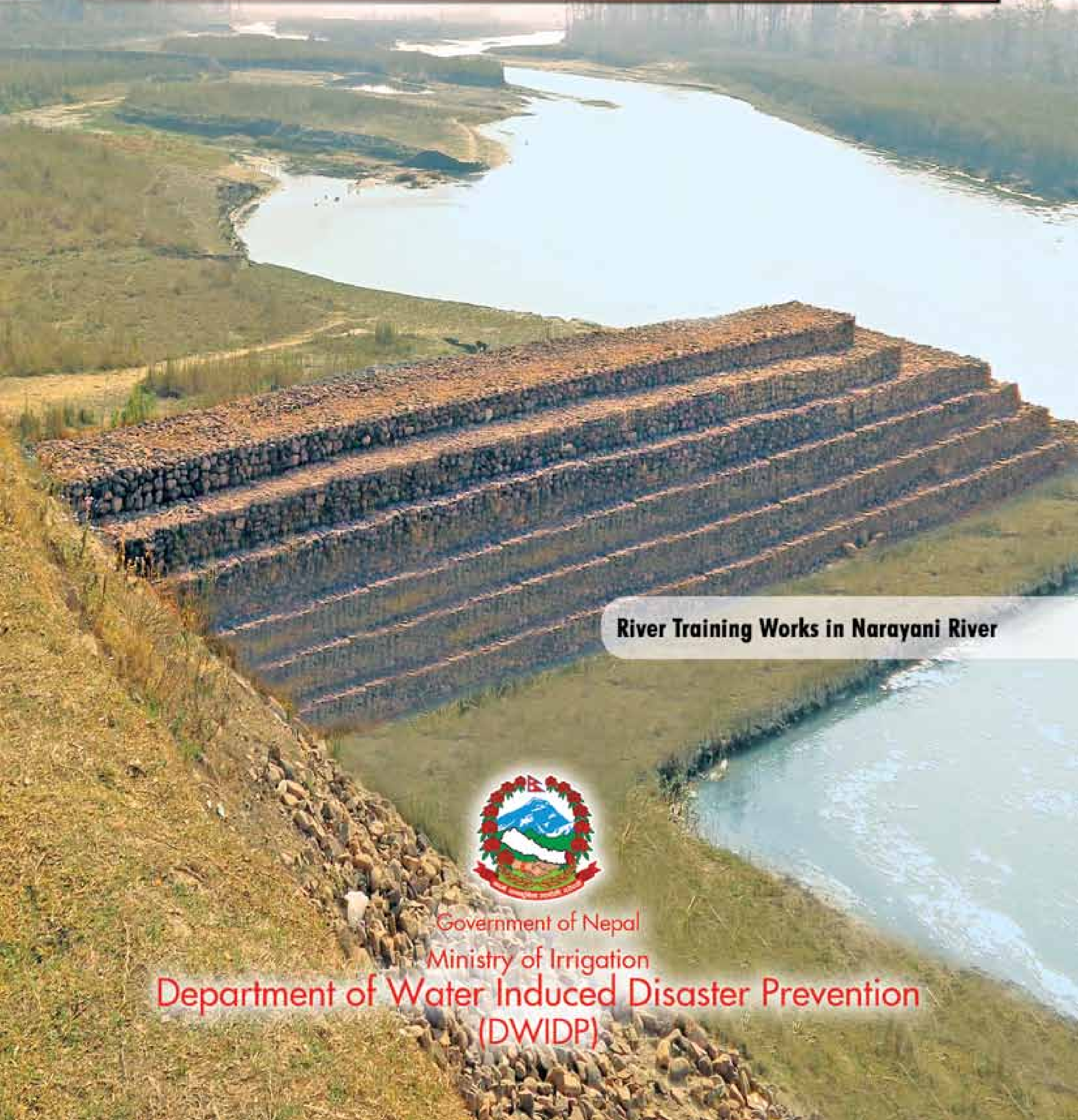
ANNUAL

Disaster Review

July 2015 Series XXII **2014**



River Training Works in Narayani River

Government of Nepal
Ministry of Irrigation
Department of Water Induced Disaster Prevention
(DWIDP)

Inauguration of Karnali River Training Project

Participants of 25th General Course
Training (GCT) : Field Visit

Public Awareness Program

Public Awareness Program: Group Work

25th GCT: Closing Remarks by Director General

DISASTER REVIEW 2014

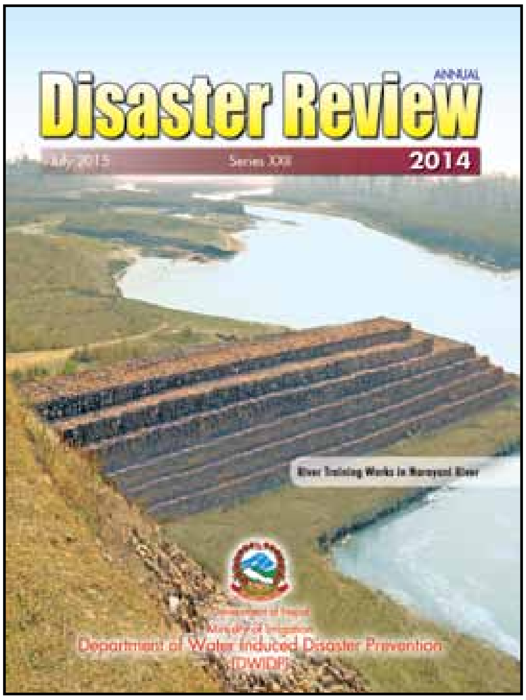
July 2015 **Series XXII** **Annual**

Published by

Government of Nepal
Ministry of Irrigation
Department of Water Induced Disaster Prevention
(DWIDP)

DISASTER REVIEW 2014

July 2015 Annual Series XXII



Photographs of Cover Picture
River Training Works in
Narayani River

CONTENTS

Layout Design : Regmi Printing Press

EDITORIAL

The unstable geo-physical feature of the Himalayas and socio cultural dimension of the region makes its people highly vulnerable to natural hazards. Climate-induced natural hazards (e.g., landslides, floods, glacial lake outburst floods, droughts, earthquakes, and epidemics) hold back socioeconomic development in the region and hamper progress in poverty reduction. Environmental and climate change is expected to lead to an increase in the frequency and intensity of natural hazards.

Time and again when ever major emergency does occur affecting several numbers of locations similar to the recent major worst earthquake events; it is observed that people suffered heavy setbacks at number of sectors at same time. The devastating earthquake disaster on April 25 and May 12, 2015 followed by the aftershocks was unpredictable and out of imagination for most common people. There used to be unavoidable destruction of infrastructures and loss of life and private assets as well in any part of the world more or less due to any such disasters depending on awareness of people, early warning communication, and preparedness to escape from accidents or follow safety methods and supply of life saving relief service and materials, etc. However it is important to learn from lessons of disaster management in many developed countries which are also well known for best welfare states and good governance; the better there are early preparedness for disaster the lesser people suffered and sooner they recovered to normal life. It is prime responsibility of a common welfare state to ensure safety of lives and valuable properties, natural resources and ensure easy access to protection from disasters and prevent as far as possible if not possible minimize vulnerable situations by all feasible measures and managing particular resources and appropriate technology. The government of Nepal has also declared similar provisions in its constitution and established a system of disaster management authority from centre to local government levels to address all kind of disaster.

The devastating consequences and situations created by major earth shocks of April 25 and May 12 and its aftershocks are not only due to natural causes but also to poor disaster management capacity of the state. And naturally, it has alarmed the people and government urgently so that adequate attention and efforts of the entire nation are concentrated on how best to deal with the devastation and repair the damage and rebuild infrastructures on the debris of the earthquake. But at the same time, there looms even larger today than in the past years, after the earthquake and its aftershocks – the earthquake exacerbated-water induced disaster (earthquake-water induced disaster). The real and potent danger of avalanches in the Himalayan region, mud flow, debris flow trigger by landslides in hilly region and inundation and river bank erosions in the terai region will take a heavy toll of life and property in several parts of the country. The earthquake has weakened the layers of earth and even developed fissure in the earth crust, this has already observed in about three thousand dry landslides, which were rare occurrences but turned regular disaster events and clear indications of larger worse events to come when the monsoon rains start, with no letup. The blockage of the Kaligandaki River for about 16 hours from debris of the earth and boulders due to such dry landslide, creating a lake and endangering settlements coming in its sweep and the past landslides like Jure in Sindhupalchowk are just two of the more prominent examples. Landslides and floods cannot be fully prevented, but their devastation effects can certainly be reduced by short-term, medium-term and long-term mitigation programs if implemented effectively.

Landslides and floods are common occurrences due to unstable geology, monsoon rain and unplanned land utilization in Nepal. Annually hundreds of people are buried or swept away alive in and many more people are rendered homeless and poorer. This year too, while the monsoon is at hand, the level of vigilance and timely measures for early warning and shifting the settlements are urgently needed. It is sure that the danger from landslides and floods in this monsoon season will be higher than in the past.

The government should move to install early warning systems of landslides and floods so that the toll of human life and animals and displacement of people could be significantly reduced. To cope with the forth coming landslides and floods during the monsoon season necessary preparation is needed and the concerned agencies should be fully prepared as well as equipped with all the immediate response materials and funds.

The recent devastation scenario after the earthquake has exposed the hollowness of high-sounding political slogans and stressed the need for well-motivated effective action in order to do something really better for the people and the country. Nepal is a country enduring with random recurrent floods and landslides happening every year. Therefore, effective and continuous programs aimed at controlling floods and landslides should receive high priority. The focus on only post-disaster response is no longer adequate or effective in dealing with disasters. A paradigm shift is necessary from response to prevention, preparedness, and mitigation of disasters.

- The Editorial Board

DWIDP Concerns: Water Induced Disaster Prevention

Background

Nepal suffers from different types of water induced disasters such as soil erosion, landslides, debris flow, flood, bank cutting etc. due to its rugged topography, weak geological formations, active seismic conditions, occasional glacier lake outburst floods and concentrated monsoon rains associated with unscientific land utilizations. These phenomena induce sever impacts on the vital infrastructures of the nation such as roads, hydropower, irrigation and drinking water facilities causing loss of agricultural lands, properties and human lives posing a severe threat to the sustainable development of the country. In order to mitigate these disasters in Nepal, Water Induced Disaster Prevention Technical Centre (DPTC) was established under the then Ministry of Water Resources as per the agreement between the Government of Nepal and the Government of Japan on 7th october1991. The programs of DPTC were continued for seven and half years with the technical co-operation/assistance from Japan International Co-operation Agency (JICA). To institutionalize the objectives and achievements of DPTC, the Department of Water Induced Disaster Prevention (DWIDP) was established on 7th February 2000 under the then Ministry of Water Resources along with seven Division and five Sub-division offices to mitigate water induced disasters throughout the country. The department is a focal agency for all water induced disaster mitigation works. To facilitate the activities of water induced disaster management and mitigation in the country River Training Division of the Department of Irrigation has been transferred to this department in 2002.

Guidelines for addressing the issues on water induced disaster mitigations have been adopted from the Water Resources Strategy-2002 and National Water Plan-2005, the government's main documents which have laid out the short, medium and long term strategies, plans, activities and resources for mitigation and management of Water Induced disasters. These documents have given DWIDP the leading role to implement the mitigation and risk reduction measures and coordinate with other related agencies. Based on the strategic visions, Water Induced Disaster Management Policy-2006 has been formulated with policy provisions: 1. To mitigate water induced disasters and reduce loss of lives and properties, 2. To enhance institutional strengthening of DWIDP and 3. To establish network with the associated institutions and agencies to cope with potential disasters.

Water Resources Strategy-2002 (WRS-2002) has defined ten strategic outputs to contribute the overall national goal as "living conditions of Nepalese people are significantly improved in a sustainable manner" by achieving short term, medium term, and long term purposes. "Effective measures to manage and mitigate water induced disasters are functional"- is one of those ten outputs, concerned of DWIDP.

TheWRS-2002 also identified the indicators (specific targets and dates) that can be used to achieve the above strategic output related to disaster as follows.

Water Induced Disaster Targets:

- By 2007, potential disaster zones are identified by type and are located on district maps,
- By 2007, emergency relief materials are available in all five regions.
- By 2017, infrastructures for mitigating predictable disaster are put into place in twenty districts.
- By 2017, warning systems are established and functioning, encompassing the country and
- By 2027, social and economic losses reduced to the levels experienced in other developed countries.

WRS-2002 puts forward the following activities to carry out the strategy to achieve the targets:

- Prepare and implement water- induced disaster management policy and plan.
- Conduct risk/vulnerability mapping and zoning.
- Strengthen the disaster network and information system.
- Carry out community awareness/education on disaster management.
- Activate inundation committee(s) with respect to neighboring countries.
- Prepare and implement flood plain action plans
- Prepare and implement landslide mitigation action plans.
- Implement disaster reduction/mitigation measures
- Strengthen institutional set-up and capacity

Prepare and implement water induced disaster management policy and plan

So far government of Nepal has already approved and enforced Water Induced Disaster Management Policy 2006 to carry out water induced disaster management activities with five- points objectives. The policy covers up 3-points for "Emergency Operation" 4-points for "Reduction of Water Induced Disasters" 5-points for "Conservation of Natural resources" 6-points for "Use of River Bank and Flood Affected Areas" and 3-points for "Institutional Provision and Development". Risks should be identified and priorities be set for different areas and for areas at similar levels of risks. Additional considerations during development of management plan should include a full range of protection and mitigation options, such as structural and non-structural protection works and use restrictions and warning systems. It should be noted that different areas may require different types of emergency preparedness and response.

DWIDP has been designated as the lead agency to coordinate the various key stakeholders related to water induced disaster including Ministry of Home Affairs (MoHA), Department of Hydrology and Meteorology (DHM), Department of Irrigation (DoI), Department of Soil Conservation and Watershed Management (DSCWM). A directive of necessary technical standards relating to river training and reclaim/development work for both private and public sectors as mentioned in the policy need to be prepared and enact as early as possible.

Conduct Risk/ Vulnerability Mapping and Zoning.

Water induced disasters include landslides, slope failures, debris flow, floods, inundation, GLOF and epidemics of water borne disease. The first step in preparedness for future disaster is to analyze the disaster mechanisms and evaluate the risk. DWIDP, in conjunction with other departments, is preparing flood and landslide risk maps for all high priority areas and define and enforce land use restrictions to prevent increasing risk due to inappropriate use of landslides and flood zones. Floods are possible in all river catchments but the danger to property and human welfare varies greatly from the mountain, valleys to the terai. Some rivers are associated with additional risk due to the potential for glacial lake outburst floods. Although, significant progress has already been made towards in an inventory of existing GLOF's, other areas at potential risk have not been inventoried. Flood risk evaluation should be centered on an assessment of potential damage and danger. Very little works so far has been done in flood risk maps and an inventory identifying the locations at risks. Landslides are often triggered by soil erosion, earthquake or saturation of ground during rainstorms and in turn can cause flooding and mud flow into lakes and rivers. Based on field investigations, very little work on preparing inventories of potentially dangerous landslides have been done, so far. DWIDP has already commenced significant studies on landslides. In each category of disaster, the locations identified in the inventories will be ranked in order of importance. The basis for setting priorities in ranking includes:

- Magnitude of the risk, consequences, expected level of mitigation or disaster reduction
- Potential for injury or loss of life, economic value of lost property or infrastructure.
- Feasibility of the alternative actions and cost of the actions.
- Loss of cultural resources, potential environment impacts, extent of disruption to transportation

Strengthen disaster Networking and Information System

The information will be disseminated to relevant agencies, local authorities and communities so that they are aware of the risks and prepare for action in the most serious high-risk areas, decisions will be made regarding necessary action.

Although as mentioned in the policy, as a lead agency DWIDP is lagging behind to carry out activities for the management, total information system, early warning system, determination of jurisdiction of control of local body as per the size and type of river, procedure of issuing license for reclaimed land etc.

Establish Disaster Relief and Rehabilitation System

DWIDP, in collaboration with MoHA, Nepal Red Cross Society, local government and non-governmental organizations, will prepare and implement a disaster relief plan for each priority area. These plans will include:

- Preparations for emergency response, rescue and relief,
- Procurement and storage of relief supplies,
- Planning for emergency shelter and feeding of victims and
- Provision for disaster response rehearsals and drills.

Carryout Community Awareness/ Education on Disaster Management

In parallel with the disaster relief/rehabilitation system, local authorities with guidance and technical assistance from DWIDP and other agencies will carry out a community awareness and education campaign. This will be linked with the disaster networking and information system.

Activate Inundation committees with respect to Neighboring Countries

Inundation caused by barrages constructed by India just downstream of Nepal represents a special and unique area of concern. Despite the ongoing nature of these concerns, the existing committees under the jurisdiction of Ministry of Irrigation (MoI), have not been effective in resolving outstanding problems. They will be strengthened and activated and will receive support to facilitate bilateral dialogue and actions. DWIDP is acting as the lead agency under MoI to carry out this work.

Prepare and Implement Flood plain Management Plans

As mentioned in this activity, during the first year of strategy implementation, efforts will focus on identifying and prioritizing high-risk areas and developing disaster management plans. In the medium term, efforts will be turned to better ways of managing the flood plains in harmony with nature. In certain river reaches where the flood plain could be developed for seasonal agricultural use, these management measures will be implemented at the community level. Adequate regularly compliance will be kept in place for the agricultural use in such flood plains, Other actions could include fisheries enhancement, recreation or aggregate extraction. In this manner, natural flooding and erosion and deposition processes could be turned into economic opportunities rather than disasters.

Implementation Disaster Reduction / Mitigation Measures

A number of studies of potential flood reduction/mitigation measures have been conducted, particularly those capable of reducing flood damages from rivers as they enter the Terai. These studies have indicated that structures are expensive and may have limited impact in the event of serious floods. None of the less, there are some areas where a significant number of people face annual flood risk and relocation is out of the question. In these critical areas, some selected civil engineering and or bio-engineering actions will be identified and studied to determine their technical, environmental and economic viability. Only economically viable schemes will be considered for implementation.

Strengthen Institutional Set-up and Capacity

Water induced disaster present regular threats to many people. However, at present there seems no coordinating agency to reduce these risks or mitigate damages. In order to put on effective disaster warning and prevention system in place, the relevant institutions must be strengthened and coordinated. The following changes are proposed to be carried out as early as possible.

- DWIDP is designated as a lead coordinating agency, its mandate and authority broadened to facilitate its planning and coordination role and adequate staff and budget need to be provided to carry out these activities,
- DHM is to be provided with the mandate and resources to be the lead agency for implementing and managing a flood warning system,
- DoI's responsibility for border inundation problems is to be transferred to DWIDP, and
- MoHA is to be provided specific resources for planning and implementing disaster relief/rehabilitation measures.

Goal of DWIDP

The main goal of DWIDP is to minimize human causalities and damages of infrastructures caused by water induced disasters by conducting appropriate water induced disaster management and mitigation works.

Objective of DWIDP

To implement the programs of river and river basins conservation, to develop related appropriate technologies, research, information systems, human resource and institutional development activities and to raise awareness of communities so as to mitigate water induced disasters.

Different Programs and Projects under DWIDP

1. River Training Program (Nadi Niyantran Karyakram)

This program has been initiated to cope with water induced disaster and probable short and long term remedies in mitigation measures focusing on river training works. Under this program the following activities are carried out:

i. Study based Disaster prevention (Adhyayan gari Garine Nadi Niyantran Karyaharu)

For the continuation of the ongoing projects that have already been studied, budget is being allocated continually. These works are being conducted by the division and sub-division offices throughout the country.

ii. People's embankment Programm (Janatako Tatabandha Karyakram)

Government of Nepal has realized the importance of river training works in terai region in order to reduce the flood and inundation problems in low lying areas. Since the fiscal year 2066/2067 a new river training program known as "Janata Ko Tatabandha" has been commenced. Janata Ko Tatabandha Karyakram has the following specific objectives:

- Land reclamation in the flood plain.
- Employment generation during project period.
- Reduction of loss of life and property from water induced disasters.

This program targeted to implement phase wise in accordance with the master plan prepared for the particular river basins. Engineering structures with the bio-engineering applications are being used in order to provide sustainable and effective combination as potential counter measures. Concerned people in this program are expected to participate with great enthusiasm. Janata Ko Tattabandha is the river training project based on people's participation. Now under this program 15 big rivers are incorporated for implementation. They are Kankai and Biring Rivers in Jhapa District, Ratuwa-Mawa River in Jhapa-Morang District, Rato River in Mahottari District, Aurahi and Jalad Rrivers in Dhanusa District, Lakhandehi and Jhim Rivers in Sarlahi District, East Rapti River in Makawanpur and Chitawan Districts, Narayani River in Chitawan and Nawalparasi Districts, Danav-Tinau Rrivers in Rupandehi District, West Rapti

River in Dang and Banke Districts, Mohana River in Kailali and Kanchanpur Districts, and Dodha and Mahakali Rivers in Kanchanpur District. By the end of the fiscal year 070/71 in total about 141 km embankment has already been constructed.

iii. River Training Project: Central Level (Nadi Niyantran yojana, Kendra)

Small as well as medium rivers have equally played a vital role for bank erosion, slope failure and inundation throughout the country. To manage and mitigate these disasters the department has planned to develop appropriate river training technology by developing some river training model sites; and establishing and conduction of material testing laboratory through this program.

iv. Master Plan based Disaster Prevention Works (Kramagat Guru yojanamaharu)

Master plan for various smaller and bigger rivers is prepared by the Division and sub-division offices throughout the country to carry out disaster prevention work systematically. At present such works are continued in the rivers- Biring, Koshi, Bakraha, Triyuga and others.

v. Institutional Infrastructure Development Program (Sanstagat Purbadhar Bikas Karyakram)

Under this program the activities such as Institutional strengthening, capacity enhancement of office personnel, study and preparation of DPR for master plan preparation of the major rivers, inundation meeting etc. are being planned to implement.

vi. Mahakali River Training Project: Drachula (Mahakali Nadi Niyantran yojana: Drachula)

A major flood had occurred in Mahakali River in the monsoon of 2070. It damaged public as well private infrastructures, agricultural land and properties in the headquarters of Drachula and the surroundings. To address and mitigate the problems, Mahakali river training project has been carried out for the implementation of emergency and rehabilitation river training works there from the last fiscal year.

vii. Kanchanpur District River training program (Kanchanpur Jilla Nadiniyantran Karya)

Intensive monsoon rainfall of 2070 generated a big flood in different torrents and rivers of Kanchanpur and adjacent districts of far Western Development Region of the country. It damages lives and properties tremendously. On the recommendation of National Disaster Relief committee the program is implemented from the fiscal year 2071/072 in 16 tributaries and rivers of the district

viii. Hill and high Mountain River Training Programm (Pahadi Tatha Uccha pahadi Nadi Niyantran Karyakram)

In order to manage and mitigate river cutting, scouring, flooding and related disasters resulting from medium size rivers of hills and mountains an embankment construction program is being implemented in seven rivers from this fiscal year2071/072. These rivers are Rawa khola of Khotang, Triyuga River of Saptari and Udayapur, Andhi Khola of Syanja, Jhimaruk Khola of Pyuthan, Bheri River of Surkhet, Rangun River of Dadeldhura and Seti River of Doti. The program will also be continued in the forth coming fiscal years accordingly in other hilly rivers.

ix Emergency Rehabilitation Program (Aapatkalin Punarsthapana Karya)

Flood and landslide disasters are recurring phenomena in mountainous country like Nepal where more than 80% rainfall occurs in monsoon period. It is urgent to consider and prepare to address the suddenly triggering landslides and floods in different areas. For emergency measures, procurement and storage of necessary construction materials such as nylon rope, gabion wires etc. for emergency river training and landslide protection and management works for various districts is planned to carriy out under this program.

x. Karnali River Training Project: Bardiya (Karnali Nadi Niyantran Ayojana)

A major flood had occurred in Karnali River basin and adjacent areas by the incessant monsoon rain fall of 2070. It damaged Karnali river banks, infrastructures, agricultural land and properties in Bardiya and nearby areas. To address and mitigate the problems, Karnali River Training project has been carried out for the implementation of emergency and rehabilitation river training works there from the fiscal year 2071/072.

2. Disaster Mitigation Support program (DMSP)

Under this Program the following water induced disaster mitigation and management programs are conducted.

i. Disaster Mitigation Support Program (DMSP)

DMSP is a model program for comprehensive sediment management. The major concerns relating the program are:

- Education and public awareness campaign
- Development of appropriate and cost effective technology
- People's participation in disaster mitigation
- Preparation of water induced hazard maps.
- Institutional development
- Survey and loss estimation
- Emergency rehabilitation-model site development.
- Development of information technology and its dissemination
- Organizing seminars and trainings
- Preparation and amendment of policies and regulations

In order to implement above state themes, local and improved technologies is to be adopted in such a way that it is less expensive and it supports to resolve the problems like landslide, soil erosion, debris flow and sedimentation. Recently, Lothar khola watershed in Chitwan and Makawanpur districts, Kerunge Khola watershed in Nawalparasi district, and Bhotekoshi (Langkhola) watershed in Sindhupalchowk district have been selected for developing model sites. Moreover, various training and seminars are being conducted to raise people's awareness about the consequences of water induced disasters, Preparation of hazard maps, landslide control works and settlement protection measures etc. have been carried out under the DMSP program.

The DMSP is also being involved in the protection of existing infrastructure like transportation, hydroelectricity plant etc. of the country. In this regard, regular maintenance programs along Muglin-Narayanghat road section and Sindhuli-Bardibas road section are being carried out in order to reduce debris flow and landslides that cause harm to human life and property. For sustainability of water induced disaster mitigation and control measures along these road sections and smooth flow of traffic the department has made a policy to allocate sufficient budget for regular maintenance.

ii. Landslide management Work (Pahiro Byabasthapan Karya)

About 83% of Nepal is covered by the hills and mountains so the country is prone to landslide, slope failure and debris flow. These landslides and debris flows are activated due to natural phenomena or due to human factors. If these landslides are not addressed in time it will have adverse effect in the flat land of Terai. So, the department and its division and sub-division offices have focused and allocated budget regularly for managing and controlling these landslides every year. In this fiscal year 2071/072 the department has also made a plan to address and manage 315 nos. of landslides of 58 districts of the country through division and sub division offices.

3. Indian Support River Training Program (Bharatiya Anudanma Sanchalit Nadi Niyantran Karyakram)

The big to small sized rivers that flow the terai to India occurring flood and inundation problems during monsoon season are considered major disasters- destroying human life and property. Embankments have been constructed in some of the river based on an agreement and understanding between Nepal and India. Joint Committee of Inundation and Flood Management (JCIFM) plays an important role to initiate the program in particular river. JCIFM is being steered by a high level team from DWIDP (Nepal) and Ganga Flood Control Commission (India) and along with the representatives from Ministry of Finance and Ministry of Foreign Affairs from both the countries. Ongoing River Training Projects supported by Indian sites are Sunsari, Gagan, Kamala, Lalbakaiya, Bagmati and Banganga. By the end of the fiscal year the total length of the embankment constructed in the above rivers is about 169 km. For the fiscal year 2071/072 additional 5 km embankment construction work in these rivers is proposed.

4. River Terrace, Settlement/Bazaar Protection Program (Basti, Tar Bazar samrakshan Karyakram)

This program is focused to implement in hills and mountains where there lies tars and Bazaars vulnerable to floods, landslide and debris flow. This program is being implemented by the division and sub-division offices.

Under this program an objective is scheduled to protect and manage the various terraces and settlements of Indrawati river corridoor, vulnerable district headquarters such as Chainpur of Bajhang, Beni of Myagdi, Diktel of Khotang,Dunai of Dolpa and Bhadrapur of Jhapa, from the potential threats of natural disasters such as landslides, slope failure, debris flow and floods . Besides, a plan to protect the potential threat of land subsidence at Armala of Kaski and inundation and flooding at Susta of Nawalparasi have also been included for the fiscal year 2071/072.

5. President Chure-Terai Madhesh Conservation Program (Rastrapati Chure Tarai Madhesh Samrakshan Karyakram)

This program is carried out from this fiscal year by the department in order to protect and conserve Chure Range from commonly occurring natural disasters such as soil erosion, landslides, slope failure debris flow and floods for enhancing livelihood of local communities and economic improvement of the country as a whole.

In this fiscal year river training and basin protection works are being carried out by division offices in those rivers originating from Chure Range for mitigating and management of the soil erosion and flooding problem.

Water Induced Disaster Management policy and DWIDP

i. Water Induced Disaster Management Policy 2062

Government of Nepal has approved" Water induced disaster management policy 2062" on 15 Chaitra 2062. In this policy the following subjects are highlighted.

- Emergency protection
- Water Induced Disaster Mitigation
- Natural resources conservation
- Utilization of flood plains
- Institutional management and development

ii. Organization of DWIDP

To cope with the changes in the development activities, address the demands of the nation on water induced disaster mitigation works, adaptation of innovative and appropriate technologies, the existing organization structure of DWIDP and its division and sub-division offices have been restructured. The new organization has been structured with four major divisions and 18 sections at the centre, 24 division and 2 sub-division offices at district level. But yet there has been no change in the number of field offices at the district/ project level. The restructured organization setup may overcome the short comings of the previous one and will boost the activities of the department and division offices for better institutional development and efficient and effective delivery of its services throughout the country.

S.N.	Class	Post	Department		Division	Sub-Division	Total
			Pool	Regular			
1	Gazetted I	Director General	0	1			1
		Deputy D G (Irr.)	0	2			2
		Deputy DG (Agr.)	0	1			1
		Deputy DG(Hydro.)	0	1			1
		Superintendent Er. (Irr.)	2	0			2
2	Gazetted II	SDE (Irr.)	12	9	24		45
		SDE (Agr.)	1	2			3
		SDHG (Hydro.)	0	2			2
		SDEG (Eng.)	0	1			1
		SDE (Mech.)	0	1			1
		Under Secretary (Admin)	0	1			1
		Under Secretary (Acc.)	0	1			1
3	Gazetted III	Engineer (Irr.)	40	14	81	2	137
		Engineer (Agr.)	3	4	7		14
		Hydr.Geologist (Hydro.)		2	3		5
		Eng. Geologist (Eng.)	1	3	6		10
		Engineer (Mech.)	0	1			1
		Engineer (Building)	0	1			1
		Engineer (Hydrology)	1	1			2
		Sociologist		1			1
		Env. Inspector		1			1
		Section Officer		1	3		4
		Account Officer		1	6		7
		Legal officer		1			1
4	Non-Gazetted I	Sub-Engineer (Irr.)	12	3	73	2	90
		Sub- Engineer (Mech.)		1	5		6
		Lab Assistant		1			1
		Nasu (Admin.)	0	10	7		17
		Lekhapal(Acc.)	0	1	15		16
		Senior A.O.			2		2
		Computer operator		2	24		26
		Typest Nasu		1			1
5	Non Gazetted II	A.O.			22		22
		Karidar (Admin.)		1	17		18
		Saha-Lekhapal (Acc)				2	2
		Librarian		1			1
6	Non classified	Driver		6	24		30
		Office Helper	0	7	48	2	57
	Total		72	87	367	8	534

iii. Physical Facilities of DWIDP

1. Central Office at Pulchowk
2. Hydraulic Laboratory at Godawari, having the following facilities.
    - River simulation model facility.
    - Debris flow simulation model facility
    - Soil testing facility
    - Concrete testing facility.
3. Heavy Equipment workshop at Baneshwor
4. Seven Division offices, five sub-division offices and four unit offices at different districts all over the country.
5. Gabion net weaving machines in Biratnagar,parwanipur, pokhara, Nepalgunj and Dhangadi.

Loss of lives by different Types of Disasters in Nepal

The recorded total loss of lives by different types of disasters from 1983 up to 2014 is 24223 (table 1). It is observed that the calamities such as flood, landslide, epidemic, fire and thunderbolt are recurring every year rather than others in the country. Among the disasters, epidemic claimed the highest loss of lives of 11519 (47.55%), which is followed by the flood and landslide within 32 years from 1983 to 2014. The table 1 also shows that 8642(35.68%) people were lost their lives by flood and landslide in 32 years from 1983 to 2014. The death rate per year by the flood and landslide in average is 270 in 32 years. These figures seem alarming. It may be due to lower awareness of people, increasing trend of calamities or lower priority of the government of Nepal in mitigating and management of the floods and landslide disasters in time. In case of epidemic the death rate, to some extent, is declining which indicates that awareness of people and health facilities by the government are improving in the country.

Number of disaster events and their consequences such as loss of lives and properties were collected in 2014(table 2). Fourteen different types of disasters were occurred in 2014. They were flood, landslide, thunderbolt, fire, snow storm, epidemic and others. In total 1354 different disaster events were recorded, among which 958 were related to fire, 178 of thunderbolt, 75 of landslide, 65 of flood, and the rest were related to other types of disasters (table2). The total number of death, missing and injured people by all types of disaster were 518, 291 and 480 respectively in 2014. Similarly 39 812 Nos. of family were affected by the disaster events. The lives claimed by the flood and landslide were 242, which is 46.71 percent of the total number of lives loss of the year. Similarly about 19.11 percent of lives were claimed by thunderbolt. Fire is equally seems sensitive which also claimed 67 numbers of people in the same year. However, in the year 2014, flood and landslide came into the first position in losing of lives which was followed by thunderbolt, fire and snowstorm (table2). The estimated loss of property as recorded was about Nrs.16815.54 million. It is concluded that the main death causing disaster in 2014 were mainly flood, landslide, thunderbolt, fire, and snow storm. The government of Nepal needs to undertake initiation for the mitigation measures to cope these disasters timely in order to save the lives and property of the people.

Table: 1 Loss of Lives by Different Disasters in Nepal (1983-2014)

Type of Disasters	1983-2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Flood &Landslide	5829	196	441	232	131	141	114	216	134	135	240	252	120	219	242	**8642**
Earthquake	726	1	0	0	0	0	0	0	0	0	0	6	1	0	0	**734**
Windstorm, Hailstorm &Thunderbolt	491	38	6	62	10	18	15	40	16	7	70	105	149	149	102	**1278**
Avalanche	98	0	0	0	0	21		6	0	2		0	11	8	13	**159**
Fire	1116	26	11	16	10	28	3	9	11	35	69	46	64	59	67	**1570**
Epidemic	10721	154	0	0	41	34	0	3	10	462	36	9	33	4	12	**11519**
Stampede	71	0		0	0	0			0	0		0			0	**71**
Rainfall	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11	11	5	6	**33**
Boat Capsize	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6	7	7	9	**29**
Bridge Collapse	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	0		0	**2**
Cold Wave	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	72	1	2	0	**75**
Air Crash	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	34	1	18	**53**
Snow Storm	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	35	**35**
Others(High Altitude, Drowning)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	7	14	**23**
Total	**19052**	**415**	**458**	**310**	**192**	**242**	**132**	**274**	**171**	**641**	**415**	**509**	**433**	**461**	**518**	**24223**

Source: MoHA

Table: 2 Loss of life and property by different Disasters in 2014

S.N.	Types of Disasters.	Number of Events	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Estimated Losses(in Rs.)
			Death	Missing	Injured			completely	partly		
1	Aasina Pani	1		0		2608					135,065,000.00
2	Air Crash	1	18	0							
3	Avalanche	2	13	6	7						
4	Boat Capsize	2	9	6							
5	Drowning	20	13	10	1						
6	Epidemic	12	12	0							
7	Fire	958	67	0	98	194	743	1255	172	727	1,712,807,800.00
8	Flood	65	129	133	36	36514	4437	8622	24447	2	14,917,613,938.00
9	Heavy Rainfall	20	6	0	6	0	9	12	4	3	4,377,000.00
10	High Altitude	1	1	0	0	0	0	0	0	0	-
11	Landslide	75	113	129	96	491	69	143	37	14	23,665,979.00
12	Snow Storm	4	35	7	0	0	0	0	0	0	-
13	Thunderbolt	178	99	0	227	5	83	2	4	10	10,446,000.00
14	Wind Storm	15	3	0	9	0	0	0	23	0	11,562,000.00
TOTAL		**1354**	**518**	**291**	**480**	**39812**	**5341**	**10034**	**24687**	**756**	**16,815,537,717.00**

source: Ministry of Home Affairs

Table: 3 (a) Loss of Lives and properties from Water Induced Disaster, Flood and Heavy Rainfall in 2014

S.N.	District	VDC/Municipality &ward No.	Date	Types of Disaster	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Land Loss		Public Property	Estimated Loss(in Rs.)
					Death	Missing	Injured			com.	partly		No.	Unit		
1	Mugu	Shree Kot	25-Oct-14	Hail storm				2608								135065000
2	Udayapur	Katari-2	24-May-14	Flood	2											
3	Kalikot	Bharta-9	4-Jun-14	Flood	1											
4	Bajura	Kolti-1,2	7-Jun-14	Flood	3		1	30		11	120					
5	Dolkha	SappaChhamabati-4	17-Jun-14	Flood												3100000
6	Baitadi	Maharudra-8	18-Jun-14	Flood	1											
7	Mahottari	Loharpatti-9	18-Jun-14	Flood	1											
8	Gulmi	Paudi Amarai-7	19-Jun-14	Flood												150000
9	Bara	Nijgad-6	21-Jun-14	Flood	2											
10	Surkhet	Birendranagar-14	5-Jul-14	Flood		2										
11	Banke	Phattepur-6	7-Jul-14	Flood	1											
12	Dolpa	Dunai-4,5	11-Jul-14	Flood												
13	Chitawan	Bagauda-8	12-Jul-14	Flood	1											
14	Solukhumbu	Gudel-1	14-Jul-14	Flood												10000000
15	Sindhupalchowk	Tatopani-4	18-Jul-14	Flood				7		7						
16	Sindhupalchowk	Tatopani-7	19-Jul-14	Flood												
17	Kanchanpur	Dodhara-8,9	19-Jul-14	Flood	1			25								
18	Dhankuta	Leguwa-7	19-Jul-14	Flood		1										
19	Kanchanpur	Bhimdutta-11,12,13	19-Jul-14	Flood				163								
20	Kanchanpur	Belauri-7	19-Jul-14	Flood				50								
21	Kailali	Ramsikharjhala-2	20-Jul-14	Flood	1											

S.N.	District	VDC/Municipality &ward No.	Date	Types of Disaster	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Land Loss		Public Property	Estimated Loss(in Rs.)
					Death	Missing	Injured			com.	partly		No.	Unit		
22	Doti	Dipayal-6	20-Jul-14	Flood		1										
23	Jajarkot	Funka-3	20-Jul-14	Flood		1										
24	Dailekh	Narayan-7	20-Jul-14	Flood		1										
25	Dadeldhura	Shreesha-7	20-Jul-14	Flood	1				47	21						
26	Kathmandu	Sundarijal-9	21-Jul-14	Flood		1										
27	Rupandehi	Butwal-11	23-Jul-14	Flood	1											
28	Nawalparasi	Dumkibas-2	24-Jul-14	Flood	1											
29	Jajarkot	Dasera-9	26-Jul-14	Flood		2										
30	Rasuwa	Dadagaun-6	27-Jul-14	Flood	1											
31	Kaski	Pokhara-17	29-Jul-14	Flood			1									
32	Accham	Mangalsen-6	29-Jul-14	Flood	1		2									
33	Rasuwa	Rapche-6	29-Jul-14	Flood	1											
34	Kathmandu	Gongabu-29	30-Jul-14	Flood		1										
35	Ramechhap	Gumdel-7,8	1-Aug-14	Flood								2				3100000
36	Dolkha	Marbu-4,5	5-Aug-14	Flood												10000000
37	Morang	Baradagi-8	13-Aug-14	Flood	1											
38	Lalitpur	Bhattedada-3	14-Aug-14	Flood	1											
39	Siraha	Bishnupur-8	14-Aug-14	Flood		1										
40	Udayapur	Triyuga-3	14-Aug-14	Flood	1											
41	Dhanusha	Tulsi-2	14-Aug-14	Flood	1											
42	Rautahat	Dharampur-6,7,8,9	14-Aug-14	Flood				250								
43	Udayapur	Siddipur-4	14-Aug-14	Flood						1						120000
44	Parsa	Buchagai-8	15-Aug-14	Flood						1						90000

S.N.	District	VDC/Municipality &ward No.	Date	Types of Disaster	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Land Loss		Public Property	Estimated Loss(in Rs.)
					Death	Missing	Injured			com.	partly		No.	Unit		
45	Salyan	Phalawang-4	16-Aug-14	Flood	1											
46	Mahottari	Bardiya Banchauri-4	17-Aug-14	Flood							1					150000
47	Sindhuli	Kamalamai-15	21-Aug-14	Flood	2	2										
48	Mahottari	Khuttapiprathi-5	28-Aug-14	Flood						1						158000
49	Mahottari	Khuttapiprathi-5	28-Aug-14	Flood						2						
50	Ramechhap	Pharpu-2	28-Aug-14	Flood	1											
51	Rautahat	Ramaulibauriya-3	25-Sep-14	Flood	1	1										
52	Kathmandu	Kathmandu-4	19-Sep-14	Flood												70000000
53	Dhankuta	Chanuba-2	19-Sep-14	Flood							4					
54	Kathmandu	Kathmandu-15	19-Sep-14	Flood												500000
55	Rukum	Mokhang-2,3	19-Sep-14	Flood	1											
56	Khotang	Chhitapokhari-8	21-Sep-14	Flood												150000
57	Bardiya	Motipur-4	13-Sep-14	Flood		1										
58	Makawanpur	Hetauda-11	29-Sep-14	Flood	1											
59	Accham	Saphaebagar-4	23-Sep-14	Flood	1											
60	Surkhet	Tatopani-3	13-Oct-14	Flood		2										
61	Chitawan	Bagauda-8	14-Oct-14	Flood	1											
62	Arghakhanchi	Chakla-4	14-Oct-14	Flood		1										
63	Surkhet	Different Places	14-Aug-14	Flood	34	91	26	3866	1846	1427	2439					10052850818
64	Bardiya	Different Places	13-Aug-14	Flood	33	15	2	17376	2052	3859	13517					3775405700
65	Banke	Different Places	13-Aug-14	Flood	15	5	2	10763	298	2771	7992					480000000
66	Dang	Different Places	14-Aug-14	Flood	14	4	2	3984	194	521	374					511839420

S.N.	District	VDC/Municipality &ward No.	Date	Types of Disaster	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Land Loss		Public Property	Estimated Loss(in Rs.)
					Death	Missing	Injured			com.	partly		No.	Unit		
67	Dhanusha	Ekarahi-1,5	17-Jun-14	Heavy Rainfall						2						200000
68	Sankhuwasabha	Tamku-8	23-Jun-14	Heavy Rainfall							1					700000
69	Mahottari	Gauribas-2	5-Jul-14	Heavy Rainfall						1						335000
70	Taplejung	Pedang-6	14-Jul-14	Heavy Rainfall						1						300000
71	Baitadi	Udayadev-7	18-Jul-14	Heavy Rainfall	2											
72	Kalikot	Siuna-4	28-Jul-14	Heavy Rainfall	1		1									
73	Nuwakot	Samundratar-3	31-Jul-14	Heavy Rainfall						1						300000
74	Dolkha	Thulopakhar-8	1-Aug-14	Heavy Rainfall			2		2	1						1200000
75	Parsa	Matihani-5	14-Aug-14	Heavy Rainfall						1						200000
76	Makawanpur	Thaha-8	14-Aug-14	Heavy Rainfall			1			3						100000
77	Dang	Satbariya-7	15-Aug-14	Heavy Rainfall	1		1			1						
78	Bara	Chatwa-5	15-Aug-14	Heavy Rainfall						1						120000
79	Rukum	Sayalpakha-1	15-Aug-14	Heavy Rainfall	1											
80	Terathum	Isibu-6	16-Aug-14	Heavy Rainfall							1					250000
81	Dolkha	Jafae-2	16-Aug-14	Heavy Rainfall							1					400000
82	Mahottari	Dharampur-8	16-Aug-14	Heavy Rainfall							1					12000
83	Khotang	Chamatar-5	21-Aug-14	Heavy Rainfall					2			1				
84	Bhojpur	Mulpani-9	25-Aug-14	Heavy Rainfall					3			1				130000
85	Bhojpur	Nepalaedanda-8	26-Aug-14	Heavy Rainfall					2			1				130000
86	Kavrepalanchowk	Panchkhal-16	17-Sep-14	Heavy Rainfall	1		1									
TOTAL					**135**	**133**	**42**	**39122**	**4446**	**8634**	**24451**	**5**	**0**	**0**	**0**	**15057055938**

Source: Ministry of Home Affairs

Table: 3 (b) Loss of Lives and properties from Water Induced Disaster, Landslide in 2014

S.N.	District	VDC/Municipality &ward No.	Date	Types of Disaster	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Land Loss		Public Property	Estimated Loss(in Rs.)
					Death	Missing	Injured			com.	partly		No.	Unit		
1	Doti	Daud-6	9-Apr-14	Landslide	3											
2	Ilam	Bajho-1	22-Apr-14	Landslide	1		2									
3	Dadeldhura	Alital-3	27-May-14	Landslide	1											
4	Pyuthan	Khung-8	19-Jun-14	Landslide	5		1			3		4				12407979
5	Gulmi	Aglung-8	19-Jun-14	Landslide	9					1						
6	Gulmi	Dohali-1	19-Jun-14	Landslide					1	1		1				170000
7	Gulmi	Aglung-8	19-Jun-14	Landslide				1		1						
8	Gulmi	Aglung-2	19-Jun-14	Landslide				1	4	1		1				218000
9	Gulmi	Aglung-4	19-Jun-14	Landslide					3			1				140000
10	Gulmi	Aglung-4	19-Jun-14	Landslide								1				150000
11	Gulmi	Aglung-2	19-Jun-14	Landslide								1				70000
12	Gulmi	Aglung-6	19-Jun-14	Landslide						1						195000
13	Pyuthan	Puja-2	20-Jun-14	Landslide				1		1						
14	Lalitpur	Gimdi-2	22-Jun-14	Landslide	1		6									
15	Taplejung	Tapethok-3	24-Jun-14	Landslide					8	1						467000
16	Sankhuwasabha	Num-4	29-Jun-14	Landslide							1					700000
17	Tanahu	Shuklagandaki-12	30-Jun-14	Landslide	1											
18	Kapilbastu	Shivaraj-1	9-Jul-14	Landslide	1											
19	Nuwakot	Gaukharka-2	12-Jul-14	Landslide					4	1						
20	Lalitpur	Lele-4	13-Jul-14	Landslide	4		3									
21	Sindhupalchowk	Chautara-1	13-Jul-14	Landslide	3		4			1						1000000
22	Sindhupalchowk	Bhotsipa-4	13-Jul-14	Landslide	1					1						600000
23	Sindhupalchowk	Dhuskun-2	13-Jul-14	Landslide	2					1						500000
24	Kalikot	Kalika Mugraha-1	16-Jul-14	Landslide	1											
25	Kaski	Lumle-9	18-Jul-14	Landslide				7	5			1				
26	Dadeldhura	Shreesha-5	19-Jul-14	Landslide	1											
27	Lamjung	Karapu-1	20-Jul-14	Landslide	1		2									
28	Kalikot	Manma-5	20-Jul-14	Landslide	1											
29	Gorkha	Ashrang-8	22-Jul-14	Landslide					14			1				
30	Kalikot	Daha-6	28-Jul-14	Landslide	1		1									

S.N.	District	VDC/Municipality &ward No.	Date	Types of Disaster	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Land Loss		Public Property	Estimated Loss(in Rs.)
					Death	Missing	Injured			com.	partly		No.	Unit		
31	Bajhang	Rilu-2	29-Jul-14	Landslide		1			4							
32	Taplejung	Taplejung-4	29-Jul-14	Landslide						1						
33	Okhaldhunga	Tarkerabari-8	29-Jul-14	Landslide						1						1500000
34	Rolpa	Ghartigaun-2	31-Jul-14	Landslide						1						500000
35	Sindhupalchowk	Mankha-1	2-Aug-14	Landslide	33	123	47	478		97	19					
36	Kalikot	Malkot-6	2-Aug-14	Landslide	1											
37	Sankhuwasabha	Sabun-3	4-Aug-14	Landslide	8	2		3		3						
38	Kavrepalanchowk	Nagregagarche-8	4-Aug-14	Landslide						10						2000000
39	Bajura	Martadi-3	5-Aug-14	Landslide			1				1					
40	Sindhupalchowk	Baskharka-3	8-Aug-14	Landslide	2					1						
41	Mugu	Mugu-9	8-Aug-14	Landslide					5							700000
42	Dolkha	Jiri-7	9-Aug-14	Landslide	4		8									
43	Jajarkot	Sakla-3	13-Aug-14	Landslide	2		3			1						
44	Jajarkot	Ramidada-9	13-Aug-14	Landslide		2	4									
45	Khotang	Phedi-5	13-Aug-14	Landslide	1											
46	Jajarkot	Ramidada-9	14-Aug-14	Landslide							5					
47	Jajarkot	Rokayagau-8	14-Aug-14	Landslide							4					
48	Jajarkot	Rokayagau-7	14-Aug-14	Landslide							2					
49	Jajarkot	Ramidada-3	14-Aug-14	Landslide					4	1		1				
50	Jajarkot	Ramidada-5	14-Aug-14	Landslide						2						
51	Jajarkot	Ramidada-5	14-Aug-14	Landslide						1						
52	Lalitpur	Chandanpur-2	14-Aug-14	Landslide	2											
53	Khotang	Jalpa-4	14-Aug-14	Landslide			1			1						286000
54	Rukum	Chunabang-8	14-Aug-14	Landslide	2		2			1						
55	Humla	Shreenagar-5	15-Aug-14	Landslide					10							
56	Gorkha	Phinam-6	15-Aug-14	Landslide	3		8									
57	Dang	Purandhara-9	15-Aug-14	Landslide	2											
58	Rolpa	Ranka-2	15-Aug-14	Landslide	2					1						
59	Salyan	Kalimati Rampur-2	15-Aug-14	Landslide	3					1						
60	Nuwakot	Mahakali-3	16-Aug-14	Landslide							1					152000
61	Nuwakot	Mahakali-5	16-Aug-14	Landslide							1					150000
62	Baglung	Adhikari Chaur-4	23-Aug-14	Landslide	1							1				

S.N.	District	VDC/Municipality &ward No.	Date	Types of Disaster	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Land Loss		Public Property	Estimated Loss(in Rs.)
					Death	Missing	Injured			com.	partly		No.	Unit		
63	Sindhupalchowk	Thulosirubari-4	23-Aug-14	Landslide	1					1						
64	Baglung	Hugdisir-3	24-Aug-14	Landslide	1					1						
65	Rasuwa	Dandagau-7	26-Aug-14	Landslide			3									150000
66	Nuwakot	Belkot-1	28-Aug-14	Landslide	3					1						
67	Nuwakot	Sunkhani-5	28-Aug-14	Landslide						1						200000
68	Rolpa	Jugar-5	16-Sep-14	Landslide	3					1						
69	Nuwakot	Madanpur-9	10-Sep-14	Landslide												500000
70	Nuwakot	Madanpur-9	10-Sep-14	Landslide						1						150000
71	Bardiya	Gulariya-23	22-Sep-14	Landslide	1											
72	Kaski	Hemja-6	19-Sep-14	Landslide							2					
73	Baglung	Jaljala-7	19-Sep-14	Landslide	1											
74	Bhojpur	Tungechha-3	14-Sep-14	Landslide					7		1	1				760000
75	Lamjung	Ilampokhari-6	23-Sep-14	Landslide		1										
Total					**113**	**129**	**96**	**491**	**69**	**143**	**37**	**14**	**0**	**0**	**0**	**23665979**

Source: Ministry of Home Affairs

Table: 3 (c) Loss of Lives and properties from Water Induced Disaster, Avalanche and Snow Storm in 2014

S.N.	District	VDC/Municipality &ward No.	Date	Types of Disaster	People			Affected family	Animal Loss	House Destroyed		Shed destroyed	Land Loss		Public Property	Estimated Loss(in Rs.)
					Death	Missing	Injured			com.	partly		No.	Unit		
1	Solukhumbu	Sagarmatha Base Camp	18-Apr-14	Avalanche	13	3	7									
2	Taplejung	Yamphudin	20-May-14	Avalanche		3										
3	Manang	Nar-4	14-Oct-14	Snow Storm	3											
4	Mustang	Treeking Route	14-Sep-14	Snow Storm	24											
5	Manang	Treeking Route	14-Sep-14	Snow Storm	3	7										
6	Myagdi	Treeking Route	14-Sep-14	Snow Storm	5											
TOTAL					**48**	**13**	**7**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Source: Ministry of Home Affairs

Comparative Disaster Scenario of Nepal Since 1983 to 2014

Our country is facing the problem of recurrent different natural disasters including water induced disasters like flood, landslide, avalanche which are vulnerable to human lives, livestock, agricultural land, public and private infrastructures and environment disrupting the socio-economic condition of the country. The table 4 and the bar diagrams show the occurrence and nature of year-wise disasters and their affect on human casualties, affected families, animal loss and houses destroyed and estimated economic losses in 32 years since 1983 to 2014. The total human deaths and injured caused by all kinds of disasters were 24223 and 24635 respectively (Table 4). Besides, 469770 houses were partially and completely damaged in 32 years. It is found that 19052 people were lost their life in first 18 years from 1983 and 5171 people were lost in 14 years from 2001 to 2014. Similarly water induced disasters like landslides and flood only claim 5829 human lives in the first 18 years from 1983 and the rest 2813 people in last 14 years up to 2014. This informed that the trend of loss of lives by water induced disasters is declining to some extent. This may due to increase in awareness of people about water induce disasters as well as the provision of mitigation measures and management efforts made by the government.

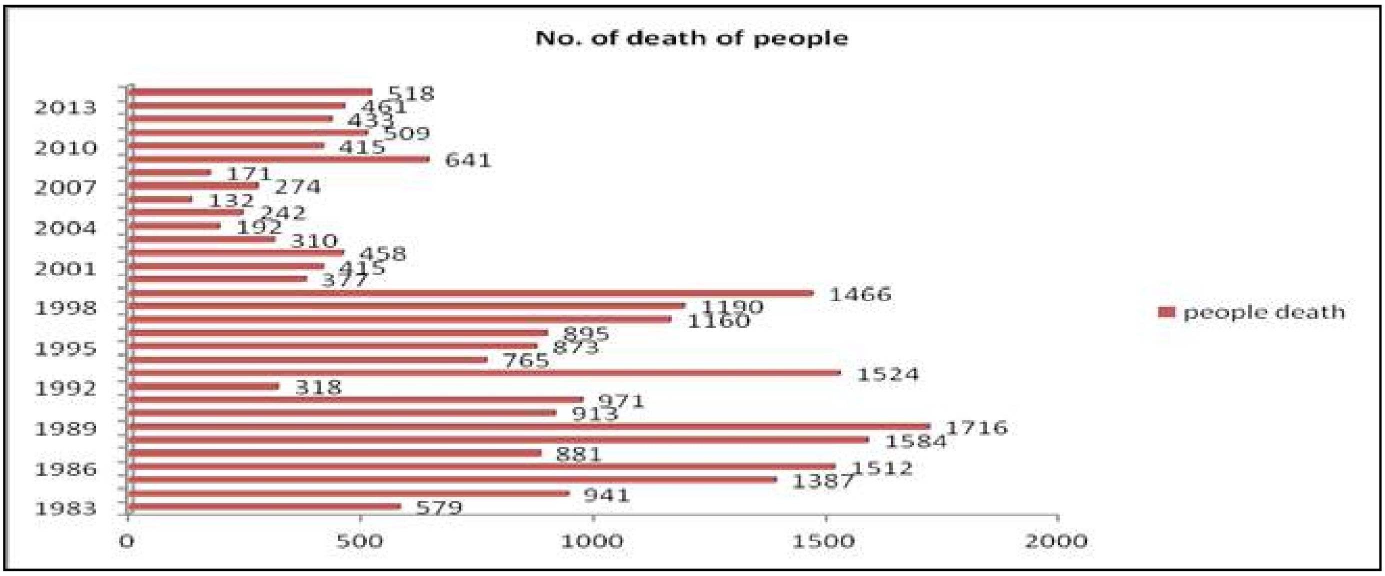
The total loss of livestock by all disasters was 90206, which shows that about 2819 animals were lost annually in 32 years from 2083. This figure also displayed alarming situation in the sector of livestock. The government needs to focus in time towards it. Altogether 469770 houses were destroyed by disasters in 32 years from 1983 to the year 2014, which indicates that in average about 14680 houses were partially as well as completely damaged annually in these years. Table 4 also indicates that the trend of destruction of the houses by the disaster is highly varying and depends on the types of houses, type of land, quality of construction material used and construction technology. The highest number of houses 108801 were destroyed in the year 1988 in 32 years from 1983 to 2014. The factor may be the occurrence of earthquake along with regularly recurring calamities like flood, landslide etc. Devastating earthquake is not a frequent it is found to occur in interval of years, when it occurs it damages tremendously. So people and the government need to consider earthquake safety measures during infrastructure construction. The numbers of families affected by different disasters were 942310. Estimated economic loss by the disaster is also tabulated in table 4. It was 55911.41million in 32 years from 1983 to 2014. It was found that the highest economic loss was NRs.16815.54 million in 2014 and the least was NRs. 23 million in 1985 and 1986 by the. After 1995 the estimated loss followed more or less similar trend up to 2013. However, the economic loss in 2014 was NRs. 16815.54 million, which was 30.07 percent of the total estimated loss of 32 years (table 4). Large area of agricultural land and many public as well as private infrastructures were washed away by the disaster in these years. The principal causes of destruction of infrastructures and wash away of large area of land were the disasters like flood, debris flow, landslide and the earthquake. Some of the statistical data of land loss and destruction of infrastructures from 1983 to 2014 are tabulated in table 4.

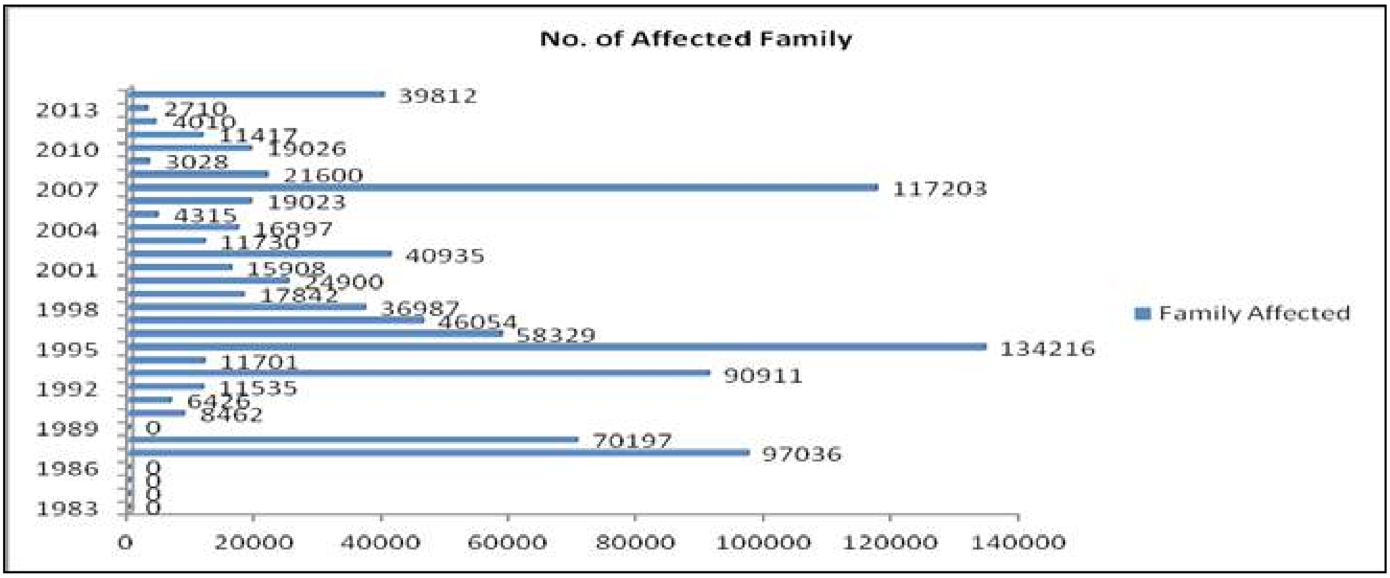
Table : 4 Comparative Disaster Scenario of Nepal since 1983-2014

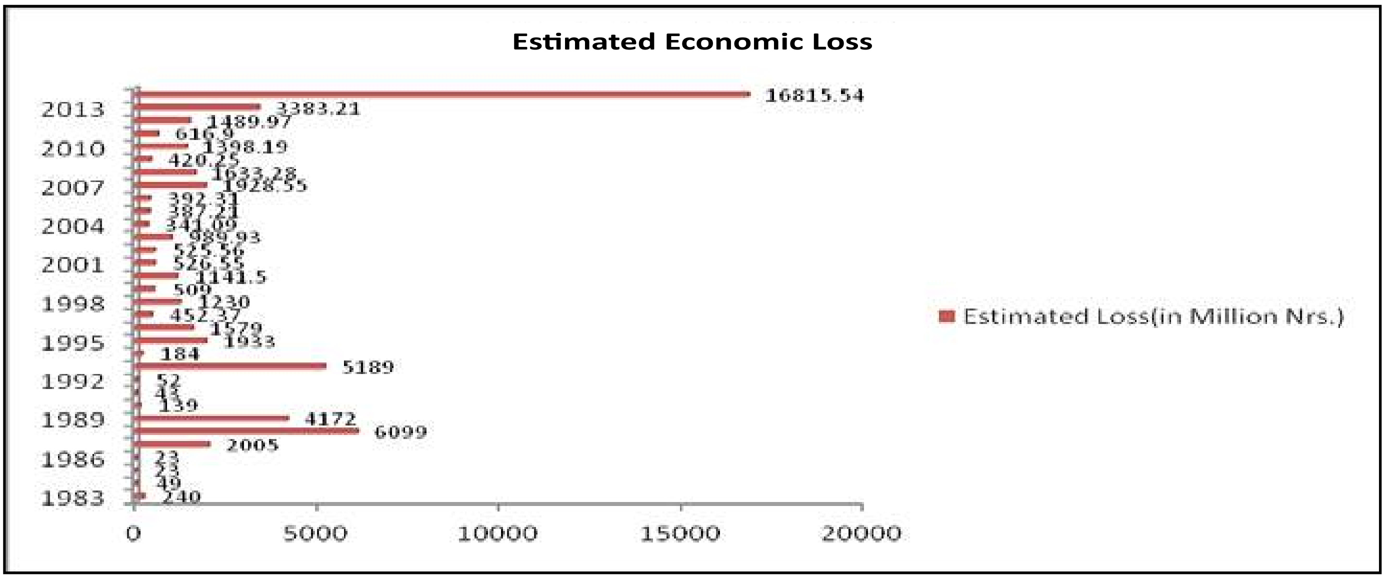
Year	People		Livestock Loss(Nos.)	Houses Destroyed(nos.)	Affected Family (nos.)	Land Affected (Ha.)	Public Infrastructure	Estimated loss (Million NRs.)	Remarks
	Death	Injured							
1983	579		248	12		0	0	240	
1984	941		3547	10597		1242	869	49	
1985	1387		3399	7166		1355	436	23	
1986	1512		6566	3370		1315	436	23	
1987	881	162	1852	36220	97036	18858	421	2005	
1988	1584	12538	2788	108801	70197		4365	6099	
1989	1716	3014	4240	7648	0		0	4172	
1990	913	196	867	6352	8462	1132	0	139	
1991	971	43	642	5510	6426	283	39	43	
1992	318	17	1586	13997	11535	135	66	52	
1993	1524	246	0	21911	90911		0	5189	
1994	765	155	1329	3234	11701	392	0	184	
1995	873	1937	2053	10275	134216	41867.26	0	1933	
1996	895	1527	2480	30014	58329	6063.4	0	1579	
1997	1160	1120	1191	4825	46054	6063.4	0	452.37	
1998	1190	117	1179	15082	36987	326.89	0	1230	
1999	1466	146	650	4304	17842	182.4	0	509	
2000	377	162	1017	6886	24900	888.9	0	1141.5	
2001	415	132	665	6103	15908	0	0	526.55	
2002	458	287	2126	19856	40935	10077.5	0	525.56	
2003	310	160	1125	6819	11730	2360	0	989.93	
2004	192	220	888	4818	16997	0	0	341.09	
2005	242	153	955	3169	4315	0	0	387.21	
2006	132	88	10098	3765	19023	3396.84	0	392.31	
2007	274	144	21861	37984	117203	513.65	0	1928.55	
2008	171	55	7066	13864	21600	21315	0	1633.28	
2009	641	117	228	1050	3028	0	4.88	420.25	
2010	415	261	1526	23370	19026	200	2.85	1398.19	
2011	509	271	254	9644	11417	120	0	616.9	
2012	433	466	1449	5500	4010	0	0	1489.97	
2013	461	421	990	2903	2710	232	0	3383.21	
2014	518	480	5341	34721	39812	0	0	16815.54	
Total	**24223**	**24635**	**90206**	**469770**	**942310**	**93999.24**	**6639.73**	**55911.41**	
Average	756.97	769.84	2818.94	14680.31	29447.19	2937.48	207.49	1747.23	

Source: Ministry of Home Affairs

Figure: 1 Number of deaths, family affected and estimated economic loss by all disasters







Use and Limitation of Landslide Hazard Map in Road Alignment Planning: Case Study of Wamitaksar-Rudrabeni Road Section, Gulmi District, West Nepal

Dinesh Pathak, PhD
Department of Geology, Tri-Chandra Campus
Tribhuvan University, Kathmandu, Nepal
(Email: dpathaktu@gmail.com)

Abstract

Better road network with enhanced connection to different parts of the country is envisaged as backbone of the development goal of Nepal. Occurrence of geo-hazard condition along the road corridor is threat to the objective of timely, efficiently and quality road construction. In addition, it causes the heavy demand of maintenance at the operational stage that greatly restricts the better utilization of the road by the beneficiaries. An ultimate goal of any road project is to avoid unstable areas prone to landslides and erosion processes. However, in case of Nepal with fragile mountain environments, road construction projects inevitably face the road side geo-hazard condition. Road alignment should avoid areas near active landslides and erosive gullies. In order to avoid such hazard prone areas, road should be aligned based on the landslide hazard map of the catchment area. However, the landslide hazard map should be utilized with care during finalization of the alignment. A landslide hazard map indicates the areas susceptible to landslide but does not tell anything about the impact at downslope/upslope area if the event occurs. Therefore, it is necessary to careful evaluation of the hazard condition and its possible impact to road before road alignment is finalized. These aspects have been presented here with example from Wamitaksar-Rudrabeni road section at Gulmi District, west Nepal.

Keywords: Geo-hazard, Landslide hazard map, Road construction, Mountainous terrain

1. INTRODUCTION

Landslide hazard mapping is the basic tool to assess, project and mitigate the water induced disaster in a basin (Pathak, 2014, Pathak et al., 2005). Likewise, it is equally important tool to assess and ensure the round the year functioning of the mountainous road (Pathak, 2013). The damages due to water induced disaster are quite significant in Nepal and it is assumed to be more severe due to changing climate (Pathak et al., 2010).

There exist various models for landslide susceptibility and hazard mapping (Guzzetti et al., 1999; Chung and Fabbri, 2003; Remondo et al 2003; Van Westen et al., 2003; Dahal et al., 2009). In this study, the information value method has been used for the landslide hazard mapping. Van Westen (1997) proposed the Information Value (InfoVal) method for landslide hazard analysis, which considers the probability of landslide occurrence within a certain area of each class of a landslide causative factor.

Thus, assessment of landslide hazard and its use for the planning and assessing the infrastructures like road alignment is inevitable. In addition, the remote sensing imageries plays vital role through reducing time, cost and efforts in the process and also enhancing the quality of the mapping and assessment (Subramani and Nanda Kumar, 2012; Pathak, 2013 and Pathak, 2014).

2. THE STUDY AREA

The study area lies in the Gulmi District, west Nepal (Fig. 1). The road section is important as it connects Butwal to Burtibang, an old and important settlement in the Baglung district. The road is under the process of upgrading from Ridi bazar to Burtibang to ensure round the year connectivity. The considered Wamitaksar-Rudrabeni road section runs along the left bank of Badigad River.

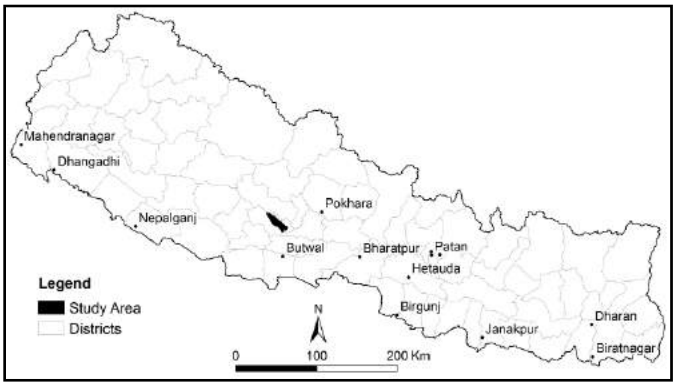


Fig. 1: Location of the study area through which the Wamitaksar-Rudrabeni road traverses.

The VDCs lying along the road corridor under the present study are Wami Taksar, Kurgha, Ampchaur, Turang, Rupakot, Juniya, Jahang, Hasara, Limgha, Thulolumpek and Aslewa (Fig. 2). There are clustered settlements at various locations along the road alignment indicating that this road section serves a large number of people in the area. Gedhi Khola, Hugdi Khola, Jumdi Khola, Lumdi Khola, Sisne Khola, Tekwa Khola, and Dahare Khola are the major tributaries of the Badigad River in the study area.

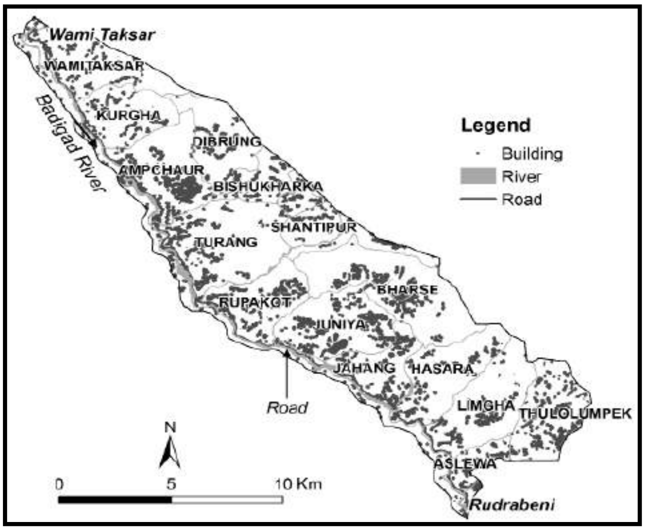


Fig. 2: VDCs and settlements lying along the Wamitaksar-Rudrabeni road corridor.

3. MATERIALS AND METHODS

The Wamitaksar-Rudrabeni road section has been evaluated with respect to the geo-hazard condition. The following data have been utilized:

- Digital topographic map of Department of Survey
- Road alignment
- Geological map of the area published by Department of Mines and Geology
- Satellite imageries
- Field data

The geological map of the area was digitized in GIS. Various thematic layers like slope, aspect, drainage density, land use, landslide distribution, and gully erosion were prepared from the digital topographic data that was updated from the satellite images. Bivariate statistical method was used for the generation of landslide hazard map of the watershed.

The geo-hazards along the alignment have been assessed by overlaying the road alignment on the satellite image, geological map and hazard map.

4. GEOLOGY OF THE STUDY AREA

The geology of the area plays vital role in the occurrence of geo-hazard condition. The present road alignment traverses the Lesser Himalayan zone consisting mainly of the Nourpul Formation, Dhading Dolomite, and Benighat Slate (Fig. 3). Alluvial deposit is distributed mainly along the Badigad River and its tributaries.

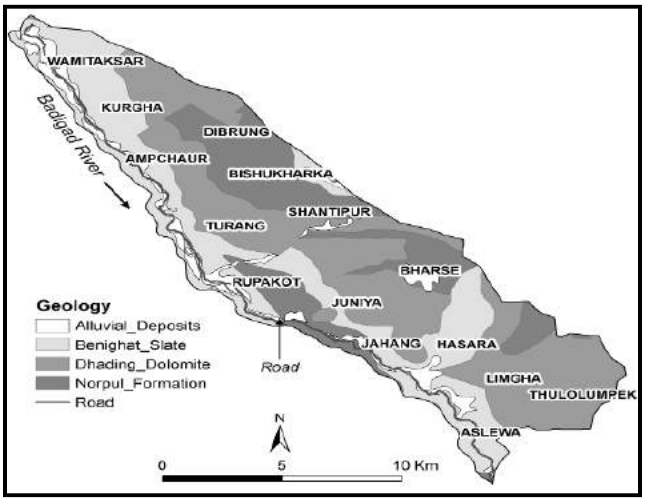


Fig. 3: Geological map of the study area.

Nourpul Formation consists of intercalated slate, phyllite and quartzite; Dhading Dolomite Formation is predominantly consisting of dolomites with stromatolites; while the Benighat Slate Formation consists of slate with calcareous bed. The Badigad River has developed terraces along the river. The road alignment mainly traverses through the alluvium deposits and occasionally through the rocks of different formations. Slate of Benighat Formation is mostly distributed rocks along the alignment.

Badigad fault traverses almost along the Badigad River and other minor faults and joints are also present in the area. These are mainly responsible for the unstable hill slope and also disintegration of the rocks.

5. TERRAIN RELATED DATA

The terrain related data are obtained from the digital topographic maps and satellite imageries. The road alignment was overlain on the satellite image to observe the terrain condition that the road alignment is passing through

(Fig. 4). It is clear that the road is aligned at the valley part with the minimum elevation that goes on increasing at the upslope in northern part. The northern part of the catchment is relatively steeper and hence the mass wasting process is more active at the upper reaches of the tributaries of the Badigad River.

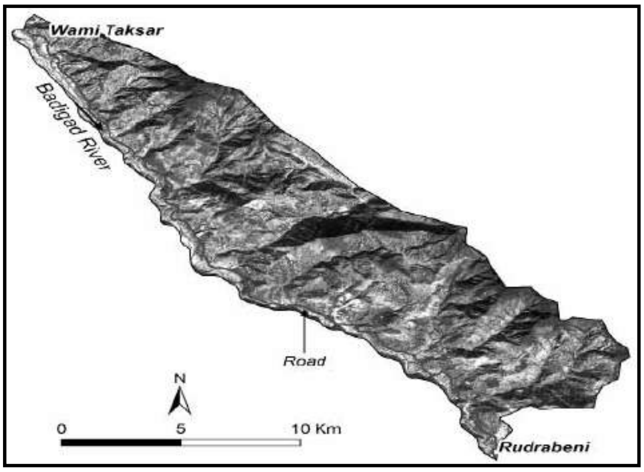


Fig. 4: Road alignment overlain on satellite image and assessment of geo-hazards.

The catchment area at the left bank of Badigad River, influencing the road corridor has also been assessed in terms of the land use condition (Fig. 5). It is observed that the area is mostly consisting of forest area, followed by cultivation. Thus, in terms of greenery of the catchment, it is good, however, the geological condition is playing vital role in the occurrence of landslide and other soil erosion condition. The road alignment mostly passes through the cultivated area lying at the valley floor with occasional crossing of the forest area.

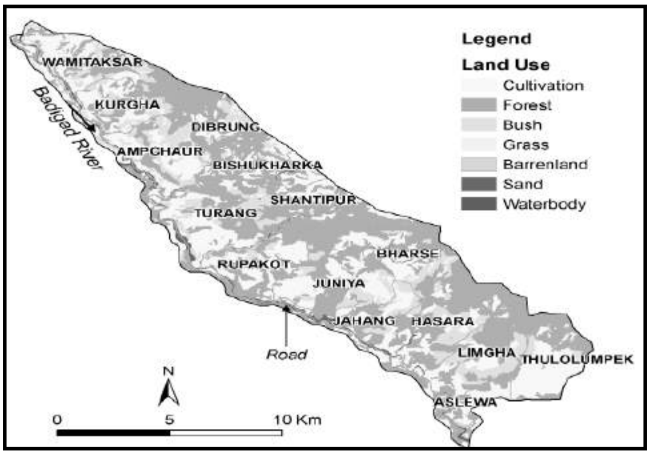


Fig. 5: Land use condition in the study area.

6. LANDSLIDE HAZARD ASSESSMENT ALONG THE ROAD CORRIDOR

Preparation of landslide inventory map is pre-requisite for the assessment of geo-hazard condition along the road alignment. Landslide inventory map has been prepared through extraction from digital topographic map, satellite imageries and field data collection (Fig. 6). The satellite imageries have been commonly used in geo-hazard assessment (Pathak et al., 2005; Pathak et al., 2009; Subramani, T. S. and Nanda Kumar, 2012.).

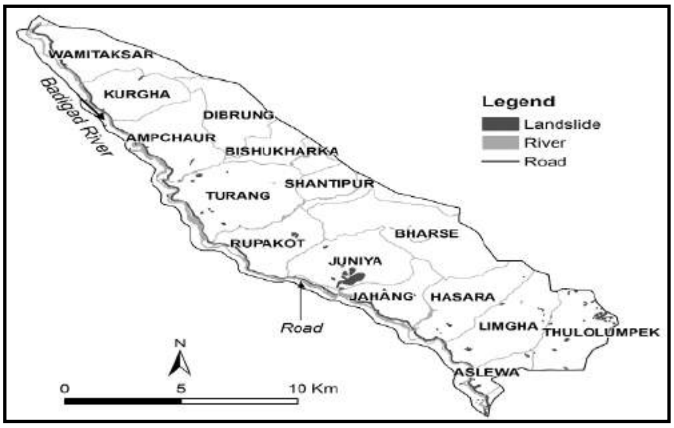


Fig. 6: Landslide inventory map of the study area.

The landslides are mainly distributed in the Turang, Rupakot, Juniya, Jahang, Harsa, Limgha and Thulolumpek VDCs. The severe condition is observed in Juniya VDC followed by Thulolumpek, Limgha and Turan VDC. A landslide hazard map of the study area has been prepared using various thematic layers like slope, aspect, drainage density, geology, land use, landslide (Fig. 7). The map was prepared through statistical bivariate method and validated with the independent landslide dataset that was not used to prepare the hazard map.

The landslide hazard map shows that most of the road stretch passes through high to very high hazard class. Even if the road doesn't exactly pass through the higher hazard classes, the adjacent landslide hazard may affect the road.

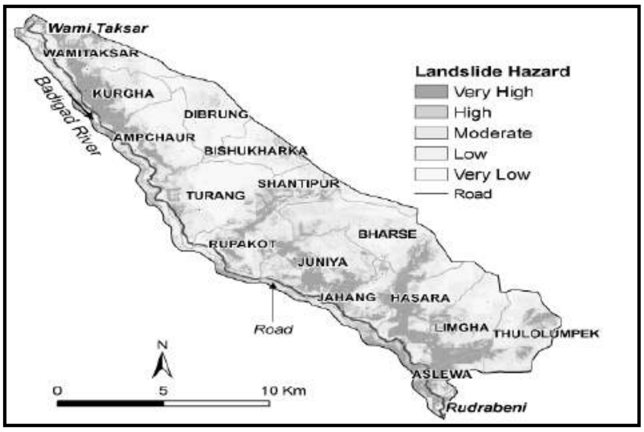


Fig. 7: Landslide hazard map of the study area.

The road stretch around Ullikhola Village, Juniya VDC and Kalwar gau, Aslewa VDC are considered to be the most critical parts in the Wamitaksar-Rudrabeni road section. The alignment crosses several tributaries of the Badigad River. These tributaries are transporting huge amount of sediments and the bed load derived from the landslides at the upper reaches of the tributaries. The site condition as observed on satellite image, field photograph and the prepared hazard map have been compared to evaluate the appropriateness of the hazard map (Figs. 8, 9 and 10).

It is clearly observed that the massive landslide zone at the upper reaches of the Dahare Khola (upstream of Ullikhola village) that is identified on the satellite image is clearly affecting the road stretch while passing through the landslide mass deposited area at the lower reaches of the stream (Fig. 8). The sediments derived from the landslide appear to cause continuous damage and affect the smooth functioning of the road during the monsoon period. Likewise, the hazard map also accurately delineated this area as very high landslide hazard class (Fig. 9). In addition, the field study has confirmed this site condition (Fig. 10) showing the massive mass wasting at the upper reaches followed by thick pile of sediments deposited at the downstream through which the road passes. However, it is to be noted that the entire risk area at the downstream part couldn't be delineated by the landslide hazard map though the source area has been accurately delineated.

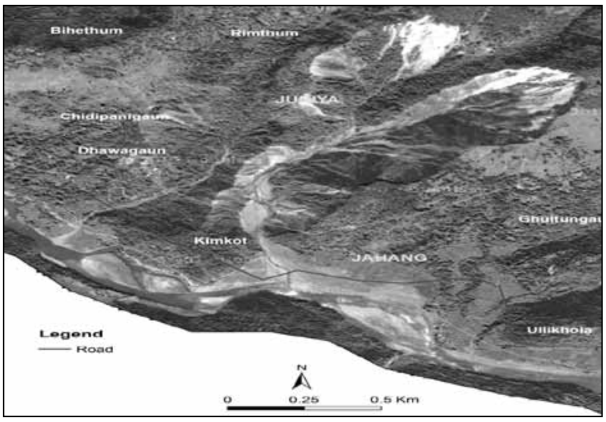


Fig. 8: Landslide observed on satellite image at the upper reaches of Dahare Khola (upstream of Ullikhola village).

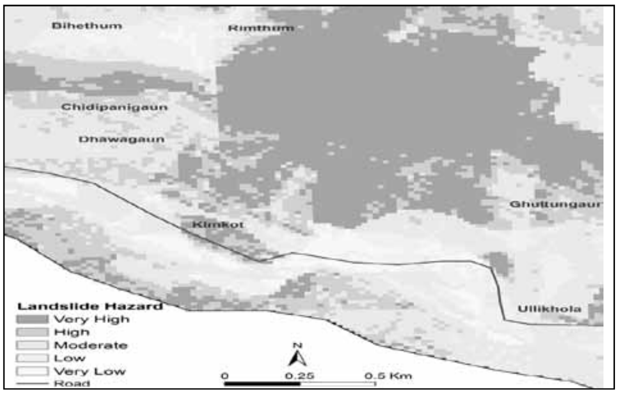


Fig. 9: Road alignment overlain on landslide hazard map around Ullikhola village

Fig. 10: Field photograph of the landslides at upper reaches of Dahare Khola (10a) and its impact to the road alignment at the downstream, around Ullikhola village (10b).

Similar evaluation was carried out at further downstream of Ullikhola village, around the Lumdi Khola crossing of the road stretch at Aslewa VDC, near Kalwargau. The satellite image shows significant mass wasting at the upper reaches of the Lumdi Khola (Fig 11). The Kalwargau area has been classified as high to very high landslide hazard classes (Fig. 12). This is quite interesting and important outcome as the road stretch passing through this area is really at risk of the debris derived from the upper reaches of Lumdi Khola.

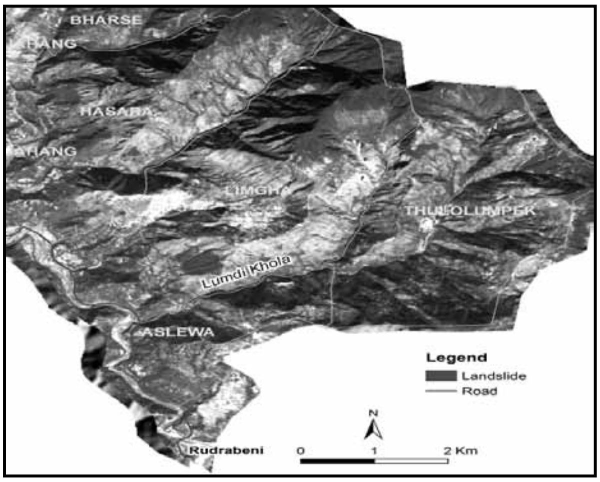


Fig. 11: Mass wasting at the upper reaches of the Lumdi Khola as observed on the satellite image.

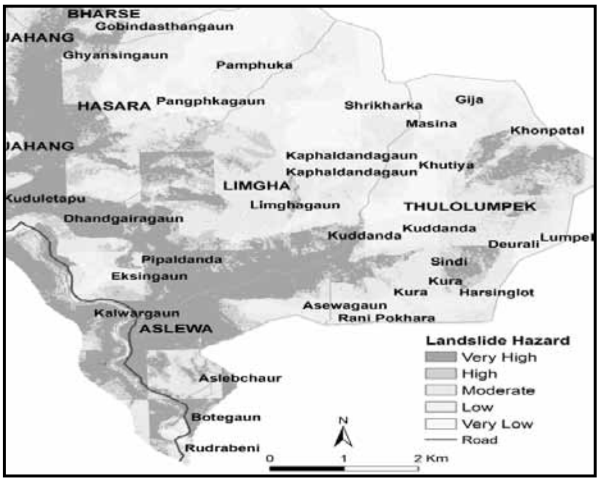


Fig. 12: Landslide hazard map shows high hazard class around Kalwargau, Aslewa VDC.

7. DISCUSSION AND CONCLUSION

The Wamitaksar-Rudrabeni road alignment traverses through the river valley along the Badigad River. The alluvial deposits as well as Benighat Slates dominantly occur along the road corridor. Various thematic layers have been prepared using the digital topographic data, satellite imageries and data collected in the field. Statistical bivariate method has been used to prepare landslide hazard map of the study area and the road corridor was evaluated with respect to the hazard condition. The field observation greatly helped to accurately assess the impact of landslide on the road alignment.

The Ullikhola village at the left bank of Badigad River is affected by the transported debris from Dahare Khola, especially during the monsoon season. The damages to the settlements, infrastructure and agriculture land at the downstream site is quite significant indicating that it has wider impact in the society. The hazard map shows that the northern part of the catchment is represented by the high hazard areas while the low lying valley area is represented by the low to moderate landslide hazard classes. The field condition at the upstream of Dahare Khola is well represented by the landslide hazard map. Similar was the case around Lumdi Khola catchment. However, at the lower reaches of Dahare Khola, around the Ullikhola village, the site is at high risk of impact due to landslide at the upper reaches but not well depicted by the hazard map. The landslide hazard map should be understood as indicative of the presence of landslide in an area, however, it may not provide direct information about the possible risk at the downstream through which the road alignment passes. This map should be further interpreted based on the possible affected areas from the debris derived from the upper reaches. Finally, rather than confining the geo-disaster assessment only along the road alignment, it is necessary to have thorough study and understanding of the entire catchment area. If this approach is well addressed during the road alignment planning and possible geo-disaster areas are identified, a better alignment can be selected and the applied mitigation measures at required site would greatly enhance the performance of the road with reduced risk.

REFERENCE

Chung, C.-J.F. and Fabbri, A. G (2003) Validation of spatial prediction models for landslide hazard mapping. Natural Hazards 30, 451–472.

Dahal, R.K., Hasegawa, S., Nonomura A., Yamanaka, M., Dhakal S., Paudyal P., 2009, Predictive modelling of rainfall-induced landslide hazard in the Lesser Himalaya of Nepal based on weights-of-evidence, Geomorphology, 102 (3-4):496-510, doi:10.1016/j.geomorph.2008.05.041. Elsevier.

Guzzetti F., Carrara A., Cardinali M., and Reichenbach P. (1999) Landslide hazard evaluation: a review of current techniques and their application in a multi-scale study, Geomorphology 31, 181–216

Pathak, D., 2013. Remote sensing input for road alignment planning with reference to geological hazard in the Nepalese Himalaya. Techno-Civil Universe, Vol. 4, August 2013, pp. 4-9.

Pathak, D., 2014. Water Induced Disaster in Tamor River Sub-Basin, East Nepal, DWIDP Bulletin, Series XV, pp 6-11.

Pathak, D., Champati Ray, P. K., Lakhera, R. C., Singh, V. K., 2005. Application of remote sensing and GIS in landslide hazard zonation and delineating debris flow susceptible zones in Garhwal Himalaya, India. Journal of Nepal Geological Society, 2005, Vol. 32 (Sp. Issue), pp. 67.

Pathak, D; Gajurel, A. P.; Mool, P. K., 2010. Climate change impacts on hazards in the Eastern Himalayas; Climate change impact and vulnerability in the Eastern Himalayas – Technical report 5. Kathmandu: ICIMOD.

Remondo, J., González, A., Ramón, J., Cendrero, A., Fabbri, A. and Chung, C.-J.F. (2003) Validation of landslide susceptibility maps: examples and applications from a case study in Northern Spain. Natural Hazards 30, 437–449.

Subramani, T. S. and Nanda Kumar, 2012. National Highway Alignment Using GIS. International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 4, pp.427-436.

Van Westen C.J., Rengers N. and Soeters R. (2003) Use of geomorphological information in indirect landslide susceptibility assessment, Natural Hazards 30, 399–419.

Van Westen, C.J. (1997) Statistical landslide hazard analysis. In: Application guide, ILWIS 2.1 for Windows. ITC, Enschede, The Netherlands, p. 73–84.

Understanding Pore Water Pressure Development and Slope Instability During Extreme Rainfall: A Case Study from Western Japan

Kiran Prasad Acharya, PhD
Assistant Professor of Civil Engineering, Nepal Engineering College

Abstract

This study was attempted to understand pore water pressure development and its effect on hillslope instability in a small catchment, known as Higashifukubegawa of Shikoku Island, western Japan. The typhoon rainfall of 19-20 October, 2004 was important in causing a total seven slope failures in the catchment though other rainfall events of various intensities in the same year did not cause failure. Two in seven slope failures were selected to investigate pore water pressure increase with rainfall infiltration and instability in this study. A series of field/laboratory experiments were performed to obtain hydro-mechanical parameters in unsaturated and saturated conditions necessary for the analysis. Seepage modeling was done in the slope profiles constructed in SEEP/W code of GeoStudio (2005) to explore porewater pressure increase during rainfall using rainfall record of 19-20 October 2004. The simulated pore water pressure is then used in limit equilibrium based slope stability modeling in SLOPE/W code so as to understand slope failure behavior and estimate time of failure. In results, very rapid transient porewater pressure regimes were observed during triggering phase in seepage modeling. The soil thickness, soil permeability, porosity and potential seepage face on the slope have been found as the major causes behind rapid transient porewater pressure response. Slope stability results showed approximate time of failure which was two hours after the maximum hourly rainfall intensity.

Keywords: Extreme typhoon rainfall, porewater pressure increase, hillslope instability, factors of safety.

1. Background, problem statement, and objectives

Slope instabilities or slope failures are typical hydro-geotechnical problems in hilly regions of the world. There are three types of extrinsic factors responsible for triggering shallow landslides, namely i) geological factors ii) hydrological factors), and iii) human interventions due to development activities. Rainfall is a common extrinsic factor. When rainfall is considered as extrinsic factor, the type of landslide depends on the intensity and duration of the rainfall events, and soil permeability (Pasuto and Silvano 1998, Guzzetti et al. 2004). Statistical models are frequently used to estimate rainfall threshold for landsliding (Caine 1980, Kim et al. 1991, Glade et al. 2000). However, a statistical modeling is possible only when there is sufficient data available in relation with landslide events and rainfall conditions. For a limited number of data, hydrological models are considered to be suitable to investigate rainfall-induced shallow landslide triggering mechanism (Terlien 1998). Hydrological models have been widely applied to predict pore water pressure development due to rainfall infiltration (Brooks and Richards 1994, Ekanayake and Phillips 1999, Iverson 2000, Frattini et al. 2009). To simulate both saturated and unsaturated failure mechanisms in the slope mass, hydrological models based on topographical flow routing have been used. These yield simulated soil saturation above the impermeable bedrock which is usually used in slope stability modeling for accurate simulation of conceivable conditions. A few examples of hydrological slope stability models are TOPMODEL (Beven and Kirkby 1979), SHALSTAB (Dietrich et al. 1998), SINMAP (Pack et al. 1998) etc. The GeoStudio (2005) is another coupled hydrological slope stability model, in which SEEP/W and SLOPE/W plugins are used to simulate the instability of slopes during extreme rainfalls.

In spite of a great deal studies which have used various methods of analyses and models, the porewater pressure development and its role in causing slope instability is not well understood topic of research as the rainfall characteristics and geotechnical properties vary over a region. In this regards, this study attempts to investigate hydrological and mechanical phenomena for triggering slope failures during an extreme rainfall event. For this purpose, a small catchment known as Higashifukubegawa catchment in Niihama city of Shikoku in western Japan, which was severely damaged by a typhoon rainfall event of 2004, was selected. The specific objectives of this study are as follows.

(i) To understand the change in negative and positive porewater pressure distribution in the slopes of sedimentary terrain during extreme rainfall.
(ii) to discover the role of hydrological parameters (i.e., soil permeability and porosity) for development of transient porewater pressure regime,
(iii) to understand the role of geotechnical properties of soil in slope failure, and
(iv) to investigate approximate time of slope failure in Higashifukubegawa.

2. Study area catchment, geological features, and slope failures in the catchment

The study area, as shown in Figure 1, is located in the northeastern part of Niihama City in Shikoku, western Japan. Geographically, it extends from (33º58′ 12″) N to (33º 58′ 27″) N latitude, and (133º 22′ 41″) E to (133º 22′ 59″) E longitude using a spatial reference system based on GCS_WGS_1984 (geographic coordinate system) and WGS_1984_UTM_Zone_53N (projected coordinate system). The area of the catchment is about 142,000 sq. m. Considering geoid as a reference surface, the elevation is found to range between 42 m and 213 m. Shikoku Island consists of three main geological units namely Ryoke, Sambagawa-Chichibu and Shimanto belts from north to south. The Higashifukuwegawa catchment falls in Ryoke belt and consists of tertiary shale and sandstone of the Izumi group. The sandstone is heavily fractured and intercalated with shale beds. In the study area, a total of seven slope failures indicated as A, B, C, D, E, F, and G in Figure 1 occurred during the heavy rainfall of 19-20 October 2004 caused by the typhoon 0423. To limit the scope of this paper, slope failure F and G were considered for the seepage and slope instability evaluation in this study.

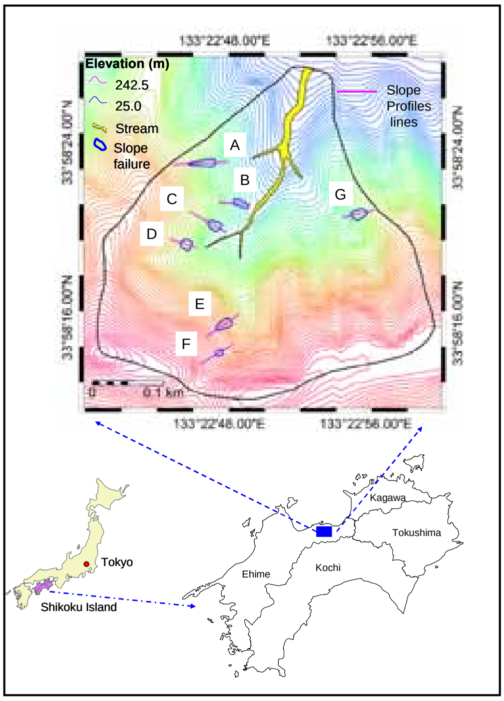


Figure1. Higashifukube catchment with seven slope failures and slope profile lines

3. Preparation of hydro-geo-mechanical parameters

A series of field/laboratory tests were conducted to obtain hydro-geo-mechanical parameters of soil in the failed spots. Based on the results of laboratory investigation and after referring to USCS, the soils found in the study area were classified into three types: silty sand (SM), silty gravel (GM) and silt (M). Among which, silty sand (SM) was dominant. Soil permeability value was found to range from 10^{-6} to 10^{-8} m/s, as obtained from in-situ permeability tests. The hydro-mechanical parameters and geomorphological properties of two failure sites are listed in Table 1.

Table 1. Results of field and laboratory investigations

Slope failure Spot	Slope failure lenght, L (m)	Slope failure breadth, B (m)	Average slope angle, θ (º)	Soil thickness D, (m)	Effective cohension* angle, c' (kN/m^2)	Unit weight* γ (kN/m^2)	Effective angle of shearing resistace*, γ (º)	Soil permeability, k (m/s)	Volumetric water content, n
F	13.81	8.67	21.78	0.55-1.78	0.13	15.83	34.21	2.35×10^{-8}	0.50
G	22.32	13.41	29.70	0.33-0.99	1.33	16.79	33.85	3.10×10^{-7}	0.49

The effective soil cohesion and effective angle of internal friction were determined by direct shear tests while volumetric water content at saturation and unit weight were determined in the laboratory. All these parameters were used in the seepage and slope stability modeling.

4. Seepage modeling and results

For seepage modeling, longitudinal profile of failed slopes F and G (Figure 2) was prepared using a Digital Elevation Model (DEM) of the study area and soil thickness data based on topographical break in the slopes. The profile continuum was discretized into a mesh of fine square elements with 4 nodes and 9 integration orders. The numbers of node were 3366 and 2300, whereas the mesh elements were 2800 and 1722. Soil water characteristics curve (SWCC) and soil permeability curve (SPC) functions were employed as main input parameters. The simulation was performed considering extreme rainfall of 19-20 October 2004 caused by the typhoon event 0423. The left vertical edge and the edge below the water table were assigned as a null flux boundary to prevent seepage contribution from upper slope sections and bedrock (Figure 3). The right vertical edge above water table was specified as null flux boundary with potential seepage face. The hourly rainfall record of 19-20 October of 2004, as the transient flux, was applied to the nodes on exposed sloping surface with potential seepage face as upper boundary condition. Figure 4 shows the result of seepage modeling. Very rapid porewater pressure response was observed with beginning of precipitation infiltration through the soil by decreasing the matric suction. The porewater pressure regime was transient which was due to soil thickness, soil permeability, porosity and potential seepage face on the slope. Initially, the porewater pressure was negative. The maximum positive porewater pressure reached at 14:00 hour of 20th October 2004 which was two hours after the maximum hourly rainfall intensity (more clearly, maximum hourly rainfall intensity was 50 mm/hr at 12:00 hourr of 20th October).

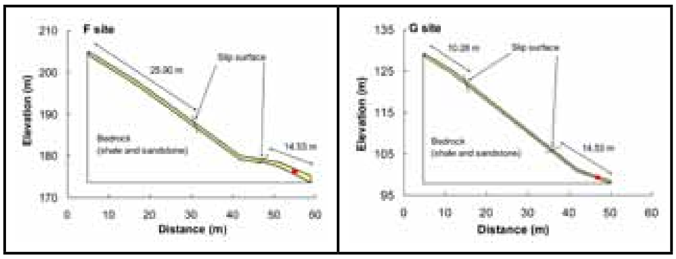


Figure 2. Slope geometry of slope failure F and G in Higashifukubegawa catchment..

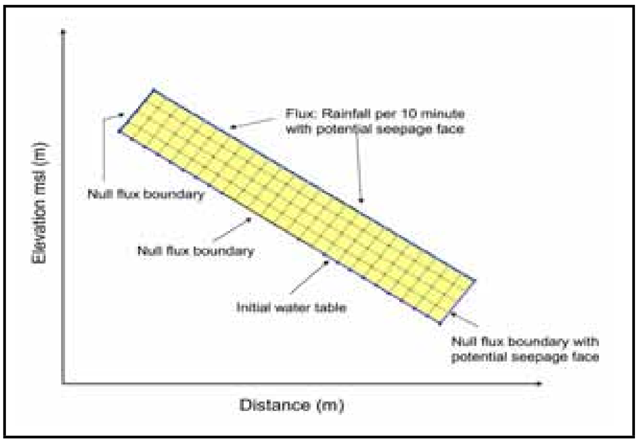


Figure 3. Finite element description of the slope model.

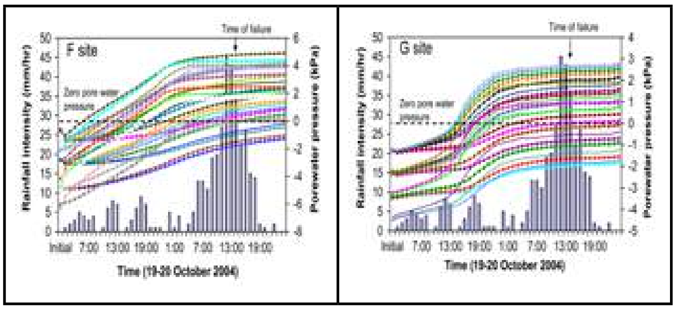


Figure 4. Porewater pressure variation in slip surface of slope failure F and G. The low porewater pressure curves represent porewater pressure at nodes of higher elevation along slip surfaces.

5. Slope stability modeling and results

The two-dimensional seepage simulated in SEEP/W is directly imported into SLOPE/W for slope stability analysis. The hydro-mechanical parameters to be used in SLOPE/W are already determined [Table 1]. To compensate uncertainties in parameters such as cohesion, angle of sharing resistance and unit weight of soil, sensitivity analysis was performed in stability analysis. For this, minimum and maximum values of cohesion, friction angle, unit weight were assigned as material properties in SLOPE/W environment. Morgenstern-Price (1965) method which satisfies both force and moment equilibrium was adopted with half-sine user specified interslice force function available in SLOPE/W to compute factor of safety. Results of slope stability modeling in slope failure F and G are shown in Figure 5. These figures illustrate that factor of safety decreases with increase in precipitation under constant soil permeability and volumetric water content values. A sudden decrease in factor of safety was observed at some significant rainfall hours accordingly 8:00, 13:00, 19:00 hours of 19th October and 8:00, 11:00, 14:00, 18:00 hours of 20th October. Immediately after each of these particular hours, the factor of safety began to recover till next significant rainfall hour was reached. At 14:00 hour of 20th October, the factor of safety reduced to <1 (i.e., 0.998 for F and 0.993 for G) which is due to rise in groundwater table up to the crest of the slope. From this, it is clear that both failures must have occurred at 14:00 hour of 20th October which is two hours after the maximum hourly rainfall intensity. The optimized critical slip surfaces and respective factor of safety on the date of failure are exhibited in Figure 6.

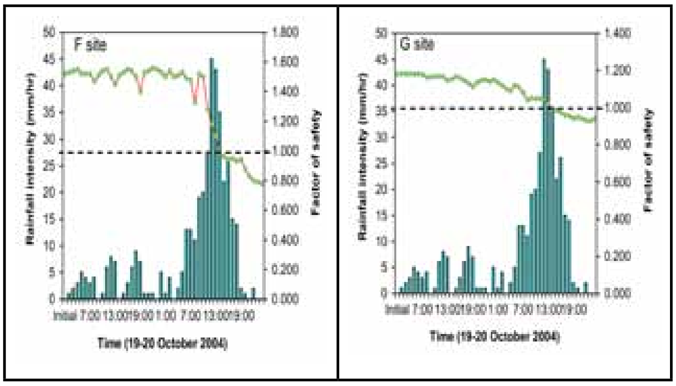


Figure 5. Factor of safety distribution in slope failure F and G with rainfall data of 19-20 October 2004

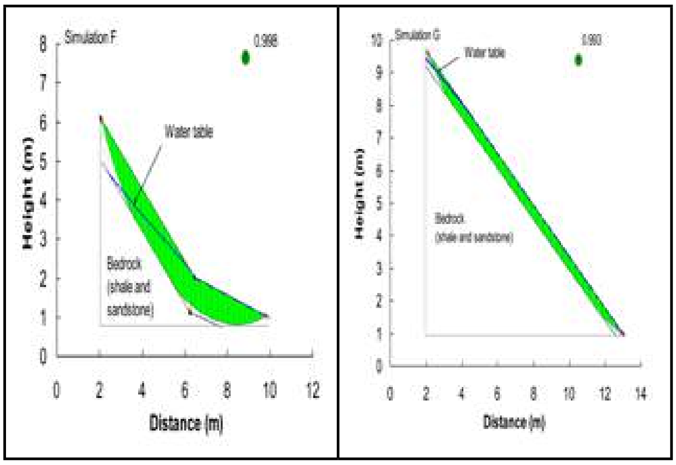


Figure 6. Optimized slip surfaces after slope stability modeling in slope failure F and G

6. Concluding remarks

The following conclusions were drawn from this study.

(i) Rainfall-induced slope failure occurs due to transient positive and negative porewater pressure development and it is observed in Higashifukubegawa catchment of Niihama.

(ii) If silty sand is the predominant soil type, the increment in porewater pressure is always rapid transient which results in slope instability or slope failure.

(iii) From the field/laboratory experiments and numerical modeling, it is understood that slope gradient, rainfall, saturated permeability of soil, porosity, and initial porewater pressure as the main controlling factors for instability in tertiary sedimentary terrain of western Japan.

(iv) The observed trends in pore water pressure distribution and factor of safety showed that the time of failure in Higashifukube catchment was two hours after the maximum hourly rainfall intensity.

References

Beven KJ, Kirkby MJ (1979) A physical based variable contributing area model of basin hydrology. Hydrological sciences Bulletin 24 (1): 43–69.

Brooks SM, Richards KS (1994) The significance of rainstorm variations to shallow translational hillslope failure. Earth Surface Processes and Landforms 19(1): 85–94.

Caine N (1980) The rainfall intensity: duration control of shallow landslides and debris flows. Geografiska Annaler. Series A, Phys Geog 62(1/2): 23–27. Accessed 18 Oct 2010.

Dietrich WE, Real de Asua R, Coyle1 J, Orr B, Trso M (1998) A validation study of the shallow slope stability model, SHALSTAB, in forested lands of Northern California. Stillwater Ecosystem, Watershed & Riverine Sciences, Berkley, USA.

Ekanayake JC, Phillips CJ (1999) A model for determining thresholds for initiation of shallow landslides under near-saturated conditions in the East Coast region, New Zealand. J Hydrol (NZ) 38(1):1–28.

Frattini P, Crosta G, Sosio R (2009) Approaches for defining thresholds and return periods for rainfall-triggered shallow landslides. Hydrological Processes 23(10):1444–1460.

GeoStudio (2005) GeoStudio Tutorials includes student edition lessons, 1st edition revised, Geo-Slope International Ltd., Calgary, Alberta, Canada.

Glade T, Crozier M, Smith P (2000) Applying probability determination to refine landslide-triggering rainfall thresholds using an empirical Antecedent Daily Rainfall Model. Pure and Applied Geophysics 157: 1059–1079.

Iverson RM (2000) Landslide triggering by rain infiltration. Water Resources Research 36(7):1897-1910.

Kim SK, Hong W P, Kim YM (1991) Prediction of rainfall-triggered landslides in Korea, in: Proceedings of the 6th International Symposium on Landslides, edited by: Bell, D. H., Christchurch, New Zealand, Balkema, Rotterdam, pp. 989–994.

Morgenstern NR, Price VE (1965) The analysis of the stability of general slip surfaces. Geotechnique 15(1): 79–93.

Pack RT, Tarboton DG, Goodwin CN (1998) SINMAP—A stability index approach to terrain stability hazard mapping. http://www.neng.usu.edu/cee/faculty/dtarb/sinmap.pdf.

Terlien MTJ (1998) The determination of statistical and deterministic hydrological landslide-triggering thresholds. Environmental Geology 35(2): 124–130.

Application of If AS Model in flood forecasting

Santosh Aryal
Civil Engineer
Nepal Electricity Authority

Abstract

The real-time flood forecasting model described in this research is intended for West Rapti basin with a hope that it can further be used with reasonable accuracy for sparsely gauged flood-prone river basins throughout Nepal. In this context, a distributed model IFAS (Integrated Flood Analysis System) is used for simulating rainfall into runoff. Two approaches have been used in this study to predict the flood hydrograph of West Rapti River – i) using available ground based hourly rainfall data and ii) using satellite based hourly rainfall data. The performance of the model for the river basin for satellite and ground-based rainfall input are calibrated using flood at Kusum on 14th August, 2014 and then validated for flood on 2nd August, 2012. The result is compared using different error analysis methods. It is observed that the model can be used with reasonable accuracy for medium sized catchment like West Rapti. The satellite based rainfall product GSMaP_NRT with proper corrections is found useful in rainfall-runoff modeling for sparsely gauged basins.

Key Words: Flood Forecasting, IFAS, Precipitation, Hydrograph.

1. Background

Flood forecasting is the process of estimating future flow stages and their time sequence at selected points along the river during floods. Real time flood forecasting systems are formulated for issuing flood warning in real time in order to prepare evacuation plan during flood. Hydrologic/hydraulic models are often used in flood forecasting and early warning systems. These models, when optimally calibrated and validated, can be an effective tool in mitigating flood damages through early warning. For formulating flood forecast in real time, the observed meteorological and flow data are transmitted to forecasting station through different means of data communication. The collected meteorological and flow data in real time are then used into calibrated & validated real time flood forecasting model to forecast the flood flow.

2. Rationale and Problem Identification

This study attempts to use both ground based and satellite-based rainfall data for flood forecasting using IFAS model. In recent years, the ready (and free) availability of global satellite-based rainfall data on the Internet offers a spectacular opportunity for enhancing the coverage and validity of traditional rain gauges. The quality of satellite-based rainfall data is high in terms of coverage but low in terms of accuracy (and resolution of peak events). This is complementary to the quality of ground-based monitoring networks, where the quality is high in terms of accuracy but low in terms of coverage. A powerful data basis can be achieved by combining the two types of data, adding their respective advantages while neutralizing their weaknesses. It is quite normal that the data availability for reliable and accurate forecasting is affected by practical implications such as

- Lack of real time rainfall data which covers whole basin;
- Lack of river network data, or low validity of such data during extreme events (due to overland flows);
- Imperfect general operation and maintenance of gauges and monitoring stations;
- Imperfect rating curves (for example not representing extreme events, or having changed in the course of time); and

- Imperfect data coverage and data transmission during extreme events (for examples due to malfunctioning or lost gauges).

3. Study Area

This study is focused on West Rapti Basin of Western Nepal. Geographically, river basin is located between 27º40′00′′N to 28º36′00″N latitude and 81º42′00″E to 83º11′00″E longitude. The total catchment area of the basin at the Nepal-India border is about 6,500 km^2 and the total length of the river is 237 km.

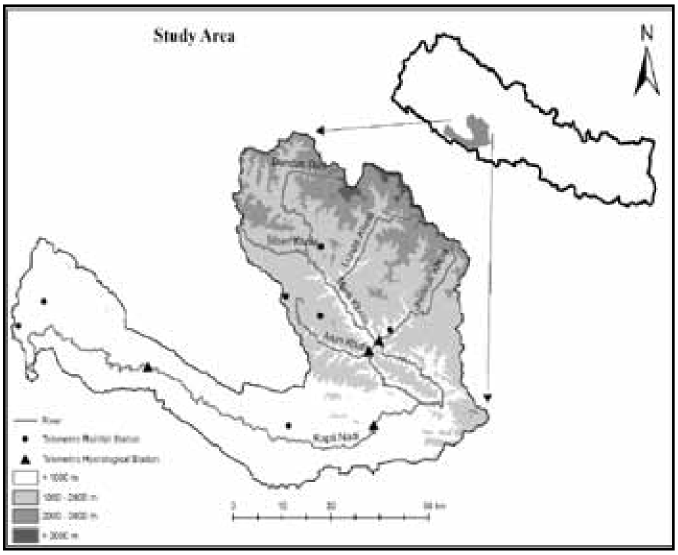


Figure 1: Study Area

4. Real Time Data Acquisition System

In this study, ground based real time data for West Rapti basin is acquired from DHM website. The satellite precipitation data, GSMaP_NRT hourly rainfall is obtained from JAXA website which is freely accessible. The spatial resolution of GSMaP_NRT data is 0.1º and the temporal resolution is 1 hour which is very good in comparison to other satellite rainfall products.

5. IFAS model (Integrated Flood Analysis System)

Integrated Flood Analysis System (IFAS), a concise flood-run-off analysis system, is developed as a toolkit for flood forecasting. This system implements interfaces to input not only ground-based but also satellite-based rainfall data, GIS functions to create flood-run-off model, a default runoff analysis model, and interfaces to display output results in order to establish flood forecast system rapidly and effectively. This study is focused on the major features, calculation results, and applications of IFAS to actual basins.

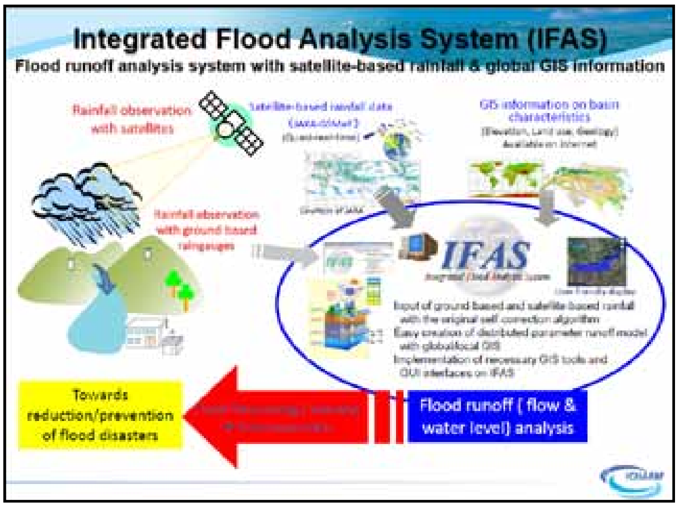


Figure 2: Scheme image of IFAS model (Fukami K., et al.,2006)

6. Result And Discussion

The applicability of Integrated Flood Analysis system for flood forecasting in Nepalese basin has been demonstrated by calibrating and validating the model in West Rapti basin using DEM of resolution 1km x 1km, land cover map, ground based hourly rainfall data. The calibration of parameters is done using flood event of 14th August, 2014 with river gauge measurement at Kusum hydro-meteorological station whereas validation of model is carried out for flood event of 2nd August, 2012 considering the flow at same station.

The possibility of using high resolution (both spatial and temporal) satellite rainfall data in place of ground gauged rainfall is checked using GSMAP_nRT data for the same period of 14th August, 2014 and 2nd August, 2012. The correlation between default satellite based and ground based rainfall is checked and correction factor is determined.

In this model, parameters are adjusted manually by trial and error method. The goodness of fit is evaluated by using the Nash-Sutcliffe efficiency (R^2), Wave shape error (E_w), Volume error (E_v) and Peak discharge error (E_p).

$$R^2 = \frac{\sum\left(Q_{O(i)} - \overline{Q_{O(i)}}\right)^2 - \sum\left(Q_{C(i)} - Q_{O(i)}\right)^2}{\sum\left(Q_{O(i)} - \overline{Q_{O(i)}}\right)^2} \qquad E_P = \frac{Q_{OP} - Q_{CP}}{Q_{OP}}$$

$$E_w = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{Q_{O(i)} - Q_{C(i)}}{Q_{O(i)}}\right)^2 \qquad E_v = \frac{\sum_{i=1}^{n} Q_{O(i)} - \sum_{i=1}^{n} Q_{C(i)}}{\sum_{i=1}^{n} Q_{O(i)}}$$

Where, E , E_W , E_V and E_P represent Error, Wave Shape Error, Volume Error and Peak Discharge Error respectively;

n : The number of calculating time ;

Q_{OP} : Measured maximum run-off;

$Q_{O(i)}$: Measured run-off at time I;

$Q_{C(i)}$: Calculated run-off at time I;

Q_{CP} : Calculated maximum run-off

Model Calibration and Validation Results

Calibration is carried out for flood event of 14th August, 2014 at Kusum station while the validation is carried out within the same catchment for the flood event of 2nd August, 2012. The final result of parameter calibration and validation is as shown in figure 3 and figure 4.

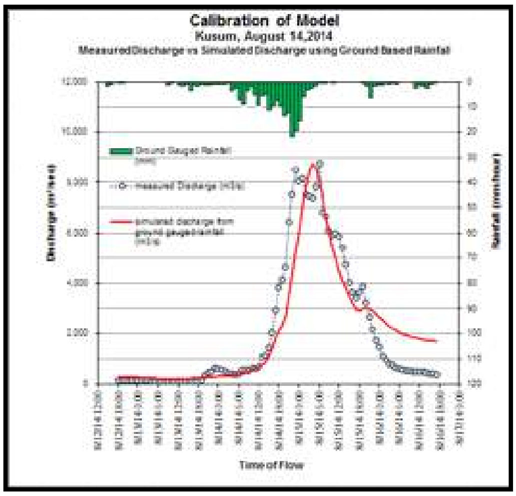
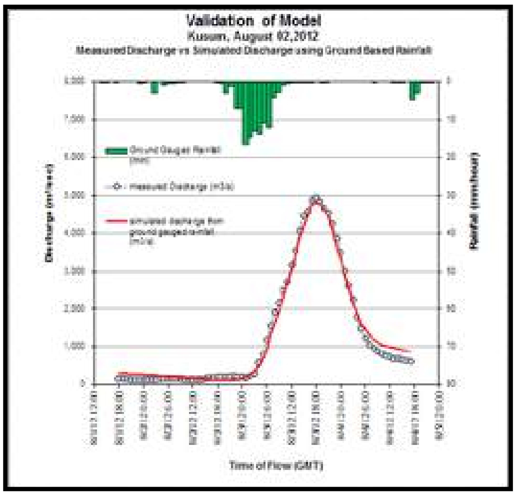
	

Figure 3: calibration result for 14th August, 2014 flood for ground rainfall	Figure 4: Validation result for 2nd August, 2012 flood for ground rainfall

For determining the applicability of GSMaP_NRT satellite precipitation data in flood forecasting, the correlation between raw satellite data and ground gauged data is determined. The comparison between ground gauged data and raw/corrected satellite data is presented in figure 5 and figure 6.

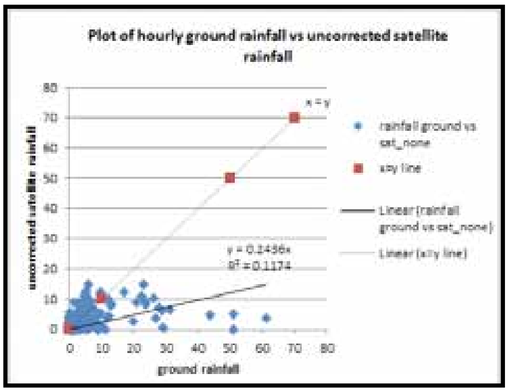
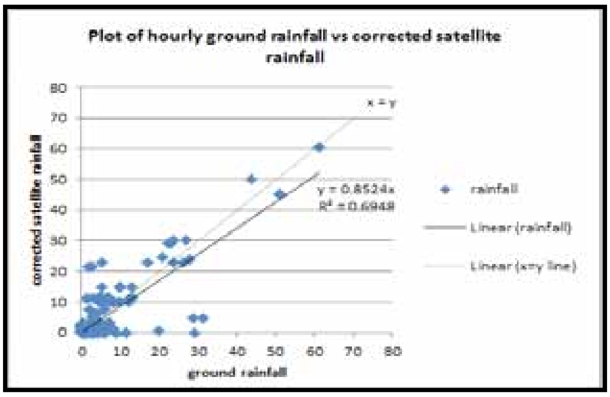
	

Figure 5: Scatter-Plot of hourly rainfall data (Ground vs Uncorrected satellite rainfall)	Figure 6: Scatter-Plot of hourly rainfall data (Ground vs corrected satellite rainfall)

The scatter plot diagram shows that the correlation between ground observed and satellite rainfall has fairly increased after undertaking self-correction function inbuilt within IFAS system.

Furthermore, Simulation is carried out for the flood events of 14th August, 2014 and 3rd August, 2012 using raw and corrected satellite based rainfall. The obtained flood-hydrographs are as shown in figure 7 and figure 8.

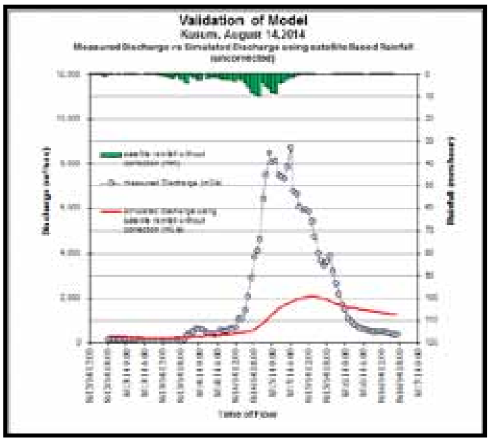


Figure 7: simulation result for 14th August, 2014 flood for uncorrected satellite rainfall

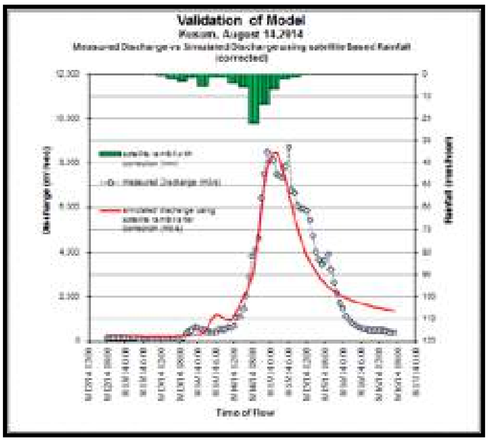


Figure 8: simulation result for 14th August, 2014 flood for corrected satellite rainfall

The above simulation result shows high under-estimation of runoff resulting from original satellite rainfall input and good fit of hydrographs after correction of rainfall. The outcome of calibration and validation using both ground based and satellite rainfall is shown in table 1:

Table 1: Error Analysis of Calibration and Validation Result

	Location	Simulated Flood resulting from	R^2 value	Wave Shape Error (Ew)	Volume Error (Ev)	Peak Discharge Error (Ep)	Remarks
Calibration	Kusum	Ground Gauged Rainfall (14th Aug, 2014)	0.854	1.383	-0.0092	0.0015	ok
Validation	Kusum	Ground Gauged Rainfall (2nd Aug, 2012)	0.959	0.125	-0.0060	0.0284	ok
	Kusum	Satellite based rainfall (corrected) (14th Aug, 2014)	0.919	0.996	-0.0240	0.0318	ok

It is observed that the result for ground rainfall based analysis is giving better result than satellite based analysis though the result in both cases is within acceptable range (R^2 value > 0.7 and $|\Delta Q| < 30\%$) (Chinh, D.D., et.al,2014)

7. Conclusion

The following conclusions are drawn from the results of this study:

a) A good resemblance is obtained between predicted peak flood and observed peak flood with better accuracy for rise part of the hydrograph which ascertains the applicability of this model for middle sized catchment like of West Rapti river.

b) Satellite based hourly rainfall data is used as an alternative to ground based hourly rainfall data. Default satellite data are found to underestimate the rainfall while a fair correlation is obtained between them after correction of satellite rainfall. Hence corrected satellite rainfall data can be used for flood forecasting.

References

1. **Aryal, S., 2013,** "Application Of IFAS Model Using Real Time Data For Flood Forecasting (A Case Study Of West Rapti Basin)" , M.Sc. Thesis, Institute of Engineering.
2. **Chinh, D. D., Thuan, N. T. T., Van, P. T., Thanh, T. N., Manh, V.V., 2014,** Research on the applicability of IFAS model in flood analysis (Pilot at Bang Giang river basin in Cao Bang Province)
3. **Fukami K., Fujiwara N., Ishikawa M, Kitano M., Kitamura T., Shimizu T., Hironaka S., Nakamura S., Goto T., Nagai M., Tomita S., 2006,** "Development of an integrated flood runoff analysis system for poorly-gauged basins", Proceeding of the 7th International Conference on Hydro informatics (HIC2006), vol.4, pp.2845-2852.
4. **IFAS manual, 2009**, ICHARM Publication no.14, Public Works Research Institute, Japan.

Narayani River Training Work

Low Cost Technology / Porcupine

River Training Work

SABO Dam: Sediment Control Structure

River Trining Works

Participants of 22nd Advance Course Training (ACT) and Departmental Dignitaries

Lab Teaching: 22nd ACT

Department of Water Induced Disaster Prevention (DWIDP)
Pulchowk, Lalitpur
Post Box No.: 13105, Kathmandu, Nepal
Phone: 977-1-5535407, 5535502, 5535503, Fax: 977-1-5523528
e-mail: dwidp@ntc.net.np
website: www.dwidp.gov.np