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TECHNICAL REPORT

HIGH MOUNTAINS ADAPTATION PARTNERSHIP

LESSONS LEARNED IN NEPAL AND PERU

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HIGH MOUNTAIN ADAPTATION PARTNERSHIP

CASE STUDIES AND LESSONS LEARNED IN NEPAL AND PERU

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ACRONYMS

CCRD	Climate Change Resilient Development
CENEPRED	National Center for Risk Assessment, Prevention and Management
ERT	Electrical resistivity tomography
GIS	Geographic Information System
GLRR	Glacier Lake Rapid Reconnaissance
GoN	Government of Nepal
GoP	Government of Peru
GPR	Ground penetrating radar
HiMAP	High Mountains Adaptation Partnership
LAPA	Local Adaptation Plans of Action
MINAM	Ministry of Environment
MOU	Memorandum of Understanding
NAPA	National Adaptation Program of Action
PDGL	Potentially dangerous glacial lake
SNP	Sagarmatha National Park
SNPBZ	Sagarmatha (Mt. Everest) National Park and Buffer Zone
TMI	The Mountain Institute
UGRH	Unit of Glaciology and Water Resources
UPCH	Universidad Peruana Cayetano Heredia
USAID	United States Agency for International Development
UT	University of Texas at Austin
VDC	Village Development Committee

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1. EXECUTIVE SUMMARY

Glacier-dominated mountains play a major role in providing water to large numbers of people. These glacier-dominated areas also pose unique challenges to downstream communities as they adapt to recent and continuing global climate change. Two of the more serious problems in high mountain regions include decreased water supply reliability and increased threats from glacial lake outburst floods (GLOFs), or moraine-dammed lakes left behind receding glaciers that can cause enormous downstream devastation if suddenly released by triggers such as an earthquake or overhanging ice.

The following report details the lessons learned during the implementation of the High Mountains Adaptation Partnership (HiMAP)(www.highmountains.org) project between March 2012 and June 2015. Located under the broader USAID Climate Change Resilient Development (CCRD) project[1], the goal of the HiMAP is to strengthen the climate change adaptation capacities of people who live in, or are dependent on, high mountain glacial watersheds and the ecosystem services which they provide[2].

The document is intended to be a resource for USAID Missions, donors, practitioners, and NGOs interested in learning more about the challenges of working in remote and roadless high altitude regions, particularly in view of USAID's growing portfolio of high mountain climate change adaptation, water management, biodiversity conservation, and livelihood improvement projects throughout the world. The lessons learned should also be of interest to those seeking to learn more about the new and emerging field of urban mountain development; highland-lowland interactive systems; and science-based, community-driven adaptation and community development projects.

The lessons and insights were derived during the course of developing Local Adaptation Plans of Action (LAPAs), concurrent with glacial field studies designed to inform the LAPA process, in the Mt. Everest region of Nepal and Cordillera Blanca of Peru. The Khumbu LAPA was the result of extensive

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[1] http://www.ccrdproject.com/

[2] Mountains cover approximately 24 per cent of the Earth's surface, are the source of all of the world's major rivers, and provide more than half of humanity with fresh water for drinking, domestic use, irrigation, hydropower, industry, and transportation. Mountains are also "hotspots" of biodiversity, and are among the world's most popular tourist destinations, such as the Khumbu and Cordillera Blanca regions covered in this document. Mountains are also particularly sensitive to changes in climate, most visible in the form of their rapidly receding glaciers and formation of hundreds of new glacial lakes.

consultations, meetings, and workshops involving over 300 participants from a wide range of stakeholder groups over a two-year period. The resulting LAPA represents a major step in the ability of local people in the region to understand, evaluate, and adapt to the impacts of climate change on their high mountain environments and lifestyles. The Quillcay LAPA demonstrates the value of conducting careful consultations with both rural and urban stakeholders to make sure that analysis of climate threats aligns with local priorities, problem definition, and funding resources.

The major lessons learned from the overall LAPA experiences in Nepal and Peru cases include the following:

- Trust and formal memoranda of understanding (MOU) with local governments and stakeholders must be established prior to commencement of the LAPA consultations in order to maximize the potential for LAPA success, effectively mainstream identified priorities into available funding opportunities, and avoid misunderstandings or surprises regarding roles and responsibilities.
- The basic LAPA methodology should be tailored to local conditions and needs in geographically uniform regions, as opposed to political delineations.
- Development goals in the context of climate change should be incorporated into the LAPA process while building strategies to work with government for their implementation.
- Marginalized populations and the poor should be included in consultations since they are the most vulnerable to the impacts of climate change and have fewer options for alternative livelihoods.
- Complementary science-based climate change knowledge should be generated in support of the LAPA process and shared with communities, government agencies, and NGOs.
- Mainstreaming LAPA actions into existing government institutions, organizations, and funding opportunities from the beginning is critical to helping local communities deal with the effects of climate change in the long term by.
- Knowledge generated in the course of the LAPA and field science process should be shared in multiple forms (publications, videos) to enhance the building of local capacity as well as the capacities of other communities around the world facing similar threats.
- Challenges resulting from the remoteness of high mountain regions and local factors must be recognized and planned for at the beginning of the LAPA process.

2. INTRODUCTION

LESSONS LEARNED FROM THE HiMAP PROJECT

Climate change is one of the most important global challenges facing humankind, and local communities living within mountainous regions are particularly vulnerable as temperatures rise, weather becomes less predictable, glaciers recede, and new glacial lakes form. Some of these lakes present a risk of glacial lake outburst floods (GLOF) that can unleash stored lake water, potentially causing enormous devastation downstream. Despite these new risks, understanding of the human dimensions of climate change is still limited in mountain regions where there is little information about climate change and its impacts, community vulnerabilities, and adaptation options.

The following report details the lessons learned during the implementation of the High Mountains Adaptation Partnership (HiMAP)(www.highmountains.org) project between March 2012 and June 2015. Located under the broader USAID Climate Change Resilient Development (CCRD) project[3], the goal of the HiMAP is to strengthen the climate change adaptation capacities of people who live in, or are dependent on, high mountain glacial watersheds and the ecosystem services which they provide.

The document is intended to be a resource for USAID Missions, donors, practitioners, and NGOs interested in learning more about the challenges of working in remote and roadless high altitude regions, particularly in view of USAID's growing portfolio of high mountain climate change adaptation, water management, biodiversity conservation, and livelihood improvement projects throughout the world. The lessons learned should also be of interest to those seeking to learn more about the new and emerging field of urban mountain development; highland-lowland interactive systems; and science-based, community-driven adaptation and community development projects. The lessons and insights were derived during the course of implementing Local Adaptation Plans of Action (LAPAs), concurrent with glacial field studies designed to inform the LAPA process, in the Mt. Everest region of Nepal and Cordillera Blanca of Peru.

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[3] http://www.ccrdproject.com/

ORIGINS

In 2009, USAID, the National Science Foundation (NSF), and The Mountain Institute (TMI) sponsored an international conference in Lima and Huaraz, Peru entitled "Adapting to a World without Glaciers," one of the first interdisciplinary climate change workshops of its kind with participants from the scientific, practitioners, policy, donor, and NGO communities. Over the course of the week's presentations, field trips, and training in the beautiful Cordillera Blanca range of Huaraz, a community of practice began to emerge that focused on science-based, community-driven approaches to climate change adaptation in high mountain environments The workshop included a three-day presentation and discussion session in Lima with government, NGO, and private sector decisions makers who outlined their understanding of climate change, the extent to which climate change information is incorporated into decision making processes, and key issues or sectors for which the workshop could develop more detailed information. In Huaraz, scientists, practitioners, and policy makers representing different disciplines, institutions, and projects continued the presentations, then formed break-out working groups that focused on the water, biodiversity, and agricultural sectors. A half-day training session in the Vulnerability and Adaptation approach to climate change was provided by USAID and IRG, and thematic field trips related to climate change and glacier recession in the Cordillera Blanca were held. Recommendations and concrete plans for future collaborative research and development projects were identified at the end of the workshop, and presented to key decision makers in Lima on July 15. The workshop was unusual in that many of these key recommendations, such as community capacity building and the promotion of better highland conservation practices, were then integrated in TMI's new USAID-funded climate change project "Building Climate Change Awareness and Resilience in the Ancash and Piura Watersheds of Northern Peru."

Two years later in 2011, an innovative 'Andean-Asian Mountains Global Knowledge Exchange on Glaciers, Glacial lakes, Water and Hazard Management' was held in the Mount Everest region of Nepal (The Mountain Institute, 2011) that was specifically focused on the sharing of Peru's 70 years of experience in controlling dangerous glacial lakes with workshop participants, local communities, and Kathmandu-based scientists. Rather than limit activities to a conference hall in Kathmandu, this 'mobile workshop' took place over an 18-day period in the Sagarmatha (Mt. Everest) National Park and Buffer Zone. Over the course of the 250km trek from the Lukla airstrip to Imja glacial lake, 35 scientists from 15 different countries (including four from Peru), related their experiences on glacial lakes and hazards, GLOF risk reduction methods, freshwater supply and the human dimensions of climate change and adaptation. At the expressed recommendation of workshop participants, the High Mountains Adaptation

Partnership (HiMAP) was officially formed in March, 2012 with funding from USAID under Engility Corporations's Climate Change Resilient Development (CCRD) Project.

THE HIGH MOUNTAINS ADAPTATION PARTNERSHIP (HiMAP)

HiMAP is designed to strengthen the scientific, social and institutional capacity for climate change adaptation and resilient development, as well as disaster risk mitigation and management for potentially dangerous glacial lakes and other climate-related disasters in Nepal and Peru. The Partnership has attempted to do so through a series of inter-related activities. They include:

- Fostering the next generation of mountain-scientists and development practitioners through competitive 'climber-scientist' small grants,
- Developing rapid reconnaissance field methods for the study of potentially dangerous glacial lakes, including the modeling of downstream flood impacts and risk reduction engineering strategies,
- Building a global community of practice for high-mountain glacial watershed technical analysis, adaptation and climate-smart development, and
- The development of climate change adaptation mechanisms for local communities which integrate the results of concurrent climate change research activities (specifically, the physical attributes, flood risks, and risk reduction methods of new high altitude glacial lakes).

The importance of, and need for, a HiMAP project becomes clear when one understands that glacier-dominated mountains play a major role in providing water to large numbers of people throughout the world[4,5]. 1.4 billion people downstream of the Himalayas depend on water from the Indus, Ganges, Brahmaputra, Yangtze and Yellow Rivers[6]. Glaciers in the Andes store precipitation in the wet season and release it in the dry season, ensuring continuous water supply to the highly populated Pacific coastal plains and western Andean slopes[7,8]. Continued and increasing glacier melting has initially increased runoff in the Peruvian Cordillera Blanca, but the lack of a glacial buffer ultimately results in decreased reliability of dry season streamflow[9]. This will, in turn, affect future water supplies, hydropower,

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[4] Portocarrero, C.A. (2014) The Glacial Lake Handbook: Reducing Risk From Dangerous Glacial Lakes in the Cordillera Blanca, Peru. USAID High Mountains Adaptation Partnership.

[5] Byers, A.C., McKinney, D.C., Thakali, S., Somos-Valenzuela, M.A. (2014) Promoting science-based, community-driven approaches to climate change adaptation in glaciated mountain ranges: HiMAP. Geography Vol. 99, No. 3: 143-152.

[6] Byers et al., 2014 (as n. 2 above)

[7] Immerzeel, W.W. (2010) Climate change will affect the Asian water towers. Science 328, 1382.

[8] Vergara, W., Deeb, M.A., Valencia, A.M., Bradley, R.S., Francou, B., Zarzar, A., Grunwaldt, A., Haeussling, S.M. (2007) Economic Impact of Rapid Glacier Retreat in the Andes. EOS, American Geophysical Union Vol. 88, No. 25.

[9] Baraer, M., Mark, B.G., McKenzie, J.M., Condom, T., Bury, J. Huh, K.-I., Portocarrero, C., Gomez, J. Rathay, S., (2012) Glacier recession and water resources in Peru's Cordillera Blanca. Journal of Glaciology, Vol. 58, No. 207.

agricultural productivity and ecosystems, and significantly impact local livelihoods. Glacier recession contributes to the formation of glacial lakes, placing communities at risk of a catastrophic glacial lake outburst flood (GLOF), a sudden release of water from a glacial lake due to a lake's natural dam sudden failure. These glacier-dominated areas pose unique challenges to downstream communities as they adapt to recent and continuing global climate change, particularly the decreased water supply reliability and increased threats from GLOFs. Given the critical importance of the world's glaciated landscapes, interdisciplinary climate change research and applied field projects – both of which span the natural, social and engineering sciences – are urgently needed[10] [11].

2.1. HIMAP CASE STUDIES

The Mt. Everest (Khumbu) region of Nepal and Cordillera Blanca of Peru were selected as HiMAP's work sites and became the base of operations for the program's glacial lake risk reduction studies concurrent with the development of Local Adaptation Plans of Action (LAPA). Both are located in high altitude, glaciated landscapes; downstream populations are heavily dependent on water originating in regional glaciers and/or watersheds; and economies are largely driven by tourism. The Khumbu region, however, is roadless and requires up to 8 days to safely climb to certain project worksites such as Imja glacial lake, while the Huaraz is an urban mountain setting with a population of over 100,000. Khumbu and Huaraz thus exhibited similarities and differences that added new dimensions of understanding and knowledge to the field of high mountain climate change processes and community adaptation mechanisms. Each region is described in detail below.

2.1.1. CASE 1—KHUMBU REGION, NEPAL

The 1423 km^2 Sagarmatha (Mt. Everest) National Park and Buffer Zone (SNPBZ) is located in northeastern Nepal in the Solu-Khumbu District of the Sagarmatha Zone (Figure 1). Mountain peaks in excess of 6000 m, including the world's highest, Mt. Everest at 8848 m, bound the park. The region is particularly vulnerable to climate change impacts because of its extreme topography, remoteness, lack of transportation facilities, and tourist driven and dependent economies. The SNPBZ contains three Village Development Committees (VDCs), the administrative units normally used as the basis for community consultations in Nepal. Communities in the SNPBZ are difficult to reach, requiring several days of trekking, proper acclimatization to high altitudes, and constant attention to changes in weather.

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[10] Byers et al., 2014 (as n. 2 above)

[11] Carey, M., McDowell, G., Huggel, C., Jackson, M., Portocarero, C., Reynolds, J. and Vicuña, L. (2014) Integrated approaches to adaptation and disaster risk reduction in dynamic socio-cryospheric systems. in Haeberli, W. and Whiteman, C. (eds) Hazards, Risks and Disasters Related to Snow and Ice. Atlanta, GA: Elsevier.

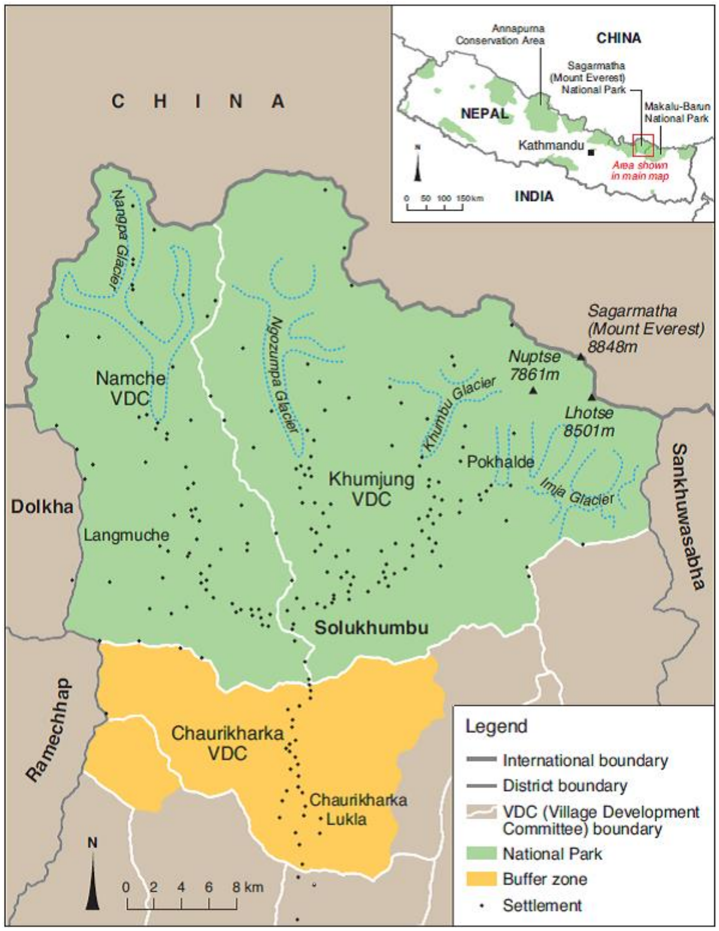

Figure 1. Map of Sagarmatha National Park and Buffer zone. Namche, Khumjung and Chaurikharka VDCs were considered as a single planning unit for Khumbu LAPA development.

In the Khumbu region of Nepal a fundamental activity of the HiMAP was facilitation of the development of a local adaptation plan of action, or LAPA. Recognizing the enormous variability within Nepal and within its various communities, the Government of Nepal developed the LAPA process in 2011. The LAPA process is designed to more fully reflect the needs and aspirations of Nepal's diverse communities, as well as the wide range of impacts experienced from climate variability. It is an important process that strengthens mountain community understanding of climate change, local assets, vulnerabilities, prospective solutions and adaptation strategies, funding mechanisms, and priority action plans.

The standard Government of Nepal LAPA Framework consists of seven steps for integrating climate change resilience into local-to-national planning processes. These steps were modified by HiMAP staff to include a greater emphasis on achieving Nepal's development goals, reflective of USAID's Climate

Resilient Development Framework, which promotes a "development-first" approach, helping to achieve development goals despite climate change (USAID 2014). The Framework walks users through a process to determine priority adaptation measures. It begins with the identification of stakeholder's development goals, inputs, and enabling conditions needed to achieve these goals, and the climate and non-climate stressors that can impede progress toward those goals. This approach emphasizes the incorporation of resultant adaptation programs into existing planning and decision-making processes (also known as mainstreaming). The resultant Khumbu LAPA framework includes the following steps:

1. Assessment of development needs and climate change awareness building
2. Assessment of assets, vulnerabilities, and adaptation mechanisms
3. Prioritization of adaptation options
4. Development of the LAPA
5. Integrating and mainstreaming the LAPA into local planning processes, decision-making, and funding sources
6. Implementing the LAPA
7. Monitoring and evaluation results and impacts of the LAPA

Figure 2. Discussing the consequences of climate change with local inhabitants of the Khumbu.

Concurrent with hosting five major community consultations as part of the LAPA process, six field surveys were conducted at Imja glacial lake, providing the most detailed information to date regarding the lake's size, volume, depth, flood modeling, potential triggers, and risk reduction options. The methods used for these lake studies were developed by HiMAP and are collectively called Glacier Lake Rapid Reconnaissance (GLRR) methods. The results of the lake studies were shared regularly with stakeholders during community consultations, and informed the LAPA process and, ultimately, the designation of glacial lakes as the foremost climate change risk reduction priority for the region.

2.1.2. CASE 2—QUILLCAY REGION, PERU

The Quillcay basin (250 km^2) is a glacial valley in the Cordillera Blanca mountain range of central Peru located immediately above the city of Huaraz (population approximately 130,000) (Figure 23). The glaciated mountains and alpine zone of the valley are located within the Huascarán National Park. The Park's buffer zone, which extends down to the border of Huaraz, is heavily populated with rural and peri-urban communities. Two rivers, the Paria and Auqi, form the Quillcay River as they enter Huaraz. The Quillcay River divides the watershed into two political units: the municipal district of Independencia and the provincial government of Huaraz (together they form the city of Huaraz). There are 14 rural settlements within the basin, seven in each of the two jurisdictions. Good roads allow easy access to the city of Huaraz and rural communities in the basin.

The LAPA methodology implemented by HiMAP in the Quillcay valley also demonstrates the diverse applicability of the "development first" approach from USAID's Climate Resilient Development Framework across scales and within variable stakeholder contexts. Here, the approach aims to improve resiliency of economic development to climate hazards and other non-climatic stressors at local scales. The development first approach to climate change adaptation is rooted in the principle of empowerment of stakeholders and in the importance of gaining understanding of their perspectives on development and vulnerability. This approach treats development outcomes as the priority and climatic changes as stresses that can undermine those priorities. Adaptation efforts are in the service of achieving development goals. The HiMAP team worked with stakeholders to develop the Quillcay Peru LAPA process, which consist of the following steps:

1. Diagnose, to understand the development context and build trust with partners through alignment with their objectives.
2. Identify vulnerabilities to climate variability and change in the context of diverse local objectives.
3. Identify and Analyze Adaptation options for the different groups while building strategies or networking with government or other stakeholders in order to facilitate implementation.
4. Select a Local Action Plan that is consistent with government or local institutions to promote mainstreaming and facilitate implementation
5. Implement Adaptations with support of local network
6. Evaluate Adaptations

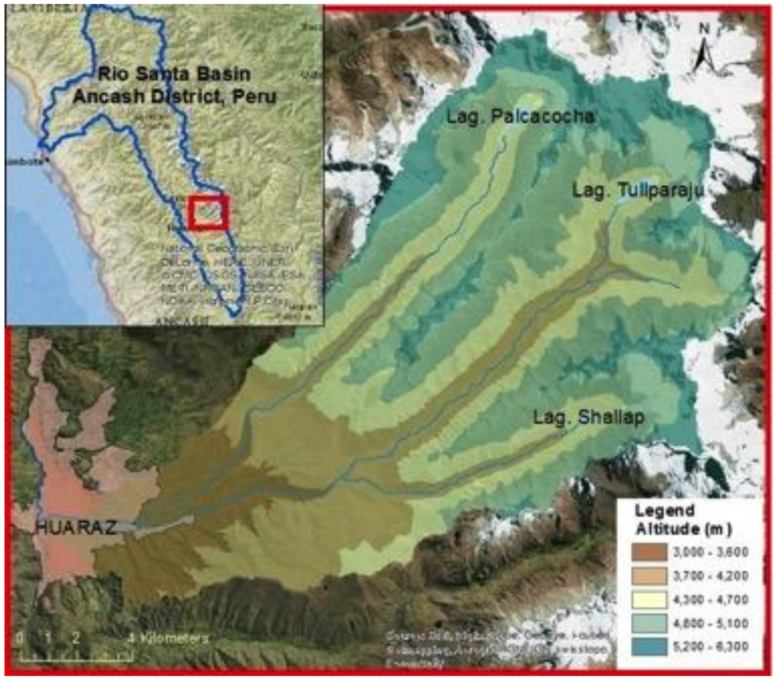

Figure 3. Map of the Quillcay Basin and Huaraz city (far left).

In Peru, the Unit of Glaciology and Water Resources (UGRH) of the National Water Authority has studied and managed Andean glacial lakes since the late 1940s[12], especially in the Cordillera Blanca region. Despite the wealth of historic scientific knowledge and experience in the region, the HiMAP team identified a need for updated studies of dangerous lakes and for raising awareness in communities about threats posed by climate change. To contribute to the body of knowledge in the region, GLRR approaches were applied to glacial lakes in the Cordillera Blanca.

[12] Portocarrero (2014) (as n. 1 above)

3. LESSONS LEARNED

This section discusses the various lessons learned from implementing and managing the LAPA, glacial lake rapid reconnaissance, Climber Scientist Small Grants, and Community of Practice components of the HiMAP project in Nepal and Peru. The insights and lessons covered should be of interest to Missions, donors, practitioners, and NGOs because of the growing number of USAID and other donor projects focused on high mountain regions and people[13]. Governments and donors alike appear to be increasingly recognizing the vulnerability of the world's mountain regions to climate change, and their importance from a physical, social, and ecosystem service point of view.

The lessons learned are grouped under the following major headings that emerged from the HiMAP field activities between 2012 and 2015:

- Establish Trust and Relationships
- Tailor LAPA Steps to Local Needs and Conditions
- Generate Scientific Knowledge to Support the LAPA Process
- Promote Sustainability of the LAPA Process
- Prepare for Challenges of Working in Remote Areas

3.1. ESTABLISH TRUST AND RELATIONSHIPS

Throughout the glacial lake assessments and community consultations, HiMAP sought to communicate with government entities and local inhabitants early in the process. In addition, HiMAP endeavored to share the results of their scientific and community based work in the region with local groups.

This early and consistent community engagement established trust and relationships with local entities and people, which facilitated further scientific work and LAPA development at the Nepal and Peru sites.

[13] These include Peaks to Coast and Securing Mountain Water and Livelihoods in Peru; Conservation and Adaptation in Asia's High Mountain Landscapes and Communities Project in Bhutan, India, Kyrgyzstan, Mongolia, Nepal, and Pakistan; Contribution to High Asia Runoff from Ice a& Snow (CHARIS) in the Hindu Kush-Himalayas; Mountain Biodiversity Increases Livelihood Security (MOBI + LISE) in Malawi; and numerous others.

Figure 4. Understanding rural concerns regarding water resources and quality in the Quillcay Basin.

3.1.1. LESSON 1—REGULARLY COMMUNICATE AND ENGAGE WITH STAKEHOLDERS

The establishment of trust and communication with governments and communities is critical to a successful LAPA process. As co-manager of the HiMAP program, TMI's decades long record of participatory project implementation in the Khumbu region was fundamental to community acceptance of both the GLRR surveys and the LAPA consultations. Likewise, TMI's work in the Huaraz region since 1995, inclusion of key Peruvian stakeholders in workshops and international glacial lake expeditions, and track record of staying at the table with government partners contributed to the success of HiMAP's facilitation of the LAPA process there. Local leaders, including religious leaders, should be identified and engaged in the project prior to commencement of the LAPA process in order to secure their support.

Regular sharing of scientific results; understanding local perceptions and priorities; incorporating local knowledge into field investigation plans; understanding community-desired levels of risk and safety; and understanding the cultural setting of the identified problems should be standard components of any climate change project. In remote mountain regions such as the Khumbu or the countryside above Huaraz, project staff should also be posted to the field site, or at least visit on a regular basis, during the

LAPA process in order to maintain regular and open communications and community rapport, share information, troubleshoot problems, and ensure continuity of the program.

3.1.2. LESSON 2—BUILD FORMAL RELATIONS WITH GOVERNMENT AND COMMUNITY PARTNERS

Both in Nepal and Peru, early contact and collaboration with the government aided in the LAPA process and in mainstreaming (integrating LAPA objectives into existing institutions and processes for funding and support) later on. Aligning LAPA objectives with those of the national and local government may encourage them to take charge in implementing actions identified through the LAPA process. Also, the role of each participating organization should be made clear from the beginning of the process to avoid misunderstandings or delays.

In Nepal, formal Memoranda of Understanding (MOUs) with government partners (e.g., Ministry of Forest and Soil Conservation and Department of National Parks and Wildlife Conservation) are required as part of any long-term partnership or as part of a LAPA implementation process. These should be obtained or be in process prior to beginning the LAPA process. Each partner's roles, responsibilities, and funding commitments should be clearly understood to avoid misunderstandings, delays, and/or surprises. For example, in Nepal the Chief Warden of the Sagarmatha (Everest) National Park participated in all of the LAPA community consultations, was highly supportive of the process, and insisted that no MOU between HiMAP and the park was necessary. In May of 2014, he was transferred and replaced by a new warden who stated that an MOU was indeed necessary for HiMAP's work to continue, thus delaying the final mainstreaming workshops by several months.

Problems such as these were avoided in Peru through the establishment of formal relationships and agreements with the municipal governments of Huaraz and Independencia prior to the community consultation process. Community consultations in the municipalities of Huaraz and Independencia were coordinated with the local government Civil Defense Task Force to promote risk reduction activities. A partnership with the Ministry of Environment (MINAM) was instrumental in the activation of Civil Defense groups in both municipalities. With support from MINAM the project reached out to the National Center for Risk Assessment, Prevention and Management (CENEPRED), thus creating better conditions to facilitate funding of adaptation measures. MINAM coordinated $400,000.00 in government funds in support of LAPA priority activities by the time the LAPA consultation process ended. In January 2015, the Peruvian President, Ollanta

Humala met with the mayor of Huaraz and committed funding to implement the early warning system. He also pledged to search for funds to reduce the waters of Lake Palcacocha to a safe level.

3.1.3. LESSON 3—COMMUNICATE SCIENTIFIC PLANS AND RESULTS TO COMMUNITIES

A strong component of public education is necessary for adaptation measures to be accepted, implemented, and maintained. This includes communication of GLRR survey plans and subsequent results to community leaders, religious leaders, and local administrators. Through this process, local stakeholders come to understand the need for the surveys and the relevance of the results to community development objectives and the LAPA process.

The importance of sharing information was well demonstrated by the experience in Nepal. During the September, 2011 Andean-Asian Mountain Global Knowledge Exchange expedition to Imja Lake, local people voiced frustration over researchers coming to and studying the lake for decades and never sharing their results, which in turn led to a significant amount of uncertainty regarding the lake's danger level. In fact, villagers in Dingboche had recently turned back a group of researchers from Kathmandu. The Andean-Asian Expedition invited community members to the lake where they exhibited a detailed knowledge and understanding of its history, growth, and potential for flooding, as well as appreciation for finally being included in the international dialogue. The experience in part led to the "science-based, community-driven" approach of the HiMAP which was established six months later, where research results were routinely shared with community's in the Khumbu region, Government of Nepal (GoN), and United Nations Development Programme/Nepal (UNDP). The sharing of results, which conclusively indicated that Imja Lake was potentially hazardous and in need of management control, may have influenced the ranking of GLOFs as the number one hazard in the Khumbu in terms of risks and impacts, despite the high level of local skepticism and uncertainty prior to HiMAP activities (2011–2013).

In Peru, the University of Texas at Austin developed models to assess the impacts of a potential GLOF from Lake Palcacocha (landslide behavior, death toll and material damage) and prepared a hazards map to support local decision-making and community consultations. Science-support to the LAPA process also included development of a geographic information system (GIS) and a hydrology model of the Quillcay basin. Generating policy-relevant information was not only useful for discussions of the technical aspects of potential climate change adaptation actions, but it also provided enhanced credibility among government authorities for the utility of the LAPAs, while also allowing community members to be more involved in decision making regarding climate change risks.

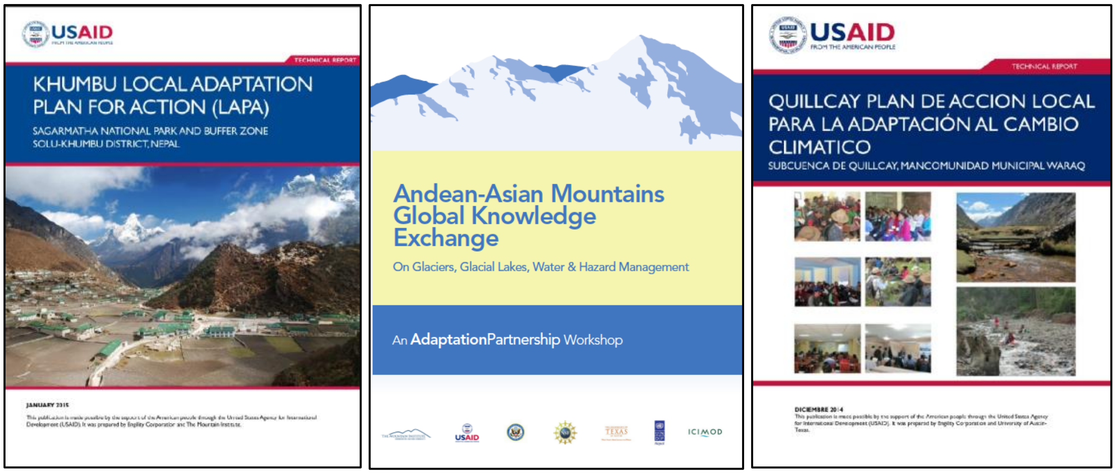

Figure 5. Cover pages of a few of HiMAP's publications related to work in Peru and Nepal [14] [15] [16]

3.1.4. LESSON 4—INCLUDE MEDIA AND OUTREACH COMPONENTS IN THE LAPA PROCESS

A 2012 study of peer reviewed literature in the climate sciences concluded that only 40 per cent of countries with glaciers have anything published on climate change adaptation, which severely limits the sharing of experiences and lessons learned[17]. Efforts should therefore be made to publish project results in the peer-reviewed literature in order to reach the scientific, development, and field practitioner communities. However, communication of project objectives, results, and achievements should also be made through more accessible, popular media—e.g., various aspects of the HiMAP were featured in Discover, Natural History, National Geographic Books, and NGS Education in addition to a range of peer reviewed journals. Short videos of the LAPA community consultations and GLRR surveys proved to be an excellent way to rapidly convey important project messages to stakeholders (e.g., local communities, donors, scientists), and they continue to be used for public and professional climate

[14] Left - USAID - US Agency for International Development (2011). Andean-Asian Mountains Global Knowledge Exchange on Glaciers, Glacial Lakes, Water and Hazard Management. An Adaptation Partnership Workshop. Proceedings. Washington, DC: US Agency for International Development

[15] Center - USAID - US Agency for International Development (2013). Khumbu Local Adaptation Plan of Action (LAPA): Sagarmatha national Park, Solu-Khumbu District, High Mountains Adaptation Partnership, Technical Report, Washington, DC.: US Agency for International Development

[16] Right - USAID - US Agency for International Development (2014). Quillcay Plan De Accion Local Para Adaptacion al Cambio Climatico: Subquenca de uillcay Mancommunidado Municipal Waraq, High Mountains Adaptation Partnership, Technical Report, Washington, DC.: US Agency for International Development

[17] McDowell, G., Ford, J., Lehner, B., Berrang-Ford, L., and Sherpa, A. 2012. Climate-related hydrological change and human vulnerability in remote mountain regions: a case study from Khumbu, Nepal. Springer-Verlag: Reg Environ Change.

change in the US and abroad. Some of these videos have received hundreds of thousands of views on the internet and allow those not involved in the scientific community of practice to better understand HiMAP's work, contributions, and impacts. See Appendix 6 for a list of HiMAP multimedia publications.

3.2. TAILOR LAPA PROCESS TO LOCAL NEEDS AND CONDITIONS

HiMAP approached the LAPA process with the understanding that local conditions would dictate the application of the LAPA methodology. This approach resulted in modifications to the basic LAPA process that made the resulting plans of action relevant to local concerns, compelling to organizations that would fund and implement the plan, and central to the LAPAs sustainability. Appendix IV presents a table comparing and contrasting the attributes of the Nepal and Peru project sites, one rural and roadless (Nepal) and one rural/urban (Peru), which in turn resulted in somewhat different strategies being used in the development of their respective LAPAs.

3.2.1. LESSON 5—IDENTIFY THE APPROPRIATE GEOGRAPHIC UNIT FOR CONDUCTING A LAPA PROCESS

Because of socio-economics, culture, and climate change similarities between all three VDCs (Chaurikharka, Namche, and Khumjung), the Khumbu LAPA considered the entire Sagarmatha National Park and Buffer Zone as the collective planning unit, in contrast to the typical GoN method of considering each VDC in separate LAPAs. This integrated and comprehensive approach was more effective and efficient in the development of a LAPA for the Khumbu region.

In Peru, two municipalities, Huaraz and Independencia, govern the Quillcay basin. In an effort to facilitate project implementation and to unite groups facing similar climate change consequences, a basin-wide approach was implemented. Although urban and rural stakeholders had different priorities, the basin-wide approach resulted in the creation of the Waraq Commonwealth as a governmental body to implement LAPA-identified actions. Additionally, some of the proposed actions overlapped between rural and urban—most notably the concern for future freshwater supplies--and the basin-wide approach proved useful in the coordination of mutual interests.

In both Peru and Nepal, conducting the LAPA process in a uniformly affected region proved to be a successful approach in terms of identifying common concerns across several communities that led to unified adaptation plans. These geographic divisions also functioned well for identifying governmental groups to implement the identified adaptation projects (mainstreaming). The Peruvian experience found a division between the priorities of rural and urban populations. Nonetheless, both populations identified related concerns and adaptation measures that can be implemented in unison. Given the heterogeneity of mountain ecosystems, however, the use of larger geographical units may not be appropriate for other regions within the high mountain world, and adequate socio-economic and environmental assessments and diagnostics should be conducted prior to the launch of the community consultations.

3.2.2. LESSON 6—INTEGRATE DEVELOPMENT OBJECTIVES INTO THE LAPA PROCESS

The Khumbu LAPA process began with an assessment of local development issues and needs in order to place climate change within the broader development context. The focus on development engaged community members to identify important development sectors, from trekking to trade to hydropower; the assets required to achieve identified goals within each sector; and the impacts of climate change upon each development goal greatly facilitated the identification of adaptation options and plans for action. Potential sources of funding were also identified in the course of this process.

By focusing on local economic development goals in Peru, particularly water supply and the reduction of risk from glacial lakes, the HiMAP was able to link the LAPA process to local government mandates. By providing awareness building and technical assistance to the government, HiMAP was able to initiate the process of implementing urgent adaptation measures, such as the design of a GLOF early warning system and long-term plans for the lowering of Palcacocha Lake.

3.2.3. LESSON 7—RECOGNIZE THE VARIATION OF DEVELOPMENT OBJECTIVES AND ADAPTATION NEEDS FOR RURAL AND URBAN STAKEHOLDERS

The LAPA experience in Peru demonstrated that although urban and rural communities face the same physical consequences from climate change, their development objectives and adaptation priorities can be quite different. These differences can be attributed to the varying economic activities that support rural and urban inhabitants. Whereas rural communities are concerned with water availability and its effects on agriculture, urban inhabitants are worried about damage to the city, infrastructure, and tourism from the effects of climate change. This experience highlights the importance of considering climate change threats through the lens of development even though stakeholder groups may have conflicting objectives. Understanding differentiated, gendered economic and other local objectives is the foundation upon which to build climate change adaptation responses. In a small mountain area like the Quillcay basin, diverse perspectives to climate threats were found between and within the urban and rural stakeholder groups involved in the LAPA process. The consultation process was the key to understanding the different interests of rural and urban inhabitants.

3.2.4. LESSON 8—INCLUDE MARGINALIZED GROUPS IN THE LAPA PROCESS

In both locations, the HiMAP found that reaching out to marginalized groups enhanced trust and enthusiasm for the LAPA process as well as for the priority adaptation projects. Marginalized groups bring new perspectives and concerns regarding the effects of climate change in the region. They are also among the most vulnerable to climate change, having fewer resources and opportunities to implement adaptation measures. In Peru, the HiMAP included women, rural, and indigenous populations in their consultations. Consultations in the Khumbu included the participation of marginalized groups such as the poor, lower castes and women. Careful attention, however, needs to be paid in the identification of suppressed groups to be sure that they are included in the LAPA dialogue. Single women with children have far less status than woman with intact families in Peru, for example, and women who speak only Quechua are considered to have less status than those speaking Quechua and Spanish.

Figure 6. HiMAP included marginalized groups, such as women, in LAPA consultations.

3.3. GENERATE SCIENTIFIC KNOWLEDGE TO SUPPORT THE LAPA PROCESS

Scientific assessments of climate change serve to validate local experiences. In addition, the results of scientific studies can challenge locals to consider potential impacts they may not see in their surroundings. This knowledge adds to the sustainability and credibility of the final LAPA, and allows participants to better understand their environment.

Residents of the Khumbu region report that they have long felt and seen the effects of climate change in the form of temperature increases, precipitation changes, glacial recession, water shortages, increases in the size and number of potentially dangerous glacial lakes, crop failure due to new diseases, increased forest fires, flooding, and landslides. Few of these can be verified because of the lack of long-term scientific hydrological, meteorological, fire, and other data in the Khumbu, a characteristic of most remote regions of Nepal as well as the high mountain world in general. With the provision of scientific data from the Imja Lake studies, however, GLOFs were included as the top climate impact of concern for their population in spite of an initial skepticism and distrust of outside researchers[18].

Figure 7. Damage from the 1941 GLOF from Palcacocha Lake through the center of Huaraz City.

Climate related impacts on the resources of the Quillcay basin include rapid recession of glaciers, resulting in increasing water scarcity and worsening quality, shifting of precipitation patterns and increased frequency of extreme precipitation events; however, the danger of a GLOF from Lake Palcacocha is paramount. This lake burst in 1941 killing about 5,000 people in Huaraz city[19].

[18] USAID (2013) (as n. 15 above)

[19] Carey, M. (2005) Living and dying with glaciers: people's historical vulnerability to avalanches and outburst floods in Peru. Global & Planetary Change 47, 122-134.

Today, the population at extreme risk of a GLOF is estimated to be near 40,000[20]. Rural and urban communities have seen climate change impacts, including increased temperatures, increased frequency of extreme weather events, glacial recession, reduced access to freshwater, decreased spring flow, deteriorating water quality, and drought impacting animal health and agriculture. Results from HiMAP research have highlighted the increasing danger posed by Lake Palcacocha and brought the issue to the attention of decision makers[21]. At present, the city of Huaraz is planning a GLOF early warning system as a direct result of the LAPA experience, which the President of Peru pledged to fund during a visit in January of 2015. He also pledged to search for funding to lower the lake to a safe level. In both Nepal and Peru, the LAPA process was key to decreasing the risk of a GLOF for thousands of people living downstream.

3.3.1. LESSON 9—CONDUCT GLACIAL LAKES ASSESSMENTS TO INFORM THE LAPA PROCESS

Compared to remote sensing analyses, field-based studies of glaciers and glacial lakes are relatively rare in the Himalaya[22,23]. Arguing that the best understandings of contemporary climate change impacts in these regions can only come from the systematic use of both laboratory and field techniques, HiMAP established the 'Glacial Lake Rapid Reconnaissance Team' in May 2012[24]. To date, the Team has completed seven field expeditions in Nepal to the SNPBZ, Makalu-Barun National Park, and the Annapurna Conservation Area; and five field expeditions in Peru to Lake Palcacocha. The purpose of these expeditions and follow-on analyses has been to quantify glacial lake characteristics, assess the risk of GLOFs to downstream communities, and develop possible remedial measures to reduce those risks to acceptable levels.

In the Khumbu, the HiMAP program studied the effects of climate change on Imja Lake and how these effects threaten local communities. The team measured how the volume of water in Imja Lake has

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[20] Somos-Valenzuela, M., Vulnerability and decision risk analysis in glacier lake outburst floods (GLOF). Case studies: Quillcay sub basin in the Cordillera Blanca in Peru and Dudh Koshi sub basin in the Everest region in Nepal, Ph.D. dissertation, University of Texas at Austin, 2014.

[21] Somos-Valenzuela, M.A., R.E. Chisolm, D.C. McKinney, D. Rivas (2014) Inundation Modeling of a Potential Glacial Lake Outburst Flood in Huaraz, Peru, High Mountain Glacial Watershed Program, CRWR Online Report 14-01, Center for Research in Water Resources, University of Texas at Austin.

[22] Byers, A.C., McKinney, D.C., Somos-Valenzuela, M., Watanabe, T., Lamsal, D. (2013) Glacial Lakes of the Hongu Valley, Makalu-Barun National Park and Buffer Zone, Nepal, Natural Hazards, 69:115–139.

[23] Byers et al. (2014) (as n. 2 above)

[24] McKinney, D., Somos-Valenzuela, M.A. and Byers, A.C. (2012) 'The importance of field work in natural disaster risk assessments in high mountains'. Poster presented at the American Geographers' Union Fall Meeting, 3-7 December.

changed from 1992 to 2012 due to meltwater from glaciers and the melting of glacier ice beneath the lake. In addition, ground penetrating radar (GPR) surveys were used to estimate the thickness of the ice in glaciers feeding Imja Lake and understand the nature of the moraine damming the lake[25]. Moraine stability is a potential risk and its failure could cause a GLOF downstream. Given the risk of a moraine failure and resulting catastrophic outburst flood, the team modeled the effects of such a potential flood to the downstream communities of Dingboche (7 km below the lake) and Phakding (38 km below the lake)[26]. The team also developed methods to predict melting of the glaciers that feed the lake and the future evolution of the lake[27]. These models help researchers understand the current and future risk posed by Imja Lake to downstream communities.

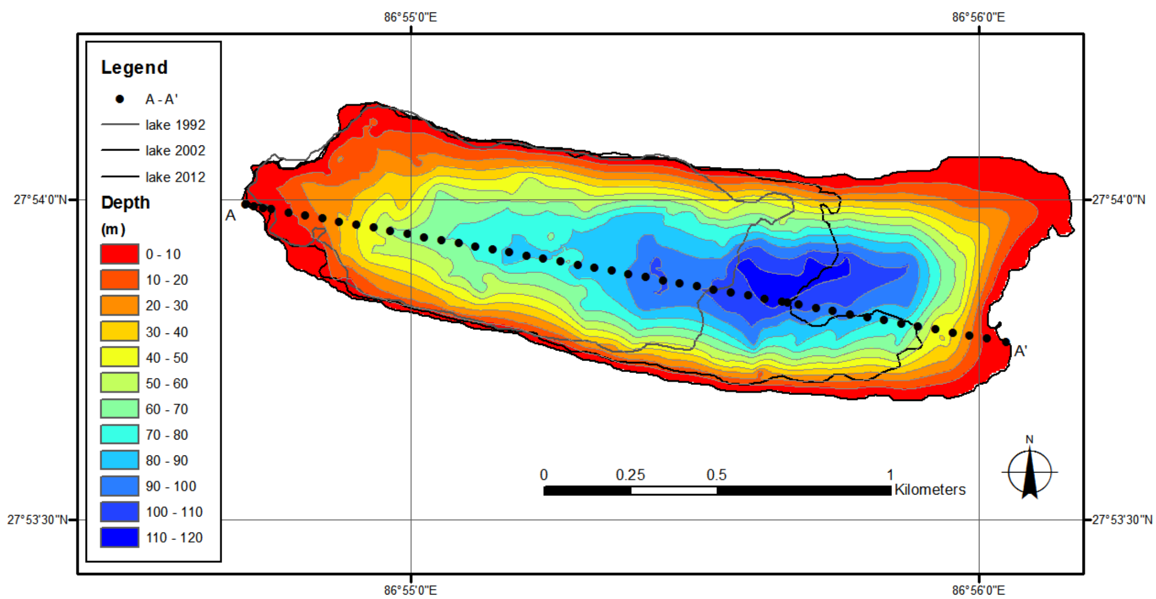

Figure 8. Results of Imja Lake bathymetry study to estimate the depth and volume of the lake.

In Peru, the HiMAP program modeled the most likely cause of an outburst flood from Lake Palcacocha: an avalanche induced wave causing erosion of the damming moraine and a GLOF, which would reach Huaraz in about an hour. Results of this work show the extent of flooding in Huaraz and, combined with census and other data, the vulnerability and potential loss of life in the event of a GLOF[28]. This work has been illustrated in an online map storytelling platform (See Appendix V, Living under flood

[25] Somos-Valenzuela, M.A., McKinney, D.C., Rounce, D.R., and Byers, A.C., (2014). Changes in Imja Tsho in the Mt. Everest Region of Nepal, The Cryosphere, 8, 1661-1671, 2014, doi:10.5194/tc-8-1661-2014.

[26] Somos-Valenzuela, M.A., McKinney, D.C., Byers, A.C., Rounce, D.R., Portocarerro, C., (2014) Assessing Downstream Flood Impacts Due to a Potential GLOF from Imja Lake in Nepal, Hydrol. Earth Syst. Sci. Discuss.,11, 1309-13053, doi: 10.5194/hessd-11-13019-2014.

[27] Rounce, D.R. and McKinney, D.C.(2014). Thermal resistances in the Everest Area (Nepal Himalaya) derived from satellite imagery using a nonlinear energy balance model, The Cryosphere, 8(4):1317–1329, doi:10.5194/tc-8-1317-2014.

[28] Somos-Valenzuela et al. (2014) (as n. 27 above)

risk in Huaraz City). The team also created tools for modeling water resource availability and demand in the Quillcay watershed.

3.3.2. LESSON 10—INCORPORATE SCIENTIFIC DATA IN THE LAPA PROCESS

"Science based, community driven development" is a fundamental component of the HiMAP approach and of LAPA implementation in Peru and Nepal. The Khumbu LAPA incorporated available scientific data and knowledge to verify or challenge local experience and perceptions of climate change impacts and vulnerabilities, particularly through the detailed study of the Imja glacial lake. Scientific information to inform the LAPA process came from the GLRR surveys at Imja Lake, which suggested that the lake was more dangerous than previously thought. The availability of this information contributed to better community understanding of GLOFs, which evolved into their number one hazard priority in terms of risks and impacts despite a high level of local skepticism at the initiation and uncertainty of HiMAP activities. Sharing the results of scientific assessments also facilitated the mainstreaming of GLOF risk reduction activities into the 2014-2015 SNPBZ Management Plan as well as local enthusiasm for the UNDP Imja Lake risk reduction project that began its field surveys in the fall of 2014.

Meetings with stakeholders about predicted climate change impacts in the Quillcay basin widened the discussion from local perceptions of climate change effects—e.g., water supply, changing precipitation patterns--to include an understanding of lesser known phenomena, such as the threat of a GLOF from Lake Palcacocha. Sharing results from the Palcacocha flood modeling analyses invigorated the LAPA discussions, as community members understood the urgency of adaptation projects and the extent of climate change impacts in the region. In addition, scientific information was presented to government entities, which aided in the discussion of technical solutions to climate change threats and created credibility with government authorities.

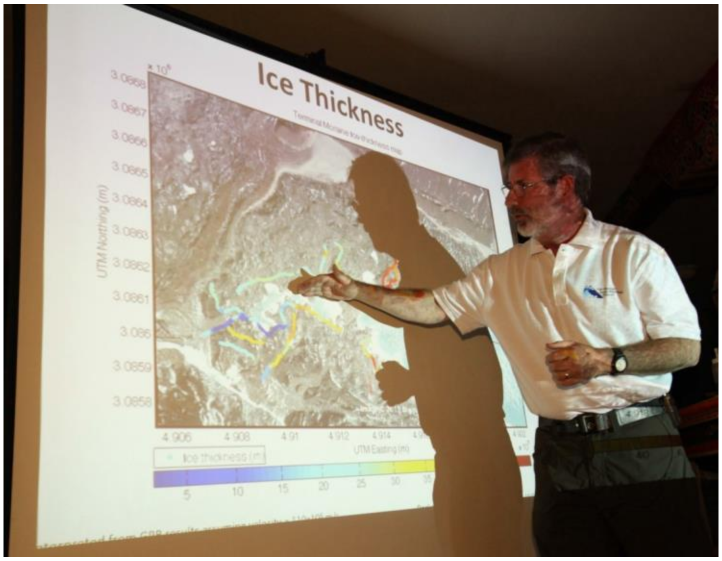

Figure 9. Presenting GLRR study results to community members in Nepal.

Community members in both regions were receptive to the inclusion of scientific information in the LAPA process. They viewed the information as legitimate and credible, and included it in their discussions of how climate change affects them. In most high mountain regions, however, little or no quantitative, long term scientific data are available which can either support or challenge the results of the LAPA vulnerability analyses. The HiMAP Climber Scientist Small Grant program closed a number of these gaps by encouraging young scientists, NGOs, and senior professionals to develop research projects focused on community, climate change, and solutions.

3.3.3. LESSON 11 USE SMALL GRANTS TO GENERATE KNOWLEDGE, CATALYZE PROJECTS, AND DEVELOP PARTNERSHIPS

CCRD's Climber Scientist Small Grants Program provided "field-based, hands-on" research opportunities to scientists and practitioners working in high mountain regions. This innovative program encouraged the blending of high tech laboratory analyses with traditional, on the ground field methods in order to achieve the best understanding of contemporary climate impacts and prospective adaptation solutions. Grantees focused on a range of topics that included the building of climate change resilience capacity of mountain people in Nepal; investigation of the origins of a May, 2012 flood in Nepal; causes of changes in glacial lakes in Nepal; impacts of glacial recession on water quality in Peru; and integrated and participatory risk management of dangerous glacial lakes in Peru. All grants facilitated the goals and objectives of the HiMAP program and in some cases were directly incorporated into LAPA priorities. Several synergistic and follow-on activities that resulted from the small grants include the following:

- Raul Loyaza from the Laboratory of Ecotoxicology of UPCH (Universidad Peruana Cayetano Heredia), conducted a study of water quality in the Quillcay watershed as impacted by receding glaciers, a climate-related impact that was identified as a high LAPA priority by rural communities.

- The Ashoka Trust for Research in Ecology and the Environment (ATREE) "Climate Change in Kanchenjunga Transboundary Conservation Area" project led to a $1.5 million USAID/India grant entitled "Managing India's Forests for Biodiversity and Human Well-being in the Face of Global Environmental Change."
- Geo-Science Innovations (GSI) "Investigation of the Seti River Disaster, Nepal" investigated the cause of a disastrous 2012 flood in central Nepal. Following this investigation, the UNDP/Nepal selected GSI in October, 2014 to perform a bathymetric survey of the Imja Lake as part of the UNDP's glacial lake risk reduction project. Imja Lake is one of the highest vulnerabilities and priorities identified in the HiMAP Local Adaptation Plan of Action (LAPA) by local communities.
- Ulyana Horodyskyj's "Quantifying Supraglacial Lake Changes" project in the Mt. Everest region of Nepal led to a Fulbright Research Grant to expand and continue the project at Ngozumba glacier through 2014.
- Laura Read's "Community Water Management in the Tres Cuencas Commonwealth" project and methods have now been absorbed into TMI's new "Securing Mountain Water and Livelihoods Project" in the Ancash region of Peru.
- Resources Himalaya Foundation's "Building Climate Change Resilience Capacity of Mountain People in Nepal" was responsible for drawing local, national, and governmental attention to the critical problem of water shortages in Ramechhap. Several NGOs are now implementing water improvement projects there now as a result.
- SUNY's "Climber-Scientist and Indigenous Herders" project in Mongolia led to breakthrough correlations between satellite-derived rangeland conditions and key ground-level parameters, with the promise of developing a rangeland disturbance monitoring tool of extremely high value.

See Appendix III for a list of Climber-Scientist small grantees.

Figure 10. Climber scientist grantees conducting research.

3.3.4. LESSON 12—LOCAL KNOWLEDGE IS CRITICAL TO UNDERSTANDING GLACIAL LAKES

Important information about climate change can be gained from local inhabitants including potential GLOF triggers that may not be obvious to the short-term field investigator (e.g., seepage, ice cored terminal moraines, local solutions to risk reduction). In the case of Imja Lake, members of the Dingboche community pointed out many changing features of the damming moraine that would otherwise have been missed in GLRR surveys. In addition, one community member (Sonam Hishi) recommended a potential site for a downstream flood control dam site that the HiMAP staff later surveyed and found to have potential to reduce downstream GLOF risk. In Peru the vast experience of Ing. Cesar Portocarrero and other retired Glaciological Unit employees was regularly sought for guidance on glacial lake problems in both Peru and Nepal.

Figure 11. Consulting with local residents on the effects of climate change in the Khumbu.

3.3.5. LESSON 13—VERIFY REMOTE SENSING RESULTS WITH FIELD DATA

Field verification has shown that some potentially dangerous glacial lakes in Nepal that were identified from remote sensing can be incorrect. Eight of the "potentially dangerous" glacial lakes (PDGLs) previously identified by remote sensing in the Makalu-Barun region of Nepal, when surveyed in the field, were found to be stable, and one that had escaped mention in previous studies (L464) appeared to be at high risk of a GLOF given the large number of potential triggers (e.g., overhanging ice, steep slopes, small terminal moraine[29].

This result suggests that the combined use of sophisticated remote sensing and modeling techniques with field-based methods provides the most thorough understanding of glacial lakes possible at this time, including the actual risks that the lakes pose[30]. Such insights formed the foundations of the Glacial Lake Rapid Reconnaissance approach in response to a scientific community in Kathmandu that seemed reticent to work in the field, based on the limited number of field-based studies of Imja Lake compared to those based on remote sensing. They were also of influence toward the establishment of the Climber-Scientist Small Grant Solicitations, which encouraged young scientists to combine three key components of high mountain research, i.e., (a) modern technologies and modeling, (b) field-based sampling and verification, and (c) community participation and consultations.

[29] Byers et al., 2013 (as n. 24 above)

[30] Byers et al., 2014 (as n. 2 above)

3.3.6. LESSON 14—FIELD SURVEYS CAN BE EFFICIENTLY PERFORMED USING GLRR METHODS

Compared to studies based entirely on remote sensing, field-based studies are comparatively rare in high mountain regions, and in some circles they have developed a reputation for being expensive, difficult, and unsafe. However, field survey methods key to defining risk and dangers of potentially dangerous glacial lakes, and as demonstrated by HiMAP's glacial lake rapid reconnaissance team, can be accomplished in a cost effective, rapid, and safe manner.

Figure 12. HiMAP conducting a bathymetric study of Imja Lake (credit: Chris Rainier)

The glacial lake rapid reconnaissance methods employed by the HiMAP at Imja Lake were performed in a period of four weeks of fieldwork at the lake with adequate time to travel to the site, always with an emphasis on health and acclimatization requirements. Geophysical methods included geophysical and bathymetric surveys, glaciological studies, geomorphological, hydrological and climatological surveys, and community and infrastructure surveys (see Appendix II). Geophysical (ground penetrating radar (GPR) and electrical resistivity tomography(ERT)), bathymetric surveys, and glaciological and climatological studies were used by the HiMAP to establish the characteristics of Imja Lake and glacier[31,32]. Safety glacial

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[31] Somos-Valenzuela et al. (2014) (as n. 27 above)

[32] Rounce and McKinney (2014) (as n. 29 above)

lake rapid reconnaissance methods included attention to seasonal variability, pre-field work conditioning, adequate acclimatization, emergency medical response capacity, and emergency evacuation plans. HiMAP glacial lake rapid reconnaissance methods are described in a series of reports and journal articles[33][34].

Figure 13. GPR survey being conducted near Imja Lake (credit: Alton Byers).

3.3.7. LESSON 15—MODELING IS CRITICAL TO IDENTIFYING RISKS TO COMMUNITIES AND INFRASTRUCTURE

Two-dimensional debris flow models and inundation mapping are necessary to estimate the possible flooding impacts downstream of PDGLs. In the case of both Imja Lake and Lake Palcacocha, two-dimensional flood modeling was used to delineate the extent, depth and velocity of floodwaters at critical locations and vulnerable communities below the lakes[35]. Erosion induced moraine dam models were also necessary in both cases. Avalanche and lake wave modeling are required in cases where debris and ice avalanches from surrounding high mountains may be GLOF triggers. In the case of Lake Palcacocha, it

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33 Somos-Valenzuela, M.A., McKinney, D.C., Byers, A.C., Rounce, D.R. (2013) Bathymetric Survey of Imja Lake, Nepal in 2012. CRWR Online Report 12-06, Center for Research in Water Resources, University of Texas at Austin, Austin TX.

34 Somos-Valenzuela, M., McKinney, D.C., Byers, A.C., Voss, K., Moss, J., McKinney, J.C. (2012). Ground Penetrating Radar Survey for Risk Reduction at Imja Lake, Nepal. CRWR Online Report 12-03, Center for Research in Water Resources, University of Texas at Austin, Austin TX.

35 Somos-Valenzuela (2014) (as n. 22 above)

was necessary to model possible avalanches into the lake as well as the generation of the resulting surge wave in the lake and overtopping of the damming moraine[36]. In Nepal the most likely flood trigger is a sudden moraine failure due to an earthquake or seepage[37]. Therefore GLOF modeling only required a simulation of the dam failure and downstream inundation. GLOF modeling provides realistic simulations of a flood and allows community members to understand the risk posed by a nearby lake.

3.3.8. LESSON 16—DETERMINE THE SPECIFIC FIELD RESEARCH NEEDS EARLY IN THE PROJECT CYCLE TO FOR THE SAKE OF EFFICIENCY AND COST EFFECTIVENESS

Imja and Palcacocha glacial lakes, and the people living downstream, benefitted immensely from the GLRR approach and selection of sampling tools utilized (bathymetric survey, GPR, flood modeling, oral testimony, repeat photography, Peru-Nepal expertise exchange, participatory research). Other lakes may require more, less, or similar levels of evaluation once the field team finishes with its initial reconnaissance, in which case a lake-specific research plan should be designed in the interests of timeliness, cost effectiveness, and provision of results to local communities and governments.

3.3.9. LESSON 17—INTEGRATED, INTERDISCIPLINARY APPROACHES TO GLACIAL LAKE ASSESSMENT AND MITIGATION WILL BE NEEDED TO REALISTICALLY ADDRESS FUTURE CONDITIONS

Glacial lakes and the growing threat of glacial lake outburst floods are a concern for both Nepal and Peru alike. Glacial lake risk reduction activities in Peru began in the 1950s and usually consisted of engineering works undertaken in absence of any community participation. The one lake lowering project to date in Nepal, Tsho Rolpa, consisted of the engineering design and limited contact with local people, such that the early warning system installed became more an object of fear than of reassurance. Future glacial lake risk reduction activities in both countries need to take a much more holistic approach to glacial lake assessment and mitigation if these new threats are to be adequately and effectively addressed.

The following steps are recommended:

Reconnaissance and Lake Selection: A rapid reconnaissance of all potentially dangerous glacial lakes first needs to be undertaken for field verification purposes. Those showing the highest levels of risk based on potential triggers (e.g., overhanging ice, size, volume, moraine stability, and other factors) will be selected for further detailed study.

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36 Somos-Valenzuela et al. (2014) (as n. 23 above)

37 Somos-Valenzuela et al. (2014) (as n. 28 above)

Field Science and Engineering: Physical assessments of the land surface, geology, geophysics, glaciology, lake bathymetry, climatology, and hydrology need to be conducted for the lakes selected for detailed study. Quantitative and qualitative risk-assessment criteria and metrics to compare the physical parameters and risk factors of each lake should be developed, as should potential flood mitigation works and detailed plans for design and implementation

Local Climate Awareness, Adaptation, and Resilience: Liaison with downstream communities vulnerable to GLOFs is essential for maintaining the trust and cooperation of local populations, incorporating their knowledge and ideas about the sites, keeping them informed of project activities, and regularly sharing project data and insights. A series of community consultations should be held that increase local awareness of climate change impacts, vulnerabilities, adaptation options, and mainstreaming opportunities for priority project implementation. Experience in Nepal and Peru has shown that the integration of field science results with Local Adaption Plans of Action (LAPAs) produces greater awareness, understanding, and local support for addressing climate change vulnerabilities and stressors, including glacial lake risk mitigation (e.g., through early warning systems) and/or control (e.g., through lowering).

Economic Impacts and Infrastructure Opportunity: Independent economic impact assessments should be conducted that include the formulation of recommendations for other ancillary beneficial infrastructure developments of a risk reduction project (e.g., hydroelectric power, roads, and bridge construction) that may enhance the overall benefits to the local communities. Critical reviews of cost and benefits associated with the implementation of alternative risk reduction designs should also be conducted. A socioeconomic/demographic survey of downstream areas affected by the glacier hydrology, potential outburst floods, and any development and environmental impact that may be associated with flood hazard mitigation should be developed. The results of this survey should be used to develop an economic impact assessment and alternative design selection.

Environmental Impacts and Conservation: Environmental impact statements and an ecological (biological resources) survey should be developed for each of the lakes selected for engineering mitigation design. Possible investments in infrastructure and human capital that improve environmental conservation and enforcement in the regions near engineering design implementation projects should also be considered.

3.3.10. LESSON 18—COMBINE CONFERENCES WITH FIELD TRAINING TO BUILD MOMENTUM AROUND HIGH MOUNTAIN CONCERNS

Figure 14. Participants in the 2011 Andean-Asian Glacial Lake Expedition in the Khumbu region of Nepal.

The "Andean-Asian Mountains Global Knowledge Exchange on Glaciers, Glacial Lakes, Water and Hazard Management Workshop" in September 2011[38] and the "Glacial Flooding and Disaster Risk Management Knowledge Exchange and Field Training Workshop" in July 2013[39] effectively promoted south-south collaboration, involved local stakeholders in project design, and brought new and poorly understood problems related to climate change in mountainous areas to the forefront of scientific and developmental concern. These field-oriented workshops pioneered the combination of traditional conference-room style presentations with extended field activities, a rare union that achieved a thorough understanding of problems and solutions in high mountain regions. During the 2011 Imja Lake expedition local communities were involved, presentations were held every night on issues related to high mountains and glacial lakes, and Peruvian experts in glacial lake management and risk reduction were introduced to Nepalese glacial lake issues and those studying them. A unique exchange of

[38] USAID (2011) (as n. 14 above)

[39] http://highmountains.org/workshop/peru-2013

information between Nepal and Peru occurred in July, 2013 during HiMAP's "Glacial Flooding and Disaster Risk Management" workshop in Huaraz, when local Peruvian farmers discussed the similarities between glacial recession and climate change in Peru and Nepal with Nepalese and Bhutanese scientists and practitioners. In addition, Nepalese and Bhutanese participants were able to see first-hand several working examples of glacial lake safety systems. These events exposed all participants to new ways of thinking about and dealing with the effects of climate change in high mountain regions. In addition, these events created fruitful partnerships and momentum around high mountain concerns.

3.4. PROMOTE SUSTAINABILITY OF THE LAPA PROCESS

Although HiMAP led the community consultations and synthesis of information for the development of a Khumbu LAPA, in the end responsibility for the implementation of the LAPA falls upon local governments and other organizations. Communicating the role of each party in the LAPA process, and creating the basic structures for continuity of the plan, is therefore an extremely important consideration for any organization seeking to prepare a LAPA. In Peru, for example, priority activities identified in the LAPA might be funded by the government's public investment fund mechanism, and many are in fact planned for implementation under TMI's new USAID-funded project, "Securing Mountain Water and Livelihoods." In Nepal, 22 of the 36 priority activities identified in the LAPA overlap with the 2014-2015 SNPBZ Management Plan, and are scheduled for implementation pending availability of funding. The village of Dingboche also received a grant of $15,000 from the SNPBZ Council in support of a new water supply system, nursery, and bridge, activities that they identified in the LAPA as high priorities.

Figure 15. Notice of Waraq Commonwealth formation in Peru.

LAPA workshop participants reported that the Khumbu LAPA is a useful document for both understanding the impacts of climate change and the various adaptation options available to reduce potential risks. They also noted that the plan is easy to understand and they will be able to implement it, provided there are sufficient resources. A five-year implementation plan for the Khumbu LAPA was developed, and prospective sources of funding for each activity were identified. The SNP and SNPBZ Management Committee were identified as the most promising organizations to integrate the high-priority adaptation activities into their existing and future annual plans and developmental budgets.

3.4.1. LESSON 19—MAINSTREAM LAPA ACTIONS INTO LOCAL INSTITUTIONS TO ENSURE SUSTAINABILITY

Mainstreaming the LAPA priorities into existing institutions in Nepal (SNP, SNPBZ, District Development Committee and VDCs) and Peru (Waraq commonwealth) helps to align the LAPA processes with existing local agency mandates. Mainstreaming also provides an efficient mechanism to access funding and ensure sustainability of the LAPA process and actions.

Mainstreaming mechanisms need to be monitored to see if they are successful in achieving project implementation. Local communities and government entities should cooperate in this monitoring step. Effort is also needed to develop steps that ensure sustainability and opportunities for mainstreaming in future LAPA processes. Organizations implementing LAPA processes should establish relationships and identify funding opportunities for adaptation projects before or at the beginning of community consultations to ensure the plan's continuity.

3.4.2. LESSON 20—PROMOTE CAPACITY BUILDING IN GLACIOLOGY, GLACIAL LAKE MITIGATION, AND RISK REDUCTION AT ALL LEVELS

Government agencies and local universities should be involved in all phases of glacial lake research and risk reduction processes, both scientific and social, through staff, faculty, and student participation. Involving local actors can provide some of the most effective training and capacity building available. In addition, affiliations with government entities charged with field studies on glaciers and glacial lakes can help build trust between governments and local stakeholders.

Empowering municipalities and local communities with the skills necessary to take full ownership of the LAPA process (consultation, planning, implementation, monitoring and adjustment) is a long-term commitment. In the HiMAP work in Nepal and Peru, some of the elements (relationships and contacts) needed to include local entities in LAPA implementation were already in place. Implementing agencies need to identify relevant local organizations and stakeholders to contact and involve at the outset of the LAPA process.

3.4.3. LESSON 21—LAPA DEVELOPMENT, IMPLEMENTATION, AND MONITORING OF RESULTS ARE LONG-TERM PROCESSES

HiMAP's LAPAs in Nepal and Peru were among the most detailed and effective ever produced, with both leading to projects that are in the process of reducing the risks of GLOFs for thousands of people while beginning the implementation of a range of other priority adaptation projects. The project period was sufficient for the development of the plan and initiation of certain activities, but not of sufficient duration to allow for the full cycle of implementation, monitoring of results, and incorporation of lessons learned into the next LAPA phase. While the communities involved are far better off today with a plan than without, future LAPA projects should attempt to build in sufficient time—i.e., at least 5 years—and funding to allow for a full project cycle.

3.4.4. LESSON 23—BUILD PARTNERSHIPS WITH A RANGE OF INTERNATIONAL AND IN-COUNTRY ORGANIZATIONS TO MAXIMIZE SYNERGY, COLLABORATION, AND NEW FUNDING OPPORTUNITIES

Partnerships with other mountain-related organizations can be an effective way to synergize respective strengths, develop new programs, and secure new funding opportunities. However, attempts to collaborate with other organizations that seem like the perfect partner can be quite challenging for reasons that seem to range from indifference to competitiveness. Project managers should nevertheless be relentless in their attempts to promote new partnerships and collaboration,, as circumstances can change at any moment, and an organization that was previously perceived as a competitor can now become an asset and ally.

3.4.5. LESSON 24—CONCURRENT WITH THE LAPA AND APPLIED RESEARCH ACTIVITIES, USE THE PROJECT TO BUILD CAPACITIES AND IDENTIFY SUSTAINABLE FUNDING OPPORTUNITIES FOR ALL INVOLVED PARTNERS

The LAPA process successfully strengthened the capacities of local communities and governments to assess development needs, vulnerabilities, adaptation options, and mainstreaming opportunities in both Nepal and Peru. Concurrently, TMI/Peru was able to use HiMAP to continue a string of climate change adaptation projects that began in 2009 with the USAID-funded Peaks to Coast project, training both highland and lowland communities in the six-step Vulnerability and Adaptation (V&A) process. This work was expanded to include glacial lake, water, and climate change impacts research through the HiMAP, positioning the Program to then secure an innovative, US $3 million grant entitled Securing Mountain Water and Livelihoods. The process illustrates how careful funding opportunity analysis, regular communications with prospective donors, and creative implementation of existing projects can help to leverage new opportunities down the road.

3.4.6. LESSON 25—RECOGNIZE THE UNIQUE AND SPECIALIZED NATURE OF HIGH MOUNTAIN PROJECT IMPLEMENTATION AND DEVELOP STRONG AND CONSISTENT SUPPORT SYSTEMS FOR FIELD STAFF

Project implementation in high, glaciated mountain regions demands a unique set of skills and experience in order to accomplish project objectives in a timely, effective, and safe manner. The range of skills can include experience in high altitude travel, climbing, research, and work; liaison with local communities; high altitude project implementation, monitoring, and evaluation; safety, first aid, and evacuations; and physical and social science field and research experience. Strong, reliable, and consistent support systems from both donors and home institutions alike need to be developed and maintained so that the high altitude field practitioner can get the job done. The need is not so critical in lower altitude regions with transportation networks, communication systems, and abundant goods and services, but remains essential for effective work with communities and climate change impacts in the world's remote, high altitude mountain glaciated watersheds.

3.5. PREPARE FOR CHALLENGES OF WORKING IN REMOTE AREAS

The LAPA process and GLRR surveys can be expensive and lengthy. They should be streamlined in remote areas to produce short, cost-effective processes and timely results, while also respecting the requirements for health and safety. Logistics, travel, in-country leadership, and resources should all be assessed at the beginning of a project to determine the most effective and realistic timeline for project activities. Challenges should be carefully assessed to determine realistic timelines and plans to avoid excessive delays or costs. As mentioned previously, the specialized expertise required to accomplish all of the above needs to be recognized, endorsed, and allowed to manage the project in the interests of project success and, most importantly, safety.

3.5.1. LESSON 26—DEVELOP ASSESSMENTS OF LOGISTICS, CULTURES, ECONOMIES, AND LEADERSHIP ISSUES PRIOR TO COMMUNITY CONSULTATION.

Figure 16. The village of Dingboche located below Imja Lake in Nepal (credit: Daene McKinney)

Community consultations in high altitude, remote, roadless regions, such as the SNP in Nepal, require careful planning and a high level of fluency in the region's cultural, physical, and political geographies. Additionally, access to these regions can be highly dependent on climate conditions, e.g., increasing cloudy days have resulted in regular flight cancellations and travel delays.

For example, the window of time in which LAPA consultative meetings can be held in the Khumbu is small and requires extensive preparation to implement workshops within a short period of time within a large geographic area. LAPA practitioners working in other regions of Nepal should be prepared to face additional challenges to program implementation such as extreme poverty, comparative remoteness, lack of airports, and outmigration of young men to other countries, changes in village demographic structure, and the lingering effects and impacts of the 1996-2006 civil war.

Figure 17. Huaraz City street scene in the Quillcay basin of Peru.

Despite the comparative ease of reaching community members in the Quillcay basin of Peru, establishing cooperation among communities was time consuming and cooperation among such socially segmented communities can be a challenge. It is important to first identify local leaders who support and endorse the LAPA process, and as mentioned previously there is no substitute for the regular and long-term presence of LAPA staff in rural settings. Gathering *campesinos* in the 21st century is also becoming a challenge as well, as many people now have day jobs in Huaraz; Saturdays are reserved for farm work; and Sundays are for church and soccer. NGOs and local government groups can, however, help to facilitate the process of cooperation and participation.

4. CONCLUSIONS

The integration of scientific information into the LAPA process in both the Quillcay basin of Peru and Khumbu region of Nepal proved to be highly successful. Stakeholders in both locations developed LAPAs to address high priority climate change impacts and achieve development objectives largely based on the glacial lake research results, in spite of considerable uncertainty and/or indifference to the threat of GLOFs when the HiMAP project began in 2012.

The Khumbu LAPA was the result of extensive consultations, meetings, and workshops involving over 300 participants from a wide range of stakeholder groups. New results and information from the Imja glacial lake research were routinely shared with workshop participants and informed the LAPA process in ways never before utilized in Nepal. The resulting LAPA represents a major step in the ability of local people in the region to understand, evaluate, and adapt to the impacts of climate change on their high mountain environments and lifestyles. It also provides a detailed plan of action for presentation to governments, donors, and NGOs for priority project funding and implementation.

The Quillcay LAPA demonstrates the value of conducting careful consultations at the community level to make sure that analysis of climate threats aligns with local priorities and problem definition. As a result of the consultative process in the Quillcay basin, it was possible to discern, design and initiate the implementation of a risk reduction strategy that differentiated the development objectives of urban and rural residents and opened the opportunity for cooperation between these two sectors of local society.

Lessons learned from the LAPA processes begin with establishing trust and relationships with local governments and people in the early stages of community consultations. Governments and communities alike need to feel a sense of ownership of the LAPA process, which in the case of Peru was facilitated by involving both groups in the goals, objectives, and design of the community and other consultations at an early stage. Good relationships serve to facilitate LAPA consultations, promote the acceptance of scientific research results, and establish the basis for mainstreaming priorities later in the process. Relationships should be strengthened and maintained by regularly sharing the results of the consultations and research in the region with communities and government entities. The regular presence of LAPA personnel in a project region also enhances communications, trust building, and credibility. The awareness building process can be enhanced by the availability of solid research results, which in both the Khumbu and Quilcay cases added credibility to the LAPA results.

Developing an effective LAPA requires tailoring the basic methodology to local conditions and needs. In Peru and Nepal, the LAPA process was applied in geographically uniform regions, rather than according to administrative divisions. Additionally, scientific information and development goals were successfully incorporated into the LAPA process discussions regarding the effects of climate change, and marginalized populations were included in consultations. In Peru, the inclusion of rural and urban populations highlighted the differences in climate change concerns stemming from the different primary economic activities of the two populations. Understanding these differences indicated necessary adaptations of the LAPA process and ultimately resulted in a plan of action that includes the concerns of both segments of the population.

In order to produce a robust and effective LAPA, scientific knowledge should be created in support of the process and shared with community members. A toolkit of rapid reconnaissance methods was developed for glacial lake studies that rely on field data, which has proven to be more accurate than relying on remotely sensed data alone. Field data combined with computer modeling of climate impacts provides results that inform community members of threats as they engage in the LAPA process. In addition, small grants can be used during the LAPA process to fill knowledge gaps and encourage young researchers to develop new skills.

LAPA sustainability is critical to help local communities deal with the effects of climate change in the long term. Therefore, implementing organizations must take steps throughout the process to ensure that LAPAs will be implemented and continually revised with new information. To ensure LAPA sustainability, mainstreaming climate change adaptation into existing organizations should be achieved early on. Additionally, knowledge generated in the process should be shared to build capacity locally and among other communities around the world facing similar threats. Ultimately, LAPA sustainability is a long-term process that requires follow up work to determine which strategies are most effective.

The LAPA processes in Peru and Nepal were not without challenges due to the remoteness of high mountain regions and local factors. Challenges are unavoidable, but by understanding the difficulty of conducting community consultations, organizations can plan for foreseeable problems and budget (time and money) for the unexpected.

Despite the success in conducting community consultations and encouraging communities to think about and prepare for climate change, glacier-dominated areas around the world will continue to pose unique challenges to communities as they adapt to the impacts of global climate change—particularly the increasing threat of GLOFs. Glaciated mountains are among the least studied environments in the world from a physical, social and climate change perspective, thus adaptation in these regions appears more complex and challenging than in other areas. Contemporary developments—such as the formation of thousands of new and, potentially, dangerous glacial lakes—are unprecedented in humankind's experience of change and adaptation. Given the critical importance of high-mountain glaciated landscapes to the millions of inhabitants of cities and communities that live in or rely upon them, interdisciplinary climate change research approaches and applied field programs—such as those practiced by the HiMAP—that actively combine the social, physical and engineering science dimensions, will be required in order to achieve the best understanding of current and future climate-induced risks. USAID's growing portfolio of projects in high mountain regions throughout the world is a promising indicator that these approaches are well underway.

APPENDIX I: PARTICIPATORY TOOLS AND TECHNIQUES USED IN THE KHUMBU LAPA

Participatory Tools and Techniques Used in the Khumbu LAPA

Tool	Technique (and outcomes)
Social map	Records settlements, villages, trails, bridges, services, forests, agricultural areas, development activities and other prominent features
Vulnerability map	Records villages, communities, forests and agricultural areas that have been or are prone to climate-induced hazards such as flooding, forest fires, GLOFs, windstorms, snowfall, drought and agricultural pests and diseases
Seasonal calendar	Analyze the local climate change experience in recent years. The experience is recorded using a monthly calendar and compares past experience with the present across climate variables
Historical timeline analysis	Analyzes the occurrence and frequency of different climate-induced hazards during the past three decades and their impacts on communities, villages, agricultural and forest land, and infrastructure
Affected areas/households analysis	Records the impacts of climate-induced hazards on villages, households and socio-economic groups based on social and vulnerability maps and historical timeline analyses
Climate-induced hazards ranking and impact analysis	Analyzes hazards identified in the vulnerability map and the impacts of these on different sectors. A scale of 0–4 was used to score the local experience of intensity and the extent of the impacts on different sectors. This process records the ranking of various hazards in terms of their impacts on sectors that have been the most affected
Climate change impacts on different sectors	Analyzes the present and potential impacts of climate change on different priority sectors as identified in the climate change ranking and impact analyses
Adaptation visioning	Records the impacts of the six most significant hazards as ranked and prioritized by climate change ranking and impact analysis tools
Adaptation prioritization	Records different adaptation programs and activities using four criteria (effectiveness, cost-effectiveness, feasibility and target group orientation) and prioritize them. A scale of 0–3 was used to score each criterion
Stakeholder analysis	Records and prioritizes different organizations and institutions, governmental and non-governmental organizations and the private sector using a Venn diagram. This tool helps define the significance and importance of climate adaptation plans as well as the roles and responsibilities of each organization
Implementation plan	Based on adaptation prioritization, a detailed implementation plan of action is developed. The plan includes the top six identified hazards, the adaptation activities and their ranking in terms of importance and priority, possible funding sources and responsible organizations

APPENDIX II: INFORMATION AND CONDITIONS NEEDED TO PERFORM GLACIAL LAKE RISK ASSESSMENTS

Through rapid reconnaissance studies and more in depth fieldwork, HiMAP researchers have determined that glacial risk assessment requires, at minimum, certain key data sets. These include:

- Digital elevation model (DEM) data at a resolution of 30 m x 30 m grid or less (5 m is recommended).
- Geophysical surveys (ground penetrating radar – GPR and electrical resistivity tomography – ERT) if buried ice is suspected in the damming moraine of the lake.
- Bathymetric survey of the lake (preferably by sonar-based system)
- Information of possible GLOF triggers (potential for rock or ice avalanches that create waves that overtop the damming moraine, seepage in the face of the damming moraine, etc.).
- Census data
- Dam breach analysis of failure of the damming moraine of the lake
- Debris flow model (two-dimensional) and results for various GLOF scenarios including potential remedial alternatives
- Information on downstream locations such as number of villages, population, cultural resources, infrastructure, extent of flood plain, etc., that need protection
- Economic data related to loss of life and assets if benefit-cost analysis of remedial measures is to be undertaken.

APPENDIX III: CLIMBER SCIENTIST SMALL GRANTS PROGRAM

The Climber-Scientist Small Grants program was an important component of HiMAP that provided field-based, hands-on research opportunities to scientists and practitioners working in high mountain regions. Particular focus was placed on the generation of knowledge regarding the impacts of climate change, interaction between highland and lowland communities, and methods for protecting fragile alpine ecosystems. The Climber-Scientist Small Grants awarded for work related to Nepal and Peru included the following:

Adam French (University of California Santa Cruz)

Integrated and Participatory Risk Management in Peru's Lake Paron Glacier Basin

Building on his extensive experience in the Cordillera Blanca, Adam French's project developed the capacity of local communities in the Santa watershed to build technical skills in hazard assessment and risk management, and in methods for meteorological and hydrologic data collection. The core of his project was the development of a community-driven, participatory data collection and monitoring program in the Lake Parón glacial basin. This project provideed vital information about the region's shifting hydrologic regime, and new information to strengthen highland-lowland linkages in the Santa River watershed to foster networks of cooperation to sustainably manage vital hydrologic resources in the region.

Ulyana Nadia Horodyskyj (University of Colorado Boulder)

Quantifying Supraglacial Lake Changes: Contributions to Glacial Ice Volume Loss and Runoff Inputs to Rivers in Nepal

Ulyana Nadia Horodyskyj's research attempts to improve our understanding of the changes occurring in debris-covered Himalayan glaciers due to the impact supraglacial lakes. Through diverse data collection techniques, including the comparison of historical and real-time imagery, terrestrial LiDAR (laser) surveys, time-lapse cameras, and isotopic foot-printing, this project has provided new insight to the hydrologic changes occurring in glaciers, with a particular focus on the impact of supraglacial lakes. In the process of completing this project, the local Sherpa and Tibetans living in the study regions were trained in data collection and hazard mitigation and curriculum was developed for elementary and middle school children to increase awareness and understanding of the changing water resources.

Raúl Augusto Loayza Muro (Universided Peruana Cayetano Herida)

Natural acid and metal leaching in Andean headwaters: an interdisciplinary approach to evaluate water quality and potential sources for remediation in a climate change context in the Cordillera Blanca (Peru)

In this project, Raúl Augusto Loayza Muro monitored the highland-lowland impacts of climate change and pollution on a glacial watershed in the Cordillera Blanca of Peru, specifically evaluating the impacts of natural acid and metal drainage on water quality and biodiversity. By monitoring the physical chemical characteristics and macro-invertebrate diversity of a watershed, a better understanding has been gained of the linkages between climate change, water quality, and biodiversity. This knowledge was used ot experiment with different native plant species to develop new solutions to monitor and remediate water pollution, with a particular focus on pollution from increased natural acid and metal leaching.

Stephanie Spray (Harvard University)

Snow River Film Project, Nepal

Stepanie Spray's *Snow River* film project is a feature-length film that documents the complex relationships local communities in three regions of Nepal—the Khumbu, Hinku and Hongu—have with the surrounding Himalaya. *Snow River*, from the literal translation of the Nepali word for glacier (*hiun nadi*), primarily focuses on local communities' perceptions of and relationships to nearby glacial environments, which contribute culturally to local identity and physically to regional water resources, but also threaten local life and livelihoods with unstably dammed and potentially dangerous glacial lakes.

Laura Read (Tufts University)

Community Water Management in the Tres Cuencas Commonwealth

In this science-to-practice project, Laura Read collaborated with the Tres Cuencas Commonwealth in Peru to support their goal to develop technical solutions for water and climate challenges. The project had three main components. First, a multi-media portfolio that includes a hydrological, social, political, and economic profile of each community in the Tres Cuencas Commonwealth was created. Second, an educational water allocation game was constructed and used as a decision-support tool for communities.

Third, the feasibility of a regional mobile telecom network to support project communication and report real-time hydrologic and climate data was assessed and developed. Though this combination of activities the Tres Cuencas Commonwealth now have expanded tools needed to more effectively and collaboratively manage their water resources.

Institute of Environmental Engineering (Zurich, Switzerland)

Including the Sherpa Factor in Water Resources Projections in the Nepalese Himalaya

The Institute of Environmental Engineering (ETH) at the University of Zurich, Switzerland is committed to increasing its efforts towards addressing global issues related to poverty, hunger, and climate change impacts. The ETH's project combined quantitative observations in the field with the soft knowledge of local communities to better predict future water resources in the glaciated watersheds of Nepal. The project trained local people in the Langtang Basin in advanced monitoring techniques for the observations of climate and hydrological changes. This observational data was combined with local knowledge of the perceived changes in the natural system to inform a glacio-hydrological model to predict future changes in snow, glacier mass balance, and runoff in the Langtang Basin. Local communities can now use the information generated from the model to inform their water management decisions.

ATREE (India-Nepal)

Climate change in Kanchenjunga TCA: Vulnerabilities and adaptive capacities

The Ashoka Trust for Research in Ecology and the Environment (ATREE) was established to bring together researchers to do interdisciplinary, applied work related to conservation, policy development, and capacity building of government and non-government organizations to solve environmental problems. ATREE's project developed a framework for climate-resilient development and adaptation to climate change risks in the Kanchenjunga Transboundary Conservation Area (KTCA). The project had four components: (1) stakeholder perception assessments, (2) knowledge synthesis including climate modeling, (3) capacity building of local organizations, and (4) improving the capacity of policy makers. A Regional Climate Awareness Forum was established to act as a vital policy advocacy organ to work with government agencies to develop climate-aware strategies with communities.

Resources Himalaya Foundation (Nepal)

Building Climate Change Resilience Capacity of Mountain People in Nepal

Resources Himalaya serves as a catalyst for conservation and development in Nepal by providing science-based information synthesized for rigorous development and action research. Through this project, Resources Himalaya increased the resilience capacity of local communities by (1) conducting training for Vulnerability Assessment of Climate Change for local government, community and local NGOs/CBOs; (2) preparing Local Adaptation Plan Guidelines and piloting a Local Adaptation Plan; and (3) disseminating this information to the decision making and planning bodies at central level. This pilot Local Adaptation Plan provided a case study for the development of future adaptation plans throughout Nepal.

Geo-Science Innovations (Nepal)

Investigation of the Seti River disaster (May 5, 2012) and assessment of past and future mountain hazards facing Pokhara, Nepal and upstream communities

Geo-Science Innovations is a center for geo-science research, training, and technical innovations for a variety of geological, geomorphological, and geotechnical problems in Nepal. This project sought to understand the cause of the May 5, 2012 Seti river outburst and to develop a concept structure for an effective, sustainable, maintainable warning system to mitigate the impact of future disasters. The research developed a current inventory of geological risks and evaluated the history of prior mass flows, floods, rockslides, and avalanches in the region. Based on this information, an assessment of future hazards was developed using a conceptual, GIS-based (Geographic Information Systems) framework to evaluate risk and develop a functional, cost- effective warning system. This warning system is rooted in the knowledge and participation of the local communities and seeks to mitigate the impact of future disasters.

APPENDIX IV: COMPARATIVE ATTRIBUTES OF THE PERU AND NEPAL HIMAP EXPERIENCE

Comparative Attributes of the Peru and Nepal Experience

PERU	NEPAL
Geography	**Geography**
Urban Mountain-excellent and reliable transportation/communication facilities	Remote Mountain—no roads, unreliable air service, all goods portered in
Population	**Population**
130,000 (~80% urban, 20% rural)	5,000 (100% rural)
Ethnicity	**Ethnicity**
Hispanic (urban), Indian (rural)	Sherpa (92%), Tamang/Rai/Dalit (8%)
Migration Pattern	**Migration Pattern**
Outmigration to urban centers common	Outmigration of wealthy Sherpas to Kathmandu, US; immigration of Rai/Tamang as laborers and lodge managers with increasing ownership
Natural Hazard Vulnerability	**Natural Hazard Vulnerability**
Very high (earthquakes, glacial lake formation above urban centers, history of catastrophic outburst floods and glacier-fed debris flows with high fatalities)	High (remoteness, no roads, steep terrain, history of GLOFs and avalanches with comparatively low fatalities)
Economies	**Economies**
Mining, business, agricultural, tourism	Tourism (increasing dependency), agriculture
Project Leadership	**Project Leadership**
Director in-country, always available, continuous meetings with rural, urban, and Lima Government of Peru stakeholders	Consultant in-country, HiMAP Co-Manager in Nepal 2-3x per year, meetings with Khumbu, KTM, and Salleri stakeholders occasional, largely determined by tourist season and weather
Mainstreaming Resources	**Mainstreaming Resources**
Excellent—royalties from mining available as public investment funds	Moderate—Buffer Zone funds a potential source but competition extremely high; other in-country or donor funds extremely limited; the GON has promised funds, though no firm timeline offered
LAPA	**LAPA**
Modified USAID 2007 V&A 6-Step 1. Diagnose in the context of development 2. Identify vulnerabilities 3. Identify and analyze adaptation options for the different groups while building strategies to work with government for implementation. 4. Develop a Local Action Plan that is consistent with government and local institutions 5. Implement priority adaptations with support of local network	**Modified GON 2010 LAPA** 1. Climate change sensitization in the context of development needs 2. Identify vulnerabilities and adaptation options 3. Prioritize adaptation options 4. Develop local adaptation plan for action 5. Mainstreaming into local planning processes 6. Implement priority adaptations

6. Evaluate adaptation effectiveness	7. Assess LAPA progress
Time to Complete LAPA	**Time to Complete LAPA**
3 months (June-August 2012)	2 years (Sept 2012-Dec 2014)
Felt CC Impacts Peru	**Felt CC Impacts Nepal**
Temperature increase, extreme climate events, glacial recession, reduction of freshwater, springs drying, water quality deteriorating, storms increasingly agriculture, drought impacting animal health	Temperature increases, glacial recession, increase in the number of potentially dangerous glacial lakes, crop failure due to new diseases, climatic variability, increased forest fires, flooding, and landslides.
Core Identified Threats Peru	**Core Identified Threats Nepal**
Rural: 1. Water (supply and quality) Urban: 1. Drinking water, 2. GLOF from Laguna Palcacocha	1. GLOFs 2. Heavy snowfall 3. Windstorms 4. Landslides 5. Forest fires 6. Floods 7. Drought 8. Agricultural pests/diseases 9. Avalanches
Priority Interventions	**Priority Interventions**
(1) Strengthen capacities for risk of disaster management; (2) Improve knowledge of hydrology and water quality; (3) Improve water quality; (4) Explore water development (reservoirs and wetlands); (5) Improve and extend irrigation infrastructure; (6) Expand and improve potable water and sewage treatment systems; (7) Develop waste collection systems for rural villages; and (8) Strengthen capacities for tourism activities.	(1) GLOF (research and monitoring of glacial lakes, EWS, disaster management systems, insurance coverage and clothing for porters, (2) Landslides (nurseries and afforestation), (3) Heavy Snowfall (weather monitoring and forecasting, snow and ice management training, green/plastic house demos), (4) Windstorms (public awareness building), (5) Forest Fires (firefighting training and equipment, public awareness building, afforestation)
Interventions/Successes to Date	**Interventions/Successes to Date**
Multi-stakeholder platform established for GLOF risk reduction, Waraq Municipal Commonwealth established Dec 2013, MINAM funding for EWS studies	GLOFs prioritized as primary threat; public acceptance and support for UNDP Imja Lake risk reduction project; $15K Buffer Zone funds procured by KACC for water supply, bridge, and nursery establishment; other mainstreaming projects in progress
No. Stakeholders Benefitting	**No. Stakeholders Benefitting**
Reduced risk for 34,783 Huaraz residents	Reduced risk for 90,000 potentially vulnerable people downstream
Climber Scientist Input	**Climber Scientist Input**
Excellent—French—Integrated Risk Management/Lake Paron; Raul Loayza Muro—Natural Acid and Heavy Metal Leaching; Laura Read—Community Water Management in the Cuencas Commonwealth	Excellent—Horodyskyj—Supraglacial lake changes/Nepal; Geo-Science Innovations—Seti River Disaster Analysis; Resources Himalaya—Building Climate Change Resilience in Nepal
Partnerships	**Partnerships**
Excellent—USAID, MINAM, Commonwealth, stakeholders	Excellent—GON, BZ, UNDP, USAID
Lessons Learned	**Lessons Learned**
i. Complex development and climate change adaptation needs from rural and urban inhabitants ii. Importance of education about climate change impacts to drive action iii. Success of a basin-wide approach iv. Establish relationships with government entities early in the LAPA process	i. Community consultation processes are expensive and time demanding ii. Build formal relations with government and community partners at the beginning of a LAPA program iii. Establish trust and partnership with all stakeholders iv. Integrate development into the LAPA process

v. Community consultations are the cornerstone of effective adaptation measures vi. Community consultation process is expensive and time demanding vii. Focus on development goals aided in streamlining with local government viii. LAPA sustainability is a long term process	v. Use larger geographical units vi. Incorporate scientific data vii. Build in-country capacity viii. Share data and information ix. Include a media and outreach component in project design x. Nurturing the community of practice
Other Notable Achievements	**Other Notable Achievements**
US $3 million USAID project "Securing Mountain Landscapes" awarded; Waraq Commonwealth established with assistance from TMI; solid partnerships developed with MINAM early on with co-financing provided for priority LAPA intervention;	Solid partnerships with KACC, SNP, DHM, UNDP; DHM endorsement of Glacial Lake Rapid Reconnaissance methods; inclusion of local people in field research; routine sharing of research results with local people; high level of trust between stakeholders and TMI/UT established; global awareness for high mountains and glaciers increased (indicator: number of new RFAs concerned with mountain water and glaciers); large portfolio of publications, presentations, videos developed; South-South collaboration and exchange; regular HiMAP presentations to donors and partners in the Khumbu, Kathmandu, and US
Challenges Encountered	**Challenges Encountered**
Cooperation among villages in the Quillcay watershed to coordinate community consultations was challenging (past inter-village conflicts). This led to more separate meetings. Although Government of Peru funds were identified to initiate LAPA implementation (under $500,000) the highest priority project, lowering the lake (a multi-million dollar project), may take years to fund. The implementing organizations (TMI, commonwealth) are subsequently held responsible for GLOF security in the eyes of local society. Establishment of the municipal commonwealth went well, but small glitches in municipal bureaucracies slowed the process. Implementing a project aimed at sustainable GLOF risk reduction strategies through short-term quarterly contracts prevented establishing a clear pathway from the beginning.	Seasonal migration of locals out of the area, unavailability of locals to meet during the busy tourist season, and conducting meetings in geographically separated regions in a short window of time when communities can meet

APPENDIX V: VARIOUS VIDEOS OF HIMAP WORK

Lake 464 (2010) The Most Dangerous Lake in Nepal: This video outlines the risk posed by Lake 464 to downstream communities.

http://youtu.be/ZN8a-pP60wk?list=UUiMlUoh_2IfMeQ2e4-qsUeA

Global Glacial Lake Partnership (2011): This video chronicles a 2011 expedition to Imja Lake and the work scientists around the world are doing to understand the threats posed by glacial lakes.

https://vimeo.com/69664837

Cesar Portocarrero (2011): This video, created by Cesar Portocarrero, provides an overview of the work the Peruvian Government has done to manage glacial lakes in the Andes.

https://vimeo.com/113177066 password: cesar

TMI Andes Program (2011): This video, created by The Mountain Institute, provides an overview of the Institute's Andean program.

https://www.youtube.com/watch?v=2yczg_f_PKY&list=PL5mEKjHczxOAjSaAu_DT9LBOnmYLXcXPs&index=1

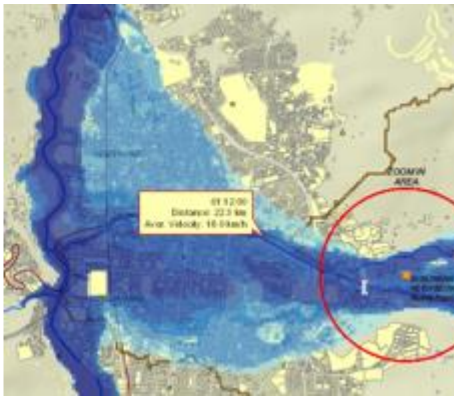
High Mountain Glacial Watershed Program (2012): This video follows scientists conducting a lake bathymetry study of Lake Imja and explains the efforts of HiMAP in the Khumbu region of Nepal.

https://vimeo.com/61653211

High Mountain Adaptation Partnership (2013): In this video HiMAP researchers conduct a workshop for GLRR in Peru and discuss the Partnership's efforts in the Peruvian Andes.

https://vimeo.com/77387853

Living under flood risk in Huaraz City (2014): Map based narrative of the risk posed by a GLOF from Palcacocha Lake in Peru and the results of flood simulations for Huaraz City.



http://wwo.maps.arcgis.com/apps/MapJournal/?appid=7bfd8b154237410a8927157296b5ea0c**,**

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