Lal Bakaiya Watershed, Nepal

Challenges and opportunities in flash flood risk management

Adarsha P Pokhrel, ADAPT-Nepal; **Narendra Raj Khanal**, Tribhuvan University; **Khadananda Dulal**, Kathmandu University; **Rishi Rijal**, ADAPT-Nepal; **Salikram Sigdel**, Tribhuvan University; **Bijaya Raj Khanal**, **Yadav Subedi**, **Chitra Acharya**, **Dhruba Thapa**, and **Bipin Acharya**, ADAPT-Nepal

Flash flooding from the Lal Bakaiya watershed, which lies in the Terai and inner Terai – the granary of Nepal – could result in the loss of fertile land, crops and infrastructure valued at USD 502 million. Development of a community-based early warning system with strong linkages between highland and lowland areas, coordination among institutions responsible for disaster risk management, and improved watershed management practices are needed immediately to reduce flash flood risk.

Introduction

The Lal Bakaiya watershed is located in the Terai and inner Terai, also known as the granary of Nepal. Highly concentrated monsoon precipitation together with frequent cloudbursts over the Mahabharat range and the presence of the geologically weak Chure hills make the Terai naturally vulnerable to flood disasters. Hundreds of lives, millions of dollars worth of property and infrastructure, and large tracts of cultivated land are lost every year. Flood risk is likely to increase in the region as a result of high population growth and an increase in infrastructure development, combined with more frequent extreme precipitation events as a result of global warming. This risk is compounded by the very low capacity of the people to manage flood risk. Flood hazard and risk mapping and assessment in the Terai is limited in terms of coverage (only a few rivers) and scope (focus has been on inundation without due consideration of other associated processes such as riverbank cutting and river channel shifting, and it has also been technically oriented without involving key local stakeholders).

Although there is no specific policy on flash flood risk management in Nepal, there are national policies and strategies in place to deal with disaster and flood management that encompass flash flood risk management. The Sustainable Agenda for Nepal, 2003; Irrigation Policy, 2003; Water Resource Strategy, 2002 and National Water Plan, 2005; Water Induced Disaster Management Policy, 2005; National Strategy for Disaster Risk Management, 2009; Hydropower Development Policy, 2011; and Climate Change Policy, 2011, all emphasize the need to adopt an integrated water resource management approach to flood risk management at the river basin level. Risk assessment and the analysis of each disaster to draw lessons to allow faster and more effective deployment in future disasters are some of the important strategies mentioned in these policies.

Accordingly, this project (jointly supported by ICIMOD and the United Nations Educational, Scientific and Cultural Organization (UNESCO)) was conducted to:

- study the causes and impacts of flash floods associated with meteorological, geomorphologic, and anthropogenic factors in the Lal Bakaiya watershed;
- prepare hazard and risk maps;
- conduct awareness programmes and create a group of rural volunteers to be involved in flash flood risk management;
- establish a community-led flood warning system; and
- disseminate research findings through meetings and workshops at the central, watershed, and community levels.

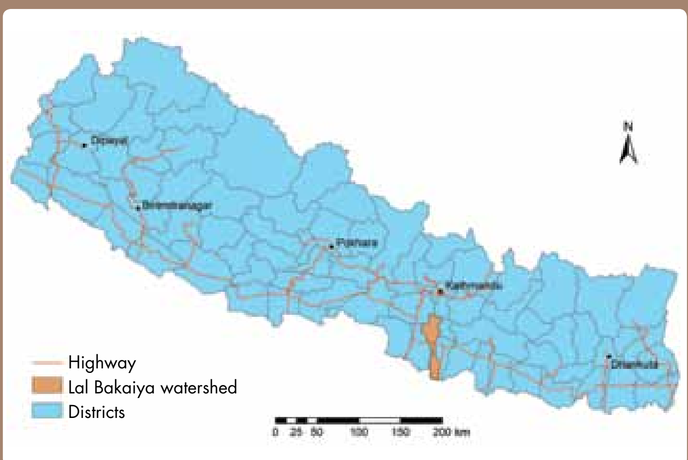
Study Area

The Lal Bakaiya watershed is located in the central southern part of Nepal and covers a total basin area of 868 km^2 (Figure 13). Geologically, the watershed can be divided into three major units – the Terai and Bhabar in the south; Chure including Dun Valley in the middle; and the Mahabharat range in the north. The mean annual precipitation is 1,434 mm at Gaur (in the south), 2,040 mm at Nijgad (Bhabar area), and 2,306 mm at Makawanpurgarhi (Mahabharat range). Mean annual precipitation seems to increase with altitude. The area frequently experiences high intensity rainfall and flash floods. The maximum 24-hour precipitation recorded in the watershed ranges from 236 mm at Gaur to 444.6 mm at Nijgad. This high intensity precipitation is highly localized. The recurrence interval of rainfall within a 24-hour period is 1.2–1.5 years for rainfall exceeding 100 mm; 3.1–6.1 years for 200 mm; and 18 years for 300 mm. All five meteorological stations located within and nearby the watershed show increasing levels of precipitation for July, which is the start of the monsoon (based on the historical data from 1970 to 2009). This may lead to more flood and flash flood events in the Lal Bakaiya River. Rivers originating from the Mahabharat and Chure ranges are generally wide, particularly in the Bhabar area, and these rivers are prone to flash floods.

There has been a significant change in land use and land cover in the Bhabar area and Chure hills including the Dun Valley. Coverage by forests and shrubs has declined from 60 per cent in 1954 to 49 per cent in 1995 and 47 per cent in 2009. At the same time, the percentage of cultivated land has increased from 34 per cent in 1954 to 44 per cent in 1995, remaining more or less the same in 2009. After the eradication of malaria in 1956, people started to migrate to Chure, Bhabar, and the Dun Valley on a large scale. Population density has increased by 7.8 times in Makawanpur District, 1.3 times in Bara District, and 2.5 times in Rautahat District since 1954. This encroachment for settlement and cultivation has intensified runoff and sediment transportation processes, increasing the frequency and magnitude of flash floods and, consequently, loss of property.

The Lal Bakaiya watershed has a total population of 421,230 across 68 Village Development Communities (VDCs): seven in Makawanpur District in the northern part of the watershed; four in Bara District in the middle; and the remaining 57 in Rautahat District in the south. Out of the total watershed area, 42 per cent lies in Makawanpur District, 20 per cent in Bara, and 38 per cent in Rautahat District.

Figure 13: **Location of Lal Bakaiya watershed**



Methodology

The project adopted a seven-step methodology for project work (Table 3). Three approaches were adopted for hazard and risk mapping: a geomorphic approach based on analysis of channel morphology and terrain using GIS and RS tools; inundation hazard zoning based on river discharge and micro-topographic variation using a HEC-RAS (Hydrologic Engineering Center-River Analysis System) model; and social flood hazard zoning based on the experiences of local communities. Discharge was estimated based on rainfall and catchment characteristics. A frequency analysis of maximum daily rainfall was conducted in order to estimate discharge for different return periods.

An inundation map was prepared using the following steps: preparation of DEM (digital elevation model) in Arc View GIS; GeoRAS (geographic river analysis system) pre-processing to generate HEC-RAS import files; running of HEC-RAS to calculate water-surface profiles; post-processing of HEC-RAS results and flood plain mapping; and flood risk assessment.

The assessment of hazard, risk, and vulnerability was based on primary data collected in the field through direct observation and measurement, group discussions, and key informant interviews. Field measurement of the river channel and water discharge was carried out at different reaches of the river. A total of 68 focus group discussions (one in each VDC in the Lal Bakaiya watershed) were organized to collect information on socioeconomic conditions, the frequency of natural disasters, and extent of past losses from natural hazards focusing on water-induced disasters. Tools to record field data, such as checklists, were prepared and used.

Analogue and digital maps for different periods were collected and analysed using RS and GIS techniques to assess existing conditions and processes of change in the watershed. Land use and land cover information was generated through toposheet maps prepared in 1956/57 and 1994, land utilization maps prepared in 1986, and recent satellite images taken in 2009.

Two workshops, one at the local level and another at the national level, were organized to communicate the findings of the research and obtain feedback for use in the finalization of the report.

Results

Floods, riverbank cutting, shifting of the river channel, water logging, sedimentation, droughts, fires, hailstorms, windstorms, lightening strikes, pests and diseases, debris flows, landslides, heat waves, and cold waves were reported as the major disasters causing loss of life and property and occurring frequently in the Lal Bakaiya watershed. Riverbank cutting, shifting of river channels, water logging, and sedimentation are some of the major geohydrological processes that are intensified during flash floods. Although landslide dam outburst floods are not common, the local people remember one landslide dam outburst flood event. Between 1954 and 2010, damages from floods were reported 21 times, which indicates that a damaging flood occurs in the watershed every 2–3 years. Out of the 21 years in which flood damage was reported, eight events (38 per cent) were highly localized covering only one or two VDCs. Only three events (14 per cent) in 1971, 1993, and 2010 were regional in terms of areal coverage.

On average, property and infrastructure valued at USD 225,700 is lost annually in different types of natural disaster in the watershed, 83 per cent of which is from floods alone, including water logging. Between 1954 and 2010, 54 per cent of the lives lost, 84 per cent of the damage to houses, 78 per cent of crop loss, and 99 per cent of the damage to cultivated land from disasters was caused by floods and inundation.

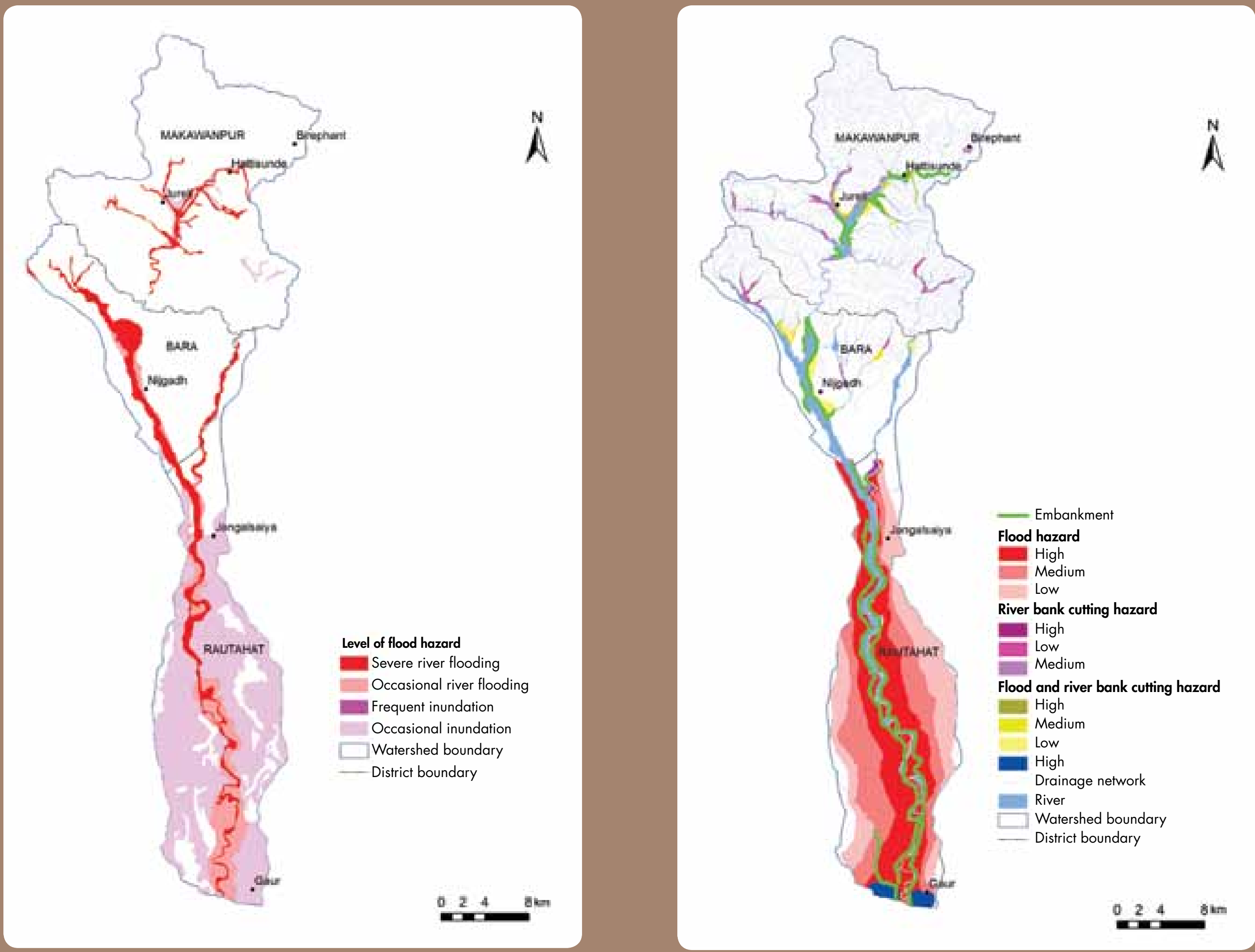
The results of hydrological modelling show that the depth of inundation is generally more than 5 m high in some parts of the Terai. The extent of inundation is less in upstream parts, such as the Siwalik hills, and extensive in the lower Terai, even in floods with a two-year return period.

Flood hazard maps based on land system units and prepared by communities during group discussions show that large areas in the lower part of the watershed are prone to flood hazard (Figure 14).

Table 3: **Seven-step project methodology**

Step	Description	Method
1	Contextualization and design of research method and tools	Literature review
2	Collection of secondary data and digitization of analogue maps	Collection of hydrometeorological and socioeconomic data, and analogue and digital maps from different sources
3	Preparation of land use maps, flood and inundation hazard maps, and landslide hazard maps based on secondary data	Frequency analysis of precipitation, estimation of flood discharge and height, flood routing and flood hazard mapping based on recorded daily precipitation data, preparation of topographic maps using the HEC-RAS model; preparation of a geomorphic hazard map based on analysis of a land system units and land use map using remote sensing and GIS
4	Verification of hazard maps, preparation of social hazard maps and a collection of relevant biophysical and socioeconomic data including the exposure of population and property to flood and landslide hazard from the field	Direct observation and measurement, focus group discussions, key informant interviews
5	Preparation and finalization of relevant maps and assessment of exposure and vulnerability	Use of data processing software such as Arc View, Microsoft Excel, and SPSS (Statistical Package for the Social Sciences)
6	Risk communication and capacity building	Workshops at local and national level, discussion with local people and establishment of network for early warning system and risk management at watershed level
7	Finalization of report	Drawing on comments and suggestions from workshops and discussions with local people and external reviewers

Figure 14: **Geomorphological flood hazard map (left) and social flood hazard map (right)**



A total of 40,657 households are exposed to flood hazards in the watershed (1,525 in Makawanpur District, 1,762 in Bara District, and 37,370 in Rautahat District) and a total population of 265,101 is likely to be affected (9,426 in Makawanpur, 10,145 in Bara, and 245,530 in Rautahat). Of the households exposed to flood hazard, 45 per cent are in high hazard zones, 36 per cent in medium hazard zones, and 18 per cent in low hazard zones.

The types of property exposed to flood disasters in the watershed include cultivated land, crops, private and public buildings, and other infrastructure. Although it is difficult to determine the probability of floods of different magnitudes and the resilience or resistance capability of the elements exposed, people and property in the area are highly likely to be affected by floods in the future (Table 4).

Property valued at USD 502 million is exposed to flood hazard in the Lal Bakaiya watershed. Of this, property valued at USD 215.4 million is in a high hazard zone, USD 177.1 million in a medium hazard zone, and USD 109.5 million in a low hazard zone. Real estate (houses, cultivated land, and housing plots) comprises about 73 per cent of exposed property, agriculture (crops and livestock) about 20 per cent, and infrastructure 7 per cent. Of the exposed property, 43 per cent is in a high hazard zone, 35 per cent is in a medium hazard zone, and 22 per cent in a low hazard zone.

The main flood and landslide hazard mitigation measures carried out in the watershed are gully and torrent control, plantation, water source conservation, trail improvement, the conservation of cultivated land, distribution of seedlings for plantation, landslide control, and river training. Interventions for the management of flash flood risk are focused on structural measures such as the construction of embankments and gully control on a limited scale (Figure 15). Embankments have been constructed on both sides of the riverbank in the lower reaches of the watershed with financial support from the Government of India.

Environmental management activities have been carried out in different parts of the watershed under the Biodiversity Sector Programme for Siwalik and Terai (BISP-ST) including the preparation of a sub-watershed management plan, control of natural calamities (landslides, floods, gullies), protection of infrastructure, implementation of a community-based soil conservation programme, organization of training and tours, school education programmes on conservation, and the production of communication materials. The Presidential Chure-Bhabar Area Preservation Programme has recently been implemented to control deforestation and improve socioeconomic and environmental conditions. However, preparedness planning for the management of flood and landslide risk, such as the establishment of an early warning system, development of public shelters, and skills development for rescue and relief operations, has not yet received high priority in the area.

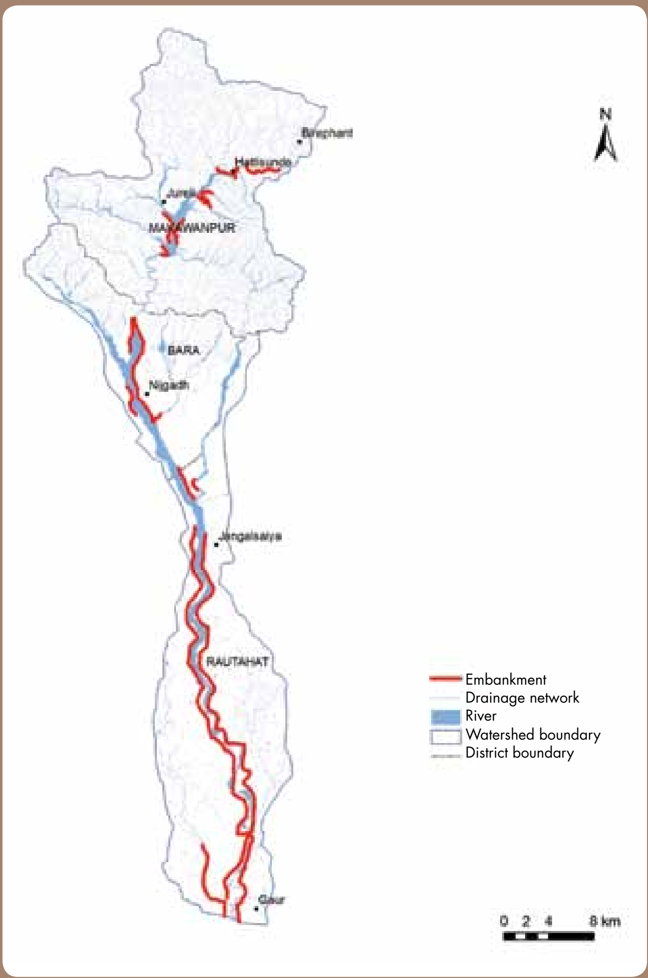
The capacity of local people to manage flash flood risk is weak as many people are poor and lack the skills and institutions to develop and implement preparedness planning for the reduction of flash flood risk. From the beginning the project built capacity by raising the awareness of flood risk and hazards among local people. Group discussions were held in 68 VDCs for data collection. Before starting the group discussions, participants were informed of the increasing risk of flash flood and the importance of flash flood risk management. An interaction workshop was held at the local level in Chandranigahapur in Rautahat District to communicate information on flood and landslide risk and obtain feedback. During the workshop, it was recommended that two VDCs – Shreepur Chhatiwan, located in the upper part of the watershed, and Nijgad, located in the middle – be made responsible for monitoring floods and providing flood warning information to communities downstream. Accordingly, a mobile set was given to the VDC secretaries of Shreepur Chhatiwan and Nijgad to initiate a flood warning system for the communities along the Lal Bakaiya River. This system was functioning well during the project period, but the current situation of this flood warning system is not known.

A national workshop was organized on 26 August 2011 in Kathmandu to disseminate the findings of this study and obtain feedback. The workshop was chaired by the Minister of Environment of the Government of Nepal and attended by representatives from relevant government ministries and departments, NGOs and INGOs, and

Table 4: **Property and infrastructure exposed to flood hazard in Lal Bakaiya watershed**

Type of property or infrastructure	Flood hazard zone			
	High	Medium	Low	Total
Irrigated land (ha)	10,385	9,227	3,551	23,163
Unirrigated land (ha)	0	47	410	457
Housing plots (ha)	6.7	5.7	12	24.4
Agricultural crops including fruits (tonnes)	84,629	69,365.7	25,279	179,273.7
Concrete houses (number)	1,662	1,042	429	3,133
Non-concrete houses (number)	14,431	12,173	5,444	32,048
Sheds (number)	4,311	4,244	2,793	11,348
School buildings (number)	94	84	31	209
Office buildings (number)	159	135	24	318
Road length (km)	58.5	45.3	21	124.8
Trail length (km)	193.3	204.7	100.2	498.2
Embankment length (km)	51.5	2	0	53.5
Bridge (number)	6	1	1	8
Watermills (number)	2	2	1	5
Pump sets (number)	172	165	39	376
Culverts (number)	0	2	1	3
Transmission lines (km)	72.5	51.8	20.6	144.9
Telephone lines (km)	21.3	6.5	0.8	28.6
Sewerage lines (km)	15.5	1	0	16.5

Figure 15: **Embankments on Lal Bakiaya River**



academicians. The workshop emphasized the importance of the effective implementation and extension of the community-based early warning system initiated by this project, formulation and enforcement of land use policies, establishment of a basin-level organization to pursue integrated water resource management, and awareness raising among local people about disaster risks and community-based disaster management practices.

Lessons Learnt

Flash floods are common in the Lal Bakaiya watershed and are often associated with highly localized extreme precipitation events. Lack of an institution to design, implement, and coordinate programmes at the watershed level for the management of flood and landslide risk is a constraint on the management of flash flood risk.

Furthermore, the lack of land-ownership certificates ('lal-poorja') means that farmers are not motivated to invest in the improvement of the land and change land use patterns, including the development of agro-forestry and other permanent crops on slopping terraces.

Structural measures alone (such as embankments) are not sufficient for flash flood risk management. Improvement of the sub-watershed condition, implementation of gully control activities, and discouragement of haphazard grazing in forest areas should be prioritized.

Recommendations

- Establish an institutional (government, non-governmental, and community) mechanism to manage flash floods at the watershed level.
- Enhance the capacity of local communities in managing flash flood events through awareness raising and training.
- Build a community-based early warning system that covers the whole watershed.
- Conduct a hydrological study and monitor floods during the rainy season in order to characterize flash floods in the rivers originating from the Mahabharat range.
- Prepare and implement a watershed management plan that adopts an integrated water resource management approach.
- Develop a comprehensive land use policy that includes distributing land ownership certificates to farmers so that local people are motivated to invest in the improvement of the land and to change land use patterns in a sustainable way.