, 2). The intention of this graphic is merely to show magnitude, high (red) to low (green) of population. *Data source: CIESIN, Columbia University 2005.*

As water stress more often than not results from increased population and associated increased demands for water and food, glacier melt will play only a small role in increasing this stress in river basins such as the Indus. The overall availability and timing of water supply will change under climate change conditions, contributing to stress, as shown in Figure 3.13.

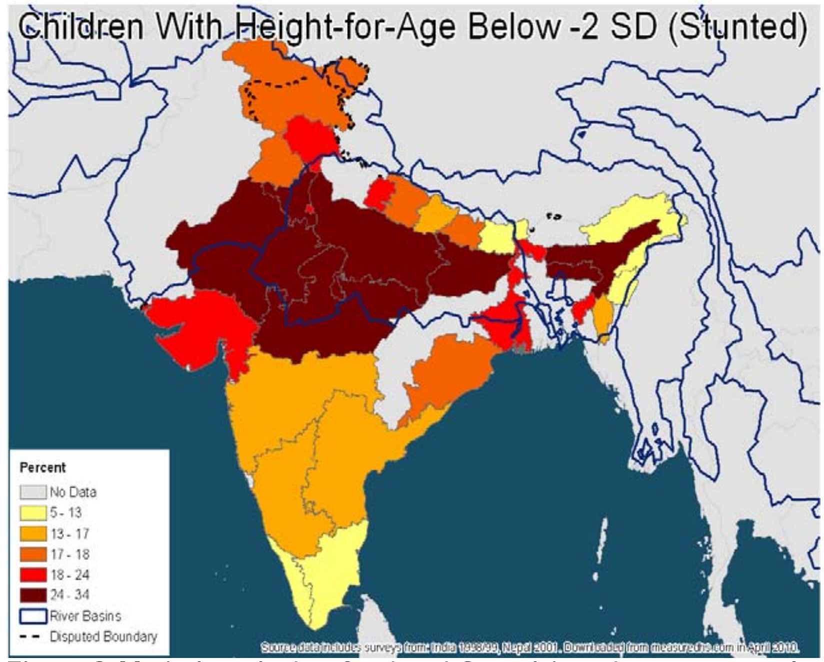


**Figure 3.11.** A closer look at South and Central Asia: the percentage of children who are stunted is highest where most children reside. See Figure 3.1 for country boundaries and basin names. *Data source: Includes surveys from India 1998-1999, Nepal 2001, downloaded from measuredhs.com April 2010.*

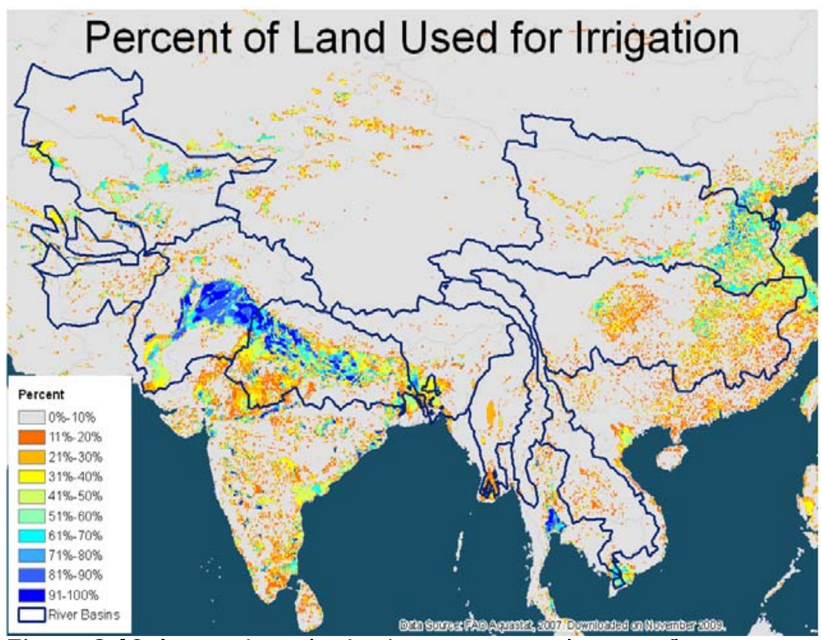


**Figure 3.12.** Irrigated cropland indicates some resilience to fluctuations in water supply but also a large dependence on continuing levels of supply of surface and/or groundwater. See Figure 3.1 for country boundaries and basin names. *Data source: FAO Aquastat 2007, downloaded December 2009.*

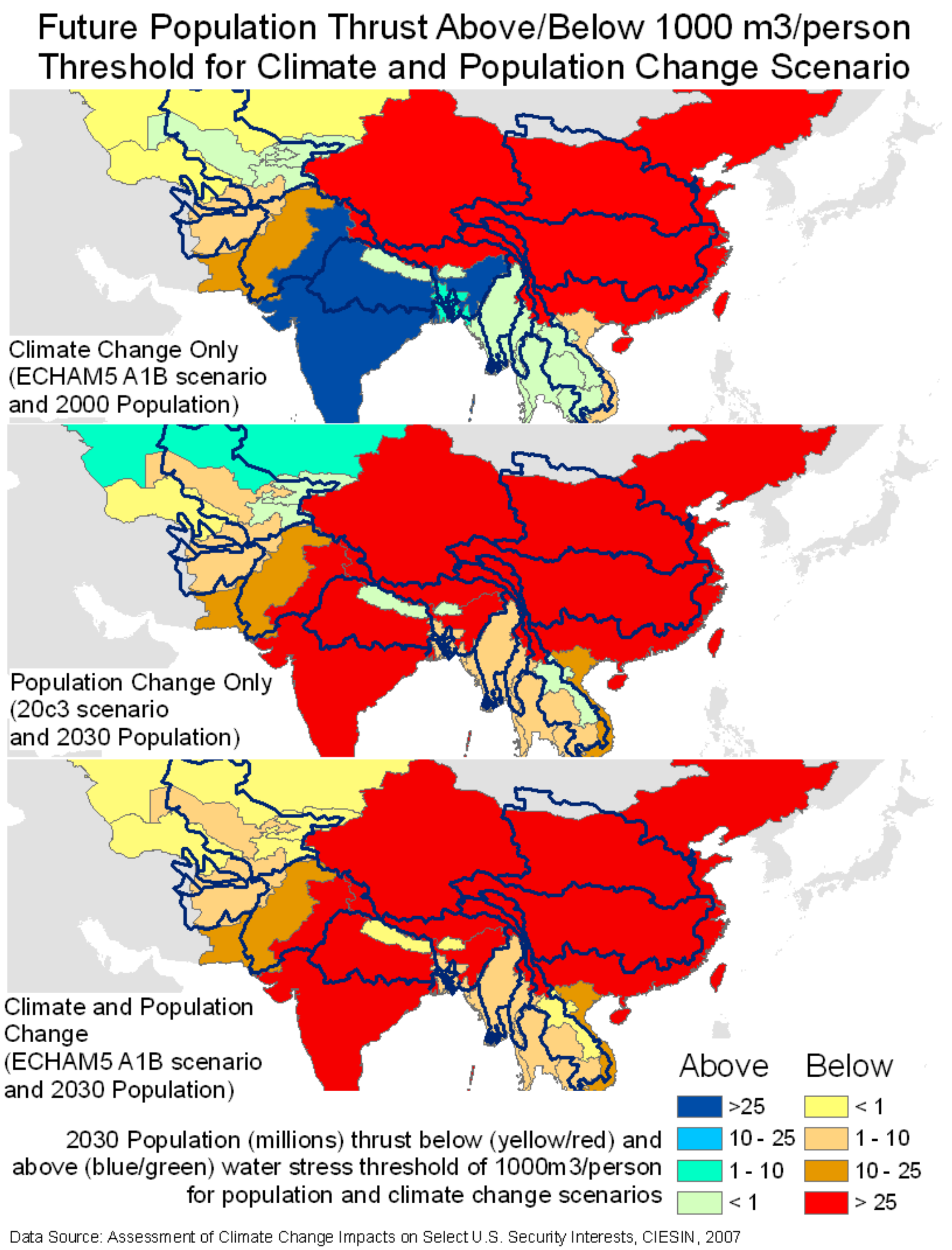


**Figure 3.13.** Projections of water stress under three scenarios: top panel shows stress conditions with climate change only, the middle panel with population change only, the bottom panel with population and climate changes. See Figure 3.1 for country boundaries and basin names. *Data source: Assessment of Climate Change Impacts on Select US Security Interests, CIESIN, Columbia University 2007.*

## 3.3 Indirect Impacts on Human Health

The World Health Organization[7] has identified potential health impacts from global climate change via three pathways: (1) direct impacts (such as exposure to pollutants); (2) impacts mediated by ecosystems (such as malnutrition and increased risk of infectious diseases); and (3) indirect, deferred, and displaced impacts (such as health consequences of livelihood loss). The World Bank (2009) uses a similar framework.

The only direct impacts of glacier melt researchers can point to are GLOFs and early disappearance of some glaciers. These impacts will be felt mostly by small, high-mountain communities who are usually living in remote areas. One of the program approaches described in Section 5 focuses on these communities, with emphasis on indirect health links to water and water stress as caused partially by population pressures.

Because glacier melt is part of the water system, impacts will be experienced across the region through changes in water quantity and quality. In those areas where glacier melt is a larger proportion of river flow (e.g., the Indus River Basin) this link will be stronger. In those areas where glacier melt is a smaller proportion (e.g., the Ganges River Basin) small changes in water quantity and timing will have large impacts on denser populations living downstream. As the maps in Figures 3.12 and 3.13 show, partially because of irrigation demands, most areas downstream from the High Asia glaciers will be at risk of water stress. Climate change will further exacerbate the difficulties of obtaining clean water and sanitation for hundreds of millions in these watersheds, as water may be less available in dry seasons (thus increasing the proportional effect of pollutants) and come in more intense rains in the monsoonal season, leading to flooding. "The main health effects of lack of access to clean water and sanitation are diarrheal and other diseases caused by biological or chemical contaminants" (Costello et al. 2009:1705). Thus, programs to address the causes and effects of diarrheal disease via water; ecosystem management; and water, sanitation and hygiene (WASH) (as described in Section 5) will address these vulnerabilities and build resilience.

A second important vulnerability is the potential for worsening under-nutrition. As the maps in Figures 3.7, 3.10, and 3.11 show, respectively, hunger, prevalence of young and therefore vulnerable children, and stunting are already problems in the downstream areas of the region. Costello et al. (2009:1704) reinforces this assessment, although speaking at a global rather than a regional level: "Chronic and acute child malnutrition, low birthweights, and suboptimal breastfeeding are estimated to cause the deaths of 3.5 million mothers and young children every year. Furthermore, one in three children under the age of 5 years in developing countries suffer [sic] from stunting due to chronic undernutrition." Costello et al. then review several studies that project declining crop yields and food availability due to climate change. Those who grow their own food are least likely to be resilient to change, lacking enough good land, inputs such as fertilizer and irrigation water, and access to markets. In India, glacier melt and projected

[7] See http://www.who.int/globalchange/environment/ecosystem_assessment_large.jpg.

uncertainties about water availability for crops worsens the situation of hundreds of millions who already live with food scarcity with limited government programs to alleviate it. Therefore, programs that address water quantity (especially efficient use) and quality, nutrition, food security, and agriculture will address these health vulnerabilities.

A third vulnerability stems from population densities that place pressure on the areas' waters and other natural resources. The map in Figure 3.5 shows the highest population density concentrated in the Ganges River Basin and high densities in parts of the Yellow and Yangtze River Basins. These are also areas of high agricultural activity (Figure 3.6), and the Ganges River Basin also has a high fertility rate (Figure 3.9). High population growth rates will increase pressures on the environment in general and water systems specifically, so vulnerability is expected to rise under climate change conditions.

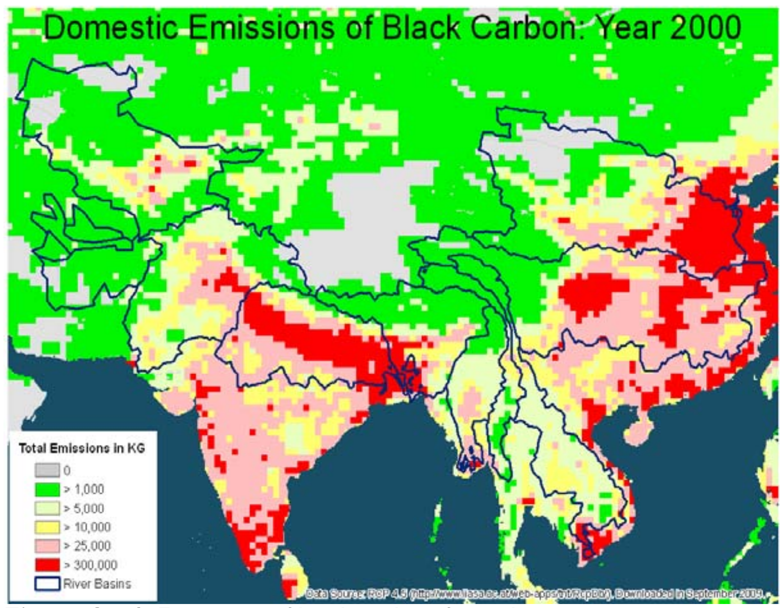


**Figure 3.14.** Emissions of black carbon from domestic sources (cooking and heating) in 2000. See Figure 3.1 for country boundaries and basin names. *Data source: ROP 4.5, http://www.iiasa.ac.at/web-apps/tnt/RopDb, downloaded September 2009.*

An additional climate-related factor is the use of biomass (wood, agricultural waste, dung, etc.) for indoor cooking. The smoke generated by biomass burning releases black carbon and other aerosols (Figure 3.14 at right) that affect regional climate and exacerbate glacier melt while also posing a severe health hazard, since the indoor air pollution contributes to premature deaths and various respiratory ailments. In addition, the South Asian Atmospheric Brown Cloud (ABC), which contains black carbon, has been singled out as a contributor to accelerated melt of the Hindu Kush-Himalayan-Tibetan glaciers (USAID-Asia 2010). Exposure to the effects of indoor air pollution from burning biomass disproportionately burdens women and young children with respiratory diseases as well as heart disease, stillbirth, cataracts and other visual problems, pre-term delivery, and low birth weight (USAID 2010). In India alone, these impacts have been estimated to cause 440,000-500,000 premature deaths per year in women and children under five years of age (Smith, cited in USAID-Asia 2010). The highest level of these emissions is found in the Ganges, Yellow, and Yangtze River Basins. Thus, programs that address maternal and child health, and meeting energy needs with low or no emissions will address these vulnerabilities while also addressing a cause of accelerated glacier melt.

## 3.4 Threats to Ecosystems

Threats to ecosystems will likely come directly and indirectly from changes in the melt rates of glaciers and other associated changes in the high-altitude hydrologic systems of High Asia. However, scientific studies that show the direct links between ecosystem health and glacier melt are lacking, especially research that separates those links from other causes, such as deforestation. This lack is analogous to the absence of studies linking health and glacier melt.

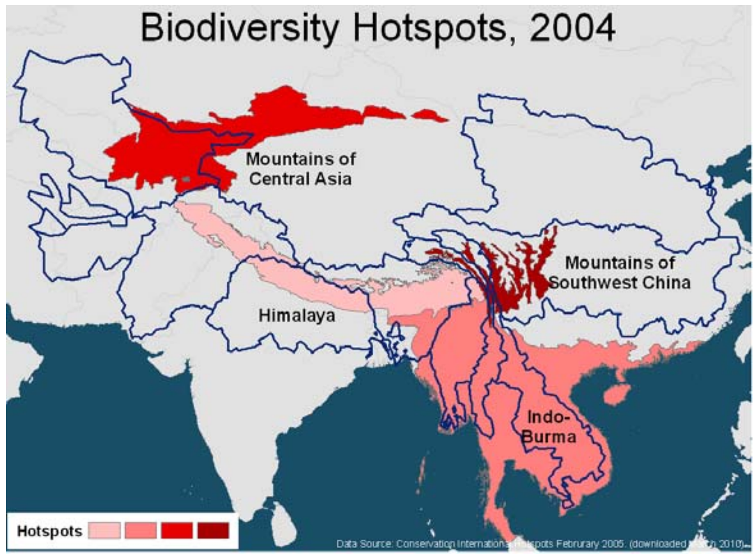


**Figure 3.15.** Large biodiversity hotspots in watersheds fed by High Asia indicate ecosystem vulnerabilities. See Figure 3.1 for country boundaries and basin names. *Data source: Conservation International Hotspots 2005, downloaded March 2010.*

However, the vulnerability perspective sees that ecological health is at risk because ecosystems are already facing other threats. The Himalayan Mountain Range is one of the biodiversity hotspots shown in Figure 3.15 at right.[8] Spanning the Indus and Ganges River Basins, it is home to 3,160 endemic plant species and contains 8 endemic threatened bird, 4 endemic threatened mammal, and 4 endemic threatened amphibian species. For example, the breeding range of the Black-Necked Crane, the only alpine crane in the world, is mostly confined to China's Qinghai-Tibetan Plateau.

Figure 3.15 illustrates additional biodiversity hotspots in South, Southeast, and Central Asia, which cover parts of almost all the major river basins fed by the hydrologic system in High Asia.

- The hottest spot is in China's southwest mountains, which support a wide array of habitats and threatened species, including the golden monkey, giant panda, red panda, and a number of pheasants; it is watered by branches of the Yangtze River and by the Mekong River, both of which originate in the glaciated regions of High Asia.

- Next in severity are the mountains of Central Asia, including the Pamir and the Tien Shan mountains. The hotspot's 860,000 square kilometers (in part of the Syr Darya

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[8] The data for this section are from Conservation International (http://www.conservation.org/explore/priority_areas/hotspots/asia-pacific/Pages/asia-pacific.aspx). Other groups have other definitions and areas.

River Basin) include southern Kazakhstan, most of Kyrgyzstan and Tajikistan, Eastern Uzbekistan, Western China, Northeastern Afghanistan, and a small part of Turkmenistan. The hotspot contains about 20,000 glaciers, has an arid climate, and is home to a highly threatened type of walnut-fruit forest, unique to this region, which contains ancestors of domestic fruit varieties and is an important storehouse of genetic diversity. The hotspot is also home to a rich variety of ungulates, including the threatened argali wild sheep.

- Finally, the entire region of Southeast Asia is a hotspot, covering all or part of four major river basins that originate in High Asia. Unique mammals are still being discovered there, and threatened turtle species and over 1,300 different bird species make their homes here.

Accelerated glacier melt is only one of the ongoing changes in these regions, which face many different pressures, among them the impacts of climate change.

Environmental change is already beginning in the high-altitude regions where glaciers are plentiful. For example, Tibet is experiencing warming temperatures, along with and generally drier conditions; the latter is at least partially attributable to unsustainable land practices (Khoday 2007).

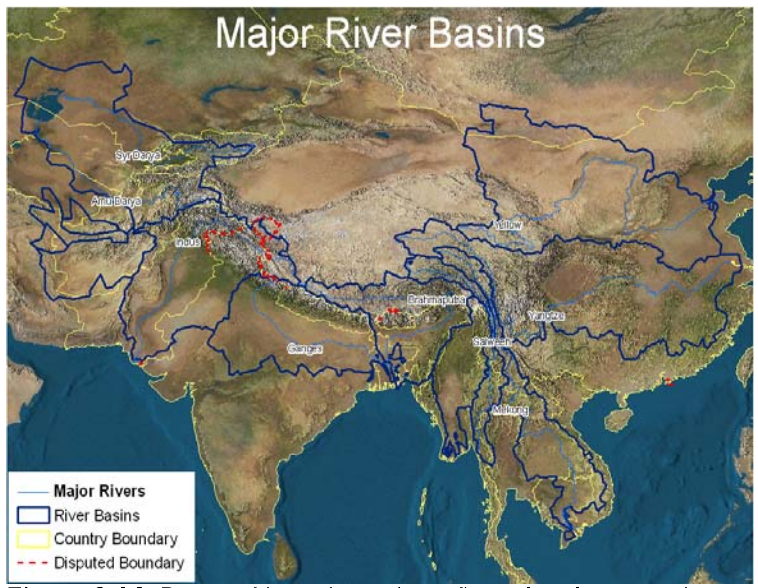


**Figure 3.16.** Disputed boundaries (in red) involve glaciers and water resources. See Figure 3.1 for country boundaries and basin names. *Disputed data source: US Department of State 2010. Map credit: Brian Melchior*

## 3.5 Potential Governance and Conflict Implications of Unstable Water Supply

Because the river basins span multiple national borders, there will inevitably be disputes between the different nations over the use of water within the basins, despite existing treaties that cover various aspects of water allocation and rights. Areas like Aksai Chin and the Siachen Regions are already disputed areas (see Figures 3.16 above and 3.17 on the following page). Increased accessibility and extraction of water resources will only exacerbate already problematic areas.

Governance issues in the region will weigh heavily in both mitigation and adaptation actions related to glacier melt in the region. The two largest countries (in terms of population, economy, and land area), India and China, will likely be most influential in climate-change-related policies and activities. Both of these countries are increasing their greenhouse gas emissions and, at the same time, emphasize their rights (as non-Annex-1 countries under the United Nations

Framework Convention on Climate Change [UNFCCC]) to both increase their level of development (and associated emissions) and be compensated for the costs of adaptation to climate change by the industrialized nations of Annex 1. Both central governments have good environmental laws, but implementation at lower levels of government has been a challenge for both.

For India, governance is an important aspect of both water management and food security, from local water user associations to central government policies on irrigation. Glacier retreat, combined with changes in precipitation (especially the monsoon) will likely increase uncertainties about when and how much water will be available in the Indo-Gangetic Plain, where almost half of India's people live. Challenges to growing crops will affect hundreds of millions of people who have only limited adaptation options and whose health may deteriorate as food scarcity increases; governmental proactive policies could ameliorate these impacts.


**Figure 3.17.** A closer look at the area where boundaries are disputed which include the Siachen Glacier. *Data source: ICIMOD 2010. Disputed data source: US Department of State 2010.*

Both floods and droughts also have the potential to exacerbate water contamination and increase diseases. This requires governments to be prepared to reduce disaster risks and respond.

China has a smaller proportion of the Earth's water than its proportion of the Earth's human population and it controls the sources of important rivers that flow out of its boundaries. These two conditions lead to the potential for China to divert available water from the Himalayan Plateau and other high mountains for its own use, putting downstream countries in South, Southeast, and Central Asia at risk of water scarcity. The scale of such diversion projects would likely result in greater central government control of water systems in the region. Water scarcity may worsen in the North China plain where farmers are already mining groundwater.

Regional water management has been both called for and lacking. India's preference for bilateral agreements and China's non-participation have tended to preclude meaningful regional action. India currently has the long-standing Indus Water Treaty with Pakistan for water-sharing and a treaty with Bangladesh providing water to the latter–both have been the subjects of dispute. China's dam-building plans are a source of concern to all countries downstream from the Chinese high mountains, but other countries (e.g., Laos and Cambodia) have dams and plans to build more (Cronin 2007). The Association of Southeast Asian Nations (ASEAN) has been weak in action and the Mekong River Commission (MRC), too, has not been a strong governance mechanism, although recent efforts are being made to make both more effective.

Water disputes are a feature of Central Asian politics as well. The upstream and glaciated countries, Tajikistan and Kyrgyzstan, have no hydrocarbon resources but ample water resources and hydropower potential–the opposite is true of Kazakhstan, Turkmenistan, and Uzbekistan. In theory, these resources should be exchanged, but withholding on both sides has taken place. This situation has been in place since the break-up of the Soviet Union and is vulnerable to changes in water availability. Glacier melt is of concern to all countries, with its implications for short- and long-term water supply.

In summary, various governance issues are contributing to current vulnerabilities, which glacier melt impacts may exacerbate. There is a strong need to build capacities in the areas of scientific cooperation, regional institutions for data gathering and water management, and environmental laws and their implementation.

# SECTION 4
# EXISTING ACTIVITIES RELATED TO GLACIER MELT

As well as scoping the extent of short- and long-term concerns stemming from glacier retreat and identifying societal vulnerabilities to these changes in the near and longer terms, the study team surveyed activities already underway relating to the issues of climate change impacts on glaciers and high-altitude hydrology. The aim of this survey was to find out what other organizations are doing in relation to glacier melt and what the gaps are that might inform the recommendations of this study. An understanding of these current activities will enable resources to be allocated appropriately to areas where no programs exist, USAID activities could complement other activities, or USAID could cooperate or partner with other funders.

The geographic scope of this task included all countries of the Himalayan Plateau and its outlying sub-ranges (including India, China, Nepal, Bhutan, Pakistan and Afghanistan), the countries of Southeast Asia, and the Central Asian Republics (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan). The approach adopted for this review involved desk-based literature review, internet searches, phone and email conversations; and in-person meetings or visits undertaken where feasible. Information requests included the activities of organizations relating to glacier melt, and key partners and recommended contacts. To help inform data analysis, more detailed phone and in-person interviews were conducted with several key stakeholders who provided additional information on impressions of data and information gaps relating to work currently being undertaken on glacier melt in Asia. Organizations contacted on country visits to India and Nepal in April 2010 were also added. Another important list of resources can be found in the feasibility study of the Asian Research Center of Excellence for Climate Change and Development (ARC) (USAID 2010).

The results from this search are presented in the form of an Excel spreadsheet (see Appendix A) with a main database (Appendix A.1) which contains all the information gleaned from this study, and two summaries: according to country or region (Appendix A.2); and thematically (Appendix A.3).

## 4.1 EMPHASES OF CURRENT ACTIVITIES

Most of the current activity specifically related to glacier melt is taking place in India and China; relatively less activity was found in the Central Asian Republics, although there is a wealth of data from the Soviet era and active research programs. The current situation is not surprising, given glacier distribution patterns and the comparative resources available for glacier melt research across the region.

Thematically, most research and activity to date has focused on glacier monitoring, although GLOF risks are receiving increased attention as a key climate change hazard in the Himalayan region. Less attention has been paid to downstream implications of glacier melt and adaptation strategies. There is very little assessment of the factors underpinning risks from glacier melt that exacerbate vulnerability on the ground. For example, despite an active effort to find evidence of work relating glacier melt and health in Asia, none was found.

Further, the database demonstrates a wealth of research-based activities, but very few actual glacier-melt-related adaptation projects on the ground. Adaptation activities in this area that do exist tend to be large-scale and technological approaches (for example, the United Nations Development Program's GLOF projects in Bhutan). The dominance of research institutes over line ministries and/or NGOs active in glacier melt activities reflects this point. However, work in this area is starting to emerge; The Mountain Institute (TMI) and WWF are two organizations that have begun work on community-based adaptation.

## 4.2 Organizations

Appendix A.1 – Main Database, shows all the information collected for this study. It organizes agencies into key "organizational groups": government donor agencies; key national agencies (key contact agencies for any potential work on glacier melt in that country); multilateral and United Nations (UN) agencies; non-governmental organizations (NGOs); and research/academic organizations. This categorization minimizes repetition (for example, because many donor and UN agencies work across the region in several different countries) and highlights where certain agencies are working on cross-regional projects. There is some overlap between categories (for example, some research organizations are NGOs). In these cases organizations are not listed twice, but rather put in the categories they chose.

## 4.3 Countries and Sub-Regions

Appendix A.2 – Summary by Region, lists the key organizations working in each country or, where there is very little activity in some countries, grouped into regions. The grouping is as follows:

- China
- India
- Nepal
- Bhutan
- Bangladesh
- Pakistan
- Central Asia (including Afghanistan)
- Southeast Asia.

Only the name of the organization is included in this table; full details must be cross-referenced to Appendix A.1 – Main Database.

## 4.4 Themes

Appendix A.3 – Summary by Theme, lists the key organizations working on five themes, chosen according to the major themes that emerged from the search:

- Glacier monitoring (glacier inventories; monitoring glacier retreat/glacier melt)
- Glacier lake monitoring and GLOF risk
- Downstream impacts of glacier melt, including water management and agricultural issues
- Black carbon studies and activity

- Community-based/bottom-up adaptation with vulnerable mountain communities.

The themes are not mutually exclusive. For example, glacier lakes are rarely studied independently of glacier melt; however, categories are defined by the "lead theme" of projects as described by the agencies undertaking the projects.

Only the name of the organization is included in this table; full details must be cross-referenced to Appendix A.1 – Main Database.

## 4.5 Gaps in Current Activities

All key informant interviewees point to a clear lack of comprehensive data and information on glacier melt in the Himalayan region. The Energy and Resources Institute (TERI) stated that one of the problems is a lack of any benchmark glacier studies in the last 60 years, so it is difficult to measure glacier recession as there is nothing to measure against (TERI is currently working to develop such a benchmark).

According to ICIMOD, part of the data gap exists because existing studies on glacier melt are based on "terminus fluctuation or changes in glacier area," neither of which provide precise information on ice mass or volume change, which are needed for accurate estimates of glacier change. China is the only country where long-term mass-balance studies have been taking place, although more recently India has also initiated such studies (see box at right). ICIMOD has been promoting mass-balance measurements of benchmark glaciers in its member countries of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. Based on its glacier inventory work and mass-balance measurement data, ICIMOD has confirmed the general trend for glacier retreat in the Himalayan region, while acknowledging that some glaciers are not showing this trend, and that further research is needed.

**India's New Investments Related to Glacier Melt**

India has been a leader among developing countries in the UNFCCC negotiations and program developments. In addition, the 2009 reports and controversies about an IPCC report statement exaggerating glacier melt projections have galvanized the Government of India to devote much more attention to the issue of glaciers and what is happening to them.

In 2008 India released its National Action Plan on Climate Change, which includes eight National Missions. One of these missions is the National Mission for Sustaining the Himalayan Ecosystem. The plan aims to conserve biodiversity, forest cover, and other ecological values in the Himalayan region, where glaciers that are a major source of India's water supply are projected to recede as a result of global warming. Three major workshops are planned to define a program of work for this mission.

The establishment and staffing of the new National Centre for Glaciology is more evidence of the intent of the Indian government to invest in glacier research. The Indian National Institute of Hydrology is also undertaking glaciological research, with new staff being hired and laboratories being furnished with state-of-the-art equipment.

Another major information gap in the field is the lack of any "on the ground" data and information on the people and environments of the Himalayan region directly related to glaciers. According to TMI, almost all data that exist about glaciers has been collected through remote sensing technology, with many influential statements and correlations based on data-deficient modeling results. There has been very little "ground-truthing" of this data or the statements made. For example, TMI recently launched a field expedition to the Everest region to assess the condition of 9 glacier lakes previously classified as "dangerous" by remote sensing technology. The expedition revealed that 7 of the lakes that were deemed "dangerous" were judged not to be, but one that had not been so classified was judged to be "very dangerous" and that a second lake, recently re-classified as "non-dangerous," was growing so rapidly that intensive monitoring and mitigation planning were called for. TMI has suggested that only by systematically combining field and laboratory-based investigations, including the insights of local people, can the tools be acquired to enable the identification of real threats, non-threats, and feasible adaptation strategies for vulnerable communities.

The paucity of adequate and reliable data on glacier melt is partially due to political dynamics. To date, most data has been collected on an ad-hoc basis with little coordination by a fragmented community of organizations. Many respondents noted that coordination should be a national responsibility, although regional coordination and cooperation are also needed. For example, ICIMOD noted that one important need is long-term longitudinal and latitudinal transect data that would allow conclusions to be drawn for sub-regions, water basins, or specific systems. However, this requires long-term commitment from governments in the region, and this requirement can be problematic, especially given that glacier research sub-regions rarely correlate with political boundaries. This was well illustrated by a *Science* article in November 2009 which stated that because of lingering tensions, a diplomatic initiative to get Chinese and Indian scientists working together on glaciers had been shelved in August over territorial disputes (Bagla 2009).

However, TMI, ICIMOD, the US National Science Foundation, and others are planning a second interdisciplinary workshop in Nepal focused on enhancing networks among scientists and policy makers. Participants will include representatives of the 8-country Himalayan-Hindu Kush region, North America, South America, and Europe, building upon the success of the 2009 workshop in Peru entitled "Adapting to a World without Glaciers."[9]

Another gap related to community-based adaptation activities in the Himalaya is the need to ensure upstream-downstream linkages between communities and any adaptation interventions, currently an area that is under-researched. This is generally more of a problem in mountain regions. TMI has been considering this issue and piloting an approach in the Andes using field-based research of highland-lowland interactions and ecosystem services; new climate change and highland-lowland curriculum development (middle to high school level); awareness raising activities; and lowland constituency building for enhanced mountain ecosystem service

[9] http://www.mountain.org/press/events/glaciers/agenda.pdf

stewardship. Similar programs may be appropriate for Asian regions, once the results of the program in the Andes become available.

One further recommendation for attention and investment is indirectly related to glacier melt issues in mountain regions: the need for large-scale conservation and restoration of highland ecosystems. Although glacier-fed freshwater supplies may be diminishing in some areas, future generations can most likely be assured of a continuous supply of freshwater if mountain ecosystems are conserved or restored.

# SECTION 5
## APPROACHES TO ADDRESSING CLIMATE-CHANGE IMPACTS ON GLACIERS AND HYDROLOGY

The three previous sections elaborate on the state of the science related to glacier melt, the potential vulnerabilities to associated impacts, and the survey of organizations already engaged in activities intended to address glacier-related hydrological changes and impacts. This section draws on these streams of information to generate cross-sectoral program concepts and approaches that are designed to produce co-benefits across sectors.

These program concepts and approaches were developed by a team of cross-sectoral specialists with the following criteria in mind:

- Address priority issues related to glacier melt and retreat in a cross-sectoral way designed to yield co-benefits in multiple sectors
- Complement or fill gaps, considering activities already underway
- Correspond with USAID's interests and mandate

The program concepts and approaches are intended to be used as a "menu" of possible programs to choose from rather than as a cookbook of recipes that must be followed. Different Missions, taking account of current conditions in their countries as well as potential partners and synergies with ongoing programs, can choose or adapt any of these or develop other programs. Programs that address cross-sectoral issues related both to glacier melt impacts and general development, such as water management and health, have the advantage of natural connections with many of USAID's programs and initiatives. As such, they yield the kind of "no regrets" co-benefits that increase the well-being of societies both in the short term and the long term.

As climate change is a long-term issue, extending program timelines beyond 3-5 years and explicitly coordinating projects across sectoral and geographic boundaries should be considered. One option would be to link projects that could be completed in sequence, in order to allow for periodic evaluation and course correction, institutionalization of best practices, and scale-up. Another option is to coordinate programs with other Missions and/or sectors, exploring mechanisms to share resources and management.

Section 2 concluded that, overall, with regard to glacier melt, scientists lack knowledge about the rate of melt and impacts of the phenomenon. This knowledge would help societies plan for the changes and adapt to them. Many questions remain about what those changes will be, especially with regard to downstream areas (see table on the following page). This lack of knowledge, also confirmed by the survey of organizations discussed in Section 4, constitutes a large vulnerability.

Therefore, the first program concept in this section addresses the need for collaborative and integrated scientific efforts to increase scientific knowledge and to engage in monitoring changes in glaciers. The program approaches associated with improving scientific knowledge and data collection are based on an ongoing effort to better understand, prepare for, mitigate, and adapt to the impacts of glacier melt. Moreover, such programs are feasible in almost all countries; experience shows that countries can cooperate on scientific programs even when they have few other cooperative efforts.

Other large vulnerabilities arise from current deficits in health and population conditions and economic resources, as shown in Section 3. Scientists may disagree about whether, for instance, there may be too much or too little water (floods or droughts), and the evidence is mixed. But in many areas people may be vulnerable (likely to be harmed) by *any* change in water supply or in the timing of water availability during the growing season. People who are ill-nourished, have more children than they want and can support, and are mired in poverty and dependent on scarce natural resources have very limited capacity to deal with or adapt to change. These vulnerabilities are identified in both projections of climate change impacts and in general development efforts, making this an area where co-benefits will naturally arise.

| Questions that Cannot Be Answered with Current Knowledge | |
|---|---|
| How will seasonal water flows change? | Will there be flooding from accelerated melt? Where? |
| Will more snow fall? More rain? How much? | Will arid lands become more arid? How much and when? |
| How will crop yields change? What will the effect on food security be? | How will economic sectors, such as tourism and energy, be impacted? |
| How will people cope with increasing water stress, including scarce water for drinking, sanitation and hygiene? | What will be the health effects, including diseases, malnutrition, and maternal and child health? |

Recognizing these existing vulnerabilities facing large populations downstream from glaciers, the second program concept in this section addresses both near-term preparedness (to GLOFs and the disappearance of some glaciers) and resilience-building to existing vulnerabilities. These vulnerabilities include water stress and associated food and nutritional deficits; health issues–particularly population pressures and diarrheal diseases associated with poor water quality–as well as malnutrition; threats to ecosystems, particularly biodiversity; and potential governance and conflict implications of unstable water supply. The three program approaches focus on (1) improving the management of water resources, (2) conserving ecosystems, and (3) preparing high-mountain communities for direct impacts of glacier melt.

Finally, efforts to reduce climate-changing emissions of black carbon and other aerosols will reduce the need to adapt to climate change – and at the same time, yield health benefits to people as they breathe less polluted air, both indoors and outdoors. These issues are discussed in both Sections 2 and 3.

The third program concept and approach address these two different issues simultaneously, thus presenting combined opportunities for program integration and co-benefits. Black carbon and other aerosols likely change the regional climate and accelerate glacier melt when black carbon is deposited on reflective glacier surfaces. Therefore, reducing these emissions mitigates climate change and thus reduces vulnerability to glacier melt. In addition, reducing these emissions brings significant health improvements, particularly to women and children in households who cook and heat their homes with biomass, and to urban dwellers where multiple sources contribute to high levels of air pollution.

An overall framework for thinking about programming is presented in Figure 5.1 on the following page.

In the broader national and international context, water resources and their reliability constitute the main concern, as well as glacier changes. Areas are especially likely to be vulnerable if they are directly affected by glaciers, either via the dangers of GLOFs or by dependence on water supply. Specific examples include the following:

- **High-Altitude Communities.** The upper Indus and Yarkand[10] River Basins involve large populations directly, or potentially, dependent on the glaciers. These communities may face the dangers of GLOFs, shrinking glaciers that supply water, and other vulnerabilities arising from poor economic and/or health status.

- **The Indus River Basin.** Despite incomplete evidence that glaciers feeding the Indus River may not yet be losing mass, the entire region is arid so water supply – and any changes – are extremely important under any circumstances. The Indus has the largest proportion of glacier melt water of any river, anywhere in the world. Nonetheless, water supply in these regions is less than one-third the global average. Moreover, the water management infrastructure is aging and poorly maintained.

- **The Ganges River Basin.** By 2050, much of Asia is expected to be under water stress, with demand exceeding available supply, not even accounting for the impact of melting glaciers. Declining water tables in northern India, for example, have been linked to unsustainable consumption of groundwater for irrigation and other human uses. The Ganges River Basin, with its dense and growing population depending on its waters and high demand for irrigation water, is particularly vulnerable to increased water stress. Even small amounts and types of changes may have large impacts.

- **The Tarim River Basin.** In China, the ecosystem in the Tarim River Basin[11] has been degenerated, largely owing to increasing population pressure and over-allocation of water resources for agricultural irrigation (Xingming 2008). Here water stress will be exacerbated as the process of glacier melt accelerates.

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[10] The Yarkand River is the principal water source in dry season for 23% of people living in extreme western China.

[11] China's largest inland river basin, with headwaters in the Karakorum Pass and Yarkand River. An estimated 8.6 million people live in the Tarim watershed and 85% are ethnic minorities (Xinjiang Uyghur Autonomous Region of extreme western China).

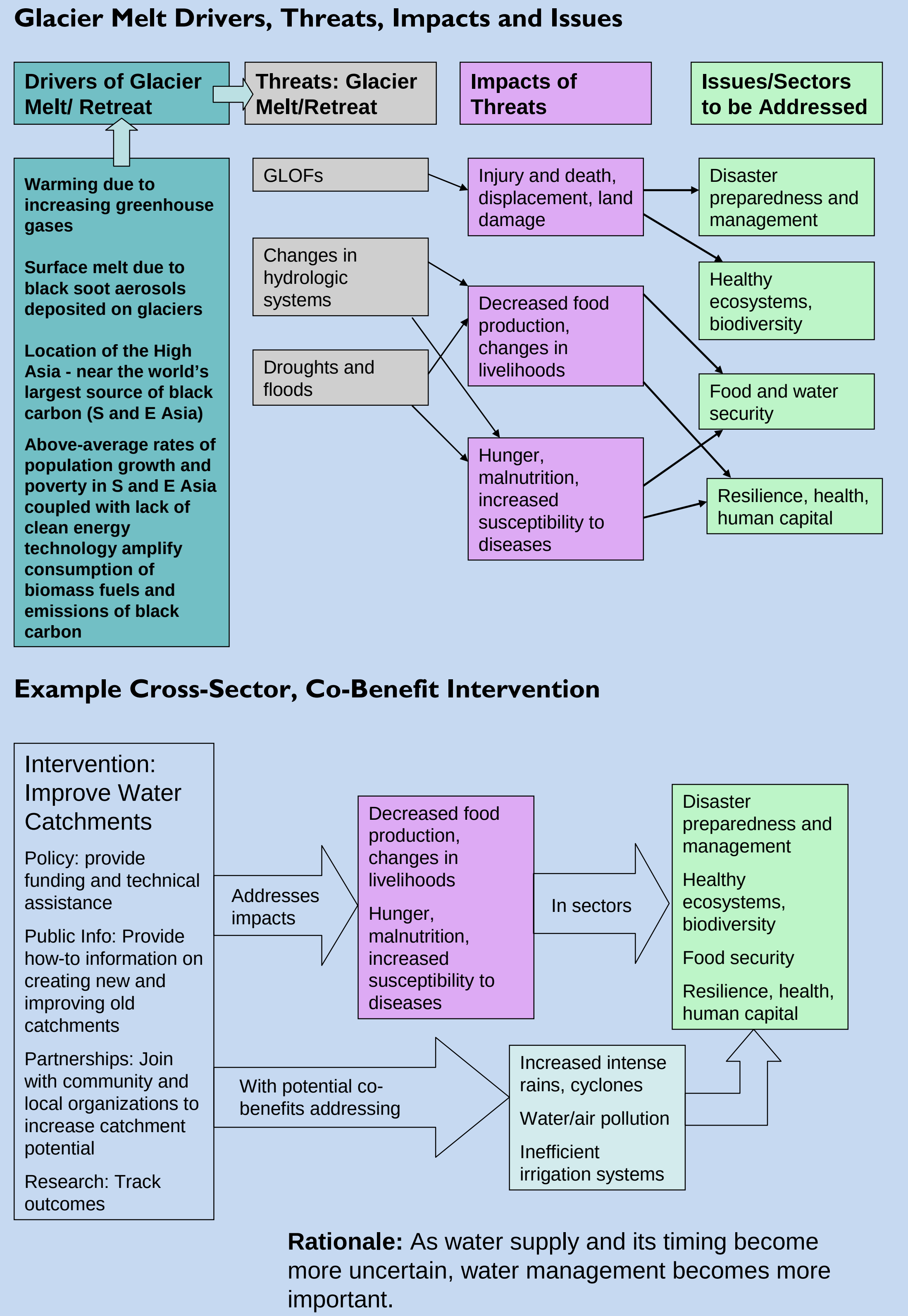


**Figure 5.1.** Framework for addressing cross-sectoral issues and realizing co-benefits. The relationships among the drivers of glacial melt, threats, and issues to be addressed are illustrated by the top graphic, and an example of how to consider cross-sectoral projects with multiple benefits is illustrated by the bottom graphic.

- **Central Asian Republics.** Like the Indus River Basin, the entire region is arid, so water supply – and any changes – are extremely important under any circumstances. Water management infrastructure problems are at least a partial legacy of the Soviet Union. Recent years have seen conflicts between upstream countries that have abundant water and downstream countries with water needs, e.g., for irrigation.

## 5.1 Responding to the Challenge of Lack of Information

The recognition of a severe knowledge gap detailed in Section 2 raises the urgent need to improve cross-boundary scientific collaboration and cooperation. Water resources management and planning in the watersheds of High Asia are by nature transboundary. Glaciers are found in the high mountains of India, China, Nepal, Bhutan, Pakistan, Afghanistan, Tajikistan, Kazakhstan, and Kyrgyzstan—but the health of the glaciers and stability of the high-altitude hydrologic regime are of concern to every country in the region. Therefore, regional cooperation and collaboration are essential in order to plan for optimal and fair water use under both current and future conditions. Such programs should demonstrate for policymakers that transboundary scientific cooperation is essential to accurately assess regional climate change impacts, including accelerated glacier melt.

A corresponding need is to expand and strengthen capacity to monitor glaciers and hydrologic changes across High Asia in order to answer questions about mass balances, rates of change and their determinants, and the role of black carbon, among other questions. Effective monitoring of climate and water resources over large mountainous regions requires the capability to characterize conditions across variable and complex terrain. Many of the knowledge gaps regarding relationships among weather, climate, hydrology, and water consumption exist because of inadequate monitoring. Such knowledge gaps can lead to predictions that are based on false assumptions, resulting in poorly informed planning. While some critical data can be acquired by satellite remote sensing, many essential parameters must be obtained by measurements on the ground, both automated and manual. Community-based observations offer a way to both involve communities and to build, at low cost, both capacity on the ground and observational data sets. Researchers also need to present data and associated analysis in a format that is both understandable and useful to policy makers as well as to the many other stakeholders involved in planning and implementing climate change mitigation and adaptation policies and programs.

### 5.1.1. Focus on Improving Regional Scientific Cooperation on Glacier, Snowpack and Water Resources in High Asia

USAID can design a program or programs of regional knowledge-sharing and scientific capacity-building that will lead to comprehensive and effective solutions to water resource problems, including changes in the amount and timing of glacier meltwater. The aim is to establish sustainable mechanisms for scientific cooperation.

**Sectors Addressed**

Programs can span all sectors open to scientific investigation, including ecology, water resources, health, agriculture, and governance. Missions can prioritize issues to be addressed by country context and by specific needs and opportunities for knowledge and collaboration.

**Illustrative Programs**

Programs can range from information-sharing forums to educational or internship-type opportunities such as:

1. Sponsorship of workshops and conferences that build cross-boundary and cross-sectoral scientific partnerships to improve knowledge about glacier melt and its impacts. This could be done in partnership with ICIMOD, which has a 25-year track record of promoting the exchange of scientific and technical information among countries that have few venues for these type of interactions. ICIMOD has programs and/or has sponsored meetings on various aspects of glaciers, hydrology, high-altitude wetlands and rangelands, and black carbon. In addition, USAID's SERVIR-Himalaya will reside at ICIMOD and should be a partner in such programs.

2. Support for in-country scientists from throughout the region for educational advancement, participation in scientific gatherings, and collaboration in cross-boundary research studies.

**Outcomes/Co-Benefits**

Current expertise and resources, as well as past experience, vary greatly across the nations making up the mountainous regions of Asia. Synergy of effort in this collaboration – including multi-country programs to achieve wider investigations using similar methods – would result in clear advantages to the lesser-developed countries while affording the more developed countries the added advantage of a regional-scale approach to water problems. The sharing of data, as well as appropriate technology (e.g. GIS methods, satellite retrieval algorithms, climate and hydrologic models), would benefit all participants. Knowledge of the optimal instrumentation for in situ measurement of climate and hydrologic parameters would benefit all and would encourage a consistent, standard set of observations across the region. This would, in turn, enhance capacity to perform comprehensive regional scale science. The ability to cooperate on scientific endeavors might become the basis for cooperation on other issues, such as controlling region-wide pollution, yielding governance and health benefits.

### 5.1.2 Focus on Strengthening Monitoring Capacity for Climate and Water Resources in High Asia

USAID can support the development of a regional meteorological and hydrologic monitoring network with spatial coverage adequate to characterize the region and to provide input variables needed by predictive models. In addition to the more typical hydro-meteorological data, these measurements would also include glacier mass balance at as many locations as feasible, as well as seasonal snow cover data acquired both from in situ measurements (depth and snow water equivalent) and satellite data (primarily snow extent). In addition, a program of black carbon (soot) and dust measurements on snow and ice surfaces at appropriate locations should be implemented (like the PAPRIKA program, discussed in Section 2, which is beginning with one glacier). In the context of hazards, monitoring of the potential for GLOFs should be included. Comprehensive data management would be essential to the success of this activity. Data describing the current demographic patterns in water use and future trends are essential to determining regional impacts of climate change (including glacier melt). Monitoring efforts can be linked with existing programs, such as the hydro-meteorological programs of USAID's Office of Foreign Disaster Assistance (OFDA).

**Sectors Addressed**

USAID programming across all sectors would benefit from the new knowledge generated by the program. For example, a monitoring program on black carbon would contribute to the health sector in addition to forestry and energy sectors. Monitoring programs would also contribute directly to USAID's cross-cutting programs on climate change and food security.

**Illustrative Programs**

Illustrative programs that would strengthen monitoring capacity for climate and water resources in High Asia include:

1. Installing weather (and air quality) monitoring stations in schools, linking students (education), teachers (monitoring and reporting), government agencies (keeping data and tracking trends), and radio stations (information to public). The public would receive information on current weather and perhaps on trends or forecasts, as well as current air quality. Students would gain hands-on experience in a scientific endeavor and potentially contribute to the meteorological database of the country or region.

2. Strengthening capacity of key institutions in data collection, data storage, and user retrieval. Such system

**Regional Integrated Multi-Hazard Early Warning System (RIMES): An Example of Community-Based Monitoring**

Established at the Asian Institute of Technology in Thailand, the RIMES program, with funding from member countries and the United Nations' Tsunami Regional Trust Fund, includes in its Master Plan for 2010-2014 "Addressing challenges from climate change: effects on trans-boundary rivers in the Greater Himalayan region; develop national/regional glaciers and glacier lakes monitoring system." One strategy to collect data for such monitoring is to tap into community knowledge. RIMES has piloted (in Mongolia) a method of community-based observations where herders (in this case) were asked to identify and detail changes in climate that they had observed. This observational data was then evaluated against instrumented data (where available) or satellite data. If the observational data was validated, the community would be set up to provide observational data which would then be used to inform adaptive management (i.e., improved water management practice). This method will be extended to the six RIMES member countries: Pakistan, India, Nepal, Bhutan, Myanmar, and Tibet/China.

development and integration could strengthen and connect existing networks or initiate new networks in any of the areas identified above. This would include the provision of high-altitude monitoring equipment.

3. Involving communities in activities to identify and detail changes in climate that they have observed. These observational data can then be evaluated against instrumented data (where available) or satellite data. If the observational data are validated, the community could be set up to provide observational data which are then used to inform adaptive management (i.e., improved water management practice) (See box on previous page).

**Outcomes/Co-Benefits**

Current monitoring networks vary greatly across the nations making up the mountainous regions of High Asia, from reasonably extensive to nearly non-existent. The synergy of effort in this collaboration would result in clear advantages to the lesser-developed countries while affording the more developed countries the added advantage of a regional-scale approach to water problems. The sharing of data, as well as appropriate technology, would benefit all participants. Knowledge of the optimal instrumentation for in situ measurement of climate and hydrologic parameters would benefit all and would encourage a consistent, standard set of observations being made across the region. In situ measurements, especially glacier mass balance and snow depth and water equivalent measurements can be very time and labor intensive. Therefore, monitoring projects could rely heavily on students and local communities, initially trained by appropriate experts, to make these observations. This would enhance the students' understanding of environmental science and would increase the appreciation of the local environment by the local communities. Local community involvement could also be used to raise awareness to climate change vulnerability and to develop adaptation strategies if/as appropriate.

## 5.2 Responding to Direct and Indirect Vulnerabilities

The program concepts described in this section address both near-term preparedness for direct glacial melt impacts (GLOFs) and longer-term resilience-building in communities particularly susceptible to glacier melt impacts. Specific focus areas are water management, ecosystem improvement, and high-altitude communities. However, no matter what the focus area is, programs will be most effective when they address all related issues in an integrated fashion: glacier melt, water management, food security and nutrition, health (including family planning), education, emissions reduction, and other community-identified vulnerabilities.

For the broader national and international contexts, water resources and their reliability constitute the main concern, as well as glacier change and its impacts. Countries in the areas where water systems are fed by the mountains of High Asia also have high rates of population growth and poverty, which further exacerbate water scarcity and affect people's ability to cope with it, potentially leading to extensive socio-economic stresses. The impacts of glacier melt and other impacts of climate change will further magnify these challenges and disproportionately affect those who are dependent on the river basins and natural resources for livelihoods. The combination of fast-growing populations and shrinking agricultural production could lead to serious food security problems in Pakistan and Nepal, in particular. Rapid population growth also puts additional stress on already weak health systems. As such, slowing the rate of population growth should be among the priority strategies implemented through national development plans and National Communications and NAPAs for Climate Change (see box below).

The approach taken in all three program approaches is integrated; that is, focusing on one main issue (water management, ecosystem health, or high mountain community preparedness), but other important issues like family planning, nutrition, and WASH are integrated. By integrating family planning programs USAID can address the need for planners to pay more attention to population dynamics and integrated strategies in building resilience while addressing glacier melt. Integrated programs should be aligned to longer-term national development plans in order to increase the likelihood of action. Integrated programs should also address the need to build resilience and adaptive capacity among populations that are (a) vulnerable to immediate glacier hazards, (b) already water-stressed or most at risk from changes in water supply as well as increasing population, (c) currently struggling with health issues related to water and harmful air quality, and (d) already vulnerable to food insecurity and malnutrition. This supports a vulnerability assessment approach that takes into consideration both biophysical and socioeconomic factors, and also considers interactions across sectors and includes "bottom-up" perspectives.

Human societies that are already vulnerable (existing water stress, poverty, high fertility, poor health status, degraded ecosystems,

**National Adaptation Programmes of Action (NAPA) for Climate Change**

The UNFCCC identified 42 Least Developed Countries (LDCs) who are particularly vulnerable to climate change. The NAPAs "provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their **urgent** and **immediate** needs to adapt to climate change – those for which further delay would increase vulnerability and/or costs at a later stage" (http://unfccc.int/national_reports/napa/items/2719.php).

A review of 41 country-specific NAPAs found widespread recognition of the central role that population dynamics play in climate change adaptation. However, only 2 NAPAs identified family planning and reproductive health (FP/RH) projects as part of priority adaptation strategy and none appropriated funding for FP/RH projects (Matunga and Hardee 2009).

The LDCs include Afghanistan, Bangladesh, Bhutan, Cambodia, Laos, all of which have submitted NAPAs without mention of population dynamics; and Myanmar and Nepal, which have not submitted NAPAs.

Thus, the opportunity exists to address this population-climate-change connection. Programs could incorporate interventions that address this connection into climate-change funded efforts and to prioritize projects that contribute to lower fertility such as access to FP/RH services, girls' education, women's empowerment, and a focus on youth. For example, the high rate of population growth in South Asia connects with increasing energy use and growing emissions of black carbon and other aerosol deposits on glaciers that accelerate melt/retreat.

insecure food supply, etc.) need to build adaptive capacity to uncertain hydrologic changes from climate change. This "no regrets" approach to vulnerability also promotes general development and improved well-being.

### 5.2.1 Focus on Improving the Management of Water Resources

A growing Asian population, with the associated increased demand for both water and food, is putting stress on water supplies in Asian river basins, especially downstream from glaciated areas. Clearly, there is a need for long-term improvements in water management as problems associated with both quality and quantity become more acute and the potential negative impacts of accelerated glacier melt become a reality. Land degradation (due to soil salinity, deteriorated irrigations systems, or nutrient depletion), deforestation, transboundary river basins with their inherent conflicts between upstream and downstream users, competition for water resources from growing cities and industries, increasing demand for water, and several other factors add to the complexity yet necessity of taking an integrated approach to management of water across many sectors of society.

The agriculture sector is the largest water user and plays a critical role in the economic and social lives of millions of people. Thus, special regard should be given to programs that improve the efficiency of water use for crop and livestock production. Effective programs of assistance can be implemented for water on the national policy level, the level of the water district as defined by an existing irrigation and drainage area, and the level of the farm field through improved agronomic practices with a water efficiency focus. The goal is to develop the capacity of institutions that manage water so that they can work on a wide range of issues—including issues related to accelerated glacier melt. The common thread that ties all of the suggested interventions together is the improved water management of both ground and surface water when used for irrigation or for household purposes.

**Reducing Emissions from Deforestation and forest Degradation (REDD) Program**

At the December 2009 Conference of the Parties to the UNFCCC in Copenhagen, the parties drafted the REDD program as part of the Copenhagen Accord, although significant questions related to its design and implementation must be resolved. Challenges include financing mechanisms, capacities and methodologies for monitoring, reporting and verification, the role of local participation, livelihood effects, permanence, and leakages. However, the program is important, not least because it has been initiated principally by developing countries and has large financial implications, as it will pay countries to preserve and restore their forests.

As part of REDD, developing nations may be eligible for funds from the sale of carbon credits, as well as from other sources, in order to enhance sustainable forest practices. To qualify for the program, participating countries need to have the necessary capacity to meet program requirements and standards for collecting forest data in the areas of monitoring, reporting and verification. USAID can provide effective assistance to countries preparing for REDD participation by providing direct technical assistance. Such assistance could strengthen national institutions so that they can improve data collection systems, establish baselines on forest inventories, estimate carbon emissions and other data, and fulfill all reporting requirements.

Another dimension of water management concerns forest management practices, which can have significant impacts on both economies and ecosystems. Forests create habitat for flora and fauna, protect watersheds, serve as storage sites for carbon and, in many places, provide livelihoods for nearby residents. As in other parts of the world, deforestation and forest degradation have increased over the past 30 years, negatively affecting the environment as well as contributing to greenhouse gases in the atmosphere. In most cases deforestation has occurred when land is cleared for agriculture. Other causes are illegal logging and cutting down trees for residential heating and cooking.

Thus, there are needs for improved forest management, afforestation programs, and incorporating trees into agricultural production schemes (agroforestry). One opportunity is presented by the UNFCCC program on Reduced Emissions from Deforestation and forest Degradation (REDD) (see box on previous page).

A broad, multifaceted program can address both agriculture and forestry. Activities related to agriculture include the development of national water policy frameworks or better coordination between national and local policies and enforcement, strengthening of regional and local government capacity to manage water resources, establishing or strengthening community-based water user associations (WUAs) or forest user groups (FUGs), establishing or strengthening centers for on-farm water efficiency, and assistance in participating in forestry programs and projects (including REDD).

**Sectors Addressed**

The primary focuses are the water, agriculture, and forestry sectors, but co-benefits can flow to the health sector through WASH interventions and ecosystems. National policies, regional water management bodies, WUAs, and FUGs will also build democratic and participatory institutions, strengthening governance. There are also economic and financial benefits as the user groups are often able to increase their incomes from sustainable practices.

**Illustrative Programs**

Programs that are focused on water management should also have components that specifically address governance, WASH, family planning, ecosystem improvement, and food security (including nutrition). For instance, effective WUAs and FUGs can be conduits to deliver health-related information and services.

1. At the national level,

    a. Develop a national water policy framework by (1) assisting governments to establish clear water rights and fair water pricing policies (including full cost pricing for the energy used in pumping), (2) transferring water management at the local level to community-based organizations, (3) establishing clear lines of water management authority, and (4) promoting water-saving practices for both rural and urban sectors.

b. Strengthen the capacity of key national level institutions to provide leadership in water management including national level planning, regulation, coordination, and monitoring and evaluation.

2. At the regional and local government level, develop the capacity of regional water management institutions such as river basin authorities and local governments to implement policies and plans.

3. At the community and household level, interventions might include:

   a. Establish and/or strengthen community-based WUAs. Such a program would empower communities to take collective action on the most critical resource to their livelihoods. In those areas of Asia where it is not possible or practical to form WUAs, there is still the opportunity to strengthen local groups to play an important role in water management. In those Missions where USAID is directly funding irrigation infrastructure (mainly Pakistan and Afghanistan), to the extent possible, strengthening local water management institutions should be a component of those construction projects.

   b. Establish and/or strengthen centers for on-farm water-efficient crop production. Water-saving activities could include (ADB and IFPRI 2009) zero till or minimum tillage practices, intensive rice production methods, planting drought-resistant crop varieties, soil and water conservation, agroforestry, small-scale irrigation schemes and other agronomic practices. USAID can help bring about these developments by creating country-level centers for on-farm, water-efficient crop production.

   c. Provide technical assistance in forest management for people and the environment. Activities could include training, demonstrations and public outreach programs in the areas of balancing harvesting forest resources with afforestation programs, developing methods of improving incomes from forest resources, emphasizing the importance of sustaining forests for long-term food and economic security, teaching intensive agricultural techniques (such as inter-planting crops and trees) as a means of increasing and diversifying sources of incomes and ecosystem protection, and teaching forest-fire prevention and control techniques.

   d. Implement WASH interventions that are directly linked to improved water management. In water-scarce countries in particular, households use the same water sources for domestic use as for agricultural use. Interventions that are aimed at providing safe water supplies, sanitation services to prevent contamination and the spread of disease, and hygiene behavior change to ensure appropriate use of water and sanitation services would be logical components of a comprehensive water management program.

**Outcomes/Co-Benefits**

For national water policy frameworks, co-benefits include integrated river basin management, strengthened water management authorities within the national and regional governments, cooperation between upstream and downstream managers, improved emergency preparedness, increased attention to WASH interventions, greater regional cooperation in management of water resources, and improved ecosystem resilience.

For new or strengthened WUAs and FUGs, co-benefits include local community empowerment; democratic practices such as elections, annual meetings, and publishing decisions and budgets to its members; integration of WASH interventions; and greater involvement of women in governance of water.

Centers for on-farm water-efficient crop production can yield co-benefits in improved water efficiency, maintained or improved crop yields, potential to keep farmers on the land and reduce migration, and improved food security and nutrition.

Other co-benefits of programs focusing on water management could include sustainable forestry practices implemented, including afforestation and agroforestry projects, reduced illegal logging and forest degradation, reduced greenhouse gas emissions, biodiversity enhancement, protection of watersheds, use of forest resources to improve livelihoods with sustainable practices, and prevention of forest fires and open burning.

### 5.2.2 Focus on Ecosystems

The health of the mountain ecosystems in High Asia is central to the health of the lowland ecosystems which support the lives and livelihoods of hundreds of millions of people in the Ganges and Indus watersheds, among others. In addition to their contributions to biodiversity conservation, these mountain ecosystems contribute directly to food security and to human health. Water from the snowpack, glaciers, and slopes of High Asia is the lifeline for all of these systems, both human and natural.

Where access to fresh water is already limited, changes in the quantity and quality of water resources will directly impact food security and human health. Human health and well-being are intimately tied to the health of life-sustaining ecosystems, yet this complex relationship is rarely taken into account in either mainstream health or environment/natural resource management programming.

This program approach is based on the premise that a human health sector approach alone is not sufficient for understanding and improving human health: economic, social, and environmental factors all play important roles. The ecosystem management approach to human health (sometimes called the EcoHealth approach) aims to build health interventions based on the web of ecologically based factors affecting human health – as well as the links between them. Equipped with knowledge about these links, local communities can better manage ecosystems to improve both human health and the health of the ecosystem while at the same time starting to think through adaptation strategies for changes induced by climate change.

USAID could design two types of programs to promote ecosystem integrity and resilience and promote human health. Although the approach is integrated in itself, the types could also be implemented together. One type focuses on ***conserving or restoring*** the natural processes of diverse ecosystems such as watersheds, flood plains, forest, and wetlands. A second type focuses on ***researching and monitoring*** the potential ecosystem and human health impacts of development activities such as adoption of industrial or agricultural technologies, and of climate change (particularly glacier melt/retreat). (This second type parallels the program approaches in Section 5.1 that relate to research into glaciers and associated water systems.)

Such programs could be implemented as new programs or modifications to new or ongoing biodiversity/natural resource management, food security and health programs that would incorporate these elements and synergies.

Good examples of human health issues that would benefit from cause- rather than symptom-focused, prevention-based EcoHealth approaches are the diarrheal diseases that result from polluted water. The focus on ecosystems for health would include managing the sources of pollution, providing safe drinking water, and managing solid waste. Another example is shown in aspects of agricultural development (insecure land tenure, lack of access to new cultivars, tainted livestock feed, excess pesticides) that affect nutritional status.

**Sectors Addressed**

Although the focus is on integrating health of humans and ecosystems, such programs also address biodiversity, agriculture, and water.

**Illustrative Programs**

Illustrative programs focusing on ecosystems include the following:

1. At the national level, interventions include the promotion of policies that focus on ecosystem integrity and resilience. Such policies would promote landscape-level mapping, planning and management; habitat conservation/management (predator-prey relationships maintained to avoid emergence of disease vectors; community-based management, with special attention to local/indigenous knowledge); and the use of natural regeneration rather than re-planting except on the most degraded sites with prerequisite local control of access to common property resources (community-based natural resource management/governance).

2. At the sub-national level, working through regional authorities and local government, these ecosystem management activities could be integrated with water management programs such as streambank conservation to prevent erosion and sedimentation, flood plain management, and improved groundwater filtration; and forest and rangeland conservation/management with a focus on non-timber forest products that directly contribute to food security, particularly food, fruit, forage and medicinal plants. Interventions at this level should be aimed at improving the understanding of these issues, developing practical interventions that can be implemented in communities, and developing the capacity of regional and local institutions to plan and implement them.

3. Applied research is also needed to develop a better understanding of ecosystem management for human health. This might include research aimed at an improved understanding of the environmental, social, and economic interactions associated with

development that predispose areas to disease emergence and spread, such as vector and habitat management (intervention strategies developed to prevent or limit the spread of emerging infectious diseases), and water and sanitation (development of safe water sources and sanitation systems).

4. At the community and household level, the following programs are suggested:

    a. Promoting of WASH interventions that are aimed at reducing the incidence of water-related diseases such as diarrhea, trachoma, and schistosomiasis. WASH interventions include improved access to domestic water supplies, improvement in drinking water quality from those sources as well as at the point-of-use, increased access to sanitation facilities for safe excreta disposal, and handwashing with soap.

    b. Strengthening community water management of WASH interventions through the development of user associations. Community water committees are representative bodies that provide a local structure responsible for operating and maintaining the water supply system and an essential entry point for hygiene behavior interventions.

    c. Increasing of family planning interventions that reduce population pressures and decrease pressure on water supplies and access to sanitation services.

    d. Promoting of interventions that improve the community's management of watersheds, flood plains, forest, and wetlands. These typically require the changing of agricultural, waste disposal, and livelihood practices.

    e. In urban and peri-urban settings, reduction of health risks from small and medium industrial enterprises through the promotion of improved technology that reduces black carbon emissions, e.g., for brick kilns (see also the next section on reducing black carbon emissions).

**Outcomes/Co-Benefits**

Ecosystem integrity and resilience programs lead to co-benefits such as the following:

- Enhanced water quantity and (equally important) quality
- Increased ratio of green water (going directly to soils) to blue water (surface and groundwater) – i.e., more percolation, reduced overland/surface flow and flooding
- Forest/rangeland regeneration, with increased carbon sequestration and reduced emissions
- Enhanced food security and healthier, more prosperous families and more resilient communities and ecosystems

- Increased ownership of cross-sectoral approaches by health and environment professionals, networks and programs

Ecosystem management for human health programs yields co-benefits such as the following:

- Improved health and well-being of the local populations
- More cost-effective prevention of water and vector-borne diseases
- Development of an analytical framework that combines ecological factors (e.g., vector ecology, climatic factors) with biological (e.g., sero-conversion rates, vector infection rates) and social factors (e.g., public services, housing patterns, water storage and garbage disposal practices, community dynamics) to produce more holistic, cost-effective health interventions for maternal and child health and child survival
- Reduced disease burden among working adults, leading to higher labor productivity and incomes (poverty reduction)
- Increased ownership of cross-sectoral approaches by health and environment professionals, networks and programs

### 5.2.3 Focus on High-Mountain Communities

This approach focuses on integrating activities to address glacier melt impacts with other development needs in high-altitude communities. High-altitude communities are chosen as a focus for two fundamental reasons. First, they are on the frontlines of GLOFs and retreating glaciers affecting their local water supplies. These changes are happening now. Secondly, these communities are at the headwaters of the major river systems of Asia. Maintaining headwater ecosystem health and the well-being of communities will benefit potentially millions of people downstream.

The changing dynamics of glacier-hydrological (snow/ice/water) regimes in High Asia and their inter-relationships with human-induced climate change have wide-ranging impacts on water, impacts that will also be felt across the inherently linked sectors of ecosystems, agriculture, energy, and human health. The dangers of GLOFs, discussed in Section 2.6, call for disaster planning in potentially affected communities. The human and environmental vulnerabilities discussed in Section 3, such as water stress, poor health status, and ecosystem degradation, increase the potential for negative impacts from glacier melt and associated water system changes.

Vulnerable groups (female-headed families, elderly, disabled, ethnic/caste groups) are likely to be among the worst affected during disasters because they lack access to resources such as social influence, transportation, literacy, livelihood skills and assets. Smallholder and subsistence farmers, fishers, pastoralists and traditional societies also are more likely to be adversely affected because they are already the most vulnerable to food insecurity and malnutrition (Costello et al. 2009).

Demographic and socioeconomic factors, including the lack of reproductive health and family planning services, influence people's ability to cope with water stress, and the impacts of glacier melt/retreat will exacerbate these challenges. Effective governance is also crucial to a society's resilience to natural and climate-change induced disasters. Weak governance and barriers that prevent people and communities from improving their lives, as well as inequalities of caste, ethnicity, religion, or tribes, all contribute to increased vulnerability.

These environmental and non-environmental factors and their inter-relationships necessitate the use of cross-sectoral and integrated approaches in the development of adaptation and mitigation strategies for glacier melt/retreat in Asia. Especially in High Asia's small and remote communities, the interrelated complex systems that include ecosystems and human systems call for integrated programming.

USAID can use integrated programming models that work cross-sectorally and through local institutions and communities to reduce vulnerability and strengthen resilience to the impacts of glacier melt/retreat in High Asia. Good governance; social mobilization; and information, education and communication (IEC) are cross-cutting themes; together with landscape-level planning, building on existing adaptive capacity, supporting low-cost adaptation, tapping existing institutional capacity, and mobilization across administrative levels.

At least two project models can be developed and tested to respond to the different hazards, risks and impacts; those associated with glacier-hydrological regimes in more populated, low-altitude (<5,300 m) communities; and those associated with less densely populated, high-altitude (>5300 m) communities. These include locations where low-altitude glaciers may be melting and pose direct threats to communities living near the glacier terminus or alongside rivers, and locations where GLOFs have occurred in the past or where advancing glaciers may impound rivers in the near future and generate floods or debris flows. These threats affect human settlements, land and infrastructure beyond the existing glacier area. USAID's OFDA is active in working on hydrometerological forecasting in Asia and its experience is a resource for pursuing these issues.

### Sectors Addressed

Human reproductive health and family planning, water resource management, biodiversity and ecosystems conservation, agriculture, energy, health, and disaster preparedness/management.

### Illustrative Programs

Illustrative programs focused on high-mountain communities include the following:

1. At the national level, programs could support the development planning processes that promote community-based and integrated approaches to glacier disaster preparedness and risk reduction that are comprehensive and include family planning and sustainable management of water resources among other coping and adaptation strategies. The programs should seek to mainstream integrated approaches into existing policies and action plans (i.e., NAPAs for the UNFCCC) rather than create new initiatives.

2. At the sub-national level, USAID can sponsor multi-sectoral working groups to facilitate coordination and collaboration among public health, environment, water/sanitation and agriculture for implementation of integrated approaches to glacier disaster preparedness/risk reduction.

3. At the local level, training programs can be initiated and supported for local actors (government and NGOs) on how to facilitate community disaster preparedness planning processes that are comprehensive and link to broader socio-economic assessment of downstream flood paths to determine potential risk to communities. Such programs may be highly integrated with health, water management, and forest restoration initiatives (as examples of community-identified needs).

4. At the community level in low-altitude locations, projects might be designed as follows:

    a. Facilitate participatory assessments to identify disaster-prone areas and prioritize risk reduction needs and activities along with potential partners and stakeholders.

    b. Train communities in how to develop local disaster preparedness and risk reduction plans based on the findings of the participatory assessment.

    c. Help communities identify and access existing resources for disaster mitigation within the community and externally from local government, NGOs, and upward links to other government disaster preparedness plans and early warning systems.

    d. Support collective actions of communities to improve disaster-prone areas. This may include hazard mapping, slope stabilization of landslide-prone areas, use of vegetation to counter landslides and erosion, and protection of waterside vegetation and forests that serve as watersheds.

    e. Provide technical assistance to organized grassroots groups (e.g., cooperative, eco-club, mothers' group) to establish a community resource center. The center will provide basic information about glacier risks/hazards and appropriate behavioral responses and coping strategies, materials on rescue and rehabilitation during disasters, and psychosocial support related to the psychological impact of a glacier melt disaster. The center will also be used to conduct informal education classes for mothers, adults and youth on family planning, water conservation, clean energy (improved cook stoves/biogas) and their co-benefits, agro-ecology topics, and more.

    f. Train local shopkeepers and vendors to distribute contraceptives and essential health products (e.g., water purification tablets, oral dehydration salts, first aid supplies) and link them with public or private supply chains (social marketing networks).

    g. Ensure that women and vulnerable groups have equal access to these opportunities.

5. At the community level in high-altitude locations prone to GLOFs, projects may be designed as above, with the following additions:

a. Strengthen the capacity of community-based organizations in emergency preparedness for GLOF damage control.

b. Create a village-level warning system for floods, landslides or earthquakes.

6. Improved Water Conservation and Ecosystem Health as noted in preceding sections. Given the presence of these communities near the headwaters of major river systems, interventions in these areas are key to adaptation for the region as a whole.

**Outcomes/Co-Benefits**

Integrated approaches to glacier disaster preparedness and risk reduction can be mainstreamed into national and local development plans with more attention paid to the population, health, and water sectors and the role of the community. Local leaders are better able to facilitate planning processes for disaster preparedness among both upstream and downstream communities. Communities will be empowered with knowledge and skills to identify and improve disaster-prone areas and to mobilize existing resources and external sources of support to do so. In the event of a disaster, loss of life will be reduced and land and infrastructure may be better preserved as a result of functional early warning systems maintained by communities. As disaster planning is integrated with other concerns, improved practice for family planning and preventive health can improve families' and communities' ability to cope with glacier melt risks and hazards via smaller family size and improved health and economic status. Measures to conserve water and counter landslides, erosion and flooding will help to maintain and enhance the integrity of the environment which, in turn, helps to sustain the flow of ecosystem services to people.

## 5.3 Responding by Mitigation

Reducing black carbon and other aerosol emissions addresses two different issues simultaneously, thus presenting opportunities for program integration and co-benefits. Black carbon and other aerosols likely change the regional climate and accelerate glacier melt when black carbon is deposited on reflective glacier surfaces, so reducing emissions mitigates climate change and thus reduces the extent of vulnerability to glacier melt. Reducing these emissions also brings significant health improvements, particularly to

**Figure 5.1.** More than 1.6 million people, mainly women and children, die prematurely each year from breathing elevated levels of indoor smoke. Inefficient biomass-burning stoves emit smoke, including black carbon. (Haigler, E. Clean cookstoves for developing countries: Improving health, reducing climate change. Partnership for Clean Indoor Air).

women and children who cook and heat their homes with biomass, and to urban dwellers where multiple sources contribute to high levels of air pollution (USAID Asia 2010; and see Figure 5.1 on previous page). Thus, the vulnerability of poor health status can be reduced.

Strong synergies can be realized from developing programs and projects that integrate ongoing research into the impacts of black carbon and other aerosol emissions (from indoor pollution to regional climate impacts) with health and glacier melt issues – i.e., partners should include researchers, government, health sector specialists, and technology developers. USAID's SERVIR-Himalaya (to be located at ICIMOD) should be a partner. SERVIR enables the use of Earth observations and predictive models; a focus of SERVIR-Himalaya is aerosol emissions and air quality.

### 5.3.1 Focus on Reducing Emissions of Black Carbon and Other Aerosols

USAID can design programs to reduce emissions of black carbon and other aerosols, especially in urban areas and in all areas where biomass cooking is common. As sources include dust, open fires (such as forest fires), biomass burning for domestic cooking and heating, and industries such as brick kilns, needed programs will be largely integrated governance (policy and enforcement) and technological development and implementation (improved cook stoves, infrastructure such as street design, industrial energy sources, and control of open fires and waste burning).

#### Sectors Addressed

Sectors included are health and energy. Forestry, agriculture, and industrial sectors can also be addressed, as the sources of black carbon and aerosols include forest fires, agriculture-related fires, and industries that emit black carbon and other aerosols.

#### Illustrative Programs

Illustrative programs with a focus on reducing emissions of black carbon and other aerosols include the following:

1. Establish weather/climate stations (including air pollution measurement for cities and also glacier lake monitoring where relevant) in educational institutions that would report data to the country-level Departments of Hydrology and Meteorology and to local radio stations for public dissemination (see also programs described in Section 5.1).

2. Develop and implement policies to control industrial emission of aerosols, including black carbon, e.g., by requiring low-emitting technologies or control technologies, such as less polluting brick kiln technologies; provide incentives that reward reduction of black carbon emissions.

3. Promote the development of several types of advanced cook stoves, with priority placed on capturing emissions rather than exporting them to the outdoors. Previous work has shown that adoption rates rise when communities realize the health impacts of black

carbon on young children. Appropriate pricing and financing programs are essential to the success of such a program.

4. Promote the substitution of clean energy (e.g. biogas, solar lamps) for traditional sources and clean energy sources for electricity as communities are provided access. Ensure local control of the technology and management rules, and provide financing for commercially available technologies on a sustainable basis via micro-finance institutions.

5. Design/redesign urban streets to control re-suspension of dust and dust emissions at construction sites.

6. Strengthen enforcement of existing laws (or create new laws) banning the use of man-made fires for clearing crop lands and provide incentives that reward reduction of black carbon emissions.

**Outcomes/Co-Benefits**

Although programs can be focused in different sectors, such as health, energy, and forestry, co-benefits will include the following:

- Reduced deaths from respiratory diseases in young children and women associated with indoor air pollution.
- Reduced air pollution and associated health risks and productivity gains for national and local economies.
- Reduced fuel use from improved cook stoves and kilns; less time spent acquiring biomass fuel.
- Improved glacier health.

# SECTION 6
## CONCLUSIONS

The review of scientific information about glacier melt in High Asia revealed, first and foremost, a lack of data and information, a lack that hampers attempts to project likely impacts and take action to adapt to changed conditions. Known near-term impacts include the increasing potential for GLOFs and the disappearance of small glaciers, especially at lower latitudes. Understanding that glacier melt/retreat, although occurring at increasing rates, is not likely to produce widespread disastrous impacts in the next decade or two means that societies have time to build their resilience to changes in the amount of water available and when it arrives during the year. However, existing vulnerabilities in human health status, population pressure, degraded ecosystems and – especially – water stress make societies and ecosystems vulnerable to *any* changes in water availability as glacier melt accelerates in the coming decades.

As a result of this analysis, the program concepts developed in consultation with USAID addressed three different elements: the challenge of lack of information, vulnerabilities related to current societal and ecosystem conditions, and the need for mitigation, focusing on black carbon. These program concepts represent "no regrets' activities, meaning that they address critical needs, however the glaciers respond to climate change.

> "The combined water resources of the greater Himalayan region are immense, almost beyond comprehension. Consequently, the need for appropriate and efficient management cannot be exaggerated. Not only the economic stability of several of the individual countries in the region, but the very well-being of many hundred million people, depend on rapid progress toward appropriate management."
>
> Jack Ives, 2006

The multi-faceted analysis presented here leads to conclusions (listed in italics) about the characteristics of programs that are likely to be effective in addressing glacier melt and its impacts:

*As glacier melt is part of complex, region-wide hydrologic changes that are happening as a result of climate change, effective programs to address glacier melt will be cross-sectoral and will achieve co-benefits across sectors.*

Below are examples of benefits that can be part of co-benefit streams:

1. Improved health outcomes (from healthier ecosystems, reduced pollution, improved sanitation, more efficient water use);
2. Reduced fertility and easing of population pressures (by meeting family planning needs);
3. Strengthened governance institutions (through environmental, agricultural, and forestry management; development of national and local policies; establishment and empowerment of local resource user groups);

4. Improved regional cooperation (through scientific cooperation, shared monitoring and information programs, common educational outreach programs, community-based monitoring, strengthened cross-boundary institutions and treaties);

5. Protection of biodiversity and maintenance of ecosystem services (through improved water management and ecosystem management for health);

6. Better water management at all levels, from transboundary/multi-country all the way to use on farm fields and for household drinking water;

7. More efficient, climate-change-resilient food production (irrigation systems, on-farm management, harvest of food and fodder from forests and rangeland, and homestead vegetable gardens);

8. Creative, effective approaches to monitoring and managing climate-change-induced threats, starting with glacier lakes;

9. And effective disaster planning for both too much water (floods, GLOFs) and too little water (droughts).

> "We have to recognize the need for much greater engagement and coordination with all our neighbors which share the Himalayas."
>
> India Prime Minister Manmohan Singh, 2009

*As climate change is a global and long-term issue, extending program timelines beyond 3-5 years and explicitly coordinating projects, especially across sectoral and geographic boundaries, should be considered.* One option is to link projects that could be completed in a decade-long sequence, in order to allow for periodic evaluation and course correction, institutionalization of best practices, and scale-up. Another option is to coordinate programs with other Missions and/or sectors, exploring mechanisms to share resources and management.

*A crucial role USAID can play is to link up partners in the government and private sector (both NGOs and for-profit organizations) to build capacity*, as many of the illustrative programs describe.

*USAID should take advantage of synergies by linking new initiatives, such as the Feed the Future initiative with its emphasis on food security and nutrition, to climate change impacts and vulnerabilities of glacier melt on water supply; such links will yield many "no regrets" programs.* As impacts of changing water supply, including glacier melt, unfold, resilience can be built through such varied strategies as diversifying diets, crops, and livelihoods; increasing productivity; and encouraging the adoption of improved water management systems such as drip irrigation, rainwater harvesting, and other water efficiency technologies.

*USAID's partnerships with forest user groups, water user associations, and other local organizations to address climate change (and other environmental) issues will strengthen governance capacity of civil society.* Such partnerships are essential parts of many illustrative programs described in Section 5.

*USAID should promote and support "south-to-south" scientific and technical exchanges such as the recently initiated Peru-Nepal exchange regarding glacier lake management*, involving governments as feasible. Intra-regional exchanges could focus on water and agricultural issues.

*In the midst of changing climate and uncertainties, greater emphasis on collecting local, indigenous knowledge of the environment and existing adaptive mechanisms may be critical for future long-term adaptation to changes in glaciers and climate.*

**Figure 6.1.** The potential for glaciers to change, or even disappear, illustrates the immense nature of changes that might come from the current potential for climate change. Photo: East Himalaya region, National Aeronautics and Space Administration, STS075-721-13.

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# APPENDIX A
## TASK 2 DATABASE

The database of activities related to glacier melt in Asia is presented in the appendix in the print version and embedded in the electronic version of this report.

The database lists organizations that have programs specifically focused on glacier melt in High Asia. The list was augmented with information gathered as part of the team's country visits. See Section 4 for more description of its contents.

The appendix is formed by the following three tables:

- A.1 – Main Database
- A.2 – Summary by Region
- A.3 – Summary by Theme

Additional resources on the more general topic of climate change in Asia can be found in USAID (2010).

# Appendix A.1
# Main Database

**Current Work on Issues Related to Glacier Melt/Retreat in Asia**
**Appendix A.1 - Main Database**

| Organization Details | | | | Geographic Area of Focus | Subject Area of Focus and Expertise in Relation to Glacial Melt | Summary of Activities | Partners | Comments/Relevant Publications and Resources |
|---|---|---|---|---|---|---|---|---|
| Name | Key Contact | Contact Details | URL | | | | | |
| **Government Agencies (donor)** | | | | | | | | |
| USAID | Heather D'Agnes, Health Advisor; Mary Melnyk, Senior Advisor, Natural Resource Management; and Kristina Yarrow, Health Advisor | hdagnes@usaid.gov, mmelnyk@usaid.gov, kyarrow@usaid.gov | www.usaid.gov/locations/asia/ | Central Asia; South Asia; China | | Changing Glaciers and Hydrology in Asia: Addressing Vulnerabilities to Glacier Melt Impacts | Asia-Pacific Regional Climate Change Adaptation Assessment is being conducted by consultants from the International Resources Group www.irgltd.com | |
| | Winston Bowman, Regional Development Mission for Asia (RDMA) | wbowman@usaid.gov | | | | Global Climate Change in the Asia Pacific Region: An analysis and roadmap in 2008, Asia-Pacific Regional Climate Change Adaptation Assessment, and Black Carbon Emissions in Asia | | |
| | Andrei Barannik, Regional Environmental Advisor for Asia (Central Asian Republics) | abarannik@usaid.gov | | Central Asian Republics | | Supported the Tajikistan weather and water forecasting agency to improve the collection, analysis, and exchange of data critical to water resource management, including the installation of a meteorological station at Fedchenko Glacier. | | |
| | Ayse Sezin Tokar (OFDA) | stokar@usaid.gov | | Pan Asia | | Disaster preparedness and hydrometeorlogical hazards | | |
| | Carrie Stokes, Global Climate Change Team | cstokes@usaid.gov | | Pan Asia | | SERVIR-Himalaya, located at ICIMOD | | |
| | LeAnna Marr (Asia Bureau Education) | | | Pan Asia | | | | |
| | Ricki Gold (Asia Bureau DG) | | | Pan Asia | | | | |
| | Neil Adlai Levine (DCHA/CMM) | | | Pan Asia | | | | |
| | Dan Henry (DCHA/OTI) | | | Pan Asia | | | | |
| | Pat Fn'Piere (DCHA/DG/G) | | | Pan Asia | | | | |
| | Jim Franckiewicz, Dan Deeley, Richard Volk (Water team) | | | Pan Asia | | | | |
| | Tjip Walker (DCHA/CMM) | | | Pan Asia | | | | |
| US State | Joseph M Bracken (Population and International Migration) | | | Pan Asia | | Looking into climate change impacts | | |
| | Sumreen Mirza (OES) | | | | | | | |
| | Maria Placht | plachtmt@state.gov | | | | | | |
| | Ingrid Specht | spechtik@state.gov | | | | | | |
| US National Intelligence Council | Rich Engel, Director, Climate Change and State Stability Program | Rich.engel@ugov.gov | | Pan Asia | | Initiated an analysis of glacial melt and other water issues in Asia | Henry L. Stimson Center in Washington, (http://www.stimson.org/home.cfm). | |
| Environmental Protection Agency (EPA) | Tony Socci | Socci.Anthony@epamail.epa.gov | | Pan Asia | | Analysis of black carbon in Asia | | |
| US Army | Barbara Sotirin, Renee Chapman | Barbara.j.sortirin@usace.army.mil | | Pan Asia | | Worked on monitoring glacial melt in the region | | |
| | Sarah Kopczyniski | Sarah.e.kopczynski@afghan.swa.army.mil | | Pan Asia, in particular Afghanistan | | Worked on monitoring glacial melt in the region in particular in Afghanistan | | |

| Organization Details | | | | Geographic Area of Focus | Subject Area of Focus and Expertise in Relation to Glacial Melt | Summary of Activities | Partners | Comments/Relevant Publications and Resources |
|---|---|---|---|---|---|---|---|---|
| **Name** | **Key Contact** | **Contact Details** | **URL** | | | | | |
| European Commission (ECHO) | Esko Kentrschynsky, Head, Asia & Latin America, Caribbean & Pacific Regions | Esko.KENT@ec.europa.eu | ec.europa.eu/echo/index_en.htm | Hindu Kush-Himalaya | | **Regional GLOF Risk Reduction Project:** supported by DIPECHO and managed by the Bureau for Crisis Prevention and Recovery, South and South-West Asia is being implemented through UNDP Country Offices in India, Pakistan, Nepal and Bhutan. The project aims to complement the structural approaches towards GLOF risk reduction with sociological and community-based strategies for GLOF risk mitigation and preparedness as community participation in GLOF risk reduction has received little or no attention to date. | UNDP | |
| German Development Cooperation (GTZ) | Mr Guenter Dresruesse, Country Director, India | gtz-indien@gtz.de | http://www.gtz.de/en/weltweit/572.htm | China, India, Pakistan | | Funding ICIMOD's **Snow, Ice and Water resources study** (Indus Region) | ICIMOD | |
| Ministry of Foreign Affairs, Finland | No specific | kirjaamo.um@formin.fi | formin.finland.fi/english | Hindu-Kush Himalaya: China, India, Afghanistan, Pakistan, Bangladesh, Bhutan. Myanmar, Nepal | | Supporting current phase of ICIMOD **Flood information system** (Hindu-Kush Himalaya) | ICIMOD | |
| SDC/Swiss Agency for Development Cooperation | Sybille Suter, Counselor and Country Director; K.R. Viswanathan, Senior Advisor (phone is 9810969235, Email: kr.viswanathan@sdc. | Chandragupta Marg, Chanakyapuri New Delhi 110 021 phone is 91.11.2687.7819 sybille.suter@sdc.net | | India | | Key stakeholders contacted by G.F. Taylor during coutry visit; beginning to engage on glaciers, urban water issues (partnered with USAID). | | |
| SIDA | Dr. Anders Granlund, Director of SENSA | anders.granlund@foreign.ministry.se | www.sida.se | Mekong sub-region; India; China | | SIDA/SENSA Funded IWMI report **"Analysis of possible rainfall and temperature change in the greater Mekong sub-region over the period 1960-2049"** (See IWMI). SIDA supported studies by the university of Gothenburg on **India Environmental and Climate Change Analysis** and also **China Environment and Climate Change Policy Brief** (both 2008) which contain some information and recommendations on glacial melt. Unclear if these have since been acted on. | IWMI; University of Gothenburg | |
| **National Agencies in Asia Managing Domestic Glacial Melt Issues** | | | | | | | | |
| China Geological Survey Institute, Ministry of Land and Resources, China | Mr.Wang Director-General | 24 Huangsi Dajie,Xicheng District, Beijing 100011 P.R.China Tel.:+86 10 51632963 51632906 | http://old.cgs.gov.cn/Ev/english.htm | China | CGS is responsible for the centralized deployment and organizing implementation of basic, public and strategic geological investigation and mineral exploration. | Part of recent study **measuring glacial melt in the Qinghai-Tibet plateau** | Qinghai-Tibet plateau study undertaken with Qinghai Provincial Geological Research Institute and China University of Geosciences | |
| The Ministry of Water Resources, China | Water Resources Information Centre | MWR, International Economic and Technical Cooperation and Exchange Centre | http://www.mwr.gov.cn/english/aboutmwr.html | China | Information not available | Has a climate change research center | | |
| Indian Meteorological Department, India | Dr. Srinivasan | sriniren@gmail.com | www.imd.ernet.in | India | India's national meteorological organization | 701 hydrometeorlogical observatories; 37 non-departmental **Glaciological Observatories** (21 snow gauges; 10 ordinary gauges; 6 seasonal snow poles). | | |

| Organization Details | | | | Geographic Area of Focus | Subject Area of Focus and Expertise in Relation to Glacial Melt | Summary of Activities | Partners | Comments/Relevant Publications and Resources |
|---|---|---|---|---|---|---|---|---|
| **Name** | **Key Contact** | **Contact Details** | **URL** | | | | | |
| Ministry of Environment and Forests, India | Dr. Jairam Ramesh, Minister | envisect@nic.in | http://moef.nic.in/index.php | India | Nodal agency of Central Government for the planning, promotion, co-ordination and overseeing the implementation of India's environmental and forestry policies and programmes. | Commissioned discussion paper: **Himalayan Glaciers: A State-of-Art Review of Glacial Studies, Glacial Retreat and Climate Change".** | Geological Survey of India (GSI) | This report questions the direct link between glacial retreat to global warming. Instead it demonstrates that many glaciers are stable or have advanced and the rate of retreat of many others has in fact slowed. Resulted in controversial statements made by Indian Prime Minister refuting links between glacial melt and climate change. |
| Department of Science and Technology, India | Dr, Akhilesh Gupta, Advisor/Scientist, Coordinator Climate Change Programme | gakhilesh2002@yahoo.co.in, akhilesh.g@nic.in | http://www.dst.gov.in/ | India | Established to promote new areas of Science & Technology and to play the role of a nodal department for organising, coordinating and promoting S&T activities in the country. | Key stakeholders contacted by G.F. Taylor during coutry visit. | | |
| The WADIA Institute of Himalayan Glaciology, Dehradun, India | Dr. R. K. Mazari, Scientist | mazarirk@wihg.res.in | http://www.wihg.res.in/ | India | Carries out basic research in Himalayan Geology and related fields which includes geodynamic evolution, mountain building processes, geoenvironment and mineral resources. | Research activites in four areas: Tectonophysics; Petrology & Geochemistry; Lithogenesis-Biostratigraphy and Earth Resources and Environment. One of the key agencies working directly on **glacial melt studies** in India. | | One of a few key institutes working directly on glacial melt water studies in India (others include National Institute of Hydrology, Roorkee; and the G.B. Pant Institute of Himalayan Environment and Development, Almora). Less attention to climate change impacts/linkages. |
| Glaciological Survey, India (GSI) | Dr. Sangewar | gewar@rediffmail.com, cvsangewar@rediffmail.com | www.portal.gsi.gov.in/ | India | Glaciological surveying in the northwest Himalaya. | **Himalayan Glaciers: A state of the Art Review of Glacial Studies, Glacial Retreat, and Climate Change.** MOEF Discussion Paper by V.K. Raina. Draws on Raina's research since 1956, backed by on-the-ground observation | | See above. |
| G. B. Pant Institute of Himalayan Environment and Development (GBPIHED), India | Dr. Varun Joshi | varunj63@yahoo.com | http://gbpihed.gov.in | India Himalayan region | An autonomous Institute of the Ministry of Environment and Forests (MoEF), Govt. of India. Focal agency for integrated management strategies, conservation of natural resource management, and environmentally sound development in the Indian Himalayan Region. | **Environmental impact of recession of Himalayan Glaciers-A case study of Dokriani Bamak Glacier.** (Completed 2008). Also involved in **Himalayan Glaciers: A state of the Art Review of Glacial Studies, Glacial Retreat, and Climate Change** (above). Currently involves in **glacial studies in Sikkim and Uttrakhand**. In Sikkim GBPIHED are working on glacial melt using RS & GIS techniques in Tista river basin. In Uttarakhand GBPIHED have two type of studie: firstly examining the hydrometry of Gangotri glacier, and secondly in Dhauli & Goriganga basin (Kumaon Himalaya). | | Resource information database of the Indian Himalaya. Envis Monograph 3. ISSN 0972 - 1819 |
| Department of Hydrology and Meteorology (DHM), Nepal | Dr. Keshav Prashad Sharma | keshav@dhm.gov.np | www.hydrology.gov.np | Nepal | Responsible for monitoring snow and Glacial Lakes, GLOF, through the establishment of monitoring stations; publication of snow/snow hydrology related data; estimation of snowmelt from high mountain region; providing guidelines for glacial melt activity in Nepal | Focal point for recent project **The role of Glaciers in the Mountain Hydrology of Nepal: A Preliminary Assessment.** Project estimated runoff from glacier-covered watersheds using area-altitude distributed models | Regular collaboration with ICIMOD on glacial melt studies; also previous collaboration with UNEP; focal point for Preliminary assessment of glaciers by NSIDC and INSTAAR (funded by Word Bank and NASA) | |

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| Water and Energy Commission Secretariat (WECS), Nepal | Sanjaya Dhungel (Sr. Divisional Engineer | info@wec.gov.np | http://www.wec.gov.np/ | Nepal | Coordinating arm of the Water and Energy Commission | Focal agency for World Bank and IWMI glacial related studies and activities | World Bank; IWMI | |
| Ministry of Forests and Soil Conservation (MOFSC), Nepal | Deepak Bohara, Minister of Forests & Soil Conservation | bohara@sca.com.np Tel: . 977-1-4211660 | | Nepal | Focal point for some of climate change activity in Nepal | Government focal point for much of the climate change activity in Nepal related to forests. Coordinating upcoming conference on glacial melt, biodiversity, payment for environmental services (PES) and REDD.Shared focal point for upcoming Alliance of Mountainous Countries Conference. | UNDP, DfID | In Nepal, climate change activites are split largely between MOE and MOFSC. While MOFSC generally deals with forestry-related issues, the recent move by a Joint Secretary responsible for much of MOE's climate change portfolio means MOFSC may play an increasingly important role in glacial melt issues. |
| Ministry of Environment (MOE), Nepal | Mr. Purushottam Ghimire Joint Secretary, Environment Division  | puru@most.gov.np , +977-9841278600 | | Nepal | Focal point for most of climate change activity in Nepal | UNFCCC focal point, led on National Comuincation and NAPA (ongoing). Likely that NAPA will include at least one project on glacial melt, or at the very least raise glacial melt as a key issue of vulnerability. Also taking leadership on forthcoming Alliance of Mountainous Countries Climate Change Conference. | UNDP, DfID, Danida | |
| Geological Survey of Bhutan, Department of Geology and Mines, Ministry of Economic Affairs | Sonam Tshering, Secretary | sting@druknet.bt | http://www.mti.gov.bt/departments.htm | Bhutan | | Government focal point for UNDP project **Reducing Climate Change-induced Risks and Vulnerabilities from Glacial Lake Outburst Floods in the Punakha-Wangdi and Chamkhar Valleys**. April 2008 - December 2012. Project involves education of GLOF risk in the Punakha-Wangdi and Chamkhar Valleys in Bhutan. See UNDP entry for details. | UNDP | |
| Bangladesh Water Development Board (WDB) | No specific | cm-bwdb@bangla.net | http://www.bwdb.gov.bd/ | Bangladesh | Leading organization for water resources management and development | No explicit work on glacial melt but would be a key contact for any work on associated downstream issues as it is a key national agency for work on flood forecasting and hydro-meteorological data management | | |
| Water Resources Planning Organization (WARPO) | Dhali Abdul Qaium, Director General | 9880879 | http://www.warpo.gov.bd/ | Bangladesh | An agency of the Government of the People's Republic of Bangladesh under the Ministry of Water Resources (WARPO is an apex body). | Deals with nation wide water resources planning and management. Assists other agencies in planning, monitoring, studies and investigations related to water resources. | | |
| Pakistan Meteorological Department | No specific | pmd@pakmet.com.pk | http://www.pakmet.com.pk/ | Pakistan | The Pakistan Meteorological Department is both a scientific and a service department, and functions under the Ministry of Defence. | Installed weather monitoring stations throughout Pakistan. Conducted study in November 2009 which concluded that the **Himalayan glaciers, particularly Siachen**, have been receding for the last 30 years, with losses accelerating to alarming levels in the past decade. | ICIMOD | In the process of being upgraded |
| Ministry of Water and Power, Pakistan | Mr. Rashid Ali Deputy Secretary (Water) ) | dswater@mowp.gov.pk | http://202.83.164.26/wps/portal/Mowp/!ut/p/c1/04_SB8K8xLLM9MSSzPy8xBz9CP0os_hQN68AZ3dnIwML82BTAyNXTz9jE0NfQwNLE_1wkA6zeAMcwNEAIo_LBEMTfT-P_NxU_YLs7DRHR0VFAGW7A9Q!/dl2/d1/L2dJQSEvUUt3QS9ZQnB3LzZfVUZKUENHQzIwODdTNTAyRUlOMzQxTTEwMTQ!/ | Pakistan | | Installed dozens of telemetry stations in the Northern Areas to **monitor glacial flow** | World Bank, ADB | Only a few of the telemetry stations are in working condition |

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| Global Change Impact Studies Centre, Pakistan | Dr. Qamar-Uz-Zaman Chaudhry Director General, Pakistan Meteorological Department | gcisc@comsats.net.pk | http://www.gcisc.org.pk/ | Pakistan | Secretariat to the Prime Minister's Committee on Climate Change | Recommended contact, specific information on glacial melt activities not available. | | Recommended contact despite no explicit work on glacial melt |
| Geological Survey of Pakistan | Head Office Director General | qta@gsp.gov.pk | www.gsp.gov.pk | Pakistan | Focal point for geological investigation | Recommended contact, specific information on glacial melt activities not available. | | |
| Afghan Ministry of Energy and Water | Information not available | Information not available | Information not available | Afghanistan | Information not available | Currently **upgrading the national hydro-meteorological network** by installing 174 new hydrological stations with facility to measure basic meteorological parameters, as part of the Emergency Irrigation Rehabilitation Project (EIRP) | EIRP funded by World Bank and facilitated by FAO | Very little national capacity for climatological, meteorological and hydrological assessment and forecasting in Afghanistan following eradication during the war. Rehabilitation has begun. US Geological Survey is currently undertaking large scale glaciological study (see research institutions). |
| Uzhydromet (Centre of Hydrometeorological Services, Uzbekistan) | Mr. Sergey Myagkov, Head of International Department, SANIGMI, Uzhydromet | phone is +998-71-235-83-29, fax: +998-71-235-20-25. | www.climate.uz | Uzbekistan | UNFCCC focal point which manages all data on climate change | National focal point for UNDP/GEF project **"Uzbekistan - country study on climate change"** which included conclusions on glacial melt contribution to water distribution patterns. Also conducted studies on **modelling accelerated glacial melting** and consequences for runoff of the Amu Darya, Zeravshan, and Syr Darya | UNDP/GEF | |
| Tajik Hydromet Agency | Mahmad Safarov, head of state Tajik Hydromet Agency | mahmad@meteo.tj | www.meteo.tj/eng/main1.html | Tajikistan | Hydromet is the main agency dealing with snow/glacial monitoring in Tajikistan. | **Hydrometeorological observations** network includes 57 hydrometeorological stations. Conduct observations over the height and temperature, glacier mass and snow reserves, water and chemical composition etc, glacial lake observations (including flow and changes to characteristics) | | Recommendations from USAID/CAR: Hydromet has a lot of needs with respect to glacial melt monitoring as a source of water for the entire Amudarya river. Main of them is lack of data monitoring and communication capacity. Only agency with resources for these activities - reflect lack of resources for academic/other instutions. |
| Institute of Geography, Ministry of Education and Science | Dr. Igor V. Severskiy, Glaciologist | 99 Pushkin Street, Almaty 040010, iseverskiy@gmail.com; phone is 7(3272)938831, fax: 7 (3272) 918102 | | Khazakhstan | Working on glacier monitoring and other scientific issues | | | |
| Ministry of Emergency Situations | | 22 Beibitshilik Street, Chancellery, Astana; phone is (7172) 60-2133 | | Khazakhstan | Disaster preparedness and response for Glacial Lakes Outburst Floods | | | |
| Institute of Hydrology and Water Problems | Duishen Mamatkanov, Director | 533, Frunze street, Bishkek; phone is +996 550 992911 | | Kyrgyzstan | This Institute has expertise in glacial monitoring, glacial lake outburst floods, and glaciers' contributions to water flow. | | | |
| State Agency for the Environment Protection and Forestry, Kyrgyzstan | Mr. Arstanbek Davletkeldiev, Director | 228, Toktogul Street 720001 Bishkek Kyrgyzstan | www.irinnews.org/Report.aspx?ReportId=80420 [URL of report on glacial melt in Kyrgyzstan] | Kyrgyzstan | | **UNFCCC focal point**, led on most recent National Communication, under which reviews of climate-change related glacial melt were carried out. | UNDP | Glacial research is based on extrapolation of results of the fragmentary monitoring of separate glaciers |

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| **Multilaterals and UN Agencies** | | | | | | | | |
| World Bank | Claudia Sadoff, Lead Economist, South Asia Region; Charles Cormier, Head, Environment Team (India); Tapas Paul, Sr. Environment Specialist, India; Sanjay Pahuja, preparing new Ganges Basin project, India | Csadoff@worldbank.org | http://www.worldbank.org/ | Afghanistan, Bangladesh, Bhutan, China, India, Pakistan, and Nepal | Mostly water management related activities related to glacial melt. | About to initiate national project on **Integrated Water Resources Management** in Kabul River Basin, **Afghanistan.** Undertook review in **2008: Europe and Central Asia Region: How Resilient is the Energy Sector to Climate Change?** Which included review of potential glacial melt impacts; **Nepal Water Resources Knowledge Base Development** project proposal to strengthen the Water and Energy Commission Secretariat (WECS) to become a centre of excellence in terms of possessing a state-of-the-art spatial knowledge base on the major basins of the country and the modelling and stakeholder facilitation skills to help develop basin plans. Will build a spatial database on water resources that will include up to date information on glaciers, glacial lakes, and **GLOF** risk. To be completed July 2010. **South Asia Water Initiative** (See DfID) | In Nepal, WB is working with WECS | |
| UNEP | Dechan Tsering, Deputy Regional Director | dechen.tsering@unep.org, | www.unep.org/geo/geo_ice/, www.rrcap.unep.org/glofbhutan/Bhutan | Regional focus on Central and South Asia. GLOF monitoring in the Hindu-Kush Himalayan region with particularly emphasis on Bhutan. Also two major conservation initiatives in Central Karakorum and Kailash Sacred Mountain areas. | Global Outlook for Ice and Snow investigates linkages between Ice, snow and climate change.GLOF research in Hindu Kush; Conservation-based adaptation and mitigation in mountain regions. | Facilitated the first major publication on **Inventory of Glaciers, Glacial Lakes and Glacial Lake Outburst Floods in Bhutan and Nepal** in 2001 with ICIMOD and other expert institutions. Facilitated the **assessment of the impacts of climate change on Himalayan glaciers and glacial lakes in 2007** with ICIMOD and other expert institutions Facilitated compilation of **Inventory of Glaciers, Glacial Lakes and the identification of potential Glacial lake Outburst Floods (GLOFs)** in the Pumqu Basin, Tibet Autonomous Region of PR China, Tista Basin, and Sikkim Himalaya. Facilitating the establishment of a **network of strategically located black carbon observatories in Hindu Kush Himalaya and Karakorum region** with EVK2-CNR. 6-year time series data on black carbon have been compiled In **Central Karakorum and Kailash Sacred Mountain areas,** UNEP are working with AIT to develop two **sustainable development master plans and mainstreaming climate change adaptation and mitigation** options in **the development agenda.** Also sponsored recent **International Workshop reviewing State of Troposphere Temperature, Pollution, Melting Glaciers and their Potential Impact on Monsoon and High Altitude Vegetation in the Himalayas-Tibetan Plateau,** Dec 28-29, 2009, New Delhi. India. Workshop report includes full discussion of recent IPCC glacial melt statement controvery, with many of the implicated actors present. | ICIMOD; AIT; WCMS | Sent short brief on potential role for UNEP in possible USAID investment programme, available on request. Inventory of Glaciers: http://www.rrcap.unep.org/issues/glof/glof/index.htm Black Carbon Data: http://www.rrcap.unep.org/abc/data/abc/index.html Assessment Report: http://www.rrcap.unep.org/abc/impact/index.cfm |
| UNDP | Gernot Laganda, Regional Technical Advisor Climate Change Adaptation | gernot.laganda@undp.org | http://sdnhq.undp.org/gef-adaptation/projects/websites/index.php?option=com_content&task=view&id=203; http://www.undp.org.bt/ | GLOF projects in India, Pakistan, Nepal and Bhutan; Community-based adaptation project in Kazakhstan | GLOF | **Reducing Climate Change-induced Risks and Vulnerabilities from Glacial Lake Outburst Floods in the Punakha-Wangdi and Chamkhar Valleys. April 2008 - December 2012.** Project involves education of GLOF risk in the Punakha-Wangdi and Chamkhar Valleys in Bhutan. The project will integrate climate risk projections into existing disaster risk management practices and implement corresponding capacity development measures. It will demonstrate practical measures to reduce climate change-induced GLOF risks from the potentially dangerous Thorthormi glacier lake, and facilitate replication of the respective lessons learned in other high-risk GLOF areas, both within and outside Bhutan. Will also ensure that early warning mechanisms for the Punakha-Wangdi Valley, which is currently not equipped to handle the full extent of potential GLOF risks, is expanded to incorporate coverage of this growing threat. Lessons learned from this initiative will enable up-scaling of early warning systems in other disaster-prone areas downstream of potentially hazardous glacier lakes. **Regional GLOF Risk Reduction Project.** The project aims to complement the structural approaches towards GLOF risk reduction with sociological and community-based strategies for GLOF risk mitigation and preparedness as community participation in GLOF risk reduction has received little or no attention to date**.**Undertaking **community based adaptation programmes with mountain communities in Kazakhstan, some of which specifically address glacial melt vulnerabilities.** | DIP-ECHO | |

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| Asian Development Bank (ADB) | Cindy Malvicini, Water Resources Management Specialist, South Asia Division | cmalvicini@adb.org | http://www.adb.org/climate-change/afg-ind-downstream.asp | ADB state that their loan operations are better aligned, in the medium-term, in the Indus river basin (Pakistan and Central and East Afghanistan, North India), given the anticipated impacts of climate change and glacial melt in the Western Himalayas. | Focus on risk management and adaptation requirements supporting the water and hydro-energy sectors | **Glacial Melt and Downstream Impacts on Indus-Dependent Water Resources and Energy (Afghanistan/India)**. An ADB Small Grant for Adaptation Project. Expected outputs include: gap-analysis on the state of knowledge (modelling, impacts, risk analysis) in Western Himalayas (Afghanistan, Pakistan and north India), and ADB water and hydro-energy project/programs area in particular; project stakeholders to formulate a practical Mountain Glacier and Downstream Water Risk Management Framework & Adaptation Guide; desk and field rapid climate impacts and risk screening of ADB's project portfolio and pipeline in the water and energy sectors in Afghanistan and Pakistan.<br>Also funded **IFPRI study "Addressing Climate Change in the Asia and Pacific Region: Building the Climate Resilience of the Agricultural Sector".** Study focuses on 4 South Asian countries (Afghanistan, Bangladesh, India and Nepal). Analyses relationship between agricultural productivity and glacier retreat, floods, droughts, erratic rainfall and other climate change impacts. | Government and NGO partners; IFPRI | |
| **Non-Government organizations** | | | | | | | | |
| The Mountain Institute | Alton Byers, Director of Research and Conservation; also Bob Davis, Chief Operating Officer; also Brian Peniston; and Florence Zapata (Instituto de Montana) | abyers@mountain.org; bdavis@mountain.org | www.mountain.org | Asia programmes in China, Nepal (Regional Office), and India | Analysis of glacial retreat by combining field and laboratory-based investigations; work on glacial lakes; also work on adaptation - community based and technical responses - with vulnerable mountain communities; focus on mountain conservation as one buffer to climate change impacts. | Study of **glacial fluctuations in Sagarmatha** (Mt Everest) National Park through ground-truthing of remote sensing data [first scientific study in Hongu valley to photograph and assess condition of 11 new glacial lakes]; **glacial lake studies** including Imja lake, Nepal, now one of the largest and most high-risk of GLOF; **Climate resilience building** through training in the use of USAID's Vulnerability and Adaptation approach; Increasing awareness for highland-lowland interactive systems and dependencies; **Promoting highland conservation as one of the best climate change buffers;** awareness building and education; **promoting south-south dialogue and technology transfer on vulnerability in glacial regions** [proposal to transfer lessons from Peru to Himalayas]; **GLOF risk reduction** through reinforcing terminal moraines of lakes/digging channels to relieve water pressure; as well as **community-based adaptation** among vulnerable mountain communities. Organising a climate change workshop in Nepal in late 2010 to share outputs of glacial lake studies and as follow-on to 2009 "Adapting to World Without Glaciers" conference in Peru. | ICIMOD;USAID; IGES; Hongu valley study funded by Waitt Grants Programme of National Geographic Society, and undertaken in partnership with glaciologists from Hokkaido University and ICIMOD. Climate change workshop in late 2010 to be organised in conjunction with USAID, National Science Foundation and ICIMOD. | One of few organizations working on ground-truthing of remote sensing in glacial retreat/glacial lake studies. Also, developing proposals to facilitate CBA approaches in mountain and glacial regions; and strengthening south-south dialogue on adaptation technologies in mountain regions; in particular the transfer of technologies for tapping glacial lakes to reduce GLOF risk and also generate small-scale hydropower; and building upstream-downstream linkages at commnity, private sector, and local government levels. ITN-TV interview by Dr Byers at the Imja lake November 2009: http://www.itnsource.com/shotlist//ITN/2009/12/01/T01120908/<br>Byers, A. 2007. An assessment of contemporary glacier fluctuations in Nepal's Khumbu Himal using repeat photography. Himalayan Journal of Sciences, 4(6). |
| Asia Disaster Preparedness Centre (ADPC), Bangkok | Mr. Subbish; also Dr. Srinivasan | sriniren@gmail.com | www.adpc.net/ | Asia and Pacific | Disaster risk reduction agency | Various climate risk management activities; early warning systems/climate forecasting | | |

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| WWF | John Miceler, Managing Director, Eastern Himalayas Program. Also Tariq Aziz, Leader of WWF Living Himalaya Initiative, Nepal. Also Shirish Sinha, Head, Climate Change and Energy Programme, WWF-India; and Dr Dipankar Ghose, Eastern Himalaya and Terai Programme, WWF-India. | tariq.aziz@wwfnepal.org, Jon.Miceler@wwfus.org; shirish@wwfindia.net; dghose@wwf.india.net | www.panda.org, www.worldwildlife.org/what/wherewework/easternhimalayas/index.html | Eastern Himalayas (Nepal, Bhutan, northern Myanmar, southeast Tibet and northeast India) | Mostly adaptation focused but also policy aspects and field research aspects including monitoring retreat at river source areas on the Tibetan plateau. | **"Climate Change Impacts on Freshwater Ecosystems in the Himalayas (CCIFEH)"** project builds on the 2 year Himalayan Glaciers and Rivers Project funded by WWF NL 2004-6, which documented the impact of climate change on glacier melt in the Himalayas. Builds on glacial research in the Indian and Nepali Himalayas and on the Tibetan Plateau and will link to ongoing freshwater and species programme work in the Ganga Basin of India. In Nepal, will implement adaptation measures in Gokyo lake, and support the High Altitude Wetlands project in Ladakh, India.<br>**An Overview of Glaciers, Glacier Retreat, and Subsequent Impacts in Nepal, India and China.** A detailed review in 2005 of glacial retreat and impacts in Nepal, India and China, which is in the process of being updated.<br>Monitoring the glaciers of the Himalayas, Nepal. In both Nepal and Bhutan, WWF are undertaking the following:<br>1. **Monitoring glacial retreat** in areas that dangerous glacial have formed<br>2. **Monitoring upper watershed flows**-water quality, quantity and frequency changes<br>3. **Establishing early warning systems** for communities at risk from GLOFs.<br>4. (Bhutan only): M**anually reducing water levels in dangerous glacial lakes** by hand through digging of trenches and pumping water out. Also doing a lot of village work in Bhutan and Nepal with **communities living near glaciers** that are receding and which have dangerous glacial lakes near them. In Tibet WWF's work focuses on:<br>1. **Climate witness** work **(community-based adpatation approach)** where designated nomads living near glaciers and wetland river source areas capacitated to report on changes in rangeland ecology, glacier shifts, weather changes<br>**2. Baseline monitoring of certain glaciers**<br>**3. General community based adaptation** | The CCIFEH project is a collaborative effort between WWF India and the Birla Institute fo technology, Extension Centre, Jaipur, India, who worked with the Forest Department, Government of India. The Glacial Retreat publication is a joint effort between WWF Nepal, WWF India and WWF China. National Governmental partners on this project included DHM/MOEST in Nepal; HIGH ICE-India Glacier Research Group, Jawaharlal Nehru University (JNU), New Delhi, India; and the Chinese Academy of Sciences (CAS) in China. In Nepal, work with Department of Hydrology and Meteorology (DHM) and Tribhuvan University. | The 2005 report "An Overview of Glaciers, Glacier Retreat and Subsequent Impacts" contains statements based on the now controversial article from The New Scientist magazine "Flooded Out - Retreating glaciers spell disaster for valley communities" published 5 June 1999. This article has recently been exposed as containing erroneous statements relating to glacial melt claims. A correction has been issued by WWF. Other relevant publications include: Witnessing Change: Glaciers in the Indian Himalayas. 2009. WWF India and BIT.<br>An Overview of Glaciers, Glacier Retreat, and Subsequent Impacts in<br>Nepal, India and China. 2005. WWF Nepal. |
| IUCN | Mr. Ahmad Saeed Principal Expert Global Change | ahmad.saeed@iucnp.org | http://www.iucn.org/about/union/secretariat/offices/asia/regional_activities/elg/?712/Finding-a-workable-conservation-model-for-high-altitude-ecosystems | Pakistan, Nepal, China | Working with Government of Pakistan on climate-related disaster management in Pakistan | **Hindu Kush-Karakoram-Himalaya regional project** (ended mid-2009): Aims to support capacity to understand/manage high altitude ecosystems from a systems perspective. Focused on three protected areas: Sagarmatha National Park in Nepal, the Central Karakoram National Park (CKNP) in Pakistan and Qomolangma Nature Preserve in the Tibet Autonomous Region of China.IUCN is supporting a number of specific activities including the development of a shared vision for the area through innovative scenario planning tools; providing resource baselines through GIS mapping and research; working to coordinate diverse actions and interests in the area; applying new planning and management tools such as Qualitative Systems Analysis and use of IUCN Protected Area Categories in zoning plans. | ICIMOD) and the Italian NGO Cooperazione e Sviluppo (CESVI) | |
| CGIAR Challenge Program on Food and Water | No specific | | http://cpwfbfp.pbworks.com/ | "Basin Focal Project" in the Indo-Ganges, Volta, Yellow River & Mekong basins | An international, multi-institutional research initiative with a strong emphasis on north-south and south-south partnerships. | Impact of Climate Change on Water Resources and Glacier Melt and Potential Adaptations for Indian Agriculture. | | Nb CIGAR is a coperative of organizations rather than one specific |
| Practical Action | Gehendra Gurung (Nepal office) | gehendra.gurung@practicalaction.org.np | http://www.practicalaction.org/nepal/region_nepal | Nepal | Technology focus, from R&D through to implementation | Porjects on community-based adpatation, especially related to water management. | | |
| LiBird | Apar Paudyal, programme officer | apaudyal@libird.org, | http://www.libird.org/ | Nepal | Community-based adpatation and development | Coordinating agency for the 2008 Nepal NGO Group Bulletin on Glacial Mel. See http://www.forestrynepal.org/images/ClimateChange_issue2_Final.pdf. | IIED; DfID | |
| Navdanya | Dr. Vandana Shiva, Director | ndana@vandanashiva.com / vandana.shiva@gmail.com / vshiva@vsnl.com | www.navdanya.org | India, Himalaya | Community-based adaptation | Over the last year, Navdanya / Research Foundation teams have worked with local communities in Uttarakhand and Ladakh to assess the impact of climate change on their ecosystems and economies and to evolve **community-based adaptation** - participatory plans for climate change adaptation. | | |
| People's Science Institute (PSI) | Dr. Ravi Chopra, Director | psiddoon@gmail.com | www.peoplesscienceinstitute.com | India | Research and development activities. Many activities around watershed management | Key stakeholders contacted by G.F. Taylor during coutry visit. | | |

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| People's Association for Himalaya Research (PAHAR) | Shekhar Pathak | (5946) 236191, 239162 | www.pahar.org/drupal | India | PAHAR is a non-profit organization dedicated to raising awareness of the fragile Himalayan environment and bringing together scientists, social activists, and common people to save the Himalayas. | Key stakeholders contacted by G.F. Taylor during coutry visit. | | |
| The Executive Committee of the International Fund for saving the Aral Sea | Sagit Ibatullin | 280, Dostyk Ave., Almaty, Kazakhstan tel.:+ 7 (727) 387 34 31 | | Aral Sea | evaluating proposals for glacial work because glaciers provide water to the Aral Sea | | | |
| Central Asian Institute for Applied Geosciences (CAIAG) | Ryskul Usubaliev | fax:+7 (727) 387 34 33 | www.caiag.kg | Central Asia | The main purpose of CAIAG is assistance in carrying out of researches in the field of geosciences | Conducted studies looking at **food security and glacier distribution** | Government of Kyrgyzstan and the German GeoForschungsZentrum, Potsdam. | |
| The Asia Foundation | Ms. Srabani Roy, Assistant Director of Programs | elmira@ec-ifas.org | | South Asia | Has mostly focused on water management and governnace issues in Himalaya. | In the early 2000's, received USAID funding (through USAEP/ECO-Asia) for a variety of water projects in India and Sri Lanka, including a "Save the Yamuna" campaign to increase awareness of the plight of the Yamuna from its glacial headwaters to the lowlands of India. From 2001-2003, again with USAID funding, worked to strengthen capacity of select forest and water user group federations and coalitions in Nepal to advocate for their interests in resource managemen. More recently, supported the publication of a special double issue of "Himal Southasia" focused specifically on the impact of climate change in the region as well as documentaries on climate change impacts as part of the Himalayan Film Festival in Kathmandu, Nepal. Has also conducted a number of technical assistance projects on water resources issues over the years. | USAID; ICIMOD. | Himal Southasia Special Issue on glciers. See www.himalmag.com |
| BIOM | Anna Kirilenko | kyrgyzstan@spareworld.org | | Kyrgyzstan | Environment and Development NGO | Released report on **climate change impacts in Kyrgyzstan** including glacial melt in 2009 | | |

| Organization Details | | | | Geographic Area of Focus | Subject Area of Focus and Expertise in Relation to Glacial Melt | Summary of Activities | Partners | Comments/Relevant Publications and Resources |
|---|---|---|---|---|---|---|---|---|
| **Name** | **Key Contact** | **Contact Details** | **URL** | | | | | |
| **Research/Academic Institutions** | | | | | | | | |
| ICIMOD | Andreas Schild (Director); Arun Shresta, Climate Change Specialist, Integrated Water and Hazard Management; Bidya Bannali Pradhan (ICIMOD/UNEP) | dir@icimod.org; abshrestha@icimod.org | www.icimod.org | Hindu Kush-Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. | 3 key strategic areas – water, environmental services, and livelihoods. Addresses glacial melt from a technical standpoint, for example through glacier and GLOF risk monitoring (ICIMOD has been working on GLOFs for several years); and also from a vulnerability perspective, taking a livelihoods based approach to adaptation in vulnerable mountain communities | Has completed study on GLOFS in HKH region. ICIMOD has initiated the development of a **database of glaciers and glacial lakes** in different basins in the region through a unified inventory approach. Linked to this, the project Capacity Building for Improved **Monitoring of Snow, Ice and Water resources in the Indus Basin** (in Afghanistan and Pakistan). Also currently establishing a regional **flood information system** in the Hindu Kush-Himalaya. Project builds on results of USAID sponsored preliminary phase 2001-2005. Undertaking **compilation of climate and hydrolic modelling in the Himalaya** . Also recently completed a two year collaborative pilot study **Too much, too little water"** , based on five field teams in China, India, Pakistan and Nepal looking at the realities facing mountain populations and hundreds of millions people downstream. ICIMOD are also in the PRELIMINARY phase of the projec**t Enhancing understanding on the impacts of Climate and Socio-Economic Changes in Kosi Basin,** in Nepal and China, which aims to increase understanding of the linkages between drivers of changes; physical and social pathways; and impacts on livelihoods in relation to water availability and water related hazards. Also developing concept **Assessing impacts of climate change on the hydrological regime of river basins in the HKH region** (AICCHYR), a tool for supporting mitigation and adaptation planning | GLOF study supported by UNEP and APN, using national partners in the respective regional countries. Snow, Ice and Water resources study funded by German Development Cooperation. Flood information system preliminary phase supported by USAID/OFDA; current phase supported by Ministry of Foreign Affairs, Finland; WMO; and local partners in six regional countries. Compilation of modelling work in conjunction with ISET and CICERO. Too much too little water in collaboration with ISET, IIED, UNEP, CICERO. AICCHYR project envisages collaboration with ETH, Zurich and University of Graz., University of Jena, etc. National Government partner in Nepal was the Department of Hydrology and Meteorology (DHM). | Nb. ICIMOD is not a research organization but a knowledge centre and platform for groups to come together to work on regional problems. In light of the recent controversy over glacial monitoring, ICIMOD highlights that it has been promoting mass balance measurements of benchmark glaciers in its member countries and has co-organised trainings to build capacity for this in the region. Relevant publications include: Shresta, A., M. Eriksson; and P. Mool. Towards a comprehensive glacial lake outburst flood risk assessment in the Hindu-Kush Himalayas - a methodological approach. Submitted to recent National Institute of Disaster Management (NIDM, India) Conference in Delhi. Also Bajracharya, S. R., and P. Mool. 2009. Glaciers, glacial lakes and glacial lake outburst floods in the Mountain Everest region, Nepal. Annals of Glaciology 50 (53). |
| Institute for Social and Environmental Transition (ISET) | Marcus Moench | moenchm@i-s-e-t.org | www.i-s-e-t.org | Working on emerging hazards in the Hindu-Kush Himalaya, with offices in Nepal, Pakistan, and soon in Bangkok | Focus on bridging science-policy-implementation divide. Engaged in research and implementation, with particular focus on the translation of global natural and social scientific insights into local contexts. | ISET provides **backstopping support to the ICIMOD** department of Integrated Water and Hazard Management Programme (IWHM) on various glacial studies projects. Work has included background literature review and summary and technical and editorial review of written materials. Also working alongside the International Institute for Environment and Development (IIED), UK, on **bottom-up adaptation planning in Nepal,** funded by DfID.<br><br>Currently ISET, in conjunction with CICERO, is working on an **inventory and compilation of past and current climate and hydrological modelling going on in the Hindu Kush -** Himalayan region, and listing of hydrological models being used. | ICIMOD, CICERO, IIED | |
| International Institute for Environment and Development (IIED), London | Simon Anderson, Group Head, Climate Change Group | simon.anderson@iied.org | www.iied.org | Ongoing climate change work in Bangaldesh; India; Nepal | Focus on adapatation to climate change | IIED are not specifically working on glacial melt, but address these issues indirectly through their work on national and commuinty based adpatation planning in India, Nepal and Bangladesh. | ICIMOD; ISET; DfID: Government of Nepal | |
| AIT | Jonathan Shaw, Director of Extension; Kiyosha Honda, Associate Professor, Remote sensing and GIS; Mahesh Pradhan, Director AIT/UNEP regional Resource Centre for Asia and the Pacific | jshaw@ait.ac.th | /www.rsgis.ait.ac.th/~honda/FS_Himalaya.htm | Himalaya | Undertaking projects on glacial melt/glacial lake monitoring in Nepal through integration of sensor network and GIS. | **Monitoring Imja Glacier Lake: Himalayan glacier monitoring project with Field Server (2007)** - Imja lake has been identified as potentially one of the most dangerous in the region at risk of GLOF. Implemented **another node at Annapurna (Himalaya) (2009)** | National Research and Education Network (Nepal); ICIMOD; Keio University (Japan); National Agricultural Research Centre (Japan); and University of Tokyo. | Honda Kiyoshi et al., 2009. Field servers and Sensor Grid as Real-time Monitoring Infrastructure for Ubiquitous Sensor Networks. Sensors (ISSN 1424-8220) 9, no. 4.(doi: 10.3390/s90402363). |

| Organization Details | | | | Geographic Area of Focus | Subject Area of Focus and Expertise in Relation to Glacial Melt | Summary of Activities | Partners | Comments/Relevant Publications and Resources |
|---|---|---|---|---|---|---|---|---|
| **Name** | **Key Contact** | **Contact Details** | **URL** | | | | | |
| Stockholm Environment Institute (SEI) | Johan Kuylenstierna (Director - York); Kevin Hicks (Research Fellow) | johan.kuylenstierna@sei.se | sei-international.org/ | Work on black carbon in Kathmandu, Nepal | Little specific work on glacial melt. Some expertise on black carbon. | Excel-based Programme of Rapid Evaluation of Air Pollution (PREPair) to evaluate black carbon in Kathmandu Nepal | | |
| Nicholas School of the Environment, Duke University | Peter McCornick | pm60@duke.edu | www.duke.edu | Ganges and Mekong river basins | Conducted broad reviews of the climate change/water situation in South Asia and South East Asia. | **Water, Climate Change, and Adaptation: Focus on the Ganges River Basin.** A working paper published August 2009 that explores the intersection between water management, climate change, and adaptation in the Ganges River system. Includes implications of glacial melt. | Study conducted in collaboration with IWMI. Part of the CPWF Basin Focal Project for the Indus-Gangetic Basin. | |
| The Energy and Resources Institute (TERI), India | Prof. Syed Iqbal Hasnain, Senior Fellow and Chairman, Glacier and Climate Change Commission, Govt. of Sikim | iqbalhasnain@hotmail.com | www.teriin.org | India | Glacial monitoring and black carbon. | **Benchmark study on Himalayan Glaciers**. Have selected four glaciers in Zanskar, Kashmir Valley, Himachal Pradesh, and Sikkim. **Himalayan Ice Climate and Black Carbon Aerosol Impacts on Water Resources**. Measuring Black Carbon in Himalayan atmosphere via an aethalometer installed at East Rathong glacier at 4,700. Conclude that concentration of black carbon due to transport emissions, is as important in accelerating glacial melt as CO2. | Working with NASA and Scripps Institution of Oceanography on Black Carbon. | |
| The National Institute of Hydrology, Roorkee | Dr. Bhishm Humar, Head, Hydrological investigations; Dr N.C.Gosh, Head, Goundwater Division; Dr. M. K. Goel, Scientist, Water Resources Systems; Dr Someshwar Rao, In-charge, Nuclear Hydrology Lab; Dr. Renoj Thayyen, Scientist. | bk@nih.ernet.in; ncg@nih.ernet.in; mkg@nih.ernet.in; someshwar@nih.ernet.in; renojthayyen@gmail.com | http://www.vigyanprasar.gov.in/comcom/develop76.htm, www.nih.ernet.in | India | Research institute focusing on hydrology | Studies on snow and glacial melt include: Snow and glacier melt contribution in Chenab river; Snow and glacial melt contribution in Ganga; Melt rate studies of Himalyan glaciers; melt water storage of a typical glacier. | | |
| Snow and Avalanche Studies Establishment (SASE) | Maj Gen Satya S Sharma, former Director | satyasharma@hotmail.com | www.drdo.org/labs/sase/index.html | India | A Laboratory of the Defence Research and Development organization, primary function is research in the field of snow and avalanches to provide avalanche control measures and forecasting support to Armed forces | Key stakeholders contacted by G.F. Taylor during coutry visit. | | |
| Jawaharlal Nehru University, New Delhi, India | Professor P.S. Ramakrishnan | psr@mail.jnu.ac.in | | | | Prof. Ramakrishnan has worked in the Indian Eastern Himalaya extensivel. JNU about to start a prorgamme on galcial melt. | US Forest Service | Contact recommended by US Forest Service |
| World Glacier Monitoring Service, Zurich | Dr. Isabelle Gärtner-Roer | isabelle.roergeo.uzh.ch | www.geo.unizh.ch/wgms/index.html | Worldwide, with specific programmes on Central Asia(Himalaya and adjacent mountain ranges) and Northern Asia | Established in 1986 to maintain and continue the collection of information on ongoing glacier changes | Collects standardised observations on changes in mass, volume, area and length of glaciers with time **(glacier fluctuations)**, as well as statistical information on the distribution of perennial surface ice in space **(glacial inventories)** | The World Glacier Monitoring Service is under the auspices of ICSU (FAGS), IUGG (IACS), UNEP, UNESCO, and WMO | |

| Organization Details | | | | Geographic Area of Focus | Subject Area of Focus and Expertise in Relation to Glacial Melt | Summary of Activities | Partners | Comments/Relevant Publications and Resources |
|---|---|---|---|---|---|---|---|---|
| **Name** | **Key Contact** | **Contact Details** | **URL** | | | | | |
| Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences ( CAREERI, | Ren jiawen | yuexiao@lzb.ac.cn | www.casnw.net | China | Have a special glaciology and cryology cente | **Glacier physics and ice core studies** relating to paleoclimate and paleoenvironment;**Snow and ice processes** in term with the current environmental and climatic variation; **Glacier change relating to Global Change.** | | Re-organized in June 1999 from former three institutes of Chinese Academy of Sciences in Lanzhou, the Institute of Glaciology and Geocryology, Institute of Desert Research and Institute of Plateau Atmospheric Physics |
| Mountain Hazard and Environment Institute, CAS | No Specific | sdb@imde.ac.cn | http://english.imde.cas.cn | China | Formation and mitigation of mountain hazards; Remote-sensing, mapping, GIS. | **Dedictaed Digital Mountain and Remote Sensing Applications Center** | | |
| Institute of Tibetan Plateau Research, Chinese Academy of Sciences (CAS) | Yao, Tandong | tdyao@itpcas.ac.cn | http://english.itpcas.cas.cn/au/ | China (Tibetan Plateau) | Focus on the climate and environment of the Tibetan Plateau and its surrounding regions | **Black soot and the survival of Tibetan glaciers.** Study published in 2009 found evidence that black soot contributed significantly to glacial melt in the Tibetan Plateau. | Other CAS departments; and NASA; using data from International Atmospheric Observatory in Nepal | Baiqing Xu et al., 2009. Black soot and the survival of Tibetan glaciers. www.pnas.org?cgi?doi?10.1073?pnas.0910444106 |
| NASA Goddard Space Flight Centre | Teppei Yasunari (for black carbon) | Teppei.Yasunari@nasa.gov. | http://climate.gsfc.nasa.gov/ | Bhutan; China (Tibetan Plateau) | Black carbon; glacier retreat/glacial lake monitoring | **Black soot and the survival of Tibetan glaciers.** As above. **Studying Glacial Lakes from Retreating Glaciers in the Himalaya -** NASA used images from the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) instrument aboard NASA's Terra satellite to show that the termini of the glaciers in the Bhutan-Himalaya. Shows that glacial lakes have been rapidly forming on the surface of the debris-covered glaciers in this region during the last few decades. | Study of glacial lakes was in conjunction with the U.S. Geological Survey. | As above. |
| International Food and Policy Research Institute (IFPRI) | Mark Rosegrant | m.rosegrant@cgiar.org | http://www.ifpri.org/ | International; but with Asia programme. Part of CGIAR alliance. | Linkages between climate change and food security | **Climate Change: Impact on Agriculture and Costs of Adaptation.** Wide ranging study on linkages between climate change and food security in Asia. Draws linkages between glacial melt (and other factors) and declining crop yields in Afghanistan, Bangladesh, India, and Nepal. | ADB | Asia section of International Food Policy Research Institute, Climate Change: Impact on Agriculture and Costs |
| International Development Research Centre, Canada (IDRC) | Dr. Sara Ahmed | sahmed@idrc.org.in | www.idrc.ca/en/ev | IDRC regional office for South Asia and China | Agriculture and Environment | Key stakeholders contacted by G.F. Taylor during coutry visit. Research includes climate change and water, agriculture and food security, environmental economics. | | |
| International Water Management Institute (IWMI) | Dr. Andrew Noble, Regional Director for Southeast and Central Asia; Dr. Bharat R. Sharma, Head of IWMI New Delhi (b.sharma@cgiar.org) | A.Noble@cgiar.org | www.iwmi.cgiar.org/ | Southeast and Central Asia division. Work in relation to glacial melt to date has focused on Mekong and Irrawady river flows. | Downstream glacial melt impacts | A study: "Analysis of possible rainfall and temperature change in the greater Mekong sub-region over the period 1960-2049" was undertaken as part o the project "Scoping Study on Natural Resources and Climate Change in Southeast Asia with a Focus on Agriculture". Background papers to the study showed that the **contribution of glacial melt to the overall flow regimes of the Mekong and the Irrawady** are negligible when compared to the total annual discharge of the two river systems. Also did work on glacier melt modelling in the Indus and Ganges basins, in the process of developing the report. | SIDA/SENSA | |
| Council of Scientific and Industrial Research (CSIR), National Institute of Science, Technology and Development Studies | Dr. Rajeswari Sarala Raina, Scientist | rajeswari_raina@yahoo.com | www.nistads.res.in | India | | Key stakeholders contacted by G.F. Taylor during coutry visit. | | |

| Organization Details | | | | Geographic Area of Focus | Subject Area of Focus and Expertise in Relation to Glacial Melt | Summary of Activities | Partners | Comments/Relevant Publications and Resources |
|---|---|---|---|---|---|---|---|---|
| **Name** | **Key Contact** | **Contact Details** | **URL** | | | | | |
| US Geological Survey Afghanistan | Jack H. Medlin, Regional Specialist | jmedlin@usgs.gov | http://afghanistan.cr.usgs.gov/potentialeffects_afghanistan.php | Afghanistan and adjacent areas of Pakistan, Tajikistan, and Kyrgyzstan. | A variety of temporal/spatial resolution remotely sensed data sets are being used to investigate glaciers | **Potential Effects of Changing Glaciers on Resources and Hazards in Afghanistan.** This project is investigating mountain glaciers in Afghanistan and adjacent areas of Pakistan, Tajikistan, and Kyrgyzstan. The project involves: Training Afghan scientists in glaciology and glacial geology; A comprehensive digital inventory of glaciers in Afghanistan and areas draining into Afghanistan; An assessment of glacier-related hazards due to glacier lake outburst flooding; and an assessment of glacial meltwater resources in Afghanistan, specifically focused on contributions to urban development, agriculture, and hydropower development. | | |
| Indian Space Research organization (ISRO) | Dr. Anil V. Kulkarni, Snow and Glacial Melt project | anilkul@sac.isro.gov.in | http://isro.org/ | India | Experience of working on glaciers spanning 25 years. Work on the technical side of measuring glacial retreat/snow cover | **Snow and Glacier Inventory, Snow pack Characterization and Mass balance modelling.** | | |
| National Snow and Ice Centre, Boulder, Colorado | Richard Armstrong, Senior Research Scientist | nsidc@nsidc.org | http://nsidc.org | Tibetan Plateau | NSIDC manages and distributes scientific data, creates tools for data access, supports data users, performs scientific research, and educates the public about the cryosphere. | **Snow Cover Validation Case Study: Tibet Plateau.** To remeasure snow cover over the Tibetan Plateau, as optical sensors may in fact undermeasure the snow cover due to uncertainties resulting from cloud cover. Also undertaking research project **Investigating temporal and spatial snow cover distribution over the Tibetan Plateau and the synoptic patterns contributing to extreme winter snowfall events** | | |
| Ice Core Paleoclimatology Research Group, University of Ohio | Lonnie Thompson , glaciologist | thompson.3@osu.edu | http://bprc.osu.edu/Icecore/ | China | Uses ice core data to explore evidence for climate change | **Dunde Ice Cap, China:** compares high resolution ice core records from the Dunde Ice Cap on the northeastern margin of the Q-T Plateau and the Guliya Ice Cap on the far western margin. **Dasuopu ice cap, China:** On the south central rim of the Tibetan Plateau, the highest and largest plateau in the world, Dasuopu - will fill a gap in paleoclimate records and become part of the Austral-Asian transect in an international project under Past Global Changes (PAGES) Pole Equator Pole (PEP) II Program. This project will attempt to recover the highest ice core ever drilled**.** Project also covers **Guliya Ice Cap, China.** | Funded by the National Science Foundation | |
| Center for Environmental and Geographic Information Services (CEGIS) | Mr Giasuddin Ahmed Choudhury, Executive Director | *cegis* @cegisbd.com | www.cegisbd.com | Bangladesh | A Public Trust under the Ministry of Water Resources. Supports the management of natural resources for sustainable socio-economic development using integrated environmental analysis, geographic information systems, remote sensing, and information technology. | **Sustainable End-to-end Climate/Flood Forecast Application Through Pilot Projects** . Applying climate and flood forecasting in pilot regions. Major tasks of CEGIS include baseline & vulnerability assessment and flood forecast dissemination & assessment of forecast applicability in pilot areas. | Asian Disaster Preparedness Centre (ADPC), Bangkok; funded by USAID. | |
| U.S. Forest Service | Toral Patel-Weynand, Senior Advisor in Bioclimatology | tpatelweynand@fs.fed.us; 703-605-4188 | www.fs.fed.us | Indian states of Sikkim and Arunchal Pradesh, Nepal, and Bhutan | | Recently initiated a program with the Indian states of Sikkim and Arunchal Pradesh, Nepal, and Bhutan on forests and climate change: (1) forest inventories, (2) fire and disaster response, (3) the climate change program REDD, and (4) adaptation to climate change. | Jawaharlal Nehru University, New Delhi, India | Not specific glacial melt work; contact recommended by project team. |
| Scripps Institute of Oceanography, University of California, San Diego (UCSD) | Veerabhadran Ramanathan | vram@ucsd.edu | www.sio.ucsd.edu | China | | **US-China Cooperation to Reduce Black Carbon**: Conference held on February 11th, 2010, as part of a Cooperative Competitors initiative. Covered the energy and climate issues relating to black carbon in China and the United States. | | |
| | Ben Orlove, Professor of Environmental Science and Policy | bsorlove@ucdavis.edu | As above | All glacial regions, no specific focus | | Author of recent article, "Glacier retreat: Reviewing the limits of human adpatation". In Environment Magazine 51(3). Includes discussion on Asia. | | Glacier retreat: Reviewing the limits of human adpatation. In Environment Magazine 51(3). |
| Oxford Centre for Water Research | | | http://ocwr.ouce.ox.ac.uk/ | India and Nepal | | Snow and Glacier Aspects of Water Resource Management in the Himalayas. Http://ocwr.ouce.ox.ac.uk/research/wmpg/sagarmatha. | | Key stakeholders contacted by G.F. Taylor during coutry visit. |

| Organization Details | | | | Geographic Area of Focus | Subject Area of Focus and Expertise in Relation to Glacial Melt | Summary of Activities | Partners | Comments/Relevant Publications and Resources |
|---|---|---|---|---|---|---|---|---|
| **Name** | **Key Contact** | **Contact Details** | **URL** | | | | | |
| Centre for Science and the Environment (CSE), India | Sunita Narain, President | | Centre for Science and the Environment | India | A public interest research and advocacy organization based in New Delhi | Commented on the IPCC controversy: "Glaciating the climate debate" http://www.cseindia.org/content/glaciating-climate-debate. Also contibuted to Global Times issue on Himalayan Glaciers, *Why talk about glaciers?* www.cseindia.org/userfiles/July09.pdf. | | |

# Appendix A.2
# Summary by Region

**Current Work on Issues Related to Glacier Melt/Retreat in Asia**
**Appendix A.2 - Summary by Region**

| Organizational Group | Organization Name |
|---|---|
| **China** | |
| Governmental Focal Points | China Geological Survey Institute, Ministry of Land and Resources<br>The Ministry of Water Resources, Water Resources Information Centre |
| Donor Agencies | USAID<br>DfID<br>GTZ<br>SIDA |
| Multilaterals and UN agencies | World Bank<br>UNEP |
| NGOs | The Mountain Institute<br>WWF<br>IUCN |
| Research Institutes | World Monitoring Glacier Service<br>NASA Goddard Space Flight Centre<br>Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences ( CAREERI, CAS)<br>Mountain Hazard and Environment Institute, Chinese Academy of Sciences (CAS)<br>Institute of Tibetan Plateau Research (CAS)<br>National Snow and Ice Centre, Boulder, Colorado<br>Scripps Institute of Oceanography, University of California, San Diego (UCSD)<br>Ice Core Paleoclimatology Research Group, University of Ohio |
| **India** | |
| Governmental Focal Points | Indian Meteorological Department<br>Ministry of Environment and Forests<br>Department of Science and Technology (DST)<br>Glaciological Survey, India (GSI)<br>The WADIA Institute of Himalayan Glaciology, Dehradun, India<br>G. B. Pant Institute of Himalayan Environment and Development (GBPIHED) |
| Donor Agencies | USAID<br>Indian Meteorological Department<br>DfID<br>GTZ<br>MOFA, Finland<br>ECHO<br>SIDA |
| Multilaterals and UN agencies | World Bank<br>UNEP<br>UNDP<br>ADB |
| NGOs | The Mountain Institute<br>WWF<br>CGIAR Challenge Program on Food and Water<br>Navdanya<br>People's Science Institute (PSI) |

**Current Work on Issues Related to Glacier Melt/Retreat in Asia**
**Appendix A.2 - Summary by Region**

| Organizational Group | Organization Name |
|---|---|
| Research Institutes | ICIMOD<br>Institute for Social and Environmental Transition (ISET)<br>IIED<br>AIT<br>Nicholas School of the Environment, Duke University<br>The Energy and Resources Institute (TERI), India<br>National Institute of Hydrology, Roorkee<br>Indian Space Research Organisation (ISRO)<br>World Glacier Monitoring Service, Zurich<br>International Food and Policy Research Institute (IFPRI)<br>International Water Management Institute (IWMI)<br>Indian Council of Agricultural Research (ICAR) - IWMI |
| **Nepal** | |
| Governmental Focal Points | Nepal Department of Hydrology and Meteorology (DHM)<br>Water and Energy Commission Secretariat (WECS)<br>Ministry of Environment (MOE)<br>Ministry of Forests and Soil Conservation (MOFSC) |
| Donor Agencies | USAID<br>DfID<br>ECHO<br>Danida |
| Multilaterals and UN agencies | World Bank<br>UNEP<br>UNDP<br>ADB |
| NGOs | The Mountain Institute (TMI)<br>WWF<br>LiBird<br>Practical Action<br>IUCN |
| Research Institutes | ICIMOD<br>IIED<br>ISET<br>AIT<br>SEI<br>World Glacier Monitoring Service, Zurich<br>International Food and Policy Research Institute (IFPRI) |
| **Bhutan** | |
| Governmental Focal Point | Geological Survey of Bhutan, Department of Geology and Mines, Ministry of Economic Affairs |
| Donor Agencies | DfID<br>ECHO<br>Ministry of Foreign Affairs, Finland |
| Multilaterals and UN agencies | World Bank<br>UNDP<br>UNEP |

## Current Work on Issues Related to Glacier Melt/Retreat in Asia
## Appendix A.2 - Summary by Region

| Organizational Group | Organization Name |
|---|---|
| NGOs | WWF |
| Research Institutes | ICIMOD<br>World Glacier Monitoring Service<br>NASA Goddard Space Flight Centre |
| **Bangladesh** | |
| Government Focal Points | Bangladesh Water Development Board (WDB)<br>Water Resources Planning Organization (WARPO) |
| Donor Agencies | USAID<br>DfID<br>Ministry of Foreign Affairs, Finland |
| Multilaterals and UN agencies | World Bank<br>ADB |
| Research Institutes | Center for Environmental and Geographic Information Services (CEGIS)<br>International Food and Policy Research Institute (IFPRI) |
| **Pakistan** | |
| Government Focal points | Pakistan Meteorological Department<br>Ministry of Water and Power, Pakistan<br>Global Change Impact Studies Centre, Pakistan<br>Geological Survey of Pakistan |
| Donor Agencies | USAID<br>GTZ<br>ECHO<br>Ministry of Foreign Affairs, Finland<br>Danida |
| Multilaterals and UN agencies | World Bank<br>UNEP<br>UNDP<br>ADB |
| NGOs | IUCN |
| Research Institutes | ICIMOD<br>ISET<br>IIED<br>US Geological Survey Afghanistan (also covers Pakistan) |
| **Central Asia (other)** | |
| Government Focal points | Afghan Ministry of Energy and Water (Afghanistan)<br>Uzhydromet (Centre of Hydrometeorological Services, Uzbekistan)<br>Tajik Hydromet Agency (Tajikistan)<br>Institute of Geography, Ministry of Education and Science (Kazakhstan)<br>Ministry of Emergency Situations (Kazakhstan)<br>Institute of Hydrology and Water Problems (Kyrgyzstan)<br>State Agency for the Environment Protection and Forestry (Kyrgyzstan ) |
| Donor Agencies | USAID<br>DfID (Afghanistan)<br>Ministry of Foreign Affairs, Finland (Afghanistan) |

**Current Work on Issues Related to Glacier Melt/Retreat in Asia**
**Appendix A.2 - Summary by Region**

| Organizational Group | Organization Name |
|---|---|
| Multilaterals and UN agencies | World Bank (Afghanistan)<br>UNEP<br>UNDP<br>ADB (Afghanistan) |
| NGOs | Central Asian Institute for Applied Geosciences (CAIAG)<br>The Executive Committee of the International Fund for saving the Aral Sea (Kazakhstan)<br>BIOM (Kyrgyzstan) |
| Research Institutes | ICIMOD (Afghanistan)<br>World Glacier Monitoring Service<br>International Food and Policy Research Institute (IFPRI)<br>US Geological Survey Afghanistan (Afghanistan and adjacent areas of Pakistan, Tajikistan, and Kyrgyzstan)<br>Southeast Asia |
| **Southeast Asia (Mekong river basin)** | |
| Donor Agencies | USAID<br>SIDA |
| Research Institutes/NGOs | CGIAR Challenge Program on Food and Water<br>International Water Management Institute (IWMI)<br>Nicholas School of the Environment, Duke University |

# Appendix A.3
# Summary by Theme

**Current Work on Issues Related to Glacier Melt/Retreat in Asia**
**Appendix A.3 - Summary by Theme**

| Organizational Group | Organization Name |
|---|---|
| **Glacier Monitoring (glacial inventories; monitoring glacial retreat/glacial melt)** | |
| Governmental Focal Points | China Geological Survey Institute<br>Indian Meteorological Department<br>Ministry of Environment and Forests, India<br>Glaciological Survey, India (GSI)<br>GBPIHED, India<br>DHM, Nepal<br>WECS, Nepal<br>Geological Survey of Bhutan<br>Pakistan Meteorological Department<br>Ministry of Water and Power, Pakistan<br>Geological Survey of Pakistan<br>Uzhydromet (Uzbekistan)<br>Tajik Hydroment Agency<br>The Wadia Institute of Himalayan Glaciology<br>State Agency for the Environment Protection and Forestry (Kyrgyzstan) |
| Donor Agencies | USAID<br>GTZ |
| Multilaterals and UN agencies | UNEP<br>ADB |
| NGOs | The Mountain Institute (TMI)<br>WWF<br>IUCN<br>Central Asian Institute for Applied Sciences (CAIAG) |
| Research Institutes | ICIMOD<br>ISET<br>TERI<br>National Institute of Hydrology, Roorkee, India<br>World Glacier Monitoring Service<br>Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences (CAS)<br>Mountain Hazard and Environment Institute, CAS<br>US Geological Survey, Pakistan<br>National Snow and Ice Centre, Colorado<br>Ice Core Paleoclimatology Research Group, University of Ohio |
| **Glacial Lake Monitoring and Glacial Lake Outburst Flood (GLOF) Risk** | |
| Governmental Focal Points | Geological Survey of Bhutan<br>Institute of Geography, Ministry of Information and Science (Kazakhstan)<br>Ministry of Emergency Situations (Kazakhstan)<br>Institute of Hydrology and Water Problems (Kyrgyzstan)<br>Tajik Hydroment Agency |
| Donor Agencies | European Commission (ECHO) |
| Multilaterals and UN agencies | UNDP<br>UNEP |

| Organizational Group | Organization Name |
|---|---|
| NGOs | The Mountain Institute<br>WWF |
| Research Institutes | ICIMOD<br>AIT<br>TERI<br>NASA Goddard Space Flight Centre |
| **Downstream Impacts of Glacial Melt Including Water Management and Agricultural Issues** | |
| Governmental Focal Points | Indian Meteorological Department<br>GBPIHED, India<br>Department of Hydrology and Meteorology, Nepal<br>WECS, Nepal<br>MOE, Nepal<br>Bangladesh Water Development Board (WDB)<br>Bangladesh Water Resources Planning Organization (WARPO)<br>Afghan Ministry of Energy and Water<br>Uzhydromet (Uzbekistan)<br>Tajik Hydromet Agency |
| Donor Agencies | USAID |
| Multilateral and UN Agencies | World Bank<br>UNEP<br>ADB |
| NGOs | The Mountain Institute<br>WWF<br>The Executive Committee of the International Fund for saving the Aral Sea (Kazakhstan)<br>CGIAR |
| Research Institutes | ICIMOD<br>ISET<br>National Institute of Hydrology, Roorkee, India<br>The Asia Foundation<br>International Development Research Centre (IDRC)<br>Nicholas School of the Environment, Duke University (Mekong)<br>IWMI (Mekong)<br>US Geological Survey, Afghanistan<br>CEGIS, Bangladesh |
| **Black Carbon Studies and Activity** | |
| Donor Agencies | USAID<br>EPA |
| Multilateral and UN Agencies | UNEP |

**Current Work on Issues Related to Glacier Melt/Retreat in Asia**
**Appendix A.3 - Summary by Theme**

| Organizational Group | Organization Name |
|---|---|
| Research Institutes | Institute of Tibetan Plateau Research, Chinese Academy of Sciences<br>NASA Goddard Space Flight Centre<br>Scripps Institute of Oceanography, University of California, San Diego (UCSD)<br>SEI<br>TERI |
| **Community-based/Bottom-up Adaptation with Vulnerable Mountain Communities** | |
| Multilateral and UN Agencies | UNDP |
| NGOs | The Mountain Institute<br>WWF<br>Navdanya (India)<br>IIED<br>Practical Action (Nepal)<br>LiBird (Nepal)<br>ISET |