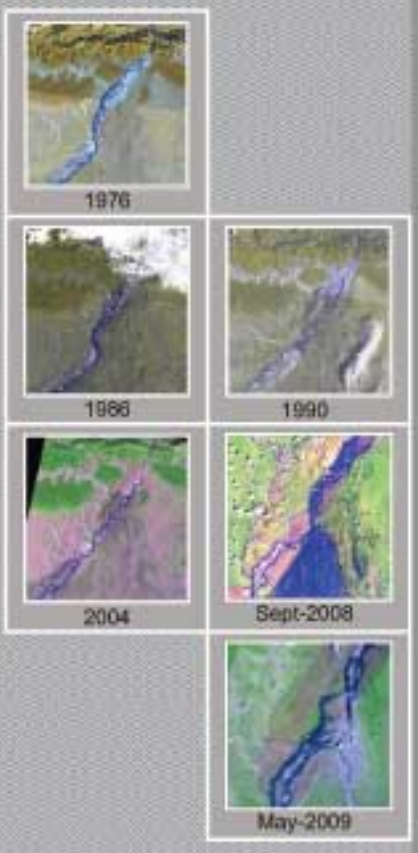
fmis

Bihar



Morphological changes of River Kosi over the years

Flood Report 2009

Flood Management Information System Cell

Water Resources Department
Government of Bihar

For official use only

Inauguration : Training Workshop on "Long-lead Flood Forecasting and Applications"

Visit of Country Director, World Bank Mr. Roberto Zhaga to FMISC

Preface

It is my pleasure to present Flood Report 2009 prepared by the Flood Management Information System Cell. This is the **third annual report** since its inception in the year 2007. Flood Management Information System Cell was set-up under the aegis of Water Resources Department with the objective of improving the flood management practices in the state by introducing the use of Remote Sensing, Geographic Information System (GIS) and modeling techniques. This was established as a Water Sector partnership matrix between the World Bank and the Govt. of Bihar. The report gives a brief account of the 2009 floods and demonstrates the usefulness of modern technological tools like GIS and Remote Sensing in flood management. This report covers the most flood-prone parts of North Bihar from Burhi-Gandak River in the West to Kosi River in the East, covering about 26000 sq. km.

The FMIS Project has in its focus area the districts of East Champaran, Sheohar, Sitamarhi, Muzaffarpur, Madhubani, Darbhanga, Samastipur, Supaul, Saharsa, Khagaria and Begusarai. To monitor the rainfall and consequential flood events in the catchment area of Burhi-Gandak, Bagmati, Kamala, Adhwara Group Rivers and river Kosi, the FMISC, like previous years, functioned in an emergency mode from 15 June to 15 October 2009. During this period, information and data regarding observed rainfall, 3 day rainfall forecast, river gauge levels, trends forecast of CWC and WRD gauge-sites within the focus area were collected and sent to the National Remote Sensing Centre, Hyderabad which in turn, delivered near real time satellite imageries and inundation layers. Based on the collected data, number of information products such as flood inundation maps, flood duration maps, breach maps etc. were prepared in Real Time and disseminated to all stakeholders.

There were two incidents of flood this year. The first one at Tilak Tajpur in the right embankment of Bagmati and another at Govindpur in Labha Chaukia Paharpur right embankment in River Mahananda. FMIS Cell provided initially probable inundation map and later value added satellite images to different stakeholder departments in time. To our satisfaction, the probable inundation maps matched greatly with the actual inundation. These were particularly very useful to Disaster Management Department. Also maps provided by FMISC proved very useful in monitoring the work of breach closure in Kosi Eastern Afflux Bund at Kusaha (Nepal) in river Kosi.

The report includes a brief history of floods in the FMIS focus area from 1999 to 2008 with an emphasis on 2009 Flood. The FMIS Phase-2 is to start with many new features and plans. The work on FMIS is to continue but it has already proved its utility in mitigating the effect of floods and helping the flood affected people in many ways.

I hope all the stakeholders will find this report very useful.

Ajay Nayak, IAS
Principal Secretary,
Water Resources Department,
Govt. of Bihar

ACKNOWLEDGEMENT

The Annual Flood Report - 2009 of FMIS Cell, Patna is a result of diligent and meticulous effort by FMIS Team. Various agencies and individuals have been instrumental in supporting the project.

We would like to acknowledge the contribution of the World Bank which has played a major role in coordinating and capacity building of FMIS and appreciate the personal visit of Mr. Roberto Zhaga, Country Director, India of the World Bank who visited the FMIS Cell at Patna on 3rd September 2009 and was happy to see Water Resoures Department has paid special attention in maintaining the continuity of the work despite the fact that the agreement with World Bank has already expired on 30.06.2008. The continuous association of World Bank especially Mr. Javier Zuleta and Dr. ST Chari deserves special thanks. We are equally thankful to ADPC, Bangkok who actively supported in organizing a brainstroming training on Flood Forecasting and modeling and furhter arranging a study tour for FMIS engineers to Thailand and Bangladesh. We are also grateful to the DFID with whose funding the project has been taken up. The softwares to understand the water profile of Mahananda, Bagmati, Chandan rivers etc. have been procured and engineers of FMIS Cell are working to prepare the Mathematical modelling and dependence on CWC, CWPRS is to end soon. We express our thanks to National Remote Sensing Centre, Hyderabad, India Meteorological Department, Delhi and Patna, Central Water Commission, Ganga Flood Control Commission, Disaster Management Department, GoB and Agriculture Department, GoB, who have constantly been cooperating with the FMIS cell. We are thankful to Flood Cell, WRD as well for providing us useful information.

Finally, our sincere and deepest gratitude are to Shri Vijendra Prasad Yadav, Hon'ble Minister, Water Resources Department, Government of Bihar, for his encouraging support and Mr. Ajay Nayak, Principal Secretary, WRD who not only took keen interest in day to day FMIS development, but is also guiding us continuously.

10.03.2010

S. A. Kabir
Project Director,
FMIS Cell, Patna

The FMIS Team

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Incharge :	Er. Ajit Kumar Samaiyar, Superintending Engineer & Joint Secretary (Engineering), WRD, GoB
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List of Maps

Acronyms

ALTM	Airborne Laser Terrain Mapper
AOI	Area of Interest
ASAR	Airborne Synthetic Aperture Radar
AWiFS	Advance Wide Field Sensor
CMIE	Centre for Monitoring Indian Economy
CWC	Central Water Commission
DEM	Digital Elevation Model
DFID	Department For International Development
DL	Danger Level
DMD	Disaster Management Department
DMSP	Disaster Management Support Program
DRF	Daily Rainfall
DSC	Decision Support Centre
FMIS	Flood Management Information System
FMISC	Flood Management Information System Cell
GDP	Gross Domestic Product
GFCC	Ganga Flood Control Commission
GIS	Geographic Information System
GoB	Government of Bihar
GoI	Government of India
GoN	Government of Nepal
HFL	Highest Flood Level
IMD	India Meteorological Department
LISS	Linear Imaging Self Scanning
Met.	Meteorological
MM5	Mesoscale Model 5
NRSA	National Remote Sensing Agency
RS	River Stage
SRTM	Shuttle Radar Topography Mission
WGS 84	World Geodetic System 1984
WiFS	Wide Field Sensor
WRD	Water Resources Department

1.0 Purpose And Overview Of Annual Report

This 'Report of 2009 Flood Season', is the third Report published at FMIS Cell. This report is in line with second report in term of Geographical coverage and content. This years' flood may be termed as general and except few incidents such as breach at Tilak Tajpur (Sitamarhi district) in river Bagmati and breach at Gobindpur (Katihar district) in Mahananda river, nothing unprecedented happened. This was only possible due to untiring efforts put up by engineers and specialist with whole hearted support of Hon'ble Minister WRD and our very dynamic Principal Secretary. This year will be remembered for a long time as there was some flood in some part of the State and severe drought condition prevailed in other parts of the State. The work of Kosi breach closure successfully withstood the 2009 flood. This report will serve as a source of information and a reference document for FMISC Technical Committee and Advisory Committee and also for key stakeholders, such as Disaster Management Department., Agriculture Department and Water Resources Department. The key objective of this exercise is to attempt to make this report coherent and standardized so much so for the reader to get the most comprehensive picture of the flood issues, benefits and stakes. It aims to fulfill two primary roles: a summary of the flood in year 2009, the hydrologic analyses and a collection of important data on the flood regime primarily through inundation maps. These data will, in time, accumulate to provide a primary regional resource for flood research and the collection of historical reference material.

The main text of the Report is laid out in such a way that there is a logical progression from the creation of awareness of the nature and history of FMISC Focus Area, which is now not a rigid one but encompasses entire North Bihar primarily based on demand and situation towards the specific evaluation of events in 2009. At times FMISC has gone a step forward in producing Maps beyond FMISC focus area on special request of our Stakeholders with the help of modern technology of GIS and Remote Sensing. Another interesting study has been carried out with Observed Rainfall and Water Level at various points of rivers in Bihar on the same time scale. Isohyets maps with rainfall station and drainage layer are sure to give a better visualization of the situation.

2.0 Flood hazard in FMIS ACTIVITY AREA

FMIS activity area has been the most flood prone area in the State consisting of Kosi, Bagmati, Burhi Gandak, Gandak, Ghaghra, Mahananda rivers. A number of minor rivers also falls in North Bihar. Furthermore this area is the saucer shaped area between the embanked river of Gandak and River Kosi.

2.1 The Physical Setting of Bihar

Bihar lies between latitude 21° 58' 10" N -27° 31' 15" N and longitude 82°19' 50" E-88° 17' 40" E. The total geographical area of Bihar is about 94 thousand sq. km (94,000 km). The FMIS focus area for phase I lies between latitude 27°02' N to 25°15' N and longitude 84°28' E to 86°53' E. and the geographical area is about twenty six thousand sq. km. (26,000 sq. km.). The geographical coverage is as shown in the figure below and the colored area is FMIS focus area.

Geographical Coverage of Bihar

Map 2.1 Geographical Coverage of Bihar (Focus Area - 11 Districts of North Bihar)

2.2 FMIS ACTIVITY AREA

The area is bounded by Himalayan foot hills and terai region of Nepal in the north, Mahananda on the east, river Ganges on the south and River Gandak on the west. The area comprises of rich alluvial plains of Indo-Gangetic plain. It comprises the tract of alluvial plains north of Ganga, falling between the Ganga and Indo-Nepal border having general slope from north-west to south-east and is drained by the rivers, Burhi Gandak, Gandak, Mahananda and Kosi falls into the Ganga and Bagmati- Adhwara, Kamla-Balan etc. which also drain into the Ganga through the Kosi.

The total geographical area of North Bihar is approximately 50000 sq. km. comprising of Districts namely Muzaffarpur, East Champaran, Sitamarhi, Seohar, Saharsa, Supaul, Darbhanga, Madhubani, Khagaria, Samastipur, Begusarai, Araria, Madhepura, Purnea, Katihar, Kishanganj, Saran, Gopalganj, West Champaran, Vaisali and Siwan

The geographical coverage in South Bihar is approximately 44000 sq. km. comprising districts namely Rohtas, Buxar, Kaimur, Bhojpur, Arwal, Patna, Jehanabad, Aurangabad, Gaya, Nalanda, Sheikhpura, Nawada, Lakhisarai, Munger, Jamui, Bhagalpur and Banka. Some major rivers lying within this region are Sone, Punpun, Kiul etc. Besides there falls many small rivers in this region.

The soil of Focus area is sandy alluvial, rich in lime and often contains high proportion of clay. There are pockets where soils are calcareous with high proportion of calcium carbonate. The

soils are among the most fertile in India and can support a variety of crops with appropriate land and water management.

2.3 Climate and Rainfall

Bihar has monsoon type tropical climate with high temperature and medium to high rainfall. The temperatures are lowest during December-January with an average minimum of 8°C to 10°C and maximum of 24°C to 25°C. The temperatures in the hottest months of April to June are minima 23°C to 25°C and maxima 35°C to 38°C.

The mean annual rainfall for the State is about 1270 mm varying from 1170 to 1580 mm in Focus area. Most of the rainfall (80% to 90%) is received from mid-June to mid-October. The late September-October rains (locally known as 'Hathia'), though only 50 to 100 mm in quantity, are very crucial to agriculture in the region and their timing and distribution make all the difference between plenty and scarcity.

2.4 River System of Bihar

2.4.1 North Bihar

Important Rivers namely Ghaghra, Gandak, Burhi Gandak, Kosi and Mahananda etc. fall into river Ganga, the master drain flowing from west to east, whereas Bagmati- Adhwara, Kamla-Balan etc. drain into the Ganga through the Kosi.

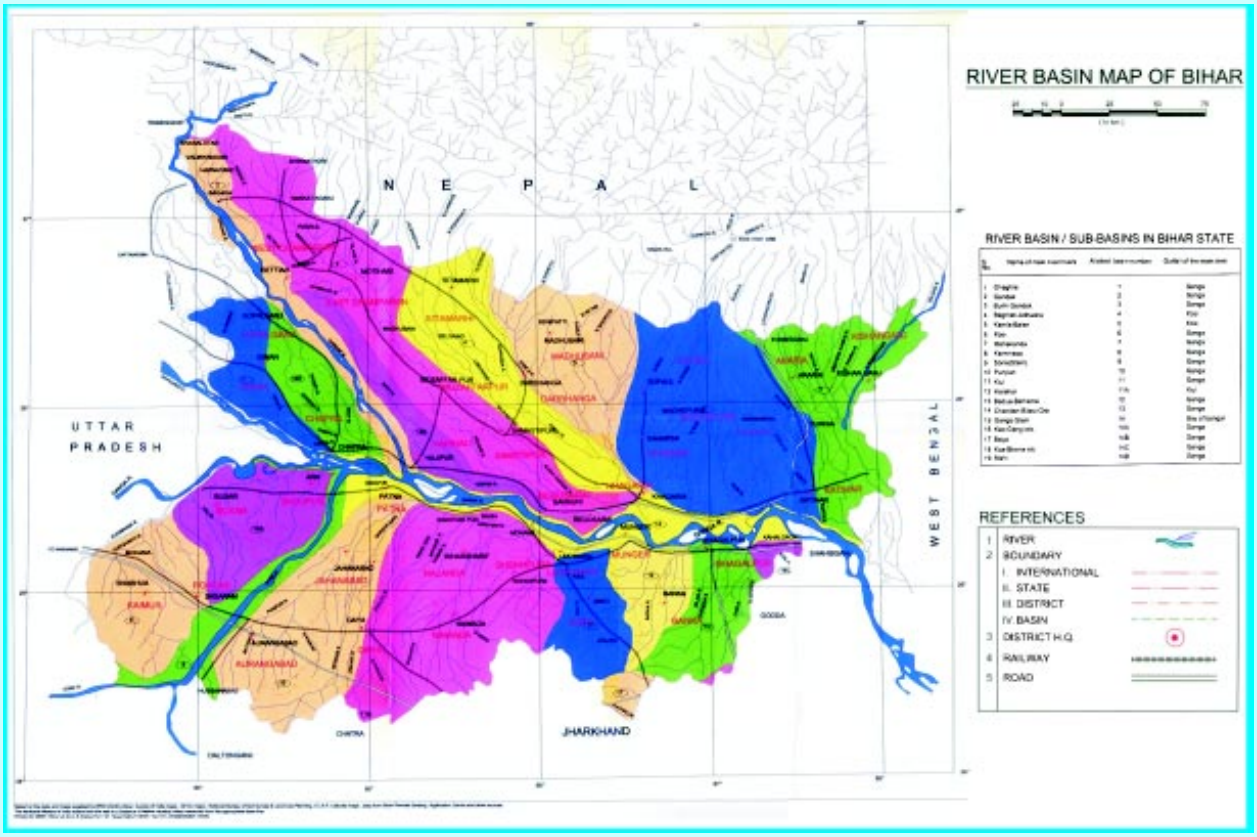
The Ghaghra, Gandak and Burhi Gandak rivers of North Bihar are now more or less stabilized. It is believed that river Gandak has travelled from near Burhi Gandak on the east to its present course on the west in course of last several hundred years. In this process of shifting, it has created numerous chaurs (saucer like depressions) and mauns (deep horse-shoe shaped water bodies formed due to avulsions/cut-offs) in the Basin. The other North Bihar rivers such as the Bagmati, Adhwara group of river, Kamla-Balan and Kosi are still very unstable due to steep slopes in their upper reaches and high silt charges and are always exerting tremendous pressure on the embankments within which they are presently contained at enormous cost and efforts. The Kosi river also shifted from near Purnea on the east to its present course on the west prior to breach last year. Again, this river has moved towards east from its course after the Kusaha breach. In its lateral travel of about 120 km. in course of about two centuries, the Kosi has created a number of swamps and marshy lands in the Basin, apart from depositing coarse silt and sand in almost entire area.

The major rivers of North Bihar have Himalayan origin and considerable portion of their catchments lie in the glacial region. They are, therefore, snow-fed and perennial in flow. These rivers have catchments in the Himalayan region in Nepal. Some of them have catchments even in Tibet. They receive very copious rainfall during monsoon when discharges of these rivers are 50 to 90 times larger than fair weather flows. This causes frequent flooding of a large portion of North Bihar. Despite existence of flood embankments on most of them, about 73.63 per cent of the geographical area of North Bihar is considered to be prone to floods.

2.4.2 South Bihar

This tract of land is drained mainly by Rivers which are rainfed, having their origins either in the Vindhyachal hills or in the hills of Chhotanagpur and Rajmahal. These rivers are either dry or carry scanty discharges in non-monsoon months. Karmanasa, Sone, Punpun, Kiul, Badua, Chandan etc. are the important rivers of this region which fall ultimately into river Ganga.

A peculiar phenomenon in this region is the formation of Tal. The southern bank of the Ganga is naturally formed as a levee obstructing the drainage of the land on the south of it, which extends up to the foot of Chhotanagpur hills. The natural slope of this land is from south to north, from foot hills of the Chhotanagpur hills to Ganga. There are several rivers in this tract which drain the rain water of the tract and accumulate them behind the high bank of Ganga. This has resulted in formation of tals viz. Mokama Tal, the area just on the south of the high Ganga bank, which comprises a group of Fatuha Tal, Bakhtiyarpur Tal, Barh Tal, More Tal, Mokama Tal, Barahiya Tal and Singhaul Tal. These tals also receive backwater of the Ganga when it is in high spate. Therefore, the tals get submerged in water during monsoon season and are thus deprived from kharif cultivation in most of the area. Even after the monsoon season, entire area does not get drained into the Ganga quickly. However bumper rabi & hot weather crops are grown in the Tal area that gets freed from water in time.



Map - 2.2 River Basin Map of Bihar

2.5 Socio-Economic Context

Bihar is one of the most populous state of India, but economically one of the most backward. Along with a very high proportion of population below the poverty line, the different social and economic indicators below amply reflect the precarious position of Bihar among the Indian States.

Human development index indicator

	India	**Bihar**
Per Capita income (in Rupees)	16707	6850
Literacy Rate	65.38%	47.5%
Infant Mortality Rate (SRS 2006)	60	60
Gross enrolment ratio (6-14 yrs, %)	65	47

Source: Director of Statistics , GOB, Census report 2001

As indicated above Bihar has a very dismal performance among the states of India- its per capita income (net GDP at factor cost at current prices) stands at a mere Rs. 6850 as against Rs.16707 for India as a whole. The state has the lowest literacy rate among the major states of India-47.5 percent as against the national average of 65.38 percent. The Child mortality rate is 60 for both Bihar and India. The gross enrolment ratio stands 47 for Bihar against 65 for India.

Agriculture

Bihar has a large alluvial river valley area. Against the backdrop of such generous natural resource in irrigation sector the overall percentage of net area irrigated in Bihar is about 38%, irrigation is largely seasonal and protective.

	India	**Bihar**
Percentage income from agriculture	29.93#	38.16#
Potential created in million hectare (mha) (Major and Medium irrigation:>2000ha)	37.05#	2.833*
Ultimate irrigation potential, (mha) (Major and Medium irrigation:>2000 ha)	58.47#	5.36*

Annual Plan 2006-07, GOB

* Annual plan report of WRD, Bihar 2007-08

The acute poverty and backwardness can be traced to the backwardness of both in agricultural and industrial sectors. The reasons for the extreme backwardness of agriculture are both institutional and technological. Where as structural and institutional factors have been operating as a powerful

barrier to the agrarian transformation, the technological factors such as poor development of infrastructure like irrigation and power, non-availability of modern inputs, low value of credit and poor extension services, etc. have also contributed much to the dismal performance of the state's agricultural sector.

Demography

	India	Bihar
% Population in rural area	72.2	89.6
Density of population (per sq km)	324	880
% Population below poverty line	26.10	42.60

Source: Annual Plan 2006-07, GOB, Census report 2001

The major explanation of the state's backwardness and poverty, however, has to be traced to the rural sector. With about 89.6 percent of the population in rural areas (as against 72.2 percent for India as a whole), it is the most rural state in the country, next only to Assam. About 42.60 percent of the state population is below poverty line as against about 26.10 percent for India as a whole.

One of the obvious reasons for the economic backwardness and poverty of Bihar is its high density of population 880 persons per sq. km against 324 per sq km for whole of India. (2001). In the wake of wide spread poverty, a substantial number of poor people go outside the state in search of livelihood.

The State's backwardness is probably more related to its socio-economic-political structures. Floods in large parts of the plains of Bihar, especially in north Bihar, are recurring features and cause havoc destroying crops and the quality of land, and threatening the conditions of life and livestock due to large-scale displacement. These factors add to woos of Bihar. Flood in North Bihar is a perennial problem. Every year, almost 22 districts get flooded, causing huge loss of property, lives, farmlands and infrastructure. A disaster management system equipped with data, technology and resources can meet ravages of cyclic natural disasters. Water logging in substantial parts of the command area of north Bihar is another chronic problem with adds up to the socio economic backwardness of Bihar

2.6 Flood Typology

Conventionally the typology of flood management classes is based on flood type, source area, warning time, flood duration and recession, and impact on agriculture. FMISC have identified 4 classes of floods which can be classified as

Class I: Flash floods - floods from Nepal rainfall, lead time is short (8 hours) in Kamla Balan, recession is fast,

Class II: River floods - lead time 24 hours, recession is 1 week or more,

Class III: Drainage congestion in river confluence- lead time > 24 hours, lasting full raining season, no Kharif season agriculture

Class IV: Permanent water logging - shrinkage in area only in Feb, local rainfall, micro-relief aspects.

Another classification which has been identified by FMIS resulted into four classes of Floods, which are following:

Not affected	<10% area inundated.
Low Flood	11%-30% area inundated.
Medium Flood	31%- 60% area inundated.
High Flood	> 60% area inundated

2.7 Occurrence of Floods in River Systems

A study has been made to see the flood stages in various river systems during floods in FMISC focus area. It was found that early flood takes place during the month of May-June in River Bagmati, Kosi and river Kamla. Thereafter flood generally comes in River Burhi Gandak in the month of mid July. During these months River Ganga generally remains low but by September River Ganga, the master drain also rises making the flood problem more acute.

2.7.1 Floods in Last Ten Years in the FMIS Focus Area

Floods have caused devastation and acute human sufferings frequently since the dawn of civilization and man has had to live with floods since time immemorial. The impact of flood was perhaps not felt to the same extent in the past as is felt now. This was due to the fact that there were smaller living population and pressures of industrial activities and other development works in the flood plains was far less compared to the present day activities. The flood problem was accentuated due to ever increasing encroachments on the flood plains by the growing population to meet its requirements of food and fiber. The destruction of forests for reclaiming areas for occupation and for obtaining fuel for domestic requirements had also caused changes in river regime. All these have resulted in an anomalous situation where, in spite of protection measures carried out so far in the State with a substantial investment on flood management works, flood damages have gone on increasing instead of decreasing. A brief summary of flood based on the Water Resources Department Annual Flood Report in chronological order during (1999-2008) is given as follows:

1999-This year rainfall in June was more than normal rainfall. In July Bagmati basin experienced more than normal rainfall. In August no significant rainfall was observed whereas in month of October the rainfall was more than normal rainfall in the focus area. Due to more than normal rainfall, the spur in Kosi river experienced threat throughout the flood season. But timely flood fighting kept the river within the embankment. In the river Burhi Gandak, the right embankment at Suratpur, Sikhaula and at left embankment at Tatitola, Pehsara, Bihulia, Mirzapur, Rajhwara, Bore-Jairam, Satmalpur, Begumpur and Balapur were threatened by flood water but timely flood fighting kept the embankment safe. In Bagmati river right embankment at Kothia and Surgahi site felt high pressure, similarly at left embankment at ch. 314 to ch. 329 and ch. 397 to ch. 405. Right embankment was kept safe by flood fighting but for the left embankment retire bund was constructed to keep the river safe from flooding the area. In Kamla-Balan right embankment 8 to 10 km., 12.7 to 13.5 km and 58.6 km felt high tension and pressure which were overcome by flood fighting. In October due to excessive rainfall at 55.5 km, the embankment breached in 215 ft length. Same way Kamla-Balan left embankment at 27 km, 31 to 42 km, 44.7 km, 46 km, 49.6 km 57 km 59.42 to 61.25 km, 62 km, 65.4 km, 66.6 km, 67.5 km and at 82 km were under threat which were overcome by flood fighting but the villagers purposely cut at 60 km, 63.5 km, 65.3 km, 78.5 km, 82 km and 86.75 km so that they could allow the river to gush in the fertile silt into their fields. Bhutahi-Balan at 8 km the right embankment breached and caused loss to the area. And at left embankment at 16 km. great pressure was overcome by flood fighting.

2000- Bagmati left embankment at chain 273 near village Madhkaul was cut by villagers. Chain 311 near village Madar was breached on 6/8/2000. Again in the last week of September and in the first week of October at km 11,12,20,35.5 and48 were cut by the villagers. Incident of embankment cut had been reported earlier also. This was done to bring silt to raise land by the villagers. Kamla-Balan and Bhutahi-Balan catchments received heavy rainfall during first and last week of July resulting in unexpected rise of water. Slope of Left embankment of Kamla-Balan embankment between km 89-90 in a length of 200 m was damaged. Spur at 2.80 km of Eastern Kosi Afflux Bund was punctured in the night of 4/8/2000 in a length of 20 m and the nose was washed away due to heavy pressure of river. A new nose and shank was constructed in a length of 563 m and spur was made safe. The spur at km 14.5 was also damaged in half of its length in the night of 29/9/2000, experts from head quarter camped at the site and brought the situation under control. Sikarhata Majhari Bund of Western Kosi embankment between Km 6-7 was damaged in the night of 13/8/2000 but saved by doing flood fighting work. Heavy pressure on spur at km 78.30 of Eastern Kosi embankment was overcome by undertaking flood fighting work.

2001-Left bank of river Burhi Gandak at Rampurwa Pulwar, Pakridayal, Enarwa Ghat Mainpurwa and right embankment at Bihkhiya, Chakarniya, Bairiya, Koral, and Balochak were experiencing pressure but was saved by timely flood fighting. Burhi Gandak left embankment at 69-70 km at village More, the bed wall which was earlier constructed, damaged due to heavy local rainfall and pressure over embankment. Burhi Gandak at right embankment at 98-99 km at village Phulwaria, anti social elements cut the embankment on 17.9.2001. The Right embankment of Bagmati River at Kothia and Surgahi and left embankment at Kansar embankments were experiencing heavy pressure throughout the entire flood season but were saved by timely flood fighting. No breach in this reach occurred. Western Kosi embankment at Ghoghardiha, Jamalpur embankment at 30.105 km and at Sikhta Manjhari there were pressure over embankment which was safely overcome by timely flood fighting. Western Kosi embankment at 2.25 km the D-part of spur nose was damaged. Bhuthi-Balan right embankment breached due to overtopping at 20.91 Km, 21.01 km, 21.4 km 22 km, and 60.7 km in first week of October.

2002-Kamla Balan left embankment at km 81.20 (Bugras) was cut by villagers in a length of 30 m which increased to 50 m. Overtopping reported in Kamla Balan left embankment at km 38 at Bhadhuar on 23.7.2002, at 39 km near Bhadhuar sluice, at 50.5 km near Pipra ghat, 51 km at junction point of rail cum road bridge and embankment and 74.8 km in Asma village on 23.07.02. Kamla Balan right embankment at km 37 near village Banaur and km 64 at village Thengha were cut by villagers, piping and by anti social elements in a length of 30 m which increased to 300 m. Bagmati right afflux bank embankment at ch. 1025 near village Dharampur was cut by the villagers on 23.7.02. Bagmati left embankment near ch. 145 of Sirsia ring bund at 20 to 30 ch and 29 to 32.5 ch the embankment was breached due to overtopping. Bagmati left embankment between ch. 145 to 149 was cut by villagers on 23.7 02. Kiroi left embankment at 7 km at village Masartharia and 5.25 km near Maasma and Kiroi right embankment at 12 km near Belwara Milki village and at 3 km near Bagwasa village it breached due to overtopping on 24.7.02. Western Kosi embankment at 29 to 30 km below Kasba Bharda was cut by villages at 2 places.

2003-Maximum discharge of 389000 cusec passed through river Kosi where as discharge in excess of 250000 cusec passed four times which resulted in continuous pressure on spurs/embankments. This resulted into damage of spurs in western Kosi embankment at 25.57, 15.80 and 15.30 km. On 1/8/2003 due to high discharge through the river, right embankment of Bagmati river at Surgahi site at chain 112-123 breached in 50 ft. which increased to 1100-2000 ft. On

1/8/2003 antisocial elements cut Kamla Balan right embankment at km 66.50 in a length of 50 ft. Status of flood in other rivers except Ganga, Gandak remained normal. In river Ganga the HFL at Bhagalpur surpassed the 1978 record of 34.18 and was 34.20 level and at Patna at Ghandighat the HFL level as of 1994 (50.27) was observed as 50.12 in 2003 due to this heavy flooding in Ganga resulted in damage to the road network in Samastipur district. In river Gandak the maximum discharge 6,69,750 cusecs passed through Valmikinagar barrage on 31.7.03

2004-2004 flood in the state of Bihar was unprecedented which proved to be very grave and damaging. Catchments area of North Bihar rivers received heavy rainfall in the first week of July itself which not only broke last three years flood record but also surpassed the 1987 flood year which was the maximum flood producing year. Flood level at Dubbadhar site on river Bagmati surpassed all time high flood level by about 1.18 m. similarly Burhi Gandak river on 15.7.04 and Kamla Balan river on 10.7.04 touched all time high flood level. This it self speaks about the fury of flood in year 2004. Many places in the embankment of North Bihar were breached resulting in flood inundation in a vast area of North Bihar area. Unprecedented flood in river Bagmati, Burhi-Gandak, Kamla and Bhutahi-Balan and Adhwara groups of river breached the embankments at many places and there was loss of life and property in a large scale. In river Kosi situation by and large remained normal and a maximum discharge of 286375 cusecs passed on 10.7.04.

2005- The flood situation during 2005 was normal in comparison to the devastating flood of 2004. Where there were 63 numbers of breaches during 2004 flood, where as only 8 breaches occurred during the year resulting in flood inundation in Madhubani and Katihar districts only. Left and right embankment of Kamla was breached at seven places during this year. Bhutahi Balan left embankment at km 21.22 and 22.80 was cut by the antisocial elements and due to flash flood, embankment was damaged at few places.

2006- The flood situation during 2006 was normal. Where there were 63 numbers of breaches during 2004 flood, this year only 1 breach occurred. Left embankment of Kamla was breached near village Asma at km 75.70 by antisocial elements but fortunately there was no loss of life or property. Flood situation in other places remained normal by and large.

2007- 2007 floods will be remembered for high degree of rainfall which was even more than year 2004 flood. Districts of Champaran, Gopalganj, Siwan, Madhubani, Darbhanga, Muzaffarpur, Samastipur, bore the fury of flood to a large extent. But fortunately compared to 2004 floods, there were fewer numbers of breaches (32 nos. in Bihar) in 2007 as compared to 63 in year 2004. Unprecedented flood in river Bagmati, Burhi-Gandak, Kamala and Bhutahi-Balan and Adhwara groups of river breached the embankments at many places and there was loss of life and property. In river Kosi situation by and large remained normal.

2008- There was an unprecedented flood due to a breach near 12.9 km of Eastern Kosi Afflux Embankment near Kushha village in Nepal on 18th August 2008 which very soon took the shape of a catastrophe leading to the miseries to lakhs of people in Sunsari and Saptari districts of Nepal, and Supaul, Madhepura, Araria, Saharsa, Katihar and Purnia districts of Bihar. River Kosi entirely changed its course from earlier one. This was again tamed to its earlier course by WRD after a tremendous effort keeping in line with the advice of Kosi Breach Closure Advisory Committee (KBCAT).

2.8 Flood Characteristics Of Focus Area

FMIS focus area comprises of Muzaffarpur, East Champaran, Sitamarhi, Sheohar, Saharsa, Supaul, Darbhanga, Madhubani, Khagaria, Samastipur and Begusarai. A study has been made with the help of data obtained from DMD level to see the flood events that took place in the Blocks of these districts in term of inundation during 1987 to 2009 (24years). A summary of the findings is given below :-

Sl. No.	Name of Districts	No. of Blocks affected more than equal to 11 years out of 24 years	No. of Blocks affected more than 5 years but less than 11 years out of 24 years	No. of Blocks affected less than equal to 5 years out of 24 years
1.	Muzaffarpur	7	3	6
2.	East Champaran	5	14	9
3.	Sitamarhi including Seohar	11	6	1
4.	Madhubani	5	11	8
5.	Darbhanga	11	6	3
6.	Supaul	6	1	5
7.	Samastipur	6	4	12
8.	Saharsa	6	0	3
9.	Begusarai	3	4	9
10	Khagaria	6	1	-
	Total	**66**	**50**	**56**

The table indicates that there are as many as 66 blocks of FMIS focus area which is chronically flood affected in terms of flood inundation.

2.9 Loss Of Public Property In Last 10 Years

Loss of Public Property															
Year	Number of Affected									Crop Damaged (Rs. Lac)	House Damaged		Public Property Damaged (in Rs. Lac)	Deaths	
				(in Lac)			Area (in Lac ha.)								
	District	Blocks	Village	Human	Animal	Agric	Non-Agric	Total	Cropped		Total	Value (in Rs. Lac)		Human	Animal
2008*	16	86	1678	18.36	1.139	1.752	.394	2.146	.835	1704.09	7007	379.9	321.1	74	2
2007*	22	264	12610	248.13	16.13				16.63	133328.39	736857	99312.49	158072.96	9604	1006
2006	14	63	959	10.89	0.1	1.52	0.297	1.81	0.87	706.63	18,637	1,225.03	8,456.17	36	31
2005	12	81	1,464	21.04	5.35	3.343	1.261	4.6	1.35	1,164.50	5,538	382.79	305	58	4
2004	20	211	9,346	212.99	86.86	20.99	6.01	27.00	13.99	52,205.64	9,29,773	75,809.51	1,03,049.60	885	3272
2003	24	172	5,077	76.02	11.96	9.943	5.14	15.08	6.10	6,266.13	45,262	2,032.10	1,035.16	251	108
2002	25	6	8,318	160.18	52.51	14.45	5.244	19.69	9.4	51,149.61	419,014	52,621.51	40,892.19	489	1450
2001	22	194	6,405	90.91	11.7	9.042	2.91	11.95	6.5	26,721.79	222,074	17,358.44	18,353.78	231	565
2000	33	213	12,351	90.18	8.09	6.57	1.476	8.05	4.43	8,303.70	343,091	20,933.82	3,780.66	336	2568
1999	24	150	5,057	65.66	13.58	6.79	1.66	8.45	3.04	24,203.88	91,813	5,384.95	5,409.99	243	136

Source: (Disaster Management Department)

Source:(http://disastermgmt.bih.nic.in/)

*** Indicates Provisional figure**

3.0 Overview

The Government of Bihar has identified improvement of flood management as a priority area for World Bank engagement in the State. The World Bank - Government of Bihar Partnership Matrix (2006) prioritizes the improvement of the institutional capacity for delivering better flood management and drainage services, as a key action for accelerating agriculture productivity in North Bihar. **The Flood Management Information System (FMIS),** identified for entry-level and short-term bank engagement in Bihar, is designed to generate and disseminate timely and customized information to move the sector agencies from disaster response to improved disaster preparedness and to effectively support flood control and management in the flood prone areas of the State of Bihar. Improved flood management that will protect the poorest farmers and tribal groups located in the low value lands in the flood plains, is also in line with the Bank/DFID partnership policy of extending Bank's support to state reforms that could lead to lasting poverty reduction.

The development of FMIS is planned in four stages: Flood hazard characterization & emergency response; improved flood preparedness and community participation; Flood hazard mitigation; and Integrated flood management. The technical improvements in flood forecasting, inundation modeling and warning, and embankment management are also coupled with expanded institutional and community linkages and expanding geographic coverage (from the most flood-prone 11 districts in North Bihar in the first stage to the whole flood prone area in the third stage). The fourth stage aims to develop integrated flood/drainage/irrigation management through upgrading FMIS into a Water Resources Information System, implementing operational community based flood management, and operationalizing regional flood knowledge base and management plans.

The first module has been implemented and operational during 2007 flood season, with focus on flood hazard characterization and operational flood management information products, supplemented by improved flood forecast, a flood website for public dissemination and access, updated flood control manuals, plans for upgrading hydrologic measurements and telemetry, and training. Incidently improved flood forecast modeling could not be completed mainly because of data constraint. Providing and disseminating information tools has moved sector agencies capacity from disaster response to improved disaster preparedness and to effectively support flood control and management in the flood prone areas of the State of Bihar. The FMIS in the first stage had covered the focus area from Burhi Gandak river in the west & Kosi river in the east in North Bihar that is most flood prone in the State.

The subsequent stages of FMIS development would cover substantially enhanced functions and products, supported by improved hydrologic observations and telemetry, more reliable and longer term rainfall forecasts, enhanced flood forecast and inundation prediction with better models, Airborne Synthetic Aperture Radar (ASAR) surveys for real-time inundation information during floods, close-contour surveys of the flood plain, mapping floodplain geomorphology including micro-relief to understand and improve drainage, improved communication links and information flow, risk and vulnerability analysis, institutional and community outreach mechanisms, and real-time flood data dissemination. The fully upgraded FMIS would support preparation of master plan for flood control and drainage, irrigation improvement, and overall water sector development in Bihar State.

3.1 FMIS Phase-I Objectives

FMIS Phase-I objectives were: To move from disaster response to improved disaster preparedness, to improve the lead time of the forecasts, develop a focal point in an institutional (e.g. a multi-disciplinary Flood Management Information System Cell) framework and information (e.g. a web-portal for Bihar Flood Management) setting, as well as improved information flow (e.g. bulletins, improved use of email/internet/cell phones) and sector preparedness (by updating flood manuals).

Along with a substantive effort of planning the development and rehabilitation of the flood and drainage control infrastructure, in the short term, there is a compelling need for adopting new technological approaches to improve the decision process before, during and after the flood events and the use and allocation of available resources.

In the short-term FMIS would help strengthen existing institutional capacity and arrangements for flood management in the state and make extensive use of modern technology (e.g. satellite remote sensing, Geographic Information System [GIS], Internet, forecast models, etc.). Relevant outcomes of the technical assistance are the strengthening of flood knowledge base and analysis, the dissemination and outreach of operational flood management information and the improvement of flood preparedness.

3.2 Activity Completion Report for Phase I

The project components included:

i) Development of FMIS

ii) Improved flood forecasting

iii) Bihar Flood Information Website

iv) Updated flood control manual

v) Training

vi) Plan for upgrading hydrologic measurements and telemetry.

The 'Activity Completion Report' received from the World Bank mentions that FMIS has been set up. FMIS website has been developed and hosted. The website (http://fmis.bih.nic.in) is operational providing public access to flood data. FMIS officers have been trained. The FMIS has addressed information needs for early warning and emergency response of three key Departments: Water Resources, Disaster Management Department and Agriculture Department. The Central and State Agencies linkages (linkage between WRD, GOB, and NRSA/ IMD / SOI/ CWC and GFCC) have been strengthened. In a nut shell, almost all the project activities except improved flood forecast modeling have been successfully completed and the project outputs and outcomes have been substantially realized with the disbursement to the tune of about 93 percent of the total project cost. The Bank has expressed its pleasure over their commitment for sustaining the FMIS by supporting continued operation with substantial augmentation of systems and staff.

3.3 Activities of FMISC in 2009

Like previous years, this year, too, FMIS Cell, Patna with all its resources and as per its mandate was ready and prepared for the flood season 2009. The satellite data for North Bihar, which were received in FMISC, Patna from NRSC, Hyderabad, were further processed, value added and disseminated almost same day or next day to the user/stakeholder departments like WRD, DMD, GFCC, Agriculture Department, NRSC, CWC etc.

3.3.1 Monitoring of Kosi breach closure

Consequent upon breach in Eastern Kosi Embankment at Kusaha in Nepal, the state witnessed one of the biggest 'water-borne' disaster of recent history. With incessant efforts of our engineers, coupled with technological support provided by FMIS cell, the magnitude of disaster was tried to be kept at the minimum. The breach was successfully closed but the wound was still to be closely watched and cared for.

All through rainy season FMIS cell monitored the site with the help of whatever satellite images were available. We watched through low resolution daily images of MODIS and we procured high resolution Cartosat images as well. This helped our engineers to study river behavior at, above and below the Barrage. They could plan layout of pilot channels as well as were able to 'see' the effect of piloting. Even now we are procuring latest satellite images to study the status of Embankment and changing river behavior.

The Kusaha episode helped us gear-up for tougher tasks.

District-Wise Damage Statistics For 2009 Flood

District-wise flood damage statistics as obtained from DMD for 2009 flood for FMIS area is given below:-

Sl. No.	District	Blocks	No. of affected village	Cropped Area (Lakh hect.)	Estd. Crop. damage (Rs. Lac)	No. of house damaged fully /partially	Estimate of Value house damaged in (Rs. Lac)	Public Properties damage (Rs. Lac)	Lives lost (Nos.) Human		
									Flood	Others	Animals
1.	Muzaffarpur	04	148	0.18	480.50	1474			14		02
2.	Sitamarhi	02	30				0		01		
3.	Saharsa	05	55			692	64.17	2.10	08		
4.	E.Champaran										
5.	Supaul	05	74			1515	150.92		01		
6.	Darbhanga	17	478	0.25	361.73	22	2.20	50.00	36	09 (Boat Accident)	
7.	Madhubani	10	200	0.19	846.51	462	59.10	214.00	08		
8.	Samastipur	01	83			0			00		
9.	Sheohar										
10.	Khagaria	06	78	0.17	0.25	65	22.75	55.00	01	19 (Boat Accident)	
11.	Begusarai										
Total		**50**	**1146**	**0.79**	**1688.99**	**4230 (KF-2182,KP-802,PF-200,PP-171, Huts-875)**	**299.14**	**321.10**	**69**	28 (Boat Accident)	

Source : Disaster Management Department

3.3.2 FMIS Cell gears up for any emergency situation during flood

Similar to previous years FMISC was ready to face any emergency situation during flood. This year too FMIS Cell geared up with the limited personnel and resources at its disposal and started collecting information, maps and satellite images from all possible sources; indigenous or global. The Cell started working in two shifts, from 7 a.m. to 2.00 p.m. and from 2 p.m. to 9 p.m. daily including holidays.

There was continuous liaison with CM Secretariat, Water Resources Department and Disaster Management Department and **value added maps** were provided as required in shortest possible time.

3.3.3 Bagmati & Mahananda Breach related flood information

On 1st of August 2009, a breach was reported at Tilak Tajpur on the right embankment of River Bagmati under Runnisaidpur block in Sitamarhi district. As soon as the news was reported to FMISC, efforts started to prepare value added maps to help district administration in fighting the disaster. For the first time an attempt was made to predict the probable path of the flood water and on the 3rd of August a map showing 'probable inundation areas' was posted on our website. Copies were also forwarded immediately to DMD and CM Secretariat for necessary action. Again;

probably for the first time; DMD was well prepared in advance to 'receive' floods. To everybody's astonishment, the prediction was found to be closely matching with real situation later witnessed. On 15th August a satellite passed over the area and beamed back an image which showed inundation (actual) too close to the predicted pattern. This was possible due to capacity building and knowledge enhancement in the cell during flood season 2007 & 2008.

In the night of 25th of August, a breach was reported at Gobindpur downstream of spur at Ch. 688 in the right embankment of Labha Chaukia Paharpur Mahananda right embankment under Katihar district. This time, too, probable inundation maps were provided by FMISC to DMD and CM Secretariat to help them preparing for the expected hazard. Actual inundation resembled to a great extent to the probable inundation predicted by FMISC and followed the pattern.

3.3.4 Information disseminated by FMIS Cell

3.3.4.1 Information provided to WRD

1. FMIS Cell by assessing Global Satellite data sources and real time data on rainfall forecasts continuously tracked the fast changing flood situation and requested NRSC for very frequent satellite coverage.

2. Although the area of operation of FMIS cell is limited to 11 districts of N. Bihar, we provided inundation maps of Punpun lower catchment to ascertain the 'real extent' of flood.

3. Closure work of Kusaha breach was closely monitored using available satellite images all through the flood season and even afterwards every type of ground work was planned with the help of satellite images acquired and processed at FMISC.

4. The flood season 2009 was relatively eventless. This gave us enough time to concentrate on other tasks of WRD. We prepared maps showing changing behavior of major rivers of North Bihar like Gandak, Kosi, Kamla, Baghmati, Burhi Gandak and some stretches of Ganga. This value addition to our GIS databank came handy in deciding Embankment maintenance works. Many schemes submitted by field officers were scrutinized with the help of these maps.

5. Nearly all large schemes, referred to GFCC for clearance, were aided by FMIS inputs in the form of latest satellite pictures overlaid with river positions of past 3 to 6 years. This helped a lot in judicious decision making at State and centre level committees.

6. FMIS cell also provided maps on events of lesser importance like reported erosion in the Terai areas of West Champaran

3.3.4.2 Information provided to DMD and CM Secretariat

As discussed earlier, probable inundation maps just after the breach were immediately prepared based on past records and landscapes and disseminated to DMD and CM Secretariat to help them get prepared to reduce the after effects of flood. Later on, the actual inundation maps based on satellite imageries were provided to DMD and other users and stakeholder departments to help them take necessary rescue and rehabilitation actions.

3.3.4.3 Information provided to RCD, Patna

We provided maps showing terrain heights with reference to danger level of different stretches of flood prone rivers to RCD & DMD for planning their preparedness.

3.3.4.4 Information provided to Bihar Police, Patna

Bihar police was in need of a map for planning *River patrolling*. FMIS came forward to help with a detail map of Rivers of Bihar. This also furnished measurements of distances for planning purposes.

3.3.5 Contribution of FMIS Cell to Technical Advisory Committee (TAC), WRD and GFCC in taking decisions for Anti-Erosion Works for Year 2009.

FMISC; this year, prepared maps showing changing behavior of major rivers of North Bihar like Gandak, Kosi, Kamla, Baghmati, Burhi Gandak and some stretches of Ganga. This value addition to our GIS databank came handy in deciding Embankment maintenance works. Many schemes submitted by field officers to TAC were scrutinized with the help of these maps.

Nearly all large schemes, referred to GFCC for clearance, were aided by FMIS inputs in the form of latest satellite pictures overlaid with river positions of past 3 to 6 years. This helped a lot in judicious decision making at State and centre level committees.

3.3.6 Capacity Building

A training workshop on the topic **"Long-lead flood forecasting and applications"** was held during 18-21 August 2009 at Hotel Mourya, Patna. The training was organized by FMISC, Water Resources Department, GoB in collaboration with World Bank and GFDRR (Global Facility for Disaster Reduction and Recovery). The training was focused on scientific aspects of flood forecasting including improved weather flood forecasting inputs, its integration into real flood forecasting and warning system and applications of long-lead forecasts for reducing impacts of floods in various sectors and at community level. The resource persons were from National Centre for Atmospheric Research, UCAR, USA, Asian Disaster Preparedness Centre, Thailand including others. All officers of FMISC participated in this training.

The Water Resources Department (WRD) of Govt. of Bihar nominated Mr. Timir Kanti Bhadury, Assistant Engineer and Mrs. Arti Sinha, Assistant Engineer presently working at FMISC to undertake a study tour of Thailand and Bangladesh regarding Long-Lead Flood Forecasting from 23rd August to 1st September 2009. The objective of the study tour was to expose to advances in technology related to flood forecasting and weather forecasting and to share successes and experiences in generation of long-lead forecast and its applications in reducing disaster risks.

In an another National level workshop on the Topic **"Flood Risk Management"** jointly organized

by NIH, Roorkee and The Institution of Engineers (India) held on 26-27 November 2009, Dr. Saroj Kumar Verma, Assistant Engineer, FMISC participated; being nominated by WRD.

3.3.7 Visit of Country Director, World Bank to FMISC

The Country Director, World Bank, Mr. Roberto Zhaga along with his team visited FMISC on 3rd September 2009. He was very much impressed with the work of FMISC, Bihar especially done during Kusaha breach last year. He assured of all possible support of World Bank to FMIS, Bihar

3.3.8 e-bulletin : e-bulletins were being issued and posted on FMIS website regularly during flood season. e-bulletin for the month of July 2009 is annexed (Appendix I).

4.0 FMIS website

URL : http://fmis.bih.nic.in

Today's web sites are a unique marriage of art and technology. The FMISC website is an information dissemination interface of the FMISC. The presentation of the information is in text & graphical maps. We have analysed the whole scenario and tried our level best to develop a system which is purely graphical. The main motto of our project is to provide the user with a platform where they can get information related to a particular area.

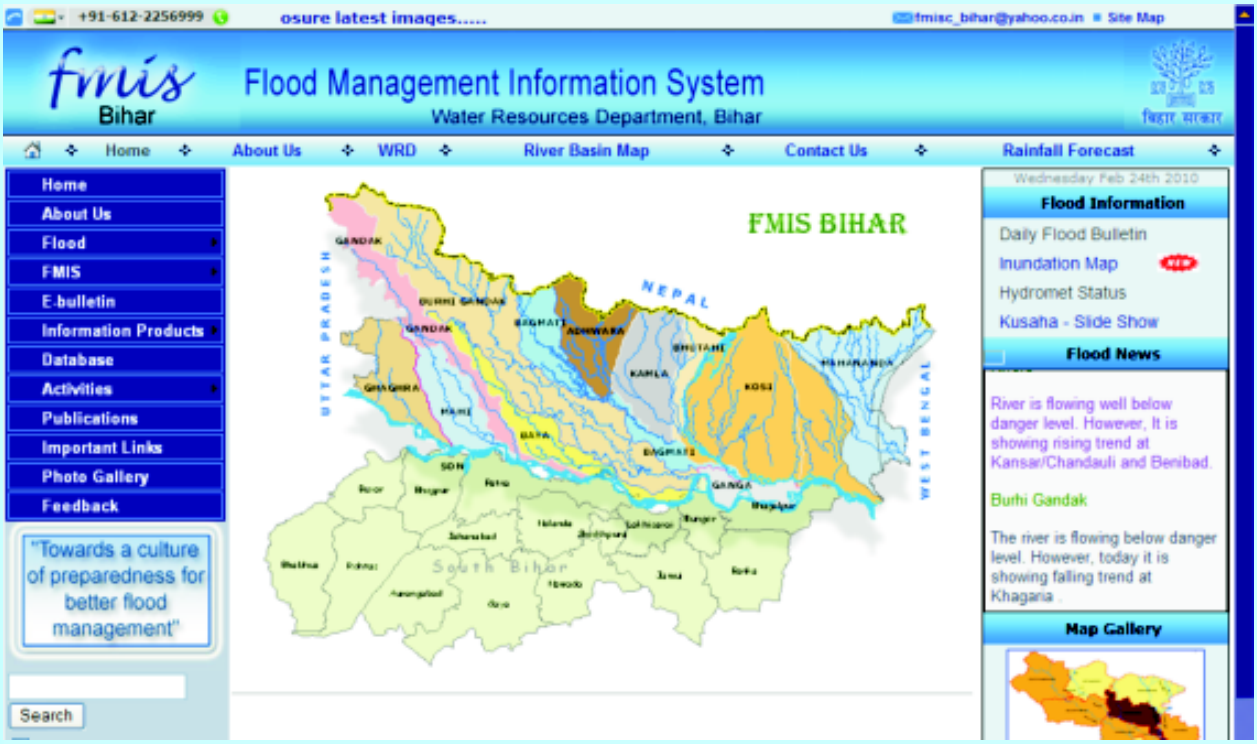
Apart from a brief discussion about the technology used & the activities carried out by the FMISC, the site also provides detailed maps related to the flood inundation status, breach points on the embankments, inundation levels etc, of the area covering flood affected districts of the northern part of the state of Bihar.

Our website includes:

- ***Daily Hydro meteorological status*** of North Bihar, having DL (Danger level) WL (Water level) and RF (Rainfall) during the flood season i.e. 15th of June to 15th of October.
- ***Daily flood bulletin*** are issued every day during the flood season. These bulletin contains summarized information about the observed rainfall, water level and basin wise maximum forecasted rainfall for 3 days based on rainfall forecast obtained from IMD.
- ***Inundation map*** for WRD and DMD, these maps show aerial extent of flood water spread. The inundation extent is derived from RADARSAT Layers/Imagery provided by NRSC in processed 1 bit image format.
- ***Monthly E-Bulletin*** is published every month during flood season. This is an in house production and gives a brief account of activities at FMISC.

- ***End Season Flood Report*** is also published at the end of flood season.
- ***District level rainfall forecast of 5 days for Bihar and Jharkhand*** as obtained from IMD are included on daily basis during flood season.
- ***Important links, Photo Gallery, Weather widget are also included in the website.***

Map 4.1 Hydro meteorological Status - North Bihar



Map 4.2 Present Home Page of FMIS website

Some essential features of our websites are outlined below.

Construction

Our website is built using the latest technologies and are highly optimised for speed so that viewers don't sit around waiting for pages to load, or even worse move on to another website.

Navigation

Clear, simple methods of website navigation for our audience are a primary aim. We have implemented a variety of navigation systems including pull-down and pop-up menus. We often undertake trials and constantly modify our website to enhance the browsing experience.

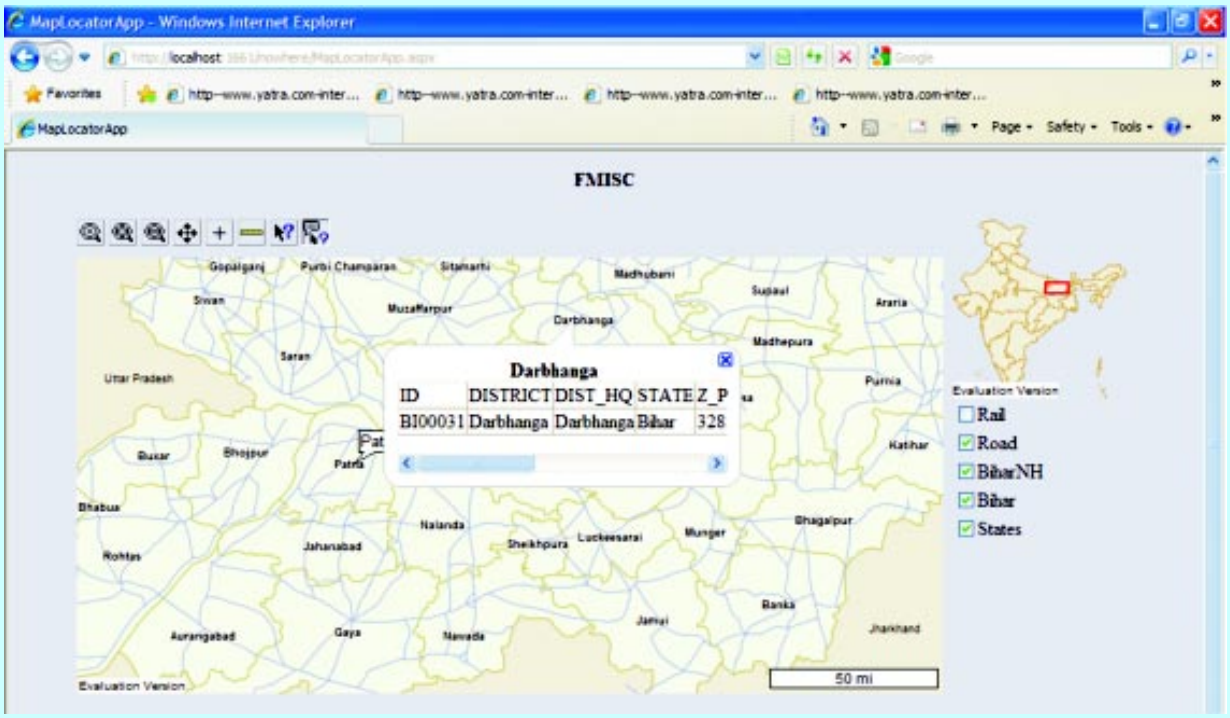
Future actions

Over the years the website has silently but surely established itself as a media which introduces the users to the activities which are being carried out in the FMISC. With the number of stake holders rising every day FMISC is trying its best to meet the myriad demands of Thematic maps and Imageries. Under these circumstances the website will have an important role in catering to increasing demands of customized maps and other information products. It is therefore mandatory to have a website that will allow the users to generate maps and other information product as per their needs. The salient features of the future website will be

- Empowering information.
- Visualizing the geography.
- Processing raw data into visual information.
- Graphic based system (more comprehensive)
- Imparting easy navigation feature
- Hierarchical storing of data
- Spatial data analysis
- Represent geographic information via a 'Visual Media'
- Faster and more extensive access to geographic information
- Ability to aggregate data for specific sub areas
- Better targeting and coordination of services
- Display a map with multiple map layers.
- Symbolize the map layers.
- Display locations stored in a database.
- Generate images, set the Image Format property to the desired image format.
- Creates map images from spatial information stored in digital format

- Ability to handle both vector and raster data
- Dynamic publication of Daily Flood Bulletin.

Map 4.3 Proposed layout of our future website



Map 4.4 Interface for dynamic map composition

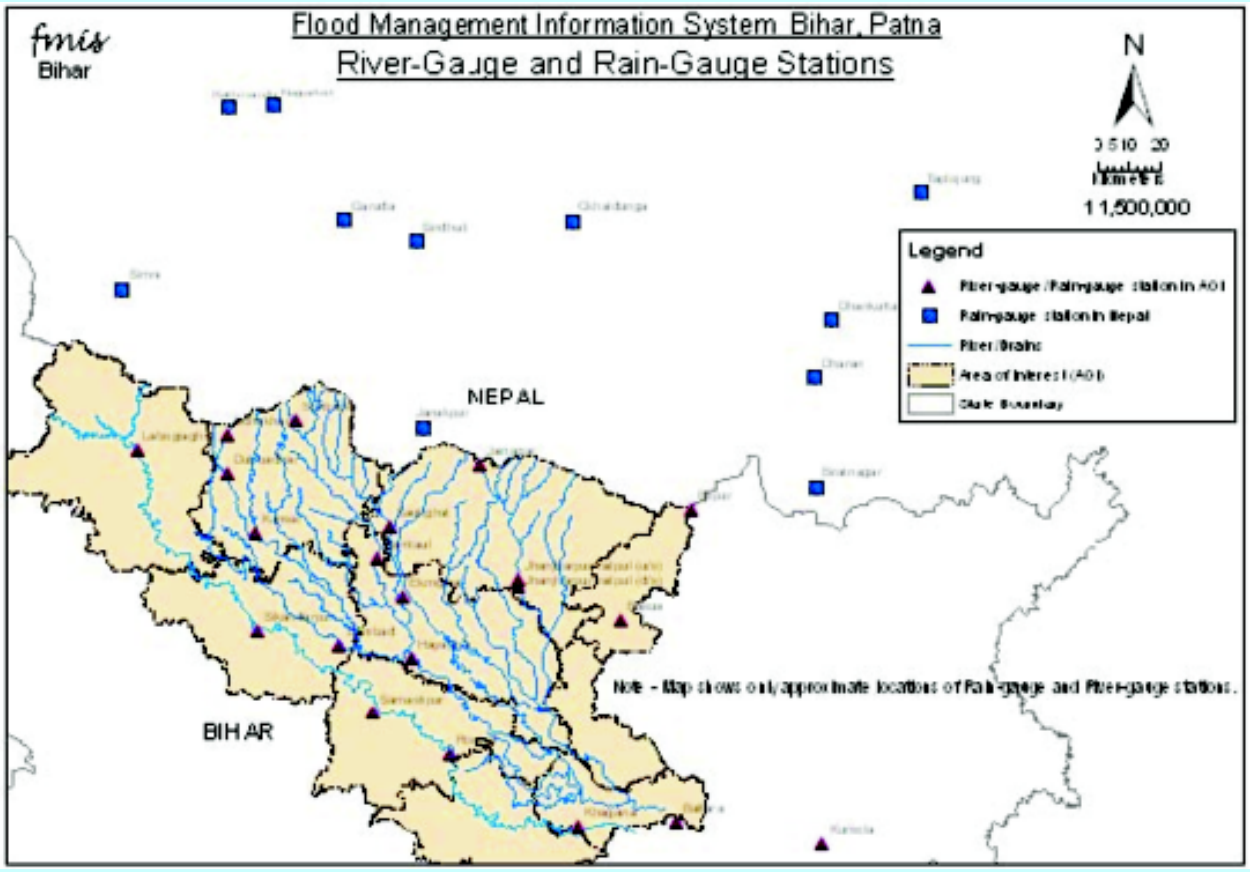
5.0 2009 Floods -Hydrologic analysis

Area of interest (AoI) of Flood Management Information System, Bihar receives flood water from vast areas of Nepal through four main streams viz Burhi Gandak, Bagmati, Kamla and Kosi. The FMIS Cell received daily rainfall / river water level data of some stations falling in these basins whose details are as follows.

Sl. No.	Name of Measuring Station	Location		Maintained by	Type of data	Mode of data acquisition
		Basin/River	(Nepal/ Bihar)			
1	2	3	4	5	6	7
1	Simara	Burhi Gandak	Nepal	GON	Daily Rainfall	Web site2
2	Kathmandu	Bagmati	Nepal	GON	Daily Rainfall	Web site2
3	Nagarkot	Bagmati	Nepal	GON	Daily Rainfall	Web site2
4	Garuda	Bagmati	Nepal	GON	Daily Rainfall	Telephone3
5	Janakpur	Kamla	Nepal	GON	Daily Rainfall	Web site2
6	Sindhuli	Kamla	Nepal	GON	Daily Rainfall	Telephone3
7	Okhaldunga	Kosi	Nepal	GON	Daily Rainfall	Web site2
8	Taplejang	Kosi	Nepal	GON	Daily Rainfall	Web site2
9	Dhankutta	Kosi	Nepal	GoN	Daily Rainfall	Web site2
10	Biratnagar	Kosi	Nepal	GoN	Daily Rainfall	Web site2
11	Dharan	Kosi	Nepal	GoN	Daily Rainfall	Web site2
12	Lalbegiaghat	Burhi Gandak	Bihar	CWC, GoI	DRF & RS1	Email4
13	Sikandarpur	Burhi Gandak	Bihar	CWC, GoI	DRF & RS1	Email4
14	Samastipur	Burhi Gandak	Bihar	CWC, GoI	DRF & RS1	Email4
15	Rosera	Burhi Gandak	Bihar	CWC, GoI	DRF & RS1	Email4
16	Khagaria	Burhi Gandak	Bihar	CWC, GoI	DRF & RS1	Email4
17	Sonakhan	Bagmati	Bihar	WRD, GoB	River Stage	Flood News5
18	Dubbadhar	Bagmati	Bihar	WRD, GoB	River Stage	Flood News5
19	Kansar	Bagmati	Bihar	WRD, GoB	River Stage	Flood News5
20	Benibad	Bagmati	Bihar	CWC, GoI	DRF & RS1	Email4
21	Hayaghat	Bagmati	Bihar	CWC, GoI	DRF & RS1	Email4
22	Kamtaul	Bagmati/Khiroi	Bihar	CWC, GoI	DRF & RS1	Email4
23	Sonbarsa	Bagmati/Khiroi	Bihar	CWC, GoI	DRF & RS1	Flood News5
24	Saulighat	Bagmati/ Darbhanga Bagmati	Bihar	CWC, GoI	DRF & RS1	Flood News5
25	Ekmighat	Bagmati/ Darbhanga Bagmati	Bihar	CWC, GoI	River Stage	Email4
26	Jainagar	Kamla	Bihar	WRD, GoB	River Stage	Flood News5
27	Jhanjharpur railpul (u/s)	Kamla	Bihar	WRD, GoB	River Stage	Flood News5
28	Jhanjharpur railpul (d/s)	Kamla	Bihar	CWC, GoI	DRF & RS1	Email4
29	Basua	Kosi	Bihar	CWC, GoI	DRF & RS1	Email4
30	Baltara	Kosi	Bihar	CWC, GoI	DRF & RS1	Email4
31	Kursela	Kosi	Bihar	CWC, GoI	DRF & RS1	Email4
32	Birpur	Kosi	Bihar	CWC, GoI	DRF & RS1	Flood News5

1 Daily Rainfall and River stage, 2 www.mfd.gov.np, 3 from CWC, 4 from CWC, 5 Daily Flood News of Water Resources Dept. GOB

Location of the above stations is depicted in the map below.



Map 5.1 - River-Gauge and Rain-Gauge Stations

5.1 Rainfall

This year, the rainfall in entire Bihar was very scanty. The situation was so aggravated that Disaster Management Department, Government of Bihar declared 26 districts as draught hit. Many districts of FMIS focus area were also included in this list. The first appreciable rainfall was recorded in the last of Month June and the start of July 09. The rainfall was 52.6 mm at Khagaria recorded on 30.06.09 and 90 mm at Benibad and 76.2 mm at Kamtaul recorded on 01.07.09. August was the wettest month. July was the next wettest. There was the least rainfall recorded in June. The delayed and insufficient rainfall delayed the sowing of Kharif crops. The natural result was shortfall in the production. There were few isolated storms at few stations of some basins in September and October.

The following Table compiles monthly / monsoon rainfall as well as number of rainy days observed at different stations falling in the concerned basins. This compilation is based on the daily rainfall data received from local Division of Central Water Commission and the Nepal website www.mfd.gov.np.

A word of precaution note here is that there have been a few days on which data was not available. Those gaps have not been filled up. So, similar information from the parent source may be a little different.

If we look at the Table below, we find that most of the places have received rainfall on less than 50% days of the monsoon period. In Bihar, all stations received rainfall on less than 50% days of the monsoon period. Of course, many stations in Nepal received more than 50% of rainfall days of the total monsoon period. Okhaldunga had the maximum 84 days of rainfall of the total of 122 days of rainfall (from 15th June to 15th October). The next was Kathmandu having 75 days of rainfall. If we compare this monsoon rainfall with the Normal Monsoon Rainfall, it reveals that the monsoon has been much below normal this year almost on all stations.

Below are the contours drawn with the rainfall figures available with us. The June rainfall is taken from 15th of the month and the October rainfall is only upto 15th of the month.

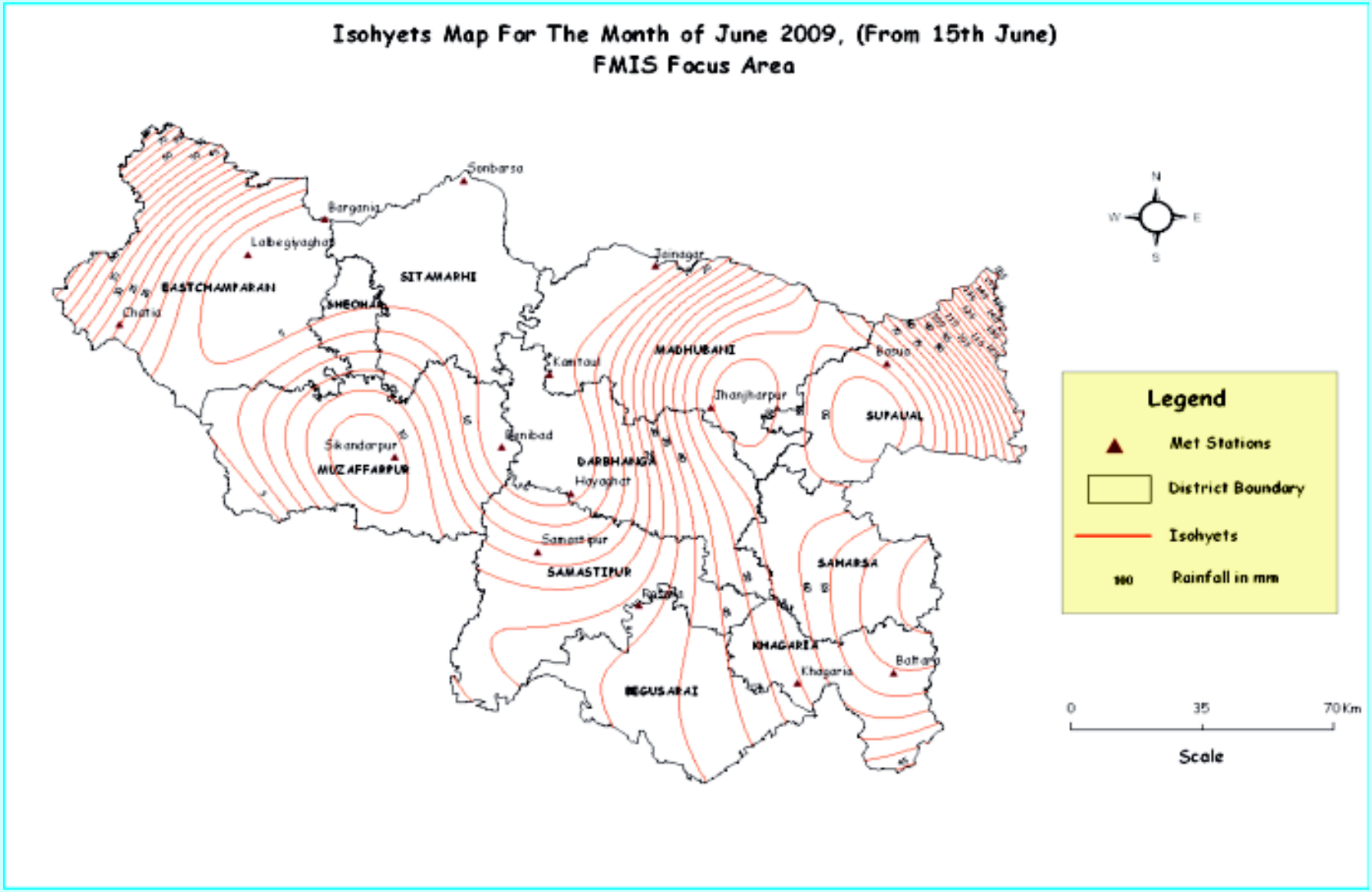
Monthly Monsoon Rainfall (mm) observed in the river basins of AOI-Flood 2009

River Basins	Rain Gauge stations	Monthly Rainfall					Monsoon 2009		Normal Monsoon Rainfall
		June (from 10 June)	July	August	September	October (up to 15 Oct)	Total	No. of Rainy days	
1	2	3	4	5	6	7	8	9	10
BURHI GANDAK	Simara	85.1	90.9	458.7	69	36.8	**739.5**	36	1497.4
	Lalbegiaghat	60.4	357.8	423.2	82.2	40.4	**964**	50	
	Sikandarpur	32	253.6	201.2	177	51	**714.8**	47	
	Samastipur	17.4	171	255.6	67.8	76.8	**588.6**	54	
	Rosera	32	228.4	257	92.4	109.4	**719.2**	52	
	Khagaria	54.4	195.8	246.9	109	132.8	**738.9**	50	
BAGMATI	***Kathmandu***	83.3	409.6	352.7	107.5	66.1	**1019.2**	75	1125.6
	Nagarkot	25.6	551.3	288.4	124.9	58.77	**1048.97**	62	1554.3
	Benibad	0	288.2	396.4	107.4	28	**820**	39	
	Hayaghat	3.3	286.9	320.8	65.3	39	**715.3**	47	
	Kamtaul	1.6	416.6	443.8	106.5	20.7	**989.2**	49	
	Sonbarsa	NA	NA	NA	NA	NA	NA	NA	
	Saulighat	NA	NA	NA	NA	NA	NA	NA	
KAMLA	Jainagar	NA	NA	NA	NA	NA	NA	NA	
	Jhanjharpur	59.2	397.1	319.8	75.8	22.8	**874.7**	49	
KOSI	***Okhaldunga***	48.8	341.4	343.9	115	19.7	**868.8**	84	1401.6
	Taplejang	89.5	181	100.5	19.4	47	**437.4**	40	1404.6
	Dhankutta	44.7	109	199.1	45	106	**503.8**	49	722.5
	Biratnagar	186.2	270.3	433.2	26.2	192.1	**1108**	52	1522.5
	Dharan	129.8	274.8	595.7	188.8	78.2	**1267.3**	64	
	Basua	57	354	363	60.2	69.8	**904**	43	
	Baltara	69.2	232.8	419	164.4	152.8	**1038.2**	41	
	Kursela	45.6	259.6	313.06	78	132.4	**828.66**	47	
	Birpur	NA	NA	NA	NA	NA	NA	NA	

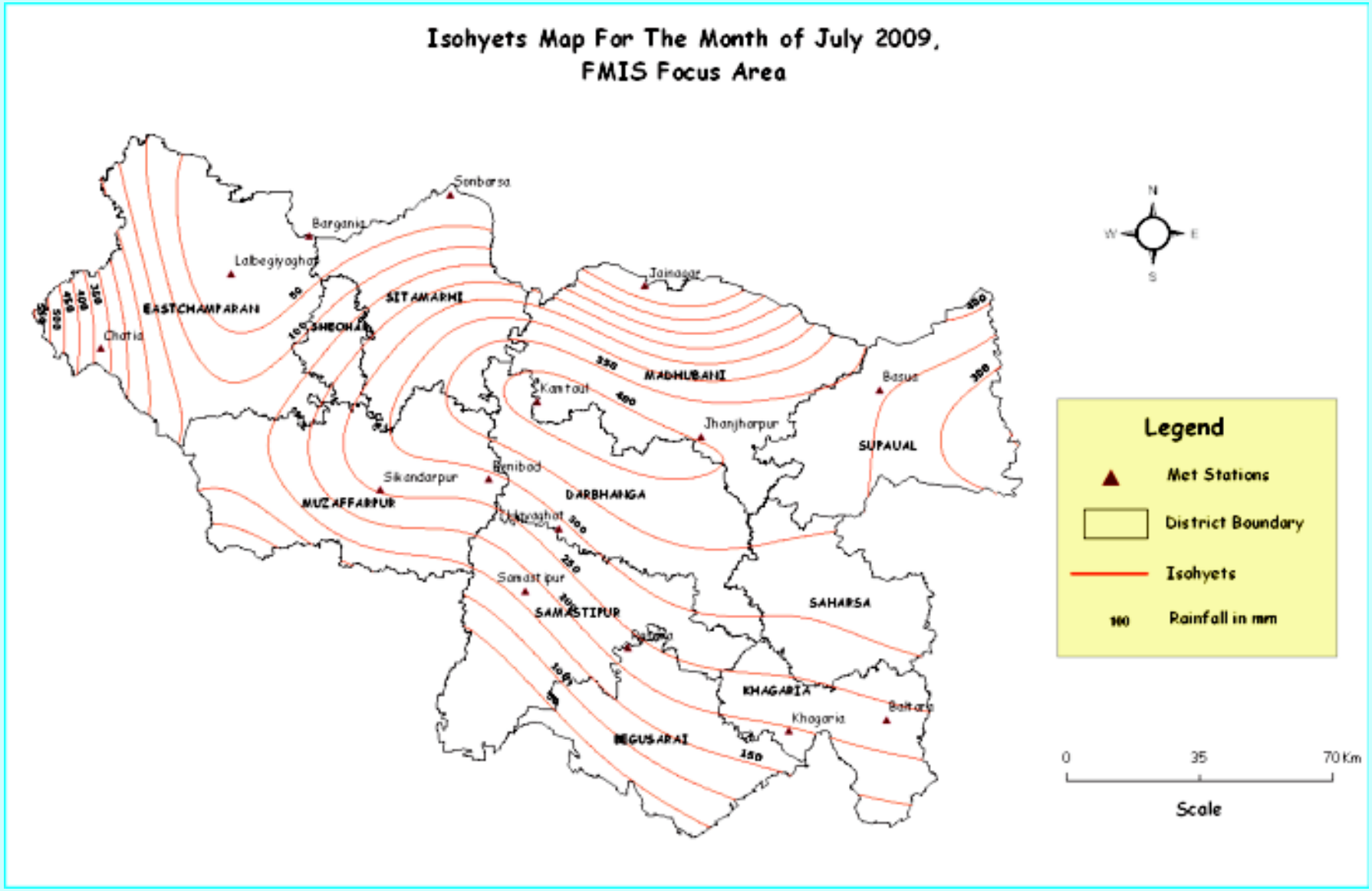
Notes: 1. Rain-gauge stations written in italics are located in Nepal.

2. Monthly / monsoon rainfall have been calculated using daily rainfall obtained from CWC and Nepal web site www.mfd.gov.np.

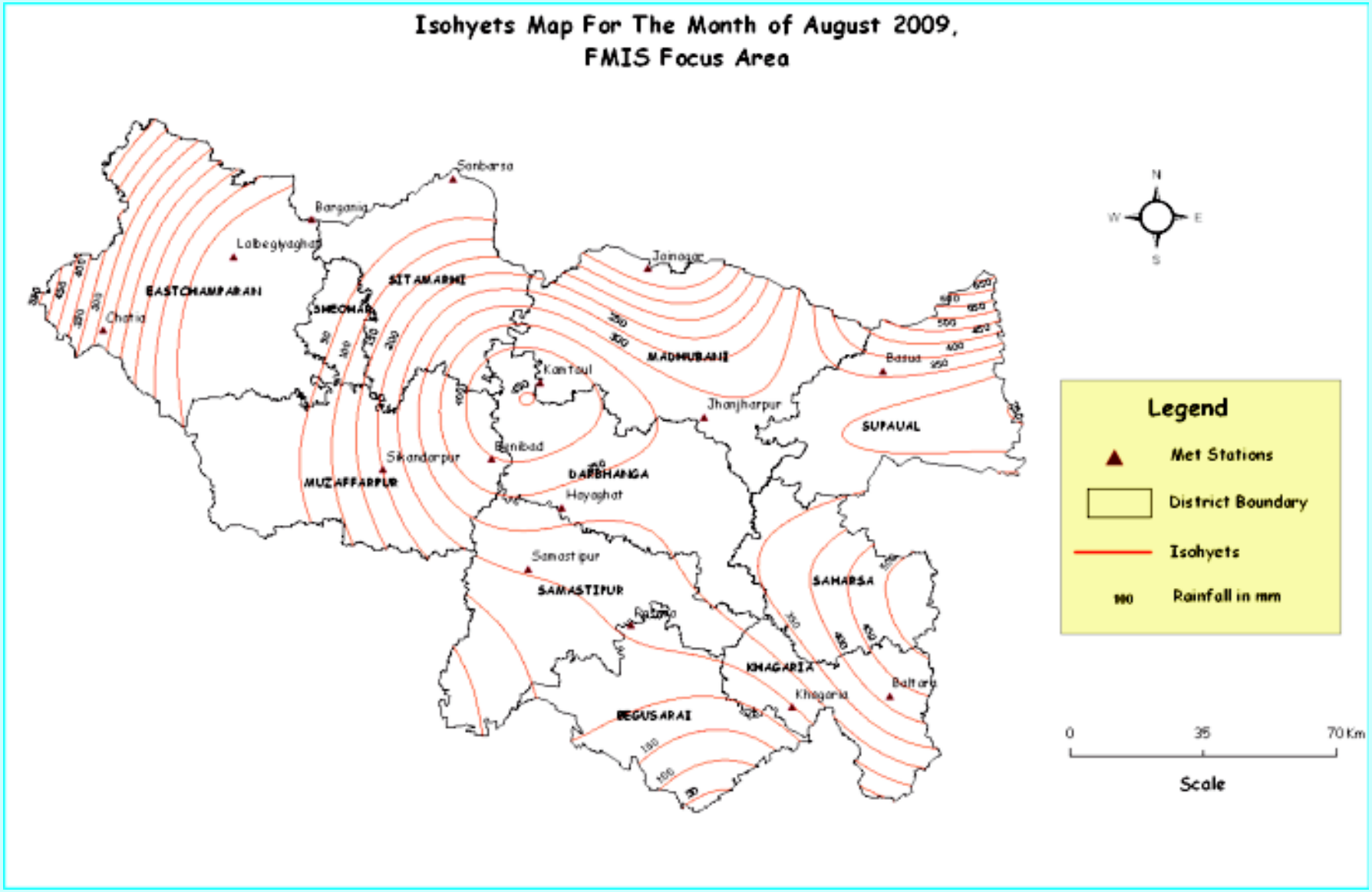
3. Source of Normal Monsoon Rainfall is the Nepal web site www.mfd.gov.np



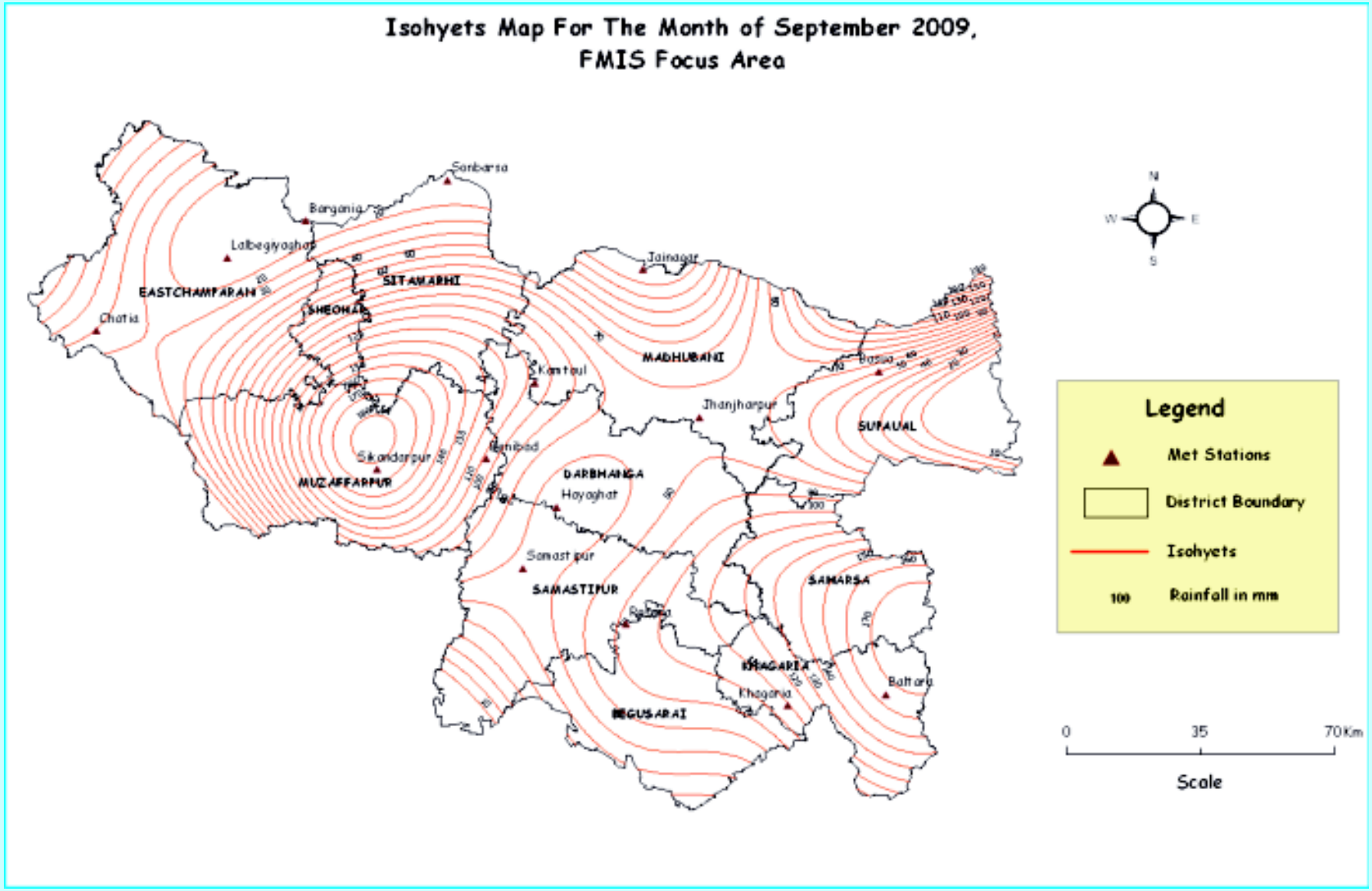
Map 5.2 Isohyets of Rainfall in June 2009 (15th to 30th)



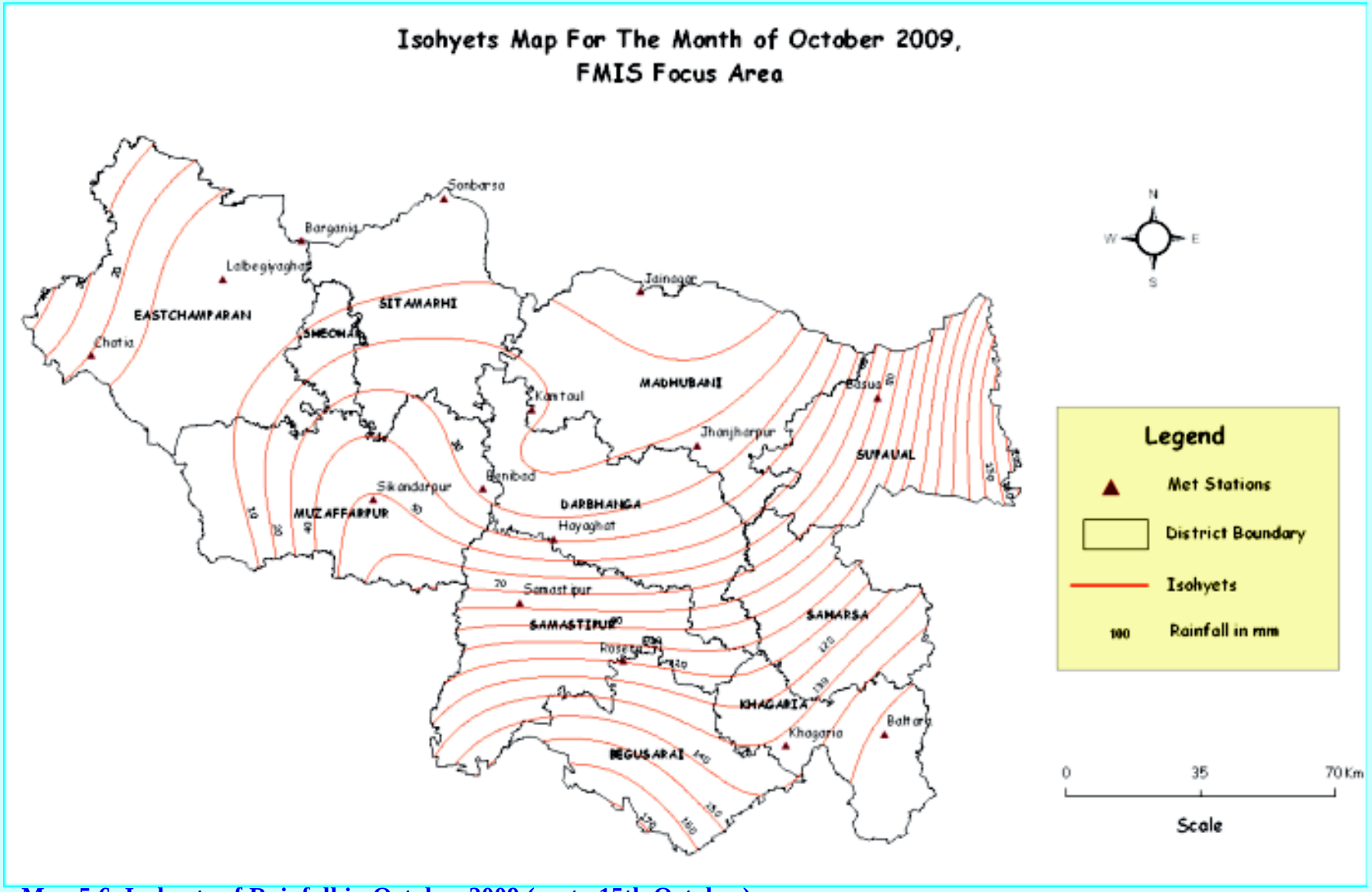
Map 5.3 Isohyets of Rainfall in July 2009



Map 5.4 Isohyets of Rainfall in August 2009



Map 5.5 Isohyets of Rainfall in September 2009



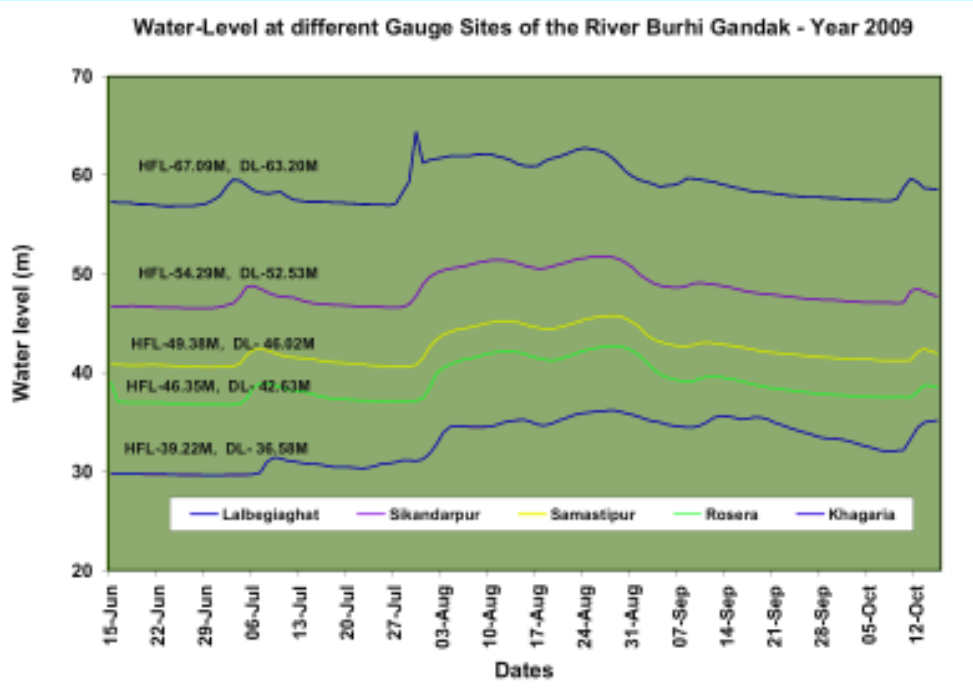
Map 5.6 Isohyets of Rainfall in October 2009 (up to 15th October)

5.2 River Stages

Daily water-levels measured (at 6:00 AM) at different gauge stations on four major rivers of the AOI have been chronologically plotted. They are discussed below.

5.2.1 Burhi Gandak

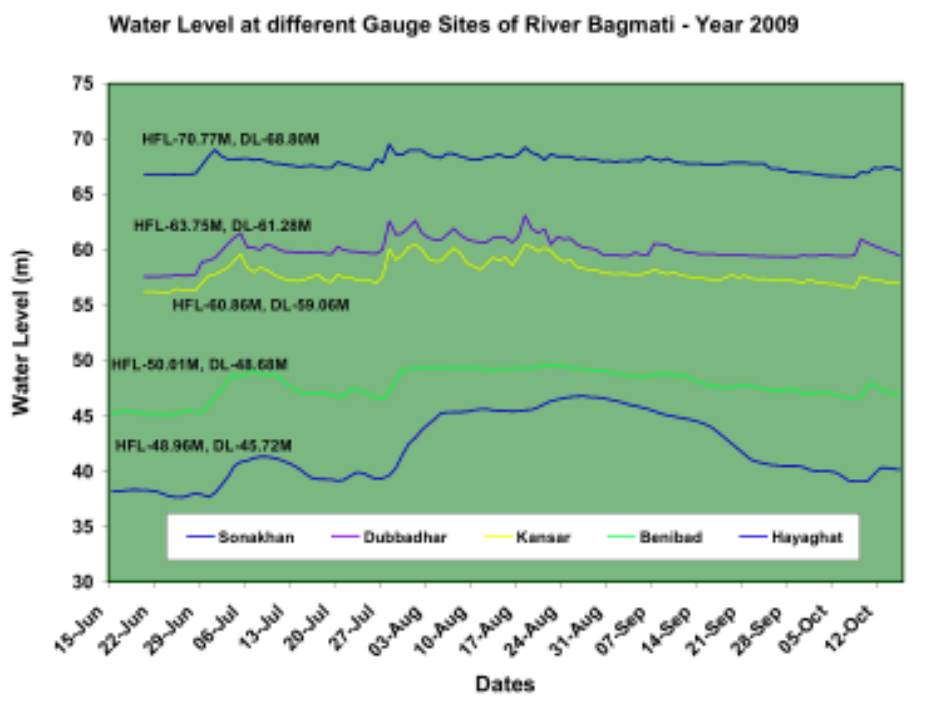
Lalbegiaghat, Sikandarpur, Samastipur, Rosera and Khagaria are five gauge-stations located in sequence from up-stream to down-stream on the river Burhi Gandak. Water level remained constant in the month of June at all stations. The first peak stage at Lalbegiaghat is on 3rd July which reached at Khagaria on 8th July. Water level then receded continuously up to 27th July. Water level reached the maximum peak of this year at Lalbegiaghat on 30th July which was 1.2 m above the danger level. In the month of August, water level remained higher than other months at all stations. There after water level receded continuously till 9th October. On 11th October, another short peak came at Lalbegiaghat and at other stations on further dates. Chronological plot of water-levels at the upper-most station Lalbegiaghat shows sharp peaks and valleys which signifies the quick response of catchments at this location. There is a sharp increase in water level at Lalbegiaghat from 59.37m on 29th July to 64.4m on 30th July as reported by CWC. This is because of continuous spell of rainfall from 26th July onwards after a gap of no spell for a longer period. Gradually the plots at down-stream stations have smoothened. Parallel pattern up to Rosera may be due to insignificant contribution of intermediate tributaries.



5.2.2 Bagmati

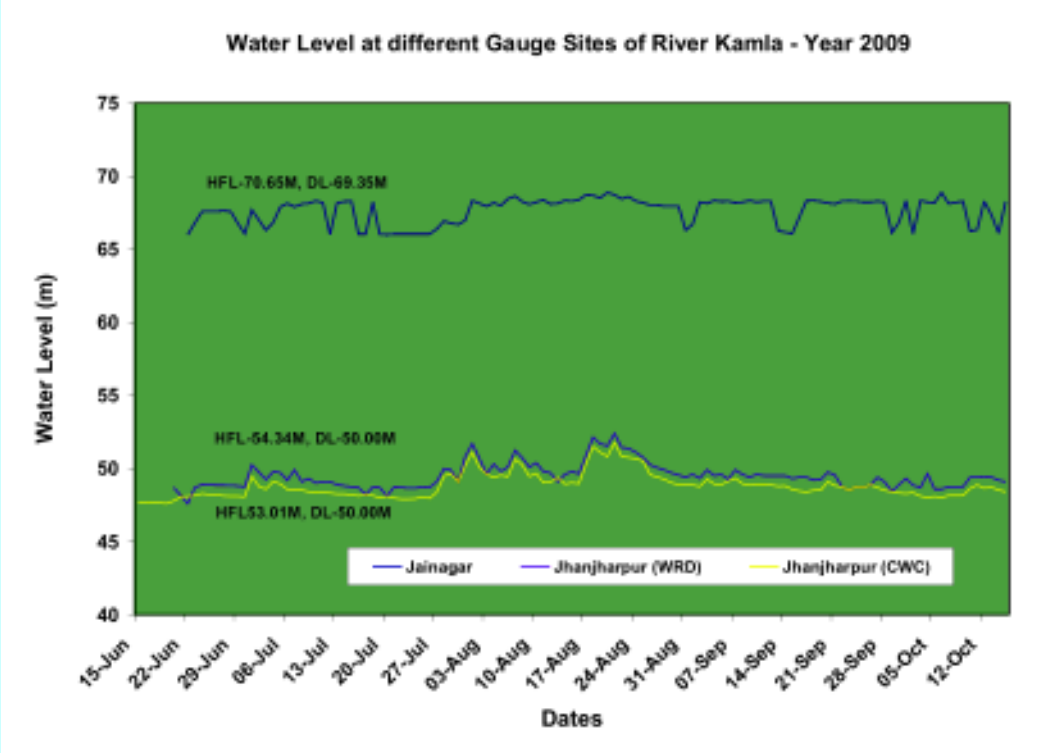
Sonakhan, Dubbadhar, Chandauli/Kansar, Benibad and Hayaghat are five gauge-stations located in sequence from up-stream to down-stream on the river Bagmati. Chronological plot of water-levels at the upper stations shows relatively less rise and fall at Sonakhan in comparison with that at Dubbadhar and Chandauli. Water levels at Dubbadhar and Kansar show the same trend of flow. At Benibad plot is much smooth which may be due to the routing effect as well as run-off contribution

of tributaries. The nature of Hayaghat plot is quite different which shows the effect of major tributary-Khiroi. Water level remains above the danger level from 20th August to 05th September at Hayaghat and from 30th July to 01 September at Benibad. Water level of a few dates are not available for Sonakhan, Dubbadhar, Benibad and Kansar. The missed out data have been interpolated.



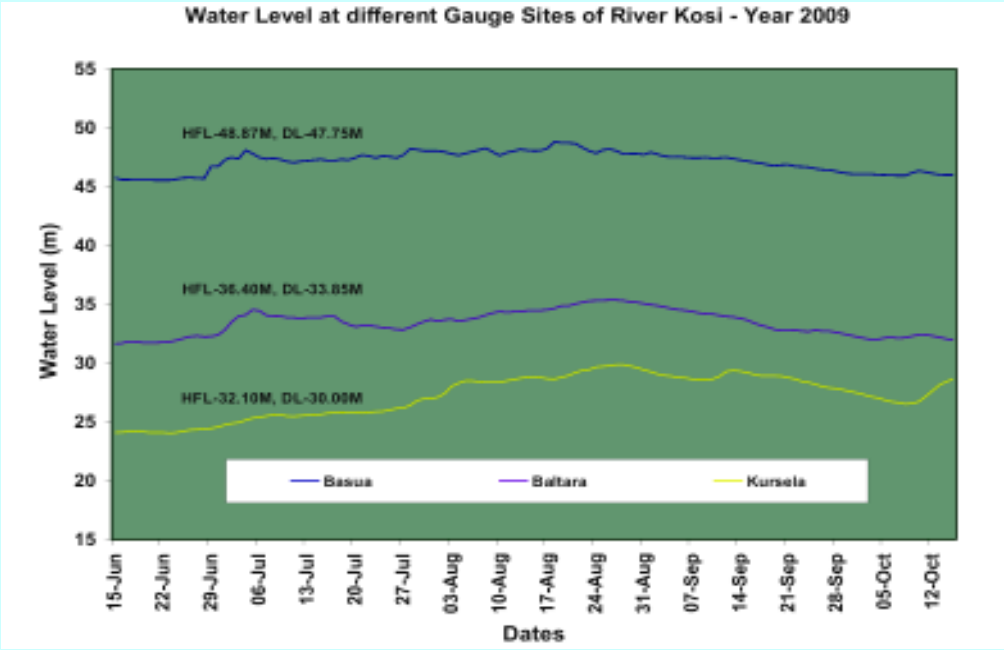
5.2.3 Kamla

Jainagar (weir site), Jhanjharpur railpul (maintained by WRD), and Jhanjharpur (downstream maintained by CWC) are three gauge-stations located in sequence from up-stream to down-stream on the river Kamla. On the observation of water level corresponding to rainfall, water level data on a few dates in July and October do not seem to be matching, may be because of observation error or error in data entry. Barring these data chronological plot of water level at these stations shows that Jainagar plot has small rise and fall. This may be due to the effect of gate operation of Jainagar weir. Water-level pattern at u/s and d/s of Jhanjharpur railpul is quite parallel. The water level characteristics at Jainagar and Jhanjharpur is different. Jhanjharpur curve is smoother than Jainagar. Water level between 28th July to 27th August remained above danger level at Jhanjharpur and for the rest of period it remained below danger level. Water level at Jainagar remained below danger level during flood period 2009. A few missing data have been interpolated.



5.2.4 Kosi

Basua, Baltara, and Kursela are three gauge-stations located in sequence from up-stream to down-stream on the river Kosi. Chronological plot of water-levels at these stations shows that this year trend of Baltara plot is more or less similar in comparison with that at Basua contrary to the last year. Water levels at these stations did not vary much till 28th June, then began to rise up to a peak of 48.09 m on 4th July at Basua. The pattern of water-levels at Kursela is continuously rising till 28th August, then it is falling and rising for a brief period and then falling at the end of the monsoon till 9th October. The water level at Kursela once again rose to 28.64 m on 15th October The pattern seems to be effected by the flow of Bagmati tributary. Water level at Kursela remained below danger level this year but at Basua and Baltara it crossed the danger level in the month of August.



5.3 Effect of rainfall in the Nepal region on the river-stages in Bihar

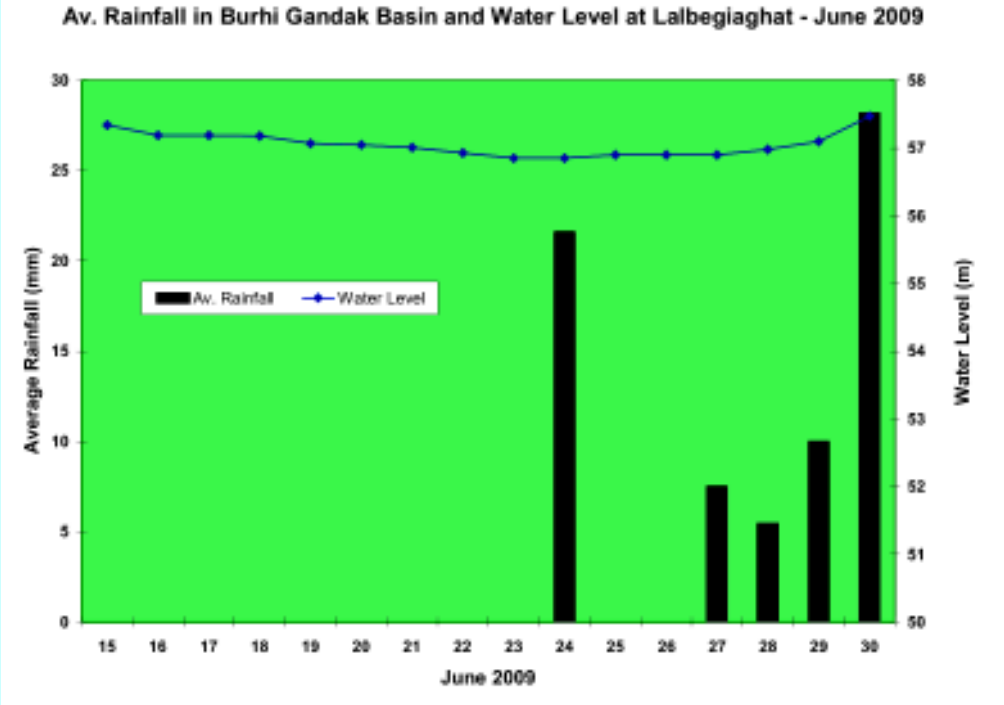
River gauge stations in AOI close to the Indo-Nepal border are Lalbegiaghat on Burhi Gandak, Sonakhan on Bagmati, Jainagar on Kamla and Basua on Kosi. Daily river water levels measured at these stations vis-a-vis daily average rainfall of the respective basin above these locations have been plotted on the same charts. Rain-gauge stations considered for averaging are as follows:

Name of basin	Part under consideration	Rain-gauge stations considered for averaging
1	2	3
Burhi Gandak	Up to Lalbegiaghat	Simara, Lalbegiaghat
Bagmati	Up to Sonakhan	Simara, Kathmandu, Nagarkot, Garuda
Kamla	Up to Jainagar	Janakpur, Sindhuli, Okhaldunga
Kosi	Up to Basua Biratnagar, Dharan, Basua	Okhaldunga, Taplejang, Dhankutta,

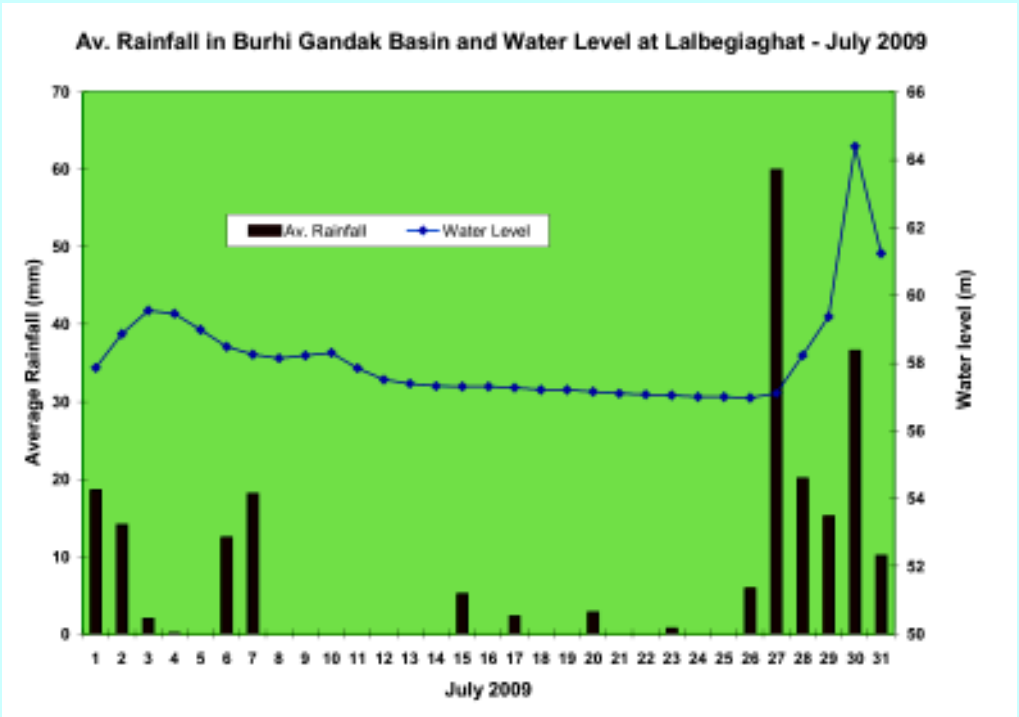
Number of rain-gauge stations is too less to account for the aerial variability of rainfall. Therefore, in stead of using rigorous methods simple arithmetic mean has been used for averaging the rainfall. Basin wise rainfall pattern and corresponding water level are discussed in the following paragraphs.

5.3.1 Burhi Gandak

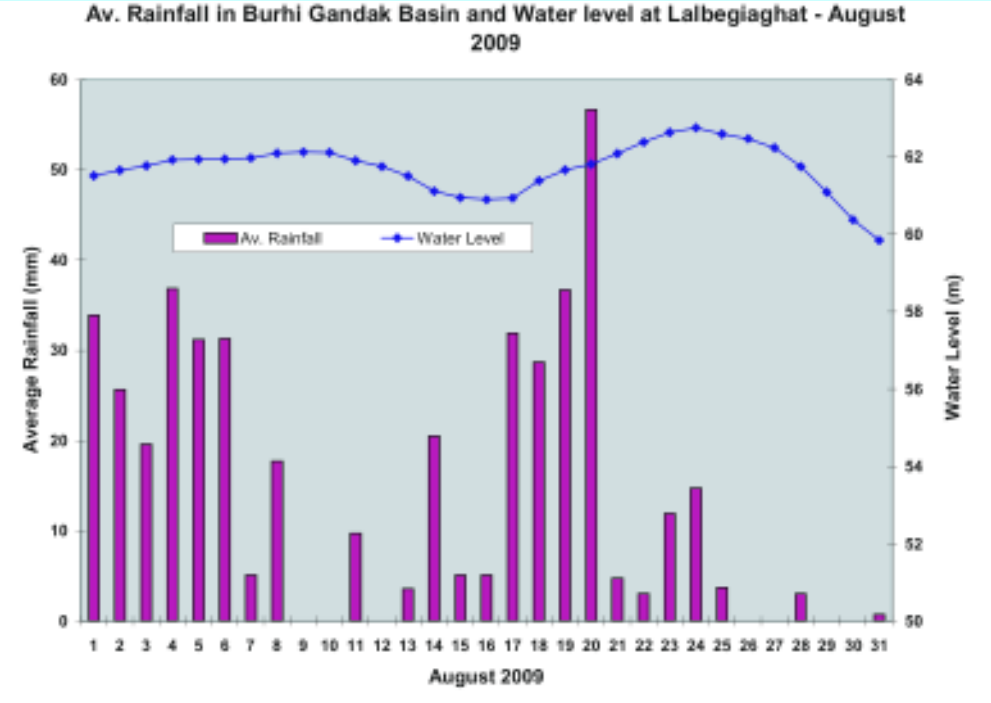
There was no rainfall up to 23rd June, so water level continuously receded till 24th June. The first rain came on 24th June having average value 21.6mm. After that there was continuous rainfall from 27th June to 30th June resulting in the rising trend of the river till last of the month June. The maximum water level and maximum rainfall during the month is 57.47 m and 28.2mm respectively on 30th June 2009.



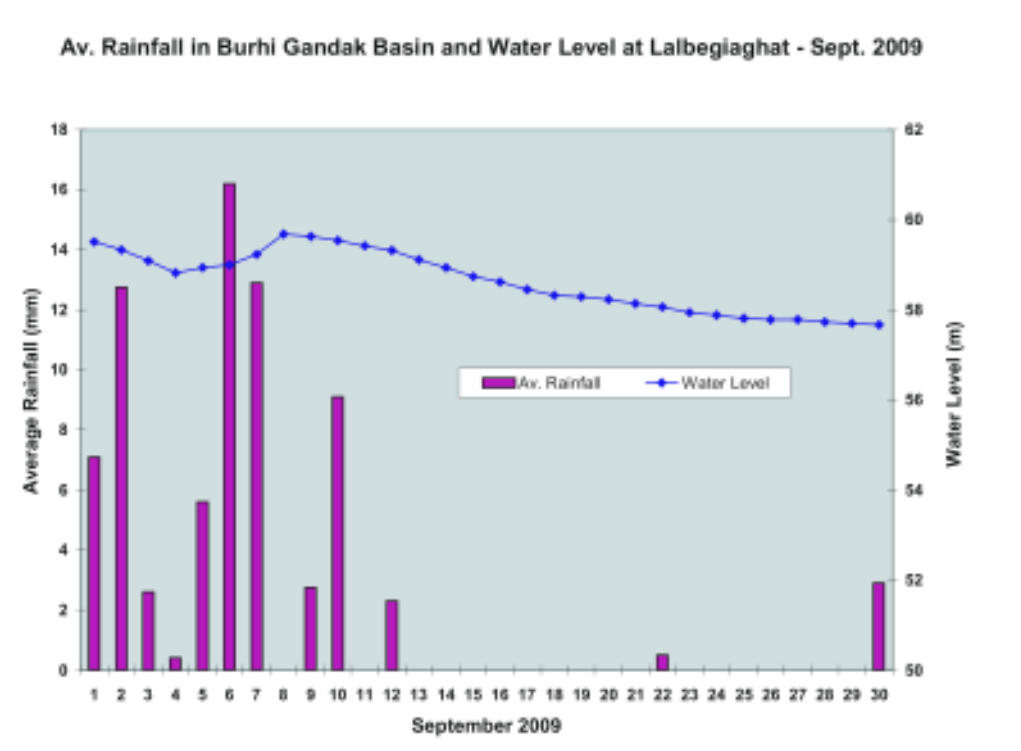
Continuous rain led the maximum water level to 59.55 mm on 3rd July. Then there was continuous fall of water level up to 26th July. The next storm of rainfall started on 26th July and continued up to 31st July. This led to the rising trend of the river and the maximum water level of 64.4 m reached on 30th july. The maximum average rainfall of 60 mm occurred on 27th July.



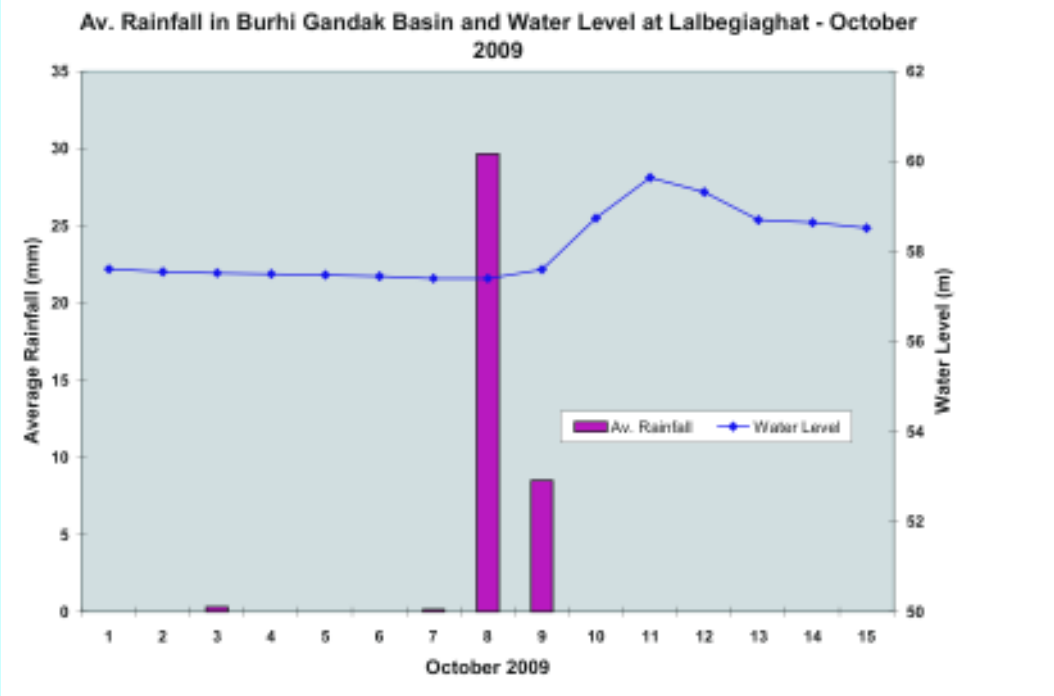
There was continuous rainfall from 1st August to 8th August and then from 13th August to 25th August. The maximum average rainfall of 56.7 mm occurred on 20th August 2009. Due to continuous rainfall in this month, water level remained at higher level and on 24th August attained maximum water level of 62.76 m. Then after it started receding.



There was continuous rainfall during the first week of September resulting in increasing water level from 4th September. Then water level continuously receded till 30th September.

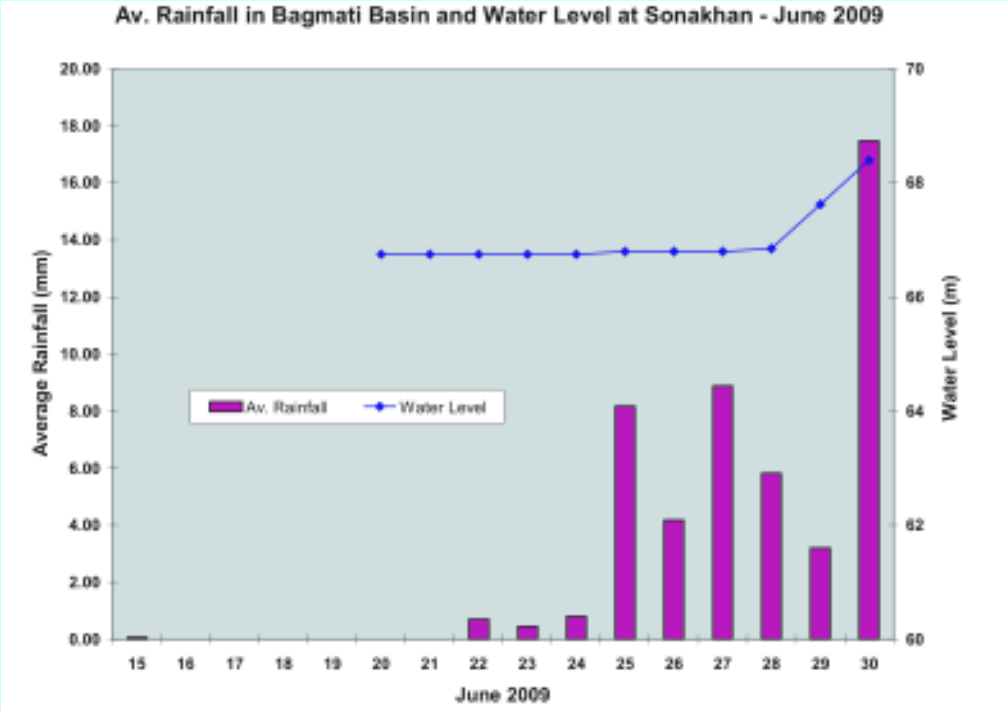


Water level remained stagnant till 8th October due to non-occurrence of rainfall during first week of October. Rainfall occurred on 8th and 9th October resulting in rise of water level and reached a peak of 59.64 m on 11th October.

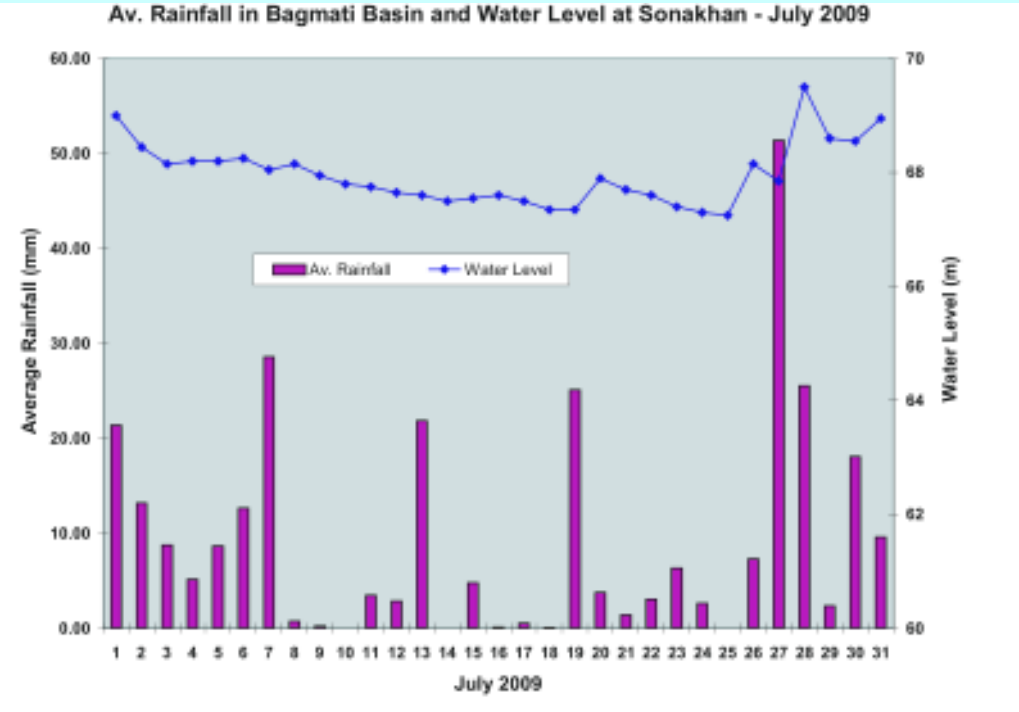


5.3.2 Bagmati

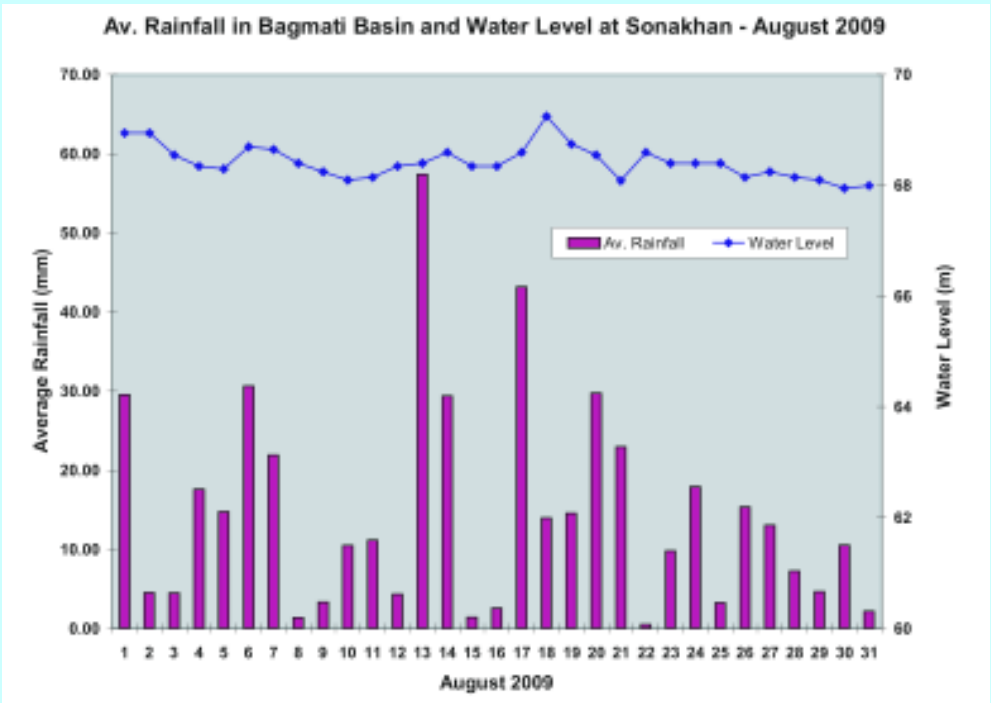
Water level remained almost constant till 28th June. Then due to rainfall in the upper catchment between 25th to 30th June, water level reached a peak of 68.4 m on 30th June.



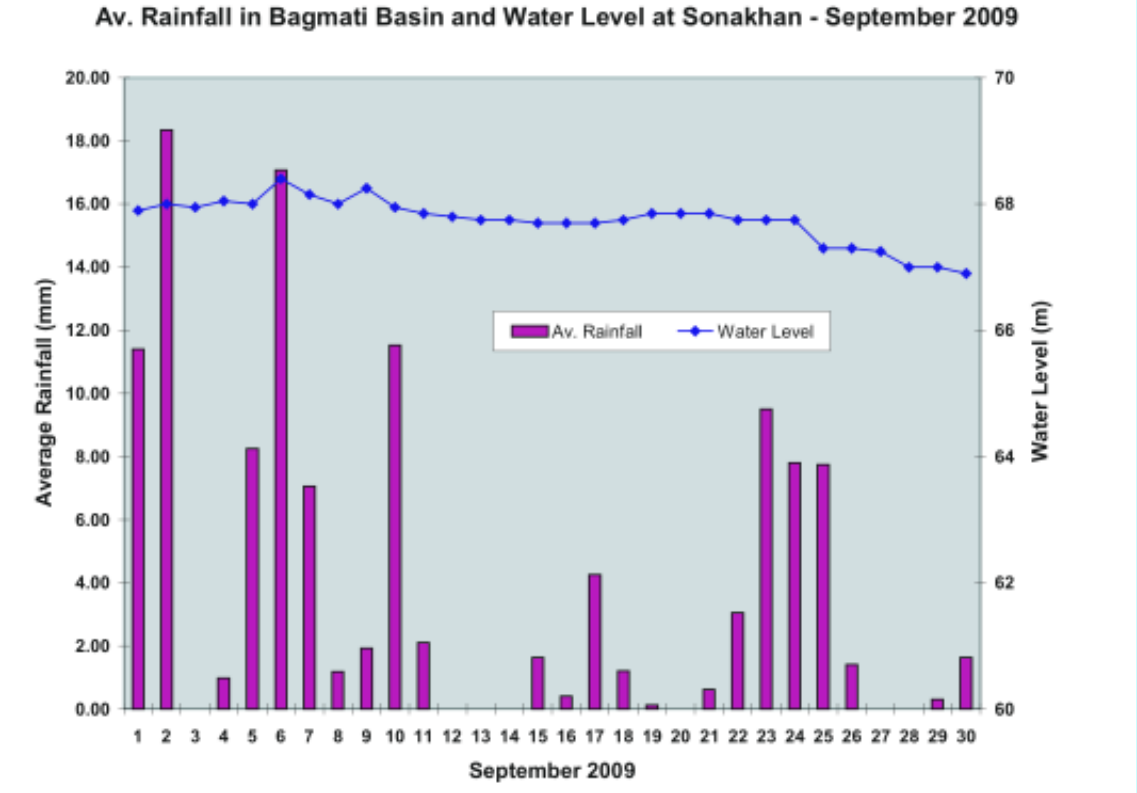
Plot for July shows continuous fall in water level due to insignificant rainfall up to 25th July. Then there was rainfall between 26th to 31st July resulting rise in water level of maximum peak of 69.5 m on 28th July.



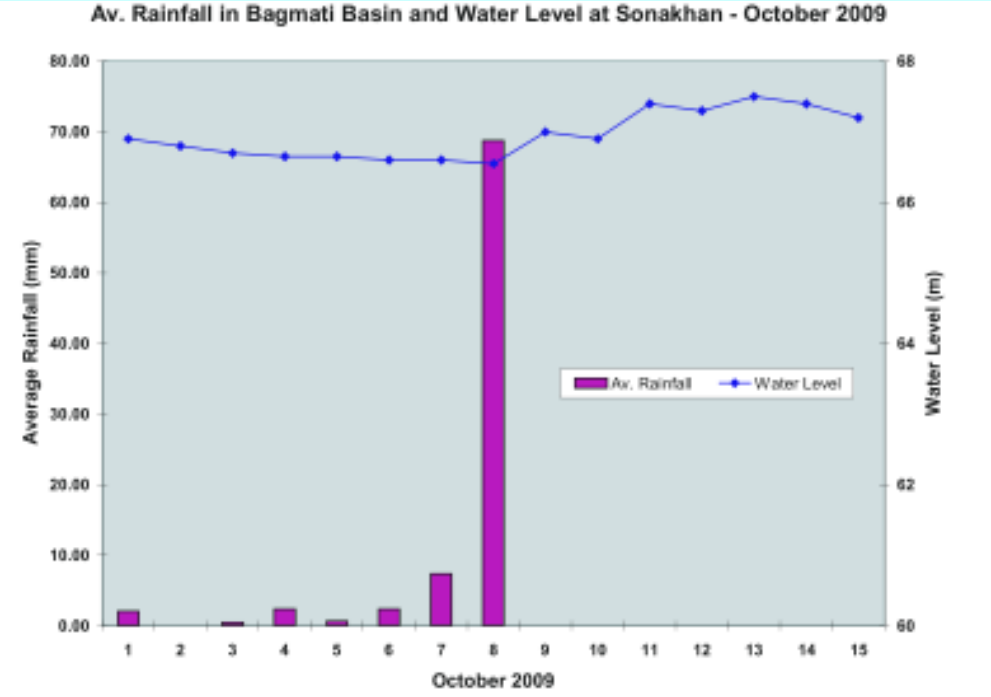
The rainfall occurred everyday in the month of August, but on most of the dates its magnitude was low. There ware some moderate rainfall of around 30 mm on a few days. Therefore, water level did not vary much during the month. The maximum average rainfall in the catchment was 57.4 mm on 13th August. Again there was a rainfall of 43.18 mm on 17th August. This resulted maximum water level of 69.25 m on 18th August.



The magnitude of rainfall remained low during the month of September. Therefore, water level remained almost constant in the earlier period and continued falling in the later period of the month leading to minimum water level of 66.9 m on 30th September.

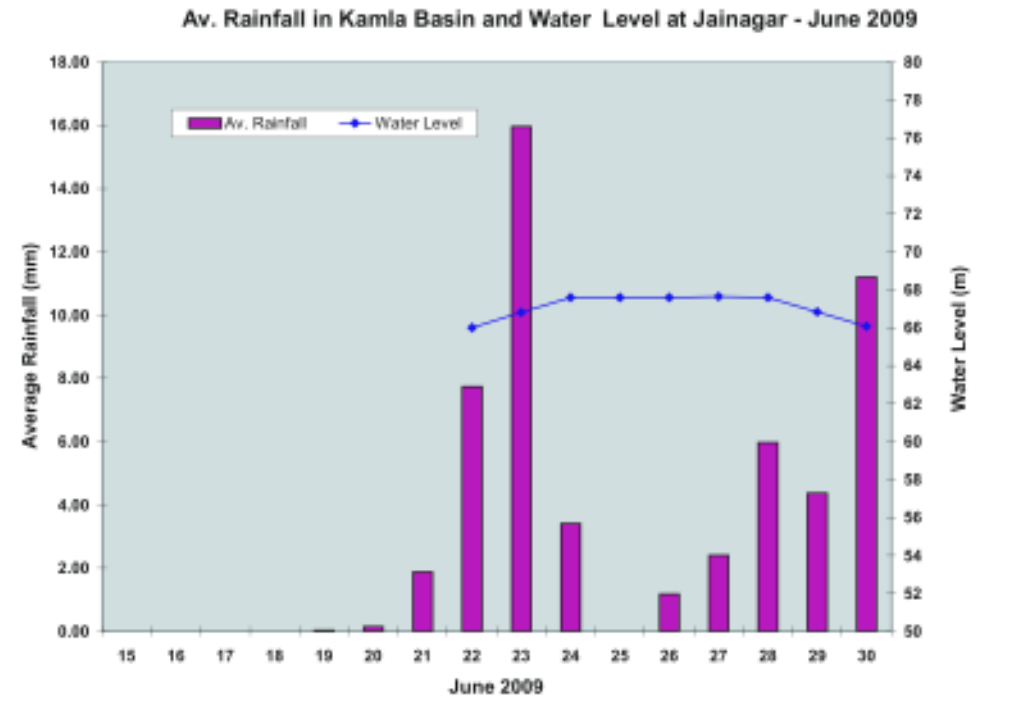


During this month, a maximum rainfall of 68.77 mm occurred on 8th October, resulting increase in water level up to 67.5 mm on 13th October. Then this started receding.

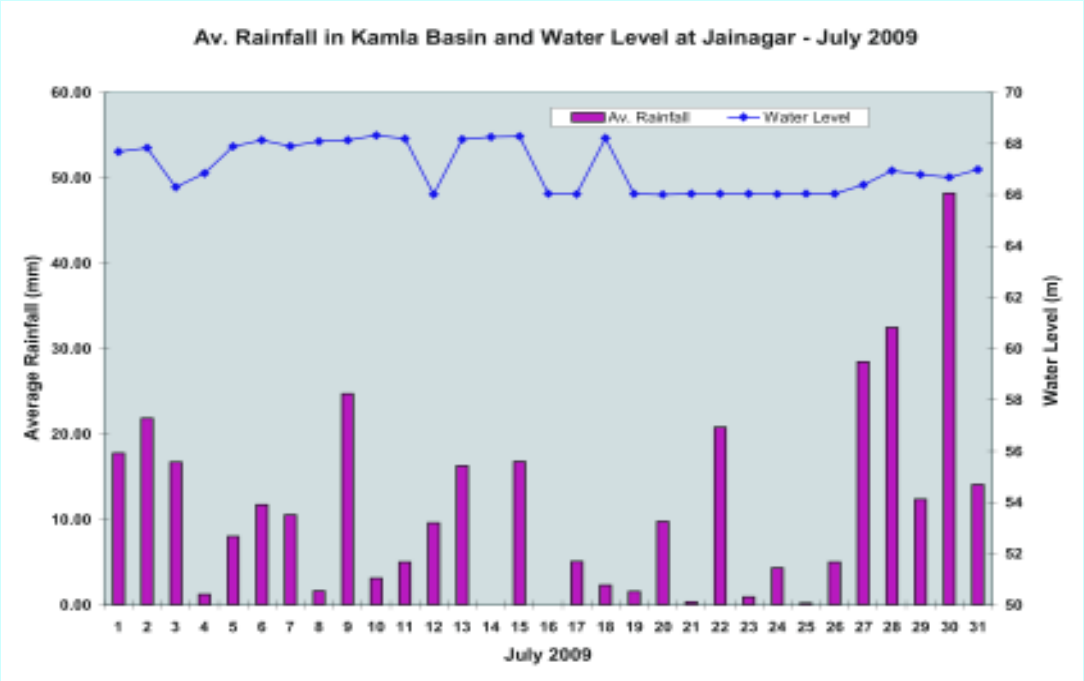


5.3.3 Kamla

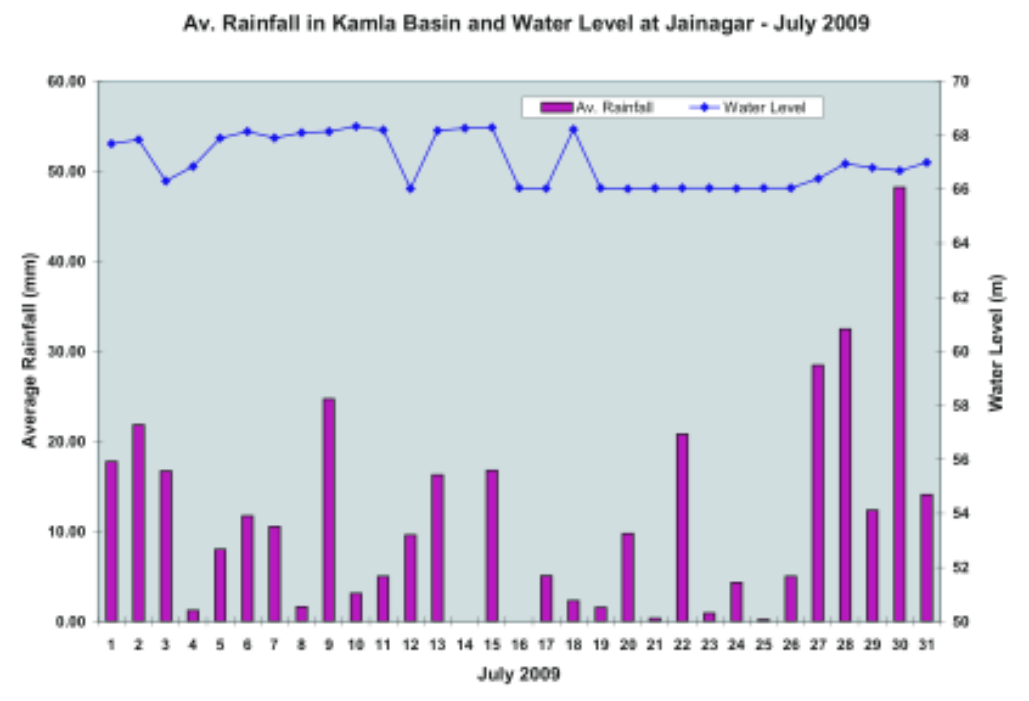
There was no significant rainfall during the month of June. Due to 15.97 mm rainfall on 23rd June, the water level rose to 67.6 m and remained constant up to 28th June and then water level receded in this month.



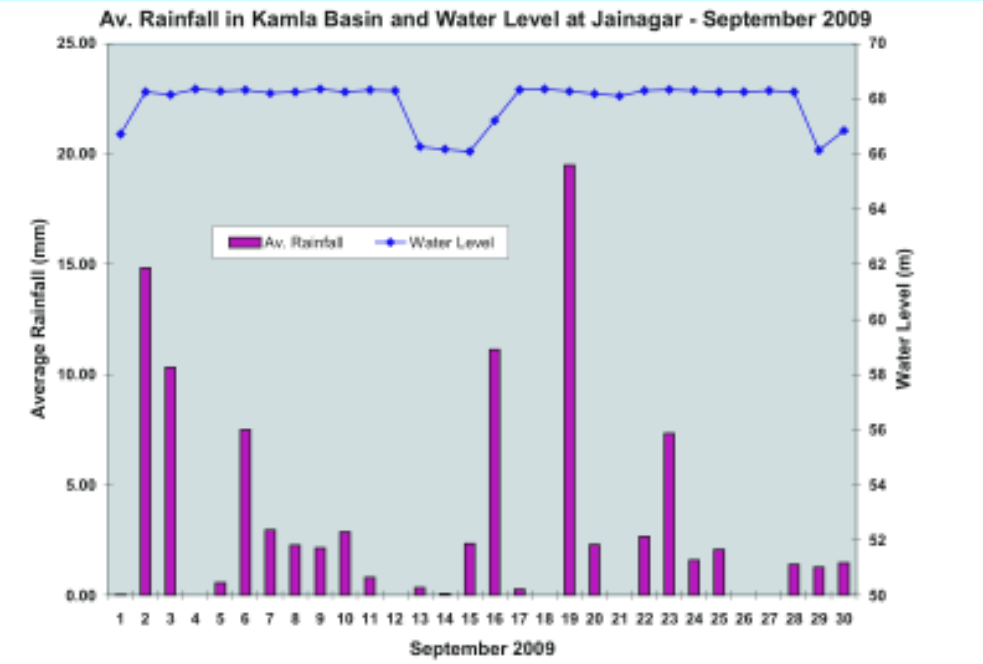
In the start of the month, there was some significant rainfall up to 3rd July. Water level started rising from 3rd to 6th July. Then after, it remained almost smooth till 11th July. The plot shows a sudden drop in water level on 12th July. Similar situation happened on 16th July. There was a sudden rise in water level on 18th July while there was no significant rainfall on the preceding days. These data of water levels seem to be incorrect, may be because of erroneous observation or data entry. This may also reflect that rainfall was not the only factor influencing the water level. This might be due to gate operation of weir. Water level remained almost constant from 19th to 26th July. In the last of the month, there was significant rainfall which led to the rising trend of the river. The maximum average rainfall in Kamla basin u/s to Jainagar was 48.23 mm on 30th July.



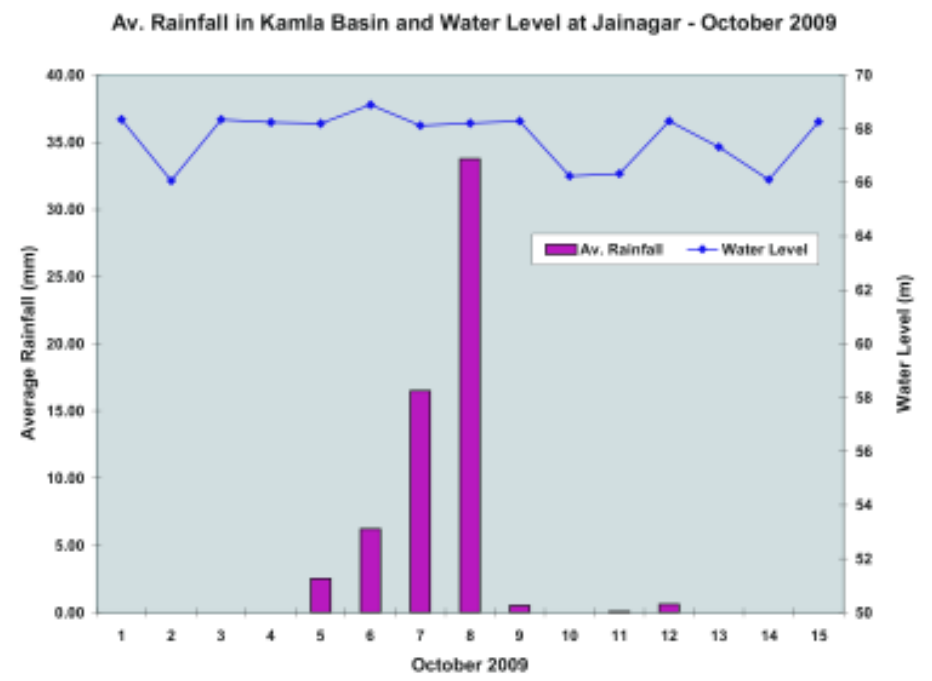
The maximum average rainfall in the basin was 116.57 mm on 17th August. Water level during this month remained almost constant during the month except a sudden fall on 31st August. The average rainfall above 25 mm was only for six days in this month.



Water level remained almost constant on most of the days in September except sudden rise or fall on few days. The rainfall in the catchment was very low in this month

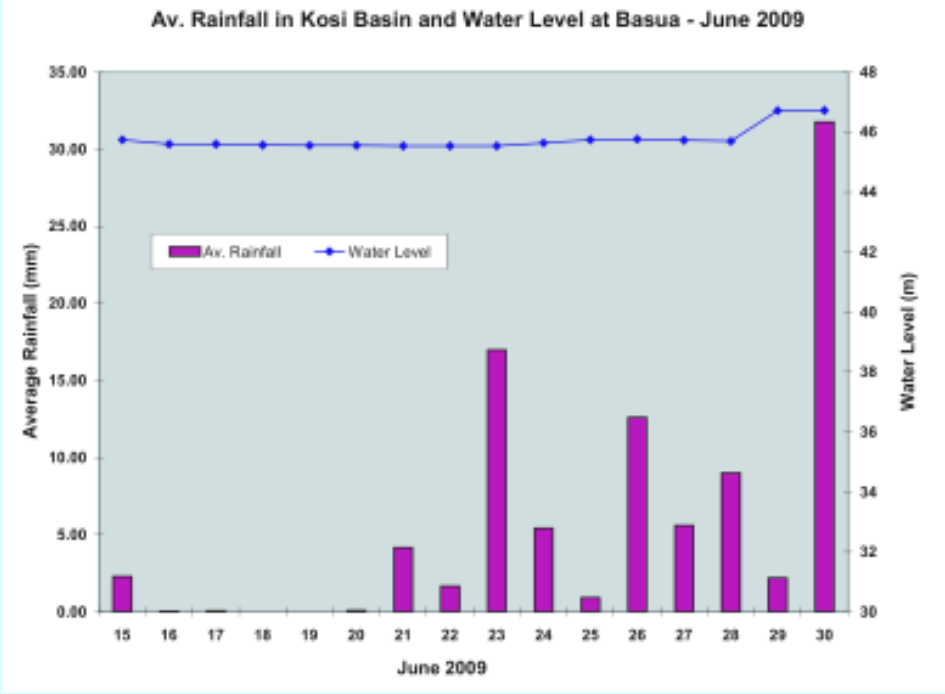


Rainfall occurred between 5th and 8th October only, but there was fluctuation in water level up to 15th October. This may be due to observation error or error in data entry on a few dates. This may also reflect that rainfall was not the only factor influencing the water level. This might be due to gate operation of weir.

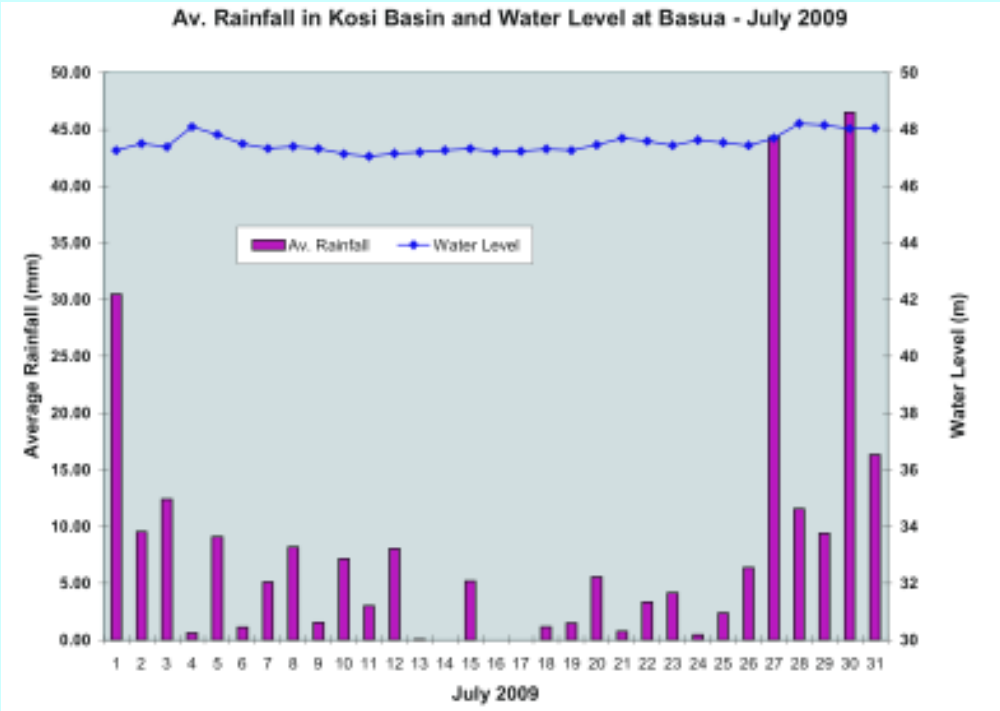


5.3.4 Kosi

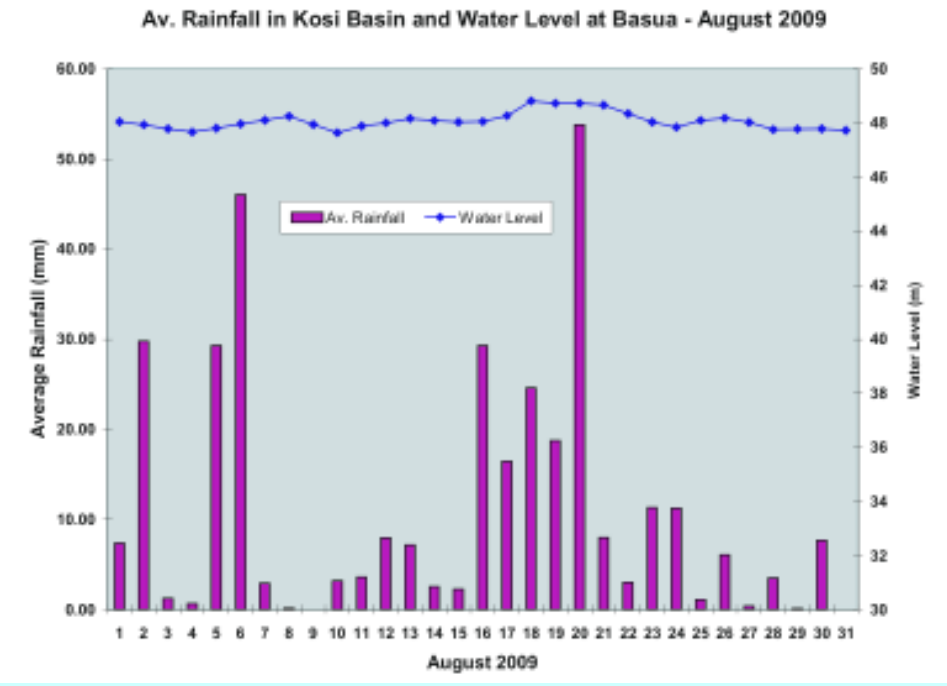
Water level fluctuated within 20 cm up to 28th June and there was a sudden rise of 1.02 m on 29th June. There was rainfall in the last week of June but not exceeding 16.98 mm except a maximum average rainfall of 31.77 mm on 30th June only.



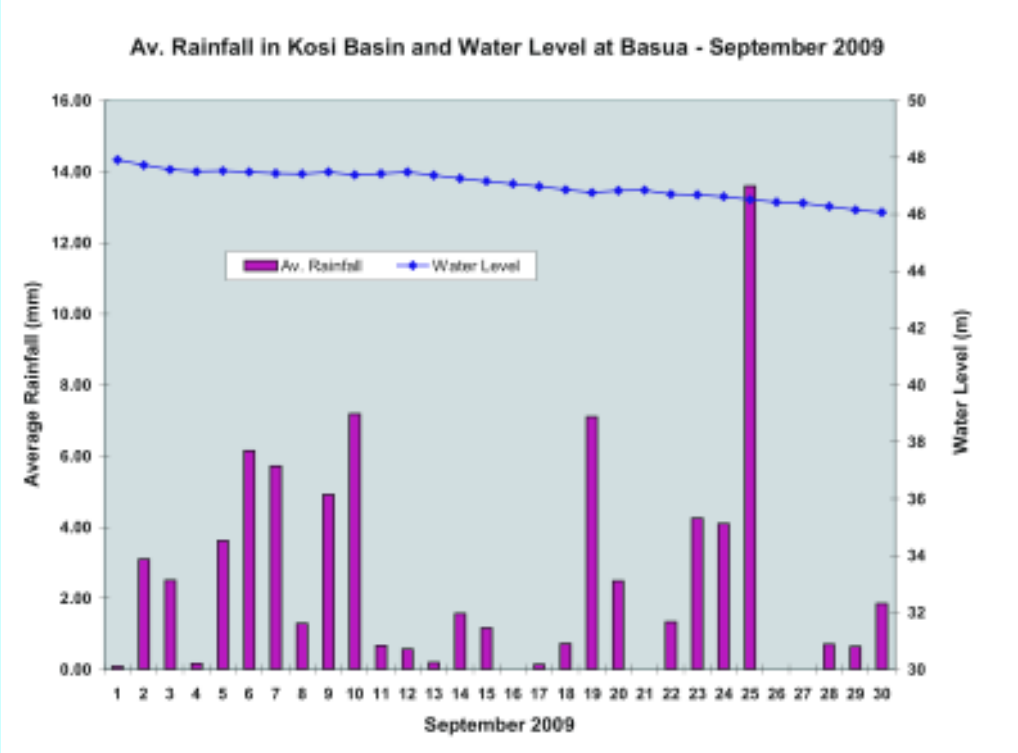
In continuation, the average rainfall in the upper catchment of Basua was 30.48 mm on 1st July leading to a rise in water level up to 48.09 m on 4th July. Afterward, there was no significant rainfall till 26th July and therefore, water level remained almost constant. Again there was an average rainfall of 44.35 mm and 46.48 mm on 27th and 30th July respectively which raised the water level above 48 m after 28th July.



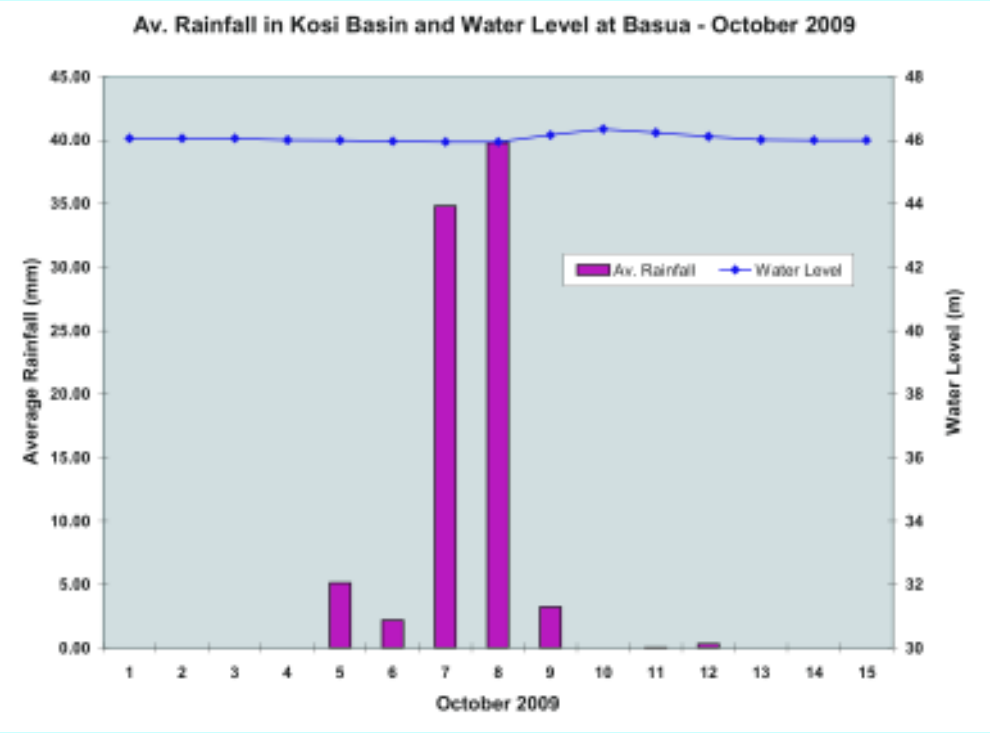
In the first week of August, there were effective rainfalls on 2nd, 5th and 6th August which raised the water level up to 48.25 m on 8th August. Similarly, the another spell of effective rainfall was between 16th and 20th August having maximum rainfall of 53.82 mm on 20th August itself. This led the maximum water level of this month as 48.82 m on 18th August. Thereafter water level receded.



Water level continuously decreased at approximately constant rate during this month. There was no significant rainfall in the basin in this month. Maximum average rainfall of 13.60 mm occurred on 25th September. The maximum water level was 47.92 m on 1st September and minimum of 46.08 m on 30th September.



The effective rainfall of 34.83 mm and 39.82 mm occurred on 7th and 8th October respectively. The water level was steady up to 8th October but due to rainfall in the upper catchment on 7th and 8th October, water level started rising and attained a maximum level of 46.35 m on 10th October, thereafter decreased continuously till 15th October.



5.3.5 Conclusions

1. Water level rises and recedes as the magnitude of rainfall in basins rise or fall, of course, with a certain lead time, still, water level doesn't seem to have a very systematic relationship with average rainfall. The possible reason may be the inadequate number of rain gauge stations used to compute average rainfall, The available rain gauge stations are too less in number to capture the spatial variability of rainfall. Secondly, arithmetic mean doesn't hold well in hilly terrain. Isohyetal method with adequate number of rain gauge stations may improve the result.
2. Rainfall - water-level relation is also bound to be affected by the control structures present upstream of the gauge sites on the rivers.
3. At Lalbegiaghat, Sonakhan, Jainagar and Basua lead time appears to be one day to two days. We can have more precise lead time if we use hourly or two-hourly data series in the analysis.

5.4 Rainfall Forecasts

Under a memorandum of understanding signed between FMISC, Bihar and IMD, New Delhi, the IMD has been providing rainfall forecast for an area between latitude 25.53° N to 28.77° N and longitude 83.24° E to 88.50° E. This area entirely covers the AOI, catchments area of all rivers lying in Nepal and some adjoining area in Bihar as well as Nepal. The forecasts were done using MM5 model for each 9 km grids, total 1386 numbers of grids covering the area. It was done every day for the next three consecutive days separately i.e. three 24-hr cumulative forecasts for day1, day2 and day3. Thus for each day 3 forecasts were available - 1st, 72 hrs in advance, 2nd, 48 hrs in advance and 3rd, 24 hrs in advance. The 3rd one was supposed to be based on more recent weather conditions hence, more accurate. With 24-hr cumulative forecasts 6-hr cumulative forecasts for the same three consecutive days were also made available by IMD.

Maximum value of forecasts for each four river basins of the AOI were extracted and provided in the Daily Flood Information Bulletin issued from the FMISC. These forecasts were used to enquire the availability of satellite images with NRSC, Hyderabad on the days likely to have critical rainfall.

Validity of the rainfall forecasts has been an issue. 45 km grid size was too coarse to compare its forecast with any point observation within the grid. IMD has provided forecasts for 9 km grid now which it plans to bring down to 5 km in the forthcoming season. While forecast for a 9 km grid is an improvement over 45 km grid size, with a 5 km grid size, the available forecasts will further improve substantially.

5.5 Satellite based analysis of Flood impact

Year 2009 happed to be a relatively eventless year, as no major inundation or breach was reported. Still we acquired information about RADARSAT passage over our area. As usual inundation layers were provided by NRSC under DMSP. Events were few and far between and except one breach at Tilak Tajpur no major event was recorded. We only acquired Liss 3 data to map the event with precision.

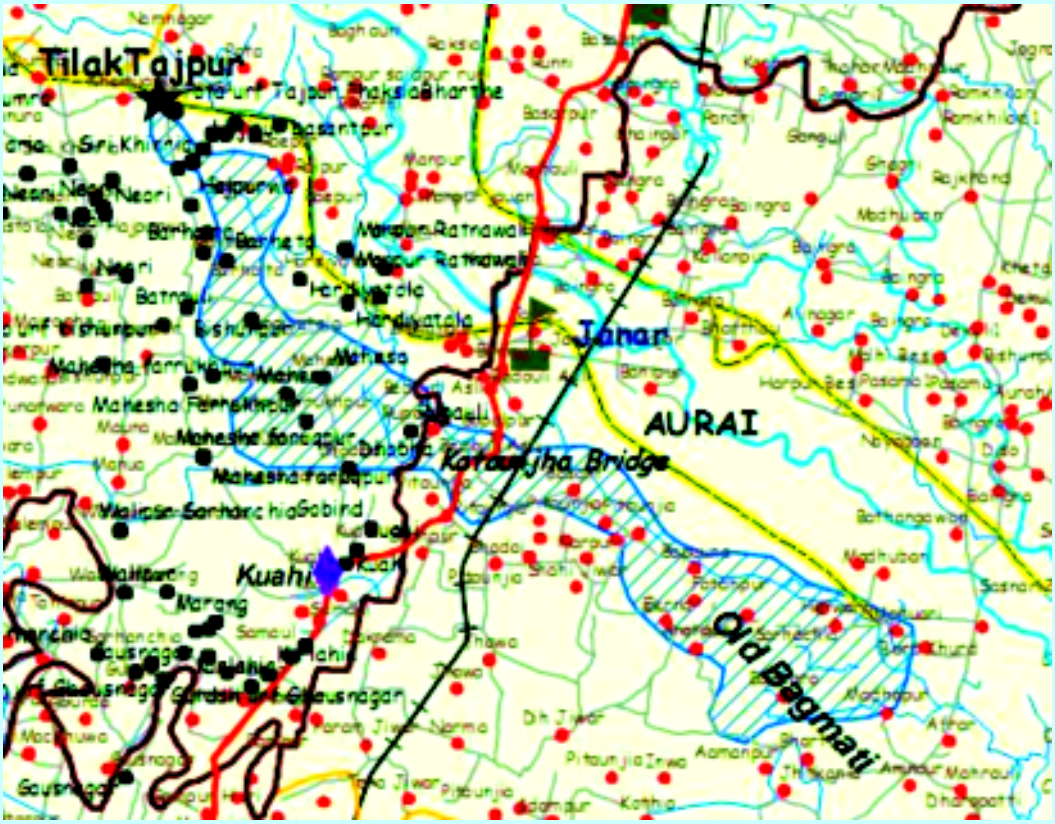
The event at Tilak Tajpur was reported to us on the same day it happened; the event was located

but we had to wait for a cloud-free satellite image. In the absence of any satellite pass over the area, we were hard pressed to provide the scenario in the form of a map which is usually expected of us.

For the first time we attempted a "likely to be inundated map" based on past flood extent and the disposition of large civil infrastructures which usually guide flood waters. We also located villages reported to be under effect of floods (as reported in newspapers) so that a glimpse of whole situation could be provided to DMD and other concerned departments.

On the 3rd of August we prepared this map and promptly provided it to DMD. Based on past year's work of FMIS they relied on this information too and pressed their men and resources to fight the disaster. To their surprise too, the "probability map" proved to be too close to reality. This way probably for the first time DMD was present beforehand at the site of an event well before it actually struck.

We also prepared maps showing location of relief camps and places where roads were overtopped by flood waters, to help DMD visualizing the scenario in totality. On the 10th of August we received an inundation layer (based on RADARSAT) from NRSC confirming the extent of flooding.



Map 5.7 : This year we attempted preparing a map showing areas likely to be inundated so that departments like DMD and district authorities could stay prepared in advance. This particular event is of breach at Tilak Tajpur in Baghmati, on 1st August 2009.

Map 5.8 : Later we obtained satellite data to ascertain the actual extent of flood. We also added location of relief camps and site of road overtopping by flood waters. This type of information came handy in reaching the areas affected by flood.

Map 5.9 : Still later we obtained RADARSAT image to map actual extent of flooding. It is notable that the prediction closely matches reality.

like previous two years, RADARSAT images covering the AOI were obtained during the flood season to view the flood impact. These images were procured and primarily processed under national disaster management support program (DMSP) by NRSC, Hyderabad, and then given to the Flood Management Information System Cell, Patna where value addition was done and disseminated to the user departments: Water Resources, Disaster Management, and Agriculture Departments. The maps depict the extent of flood inundation. The statistics elaborates district wise inundation area and percentage inundation. **Details of the satellite data acquired are as mentioned in the following table.**

Details of Customized Maps Produced:

SL. No	Date of Satellite data Received	Date of Dissemination/ Web Hosting	Type of Satellite Data	Trigger / Incidence
1	3-Aug-09	3-Aug-09	Radarsat-1	Flood inundation, Bagmati Breach in North Bihar
2	5-Aug-09	5-Aug-09	Radarsat-1	Flood inundation, Bagmati Breach in North Bihar
3	7-Aug-09	7-Aug-09	Radarsat-2	Flood inundation, Bagmati Breach in North Bihar
4	10-Aug-09	10-Aug-09	Radarsat-2	Flood inundation, Bagmati Breach in North Bihar
5	15-Aug-09	15-Aug-09	Radarsat-2	Flood inundation, Bagmati Breach in North Bihar
6	22-Aug-09	22-Aug-09	Radarsat-2	Flood Inundation in North Bihar
7	27-Aug-09	27-Aug-09	Radarsat-2	Flood Inundation in North Bihar
8	29-Aug-09	29-Aug-09	Radarsat-2	Flood Inundation in North Bihar
9	1-Sep-09	1-Sep-09	Radarsat-2	Flood Inundation in North Bihar
10	3-Sep-09	3-Sep-09	Radarsat-1	Flood Inundation in North Bihar
11	5-Sep-09	5-Sep-09	Radarsat-1	Flood Inundation in North Bihar
12	8-Sep-09	8-Sep-09	Radarsat-2	Flood Inundation in North Bihar
13	10-Sep-09	10-Sep-09	Radarsat-2	Flood Inundation in North Bihar
14	13-Sep-09	13-Sep-09	Radarsat-1	Flood Inundation in North Bihar
15	15-Sep-09	15-Sep-09	Radarsat-2	Flood Inundation in North Bihar
16	10-Oct-09	10-Oct-09	IRS LISS-III	Flood Inundation in North Bihar

Inundation Maps	**60**
Breach Maps	**10**
Area Specific Products	**7**
Others	**44**

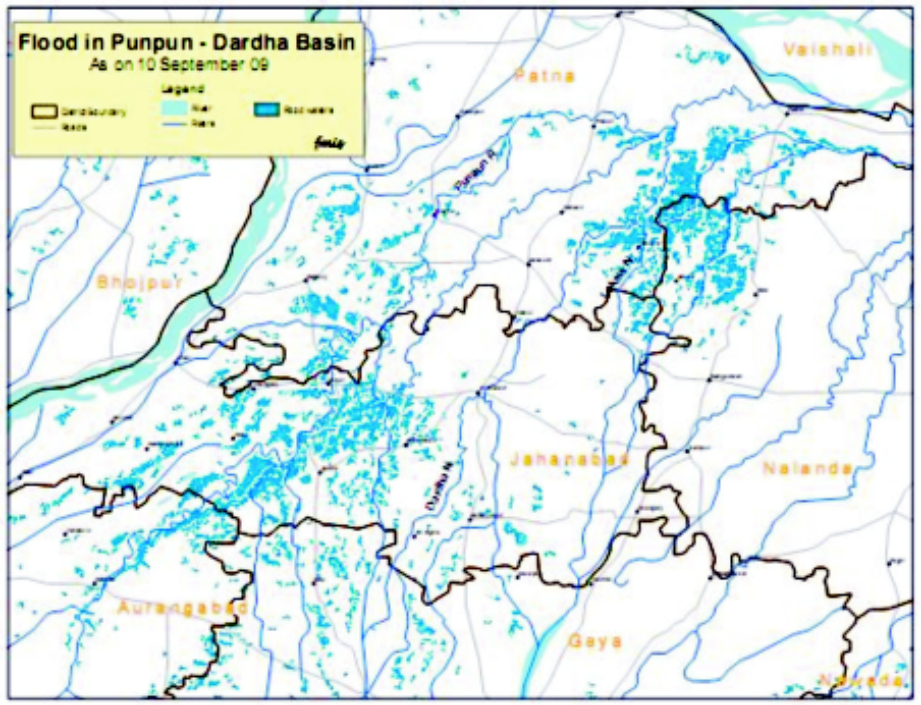
5.5.1 Value Added Inundation Maps

Based on our past experience with two flood seasons we have tried to make our maps more useful to a greater number of users with varied interest and responsibilities. Previously we used to deliver maps

Map 5.10 Inundation Map of Part of North Bihar showing Block boundaries (Based on Radarsat-1 Satellite Image of 03rd August 2009)

with administrative boundaries and some important locations. This year we have added location of gauge sites; both for water level and rainfall along with trend of water level; relief camps as well as location of sites where roads have been overtopped by flood waters. This type of information was found to be very useful in planning movement of officials and material for flood affected areas. The same information is posted over our website as soon as the product is ready.

Map : 5.11 Flood Inundation Map of Part of North Bihar showing District boundaries This season we added some more information, of great value to DMD and district authorities; like Rail heads, Guage stations Water level and spots on roads where it was overtopped by flood waters.



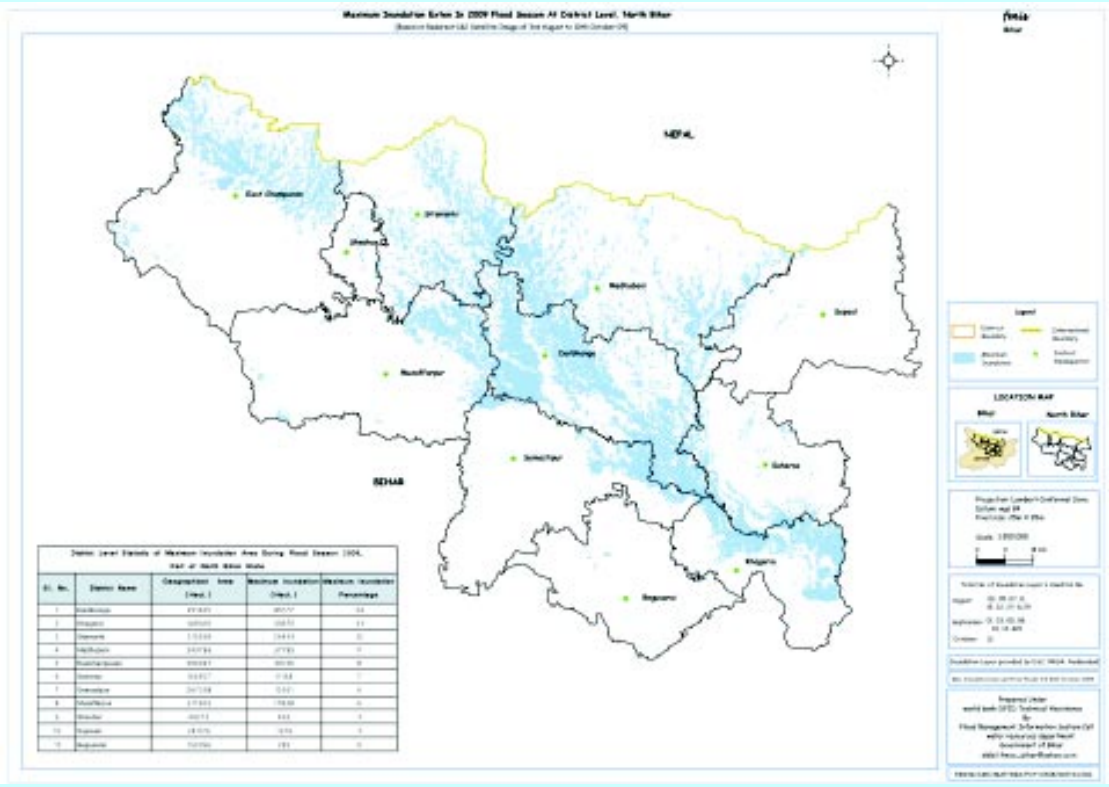
Map 5.12 Although the mandated area under study at FMIS is restricted to 11 districts of North Bihar, we also prepared maps for areas outside our mandated area. This one map shows flooding in South Bihar plain, caused by floods of Punpun and Dardha.

5.5.2 Maximum Inundation Extent Map

Maximum Extent of Inundation map is derived from RADARSAT data from 3rd August to 10th October 09. 16 numbers of scenes of the focus area were taken to prepare the layers of inundation maps. These layers were used to generate the maximum extent of inundation during the flood season 2009. The map shows the area is flooded at least once in the given period (3rd August to 10th October). The maps were prepared for Water Resources Department and Disaster Management Department.

Statistics of Inundated Geographic Area of Part of Bihar state on till 10th October 2009:

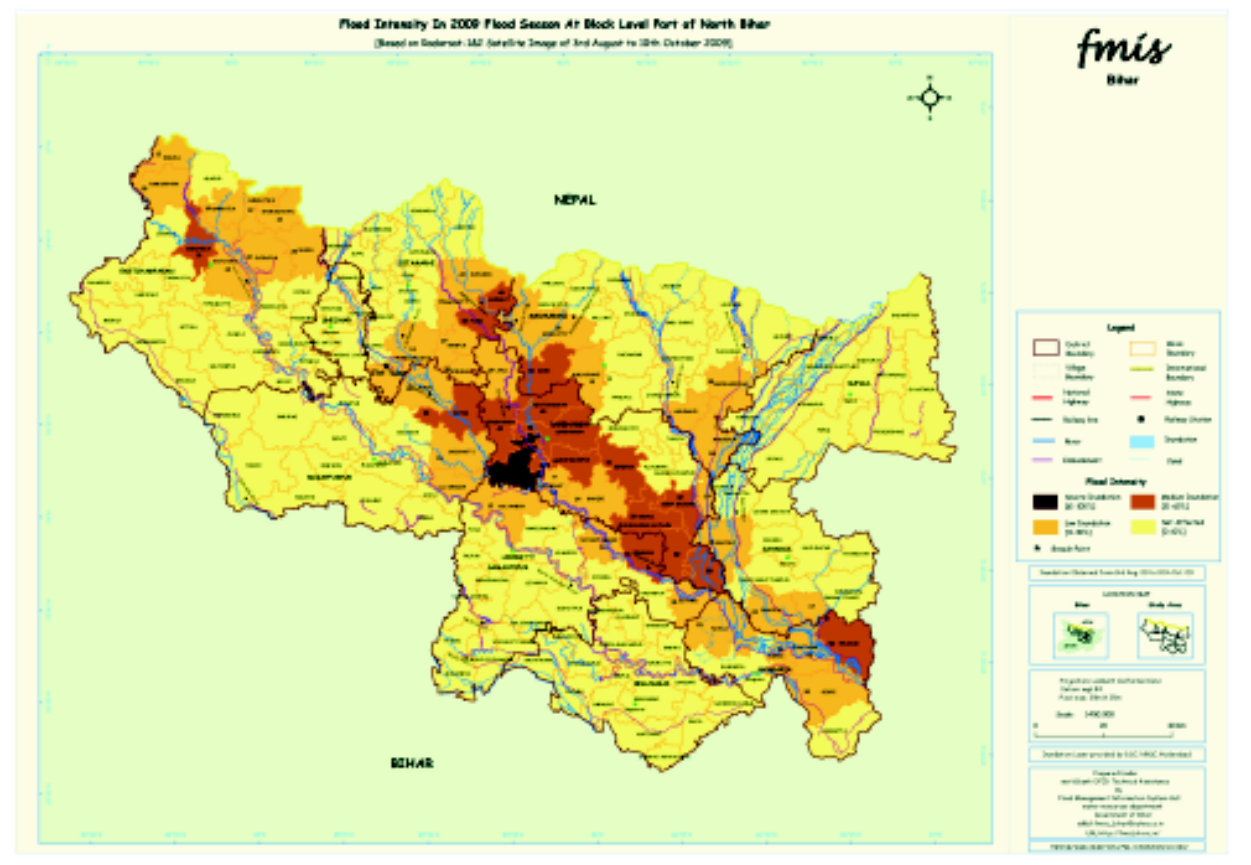
Sl. No.	District Name	Geographical Area (Hect.)	Maximum Inundation (Hect.)	Maximum Inundation Percentage
1	Darbhanga	251425	85177	34
2	Khagaria	149020	30676	21
3	Sitamarhi	219298	26439	12
4	Madhubani	349786	37785	11
5	Eastchamparan	396947	30136	8
6	Saharsa	166557	11168	7
7	Samastipur	267398	15951	6
8	Muzaffarpur	317303	17838	6
9	Sheohar	44273	493	1
10	Supaual	241176	1976	1
11	Begusarai	192096	285	0



Map 5.13 Maximum Inundation Map of Flood Season 2009

5.5.3 Flood Intensity Map

This map is prepared using the Radarsat images acquired during this flood season. This has been prepared for district level and block level at the end of season of monsoon 2009.

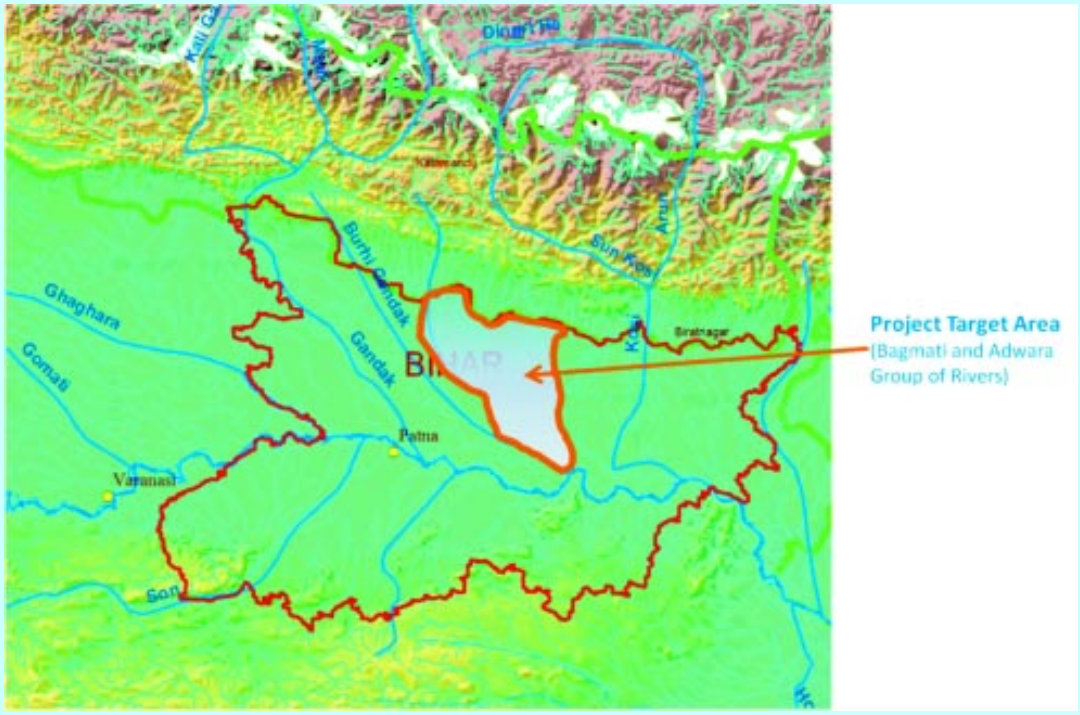


Map 5.14 Block Level Flood Intensity Map of Flood Season 2009

6.0 Bihar FMIS Phase II

As FMIS Phase I came to an end on 30.06.08, a fresh Grant proposal for Bihar FMIS - Phase-2 worth US $ 3.03 million (client executed) was submitted for consideration of the World Bank through Department of Economic Affairs (DEA) for Bank's priority assistance for extended focus area covering whole of North Bihar, with the objective of improved flood forecasting and early spatial warning.

After extensive consultation and frequent discussions with the stakeholders and field visits to the project area by the World Bank team in Feb 2009 the original proposal of FMIS Phase II submitted by GoB, was restructured and updated by the World Bank, based on fresh as well as actual needs (especially after post Kosi flood 2008) and capacity of the implementing agency. Accordingly the project cost was updated by the Bank to nearly US $ 5.98 million (client + WB executed). In the meantime the DEA, MOF, GOI down scaled the project to US $ 1.5 million to accommodate other proposals within the overall DFID fund availability. Therefore the project has been re- restructured within available 1.5 million U S $ cost and is being processed in Bank Office and may launch in beginning of next fiscal year (2010-2011).



Project Components

The TA will have the following components:

Component A: Institutional Strengthening for Flood Management

This Component will include support for the institutional strengthening essential to achieve and sustain the aims of the project. This will include support for a multi-sectoral focal point Center on flood information and analysis (transitioning from the current FMIS Cell), the Water Resources Department (WRD), as well as in linking with partner agencies (in particular, the Disaster Management Department). Support will be provided for strengthening FMIS Centre and setting up emergency flood control rooms, including office and equipment upgradation, , improved connectivity, video conferencing facility, as well as training and other capacity building (including upgradation of manuals) and moving to a comprehensive strategy for modernizing policy, institutional, and technical aspects of flood management in Bihar. In addition, Bank-financed activities will support a Panel of Experts to help improve quality of the entire project, as well as special studies and international training. The two proposed focus areas are:

A1. Capacity Building and training

This includes support for improving flood management through:

- Flood Management Improvement Support Center strengthening through recruitment of specialist staff, office upgrading, equipment including connectivity upgrading, and incremental operational expenses, building on the current FMIS Cell, as a focal point to provide state-of-the-art flood information and analytical services to flood-related departments.
- Strengthening the Water Resources Department's Flood Monitoring Cell and Hydrology Directorate, through recruitment of specialist staff, office upgrading, equipment including connectivity upgrading, and incremental operational expenses, to improve their current activities and interface with the Flood Management Improvement Support Center. In addition, WRD offices will be strengthened, including higher-level offices in flood-affected areas, and field offices in the targeted area (e.g. Sitamarhi, Sheohar, Runnisaidpur Divisions, SE Sitamarhi, CE Muzzafarpur) through office and equipment upgrading including connectivity, critical specialist staff and incremental office expenses.

A2 Flood management strategy and planning

An Integrated Flood Management Plan will be developed for the Bagmati Basin by considering flood issues with other interlinked water resources management issues. In addition, this activity would support special studies to upgrade flood management manuals and outline larger-scale institutional strengthening for the Water Resources Department.

Component B: Development of Flood Management Information Systems

This Component will include support for the development of a modern flood management information system for Bihar, with an initial demonstration in selected areas of the Bagmati/Adwara Group basin. This will include support for improving the spatial knowledge base for flood management, developing and using models for forecasting flood flow and inundation, and the establishment of a much-needed embankment asset management system. Support will be provided for associated consultancies, surveys, satellite imagery and other data procurement, and related operating expenses. The proposed focus areas are:

B1 Improve Knowledge Base for Flood Management

This activity will support activities to strengthen the knowledge base to improve flood management. This includes support for critical topographic and other surveys (e.g. cross-sections/longitudinal sections of embankments and river) in the focus areas of the Bagmati Basin and Adwara Group. In addition, support will be provided to immediately upgrade the inadequate and very outdated monitoring network for precipitation, flood flows, and sediment. New institutional arrangements will be piloted under which the network stations will be owned and operated by the concerned Chief Engineer's field offices, while the data compilation, archival and processing in the Hydrological Information System will be centrally performed by the Hydrology Directorate. This would require issue of necessary office order assigning the site operation and measurement responsibility to Chief Engineer office in Bagmati-Adhwara basin, and strengthening the Hydrology Directorate at Patna with additional WRD staff who will be provided requisite training through Short Term Consultants recruited under this project. The activity will also provide support for the development of a satellite imagery based spatial database covering flood-prone North Bihar.

B2 Improve Modeling/Analysis for Flood Warning

This activity supports flood forecasting and flood inundation modeling in the Bagmati/Adwara Group basin, (enhancing the stage level warnings based on gage-to-gage correlation today). Both traditional and innovative modeling approaches will be attempted. In addition the component will support studies on river course migration and analysis of flood hazard/risk/vulnerability.

B3 Establish an Embankment Asset Management System

The embankment system in North Bihar is extensive, but suffers from extensive problems of poor construction and negligible maintenance, exacerbated by the lack of any systematic inspection programs and techniques and data to assess current embankment status or prioritize embankment investments. This activity will support the development of a systematic Embankment Asset Management System (EAMS) for Bagmati-Adhwara basin supported by detailed modern surveys of the embankment status in the Bagmati -Adhwara basin that is partially embanked and where substantial investments for new embankments are planned. Community participation for embankment surveillance, and to update embankment safety information in the EAMS will be piloted

Component C: Community-Based Flood Risk Management in Targeted Areas

This Component will include support for the planning and implementation of community-based flood management in selected areas of the Bagmati-Adwara basin. This will include support for consultancies, communication systems, and associated operating expenses. The proposed focus areas are:

C1. Planning Community Outreach for Flood Management

This activity will support the planning for community outreach for effective flood management, focused on the situation on the ground in the targeted areas of the Bagmati-Adwara Basin. Technical assistance will be provided to develop strategies to improve community awareness, preparedness, and response, including institutional arrangements and tools for improved early warning communication and dissemination and for community reporting of flood problems.

C2. Enhancing Community Participation for Flood Management

This activity will support the implementation of efforts to improve community participation for selected flood-prone areas of the Bagmati-Adwara Basin. This will include support for technical assistance, communication tools, and community participation to demonstrate the "last mile" connectivity and involving the WRD, Disaster Management Department, District administration, and other institutions. Synergies with the existing Bank-financed Bihar Livelihoods Project are also being explored.

Budget Table

Client-Executed

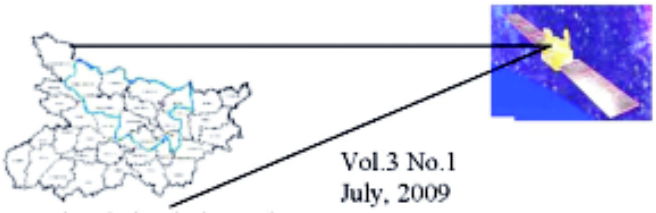
Component	Sub-Component	Total (US$)
A. Institutional Strengthening for Flood Management	A1. Capacity Building and training	492377
	A2 Flood management strategy and planning	132300
	Total	**624677**
B. Development of Flood Management Information Systems	B1 Improve Knowledge Base for Flood Management	456374
	B2 Improve Modeling/Analysis for Flood Warning	110250
	B3 Establish an Embankment Asset Management System	170888
	Total	**737512**
C. Community-Based Flood Risk Management	C1. Planning Community Outreach for Flood Management	27563
	C2. Enhancing Community Participation for Flood Management in Targeted Areas	110250
	Total	**137813**
	Total Project Costs	**1500002**

This will be complemented by **Bank-Executed** activities related to:

- Panel of Experts
- Supervision Support

fmis e-bulletin

Flood Management Information System
Water Resources Department
Bihar



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Contents

Home page of fmis website

"Towards a culture of preparedness for better flood management"

FROM PROJECT DIRECTOR'S DESK

Welcome to a fresh edition of FMIS E-Bulletin. After successful completion of FMIS Phase-I project of our team is busy in finalization of FMIS Phase-II activities. This year, till date we have insignificant flood episode in the State. The Cell as usual started working in two shifts from 7 AM to 2 PM and from 2 PM to 9 PM daily including holidays starting from 15th June 09. The rainfall this year upto 31/07/09 is 45% lower than the normal rainfall which is of course has developed draught like situation in the State. The pre-monsoon rainfall was as usual but then came the cyclone "Aaila" and movement of Monsoon was disturbed. The World Bank mission team visited Bagmati-Adhwara basin during early April 09 to have a first hand knowledge of existing structure and non-structural infrastructures of flood management in the Bagmati Basin. The visit was highly successful.

FMISC Phase-II final activities of package formulation started with a visit of Bank consultant Dr. Chari during 18-25 June 09 and for that the ToR/estimates are being finalized. Knowledge enhancement and capacity building remained a hallmark of FMISC activity and extending this an International Training on "Long-Lead Flood Forecasting and Applications" is scheduled to be held at Patna from 18th August 09 to 21st August 09. This will be conducted by ADPC, Bangkok. The trainees will be from Water Resources Department, Disaster Management Department, Agriculture Department, GFCC, IMD and participants from MP, Orissa and Uttar Pradesh. The training would focus on scientific aspects of flood forecasting, including weather forecasting inputs, its integration into local flood forecasting and warning systems and applications of long-lead forecasts for reducing impacts of floods in various sectors and at community levels.

The Cell remained busy in capturing post Kosi episode and disseminated customized breach site map dated 6th Jan, 20th April , 5th May, 8th June & 16th July 09. These maps were proved to be of great help in monitoring Kosi breach closure work. Another significant development is in term of use of Remote Sensing and GIS capabilities available with the Cell in deciding the Anti-erosion scheme by TAC. The Cell has also worked on the morphological changes of river Kosi from the gorge at Chatra to Birpur barrage site during 1976 to 2008 through satellite imageries and came up with a brief report that has been proved to be useful in knowing the behaviour of river . Also we have comeup with a new face of our website which has some important features like hydro-met status map and value added daily flood bulletin. In the nutshell, it is to be reiterated that FMISC is on the job and it will not rest till the suffering of the people from flood fury is minimized.

News in Pics

Porcupines used to tame the flow in kosi.

Heavy machine on work at breach closure site at Kusaha

Final closure of kosi breach at Kushaha

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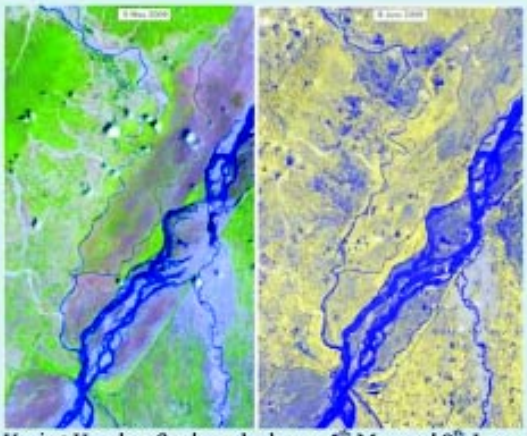
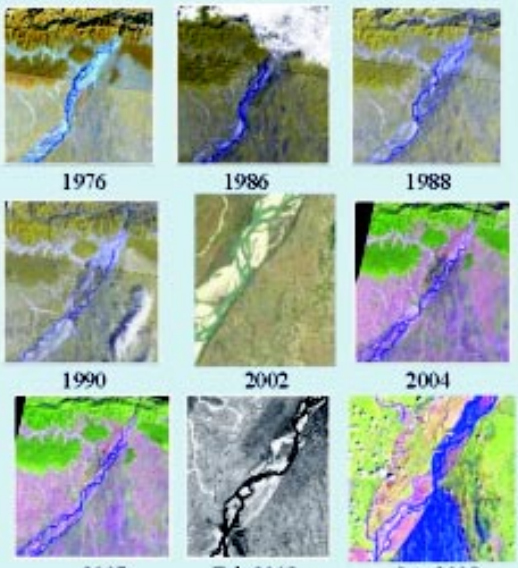
Information Products



Kosi at Kusaha after breach closure 5th May and 8th June.



Morphological change of River Kosi Between Gorge And Barrage Since 1976 to 2008

News and Activities

- World Bank mission visited Bagmati-Adhwara basin during April'09
- Scheme for anti-erosion work finalised using latest satellite imagery. Members of TAC appreciated the maps prepared at FMIS Cell
- The flood report 2008 published and disseminated to all stakeholders.
- Seven assistant engineers are working in cell and 2 junior engineers.
- Cell working from 7 am to 9 pm. Web site upgraded and updated regularly.

Designed and produced at FMISC, Patna.

Capacity Building : A group photo of Trainers, Trainees and officers of WRD

FMISC officers on a study tour to Bangkok.