# Part One

## INTRODUCTION TO THE WORKSHOP

The Workshop on Hazard Mitigation in the Northern Sunkoshi and Bhote Koshi Water Catchment Area took place at the ICIMOD headquarters in Kathmandu from the 8th to the 10th of May 1996, inclusive. The first day's sessions consisted of an inaugural session, followed by lectures by **Mr. Alexis Wagner** and **Dr. Andre Pugin** on the work carried out during the two and a half year project period. A project completion report was made available to the participants in draft form and examples of hazard maps of the area were displayed for their convenience. The second day was taken up by a field trip to the study area along the Arniko Highway (Dolalghat to Kodari).The third day was completely devoted to discussions of the findings of the project by two distinctly-focussed groups, presentation of group recommendations, and final discussions. The Workshop participants were able to reach a positive consensus concerning directions for the future in the context of the project's findings.Throughout, the Workshop did not confine itself within a rigid time framework in terms of delineating session periods, and this made it possible to concentrate on issues that participants deemed to be of critical importance. The Workshop Programme is given in Annex One and the names of participants in Annex Two.

## DAY ONE: INAUGURAL SESSION

### Welcome Address

This session was chaired by **Professor Suresh Raj Chalise** and opened with a welcoming address by **Mr. Egbert Pelinck**,Director General of ICIMOD. In his opening address, Mr. Pelinck stressed the importance of work on hazard mitigation, especially in a fragile environment like that of the Hindu Kush-Himalayas. He assured the participants of ICIMOD's interest in providing a forum for discussion and debate that would lead to measures to improve sustainable mountain development and the standards of living of mountain people. He wished the Workshop success and assured them that, even though he was not able to attend the workshop throughout, his interest in this topic was such that he would make every effort to join in the deliberations to the greatest extent possible.

### Background to the Workshop

Mr. Alexis Wagner stated that this was the final workshop of the Nepal-Switzerland Cooperation Project on Hazard Mitigation in the Northern Sunkoshi and Bhote Koshi Water Catchment Areas carried

out by ITECO in collaboration with ICIMOD.He referred to the fact that a draft report had been prepared for use by the participants and that they were here to discuss the findings and analyse them. For this reason the forty-five participants invited included professionals from HMG line departments, scientists, representatives of development cooperation agencies, and practitioners from private companies. This would allow for comprehensive discussion and analysis of the project findings. The results of the project were to be presented by Dr. Andre Pugin during Session One, this would be followed by a discussion on Instabilities and Hazard Mapping in Glacial Deposits during Session Two, which would be conducted by Mr. Wagner himself. On the second day there would be a field trip along the Arniko Highway. During this field trip, the participants would examine glacial deposit exposures and landslides along the highway. Finally, on the last day, there would be group discussions in three groups (this was reduced on the final day to two groups, see Annex 3) to discuss the scientific aspects and practical issues that had arisen as a result of the project work. Conclusions and recommendations would be formulated by these groups and there would be a final discussion to arrive at coordinated recommendations from the workshop as a whole.

In giving the background to the project, Mr. Wagner stated that it had been implemented by ITECO Eng.LTD, a Swiss company that had acquired a great deal of experience in the Himalayan Region, particularly in Nepal. ITECO had worked with ICIMOD, ITECO/ Nepal, and the Swiss National Service of Hydrology and Geology.The Project was funded by the International Decade for Natural Disaster Reduction (IDNDR) of the United Nations (UN), the Swiss National Service of Hydrology and Geology, and partly by the Swiss Development Cooperation (SDC) as a contribution to the UN's IDNDR. A Steering Committee of HMG line agencies had guided the project work from its inception.

The project had carried out research on the fragile thick Quaternary deposits of the Bhote Koshi and Upper Sunkoshi catchment areas. Geological and hazard mapping and surveying of specific instabilities damaging farmland and threatening the Arniko Highway were carried out. Small-scale engineering and bio-engineering measures to control these instabilities had also been finalised. Hydrological studies linked to debris flows and instabilities on specific streams and sites had also been carried out. Several teachers and graduates from the Department of Geology of Tribhuvan University and a number of other professionals from related departments had received on-the-job training on the above topics, subsequently forming the project survey team. Along with these, six Swiss personnel (their disciplines

including geology, geophysics, bio-engineering, and hydrology) had participated in the project as trainers and implementors.

In July 1987, in this area, the monsoon rains were exceptionally strong and the rainfall events caused critical undermining of rivers and streams with undercutting of banks. Quaternary deposits were heavily saturated with water. Consequently, many landslides were triggered and heavy damage was caused by stream erosion. Many farms and long sections of road were affected.

In the area chosen for the project, about two kilometres of the Arniko Highway were washed out and one kilometre of the Lamosangu-Jiri road was heavily damaged and seriously threatened by landslides at the Charnawati River crossing. A bridge was swept away, disrupting traffic for a considerable period of time.

Investigations carried out by road rehabilitation projects revealed that most damage had occurred in areas where there was significant thickening in the Quaternary material on the banks or within the catchment and sub-catchment areas of the rivers and their tributaries. Water tables had risen in many areas and farmlands were subjected to sliding. The process was intensified due to environmental stress caused by inappropriate road construction and poor maintenance as well as the heavy floods. Specific features coming to light during the work being carried out were demonstrating factors not identified before in Nepal. Considering the damage suffered along the road corridors, it was assumed that damage must be substantial beyond them; in fact, this was observed in the Charnawati River's catchment area which is crossed by the Lamosangu-Jiri Road.The streamflow alteration during the 1987 flood for this small river alone was from 40$m^3$/sec to 160$m^3$/sec.

It was argued that, due to active deforestation, it could be expected that the condition of human settlements and land would deteriorate rapidly in the absence of mitigation measures, especially in the areas of fragile Quaternary deposits. In addition, the construction of another 10,000 kilometres of new roads is foreseen within the next 20 years; most of them being north-south link roads which will have to cut through fragile deposits. The nature of such deposits may be glacial, as inferred by investigations, and was to be discussed in more detail in the remainder of Session One and during the field studies. Therefore, a thorough knowledge of the geological, geotechnical, and sedimentological nature of the terrain was a *sine qua non* for the establishment of additional infrastructure.

The Nepal-Switzerland Project on Hazard Mitigation in the Northern Sunkoshi and Bhotekoshi Water Catchment Areas (HMWA) was commissioned on the basis of these considerations.The main

objectives were directed by the need to undertake complementary geological and geophysical research on the inferred glacial deposits. Accordingly, the detailed project objectives were the following.

1. To train Nepalese geologists to identify glacial deposits recently discovered, even at low altitudes, in the valleys of the Sunkoshi and Bhote Koshi rivers, as well as in the valleys of their tributaries and other rivers of the region.

2. To carry out geological, geomorphological, sedimentological, and geophysical research on the inferred glacial deposits and to train Nepalese geologists in the production of geological and hazard maps of the inferred glacial deposits.

3. To train a botanist and civil engineer in the above-mentioned stabilising techniques.

4. To conduct hydrological studies of the streams affecting the inferred glacial deposits and to train two Nepalese hydrologists on relevant hydrological methods.

## Session One

*Glacial Basin Analysis of the Northern Sunkoshi and Bhote Koshi Water Catchment Areas*

**Dr. Andre Pugin** conducted this session. He described the findings of the project and discussed the glaciation and glacial deposits which were illustrated by figures. Among the figures were geological maps which gave a better understanding of the Quaternary deposits described. One of the figures indicated the locations of the major Quaternary deposits in the area.(Dr.Pugin noted that the draft report had been made available for the participants' reference.)

He believed that, as a result of the research, it was confirmed that the fragile and thick Quaternary deposits in the areas (which covered about 70sq.km.) were of glacial origin. Dr. Pugin referred to the identification of three glacial stages: namely, i) the Bahrabise Glacial Stage,the maximum extension limit being upstream from Bahrabise Bazaar near the confluence of the Bhote Koshi and the Khagdal *Khola;* ii) the Lamosangu Glacial Stage,the maximum extension limit of this stage being visible at Kilometre 80 on the Arniko Highway close to Lamosangu; and iii) the Balephi Glacial Stage, the maximum extension limit being at Kilometre 71, or a little downstream from there. Dr. Pugin briefly described the main deposits.

Very deep Paleo-valleys infilled with glacial or glacio-fluvial sediments could be identified down to an altitude of 700masl. This

was made possible by the use of the seismic reflection and refraction methods and confirmed the results of earlier electrical soundings carried out during the Arniko Highway Rehabilitation Project.The Paleo-valleys were found below or beside the current river beds. Study of sediment exposures with features typical of glacial deposits, the presence of pollen deposits indicating cold climate vegetation, and other findings; all of these suggested that the valleys were glaciated in the remote past.The Charnawati Rehabilitation Project too had identified typical glacial till and thick sediments in the Charnawati catchment area. It was highly probable, therefore, that other valleys in the northern hills had been glaciated at low altitudes during the same period.

This was a new and important geological finding in Nepal.Much could be inferred from new findings of Quaternary deposits. In addition to a better understanding of glaciology itself, a better insight on the impact of low altitude glaciation on climatic changes during the Quaternary period can be attained. The presence of major glacial deposits within these populated northern areas has, however, other implications.

One critical issue is the extent to which undercutting of river banks and river beds takes place during high flow and flood periods in streams and rivers. Such processes resulted in landslides which filled in streams and riverbeds, perhaps damming them, with serious consequences such as floods and debris flows.This was a recurring process. Sediment characteristics were also favourable to the establishment of perched water tables which were also a triggering factor for landslides and mudslides.

While throwing light on the causes of recurring landslides and erosion processes experienced throughout the region,it also indicated that bridges constructed on the margins or within corridors influenced by these stream and river erosion processes were not safe; and the same was applicable to dams and reservoirs. In the reservoirs, slopes constituted of glacial deposits could be weakened by the buoyancy effect and could fail, causing the reservoir to silt up rapidly or, in the case of a major landslide, to be subjected to wave flooding.In the worst possible scenario, damage to or breaching of the dam would occur with the associated catastrophic consequences. The implications of glacial deposits at low altitudes meant that there should be a new approach to developing infrastructure as well as to watershed management in such areas.

Studies had been carried out in detail within an area of 70 sq.km. It was the first time in Nepal that such detailed work had been undertaken.

*Discussion*

The second half of Session One was taken up by further details of glacial analysis and discussion. During discussion, debate arose concerning the glaciation theory. Dr. D.R. Kansakar stated that he had found glacial deposits close to 1,000masl in the Hongu *Khola* Valley (Khumbu). However, another participant pointed out that there could be other explanations. A great deal of discussion ensued. Most of the participants were extremely interested in the findings and were enthusiastic to visit the field.

## SESSION TWO

### Instabilities and Hazard Mapping in Glacial Deposits

**Mr. Alexis Wagner** conducted this session.He informed the participants that three geophysical methods had been used by the project:namely; electrical sounding, seismic refraction, and seismic reflection.

The electrical sounding method involved identification of the glacial morphology and depositional features, as well as identification of layers prone to sliding and erosional processes according to resistivity.

The seismic refraction method helped to attain a more accurate picture of the shallow beds.It made possible the identification of layers that were prone to sliding processes according to velocity. A table of interpretation helped analyse the behaviour of the material.

Seismic reflection was useful for the detailed study of the valleys. It also helped to acquire morphological and lithological information of the overburden and bedrocks.

Mr. Wagner went on to discuss a model for hazard mapping and described the computer software SHIVA and its use.He described a hazard as *'a phenomenon of natural instability, active or latent, which included the potential of occurrence and extension,both occurrence and extension being inseparable'*.

Hazard map components were discussed. The main components were:

- nature/thickness of the material,
- material friction angle vs. slope angle,
- hydrodynamics of the streams vs slope,

- hydrogeology,
- till vs slope,
- landslide/gully erosion,
- land use,
- faults and thrust faults - reactivation, and
- reactivation of old slides.

Each component gives an indication of what type of failure is likely to occur, hence the components are rated accordingly. Mr. Wagner used transparencies to show the ratings for different components. This was followed by slides of hazard maps.

In discussing case studies and mitigation measures, it was stressed that farmers' participation and responses were extremely important in hazard mitigation. A number of landslides and gullies had been chosen for study. Landslides had been observed at Naguche, Hariyabesi, Kapre *Khola*, Bahrabise, Sano Palati, Sime, Dhuskung, and one gully at Dhuskung.The participants were shown slides of many of these places in addition to summary sheets of cost estimates for mitigation. A list of plant species that could be used to carry out bio-engineering methods of mitigation was shown and small-scale engineering methods of landslide control described.

*Discussion*

Some discussion took place. A question pertaining to the hydrological studies, particularly those pertaining to the capacity of the tributaries of the Khare *Khola*, Sani *Khola*,. Malati *Khola*, and Kagdhal *Khola* to dam the Bhote Koshi was asked. Dr. M.R. Dhital observed that there were four tributaries in the assessment. He noted that the bedrock could either collapse and form a rapid, or that sediments could form over a long time causing damming. The question was which could have occurred in this case. The answer was that it was believed that both processes could have occurred.

The speaker was alluding to the studies demonstrating that the four tributaries had capacity, under given conditions, that were likely to be met in the short-, medium-, or long-term, to dam the Bhote Koshi when significant peak rainfall occurs.This is due to the fact that, in given conditions, the Bhote Koshi does not have the immediate capacity, owing to its relatively low gradient, to move the debris inputs coming from its tributaries.

Another participant asked if it was a fact that geologists, according to a 1976 report, had believed the Arniko Highway to be well planned. There were supposed to be few landslides. In Langtang,

there were glacial deposits at 2,500m , in Khumbu at 4,000m, and in Ganesh Himal too the glacial deposits were at high altitude. But, at the last point under discussion, it had become very low.Why the sudden drop?The answer was that this was because of the younger glaciation.

Finally, some discussion centred once more around whether a single field investigation could prove conclusively that glaciation had taken place. Participants were invited to observe the points made during the field trip the following day. The third day of the Workshop would be reserved for group discussions, discussion in plenary, and conclusions and recommendations.