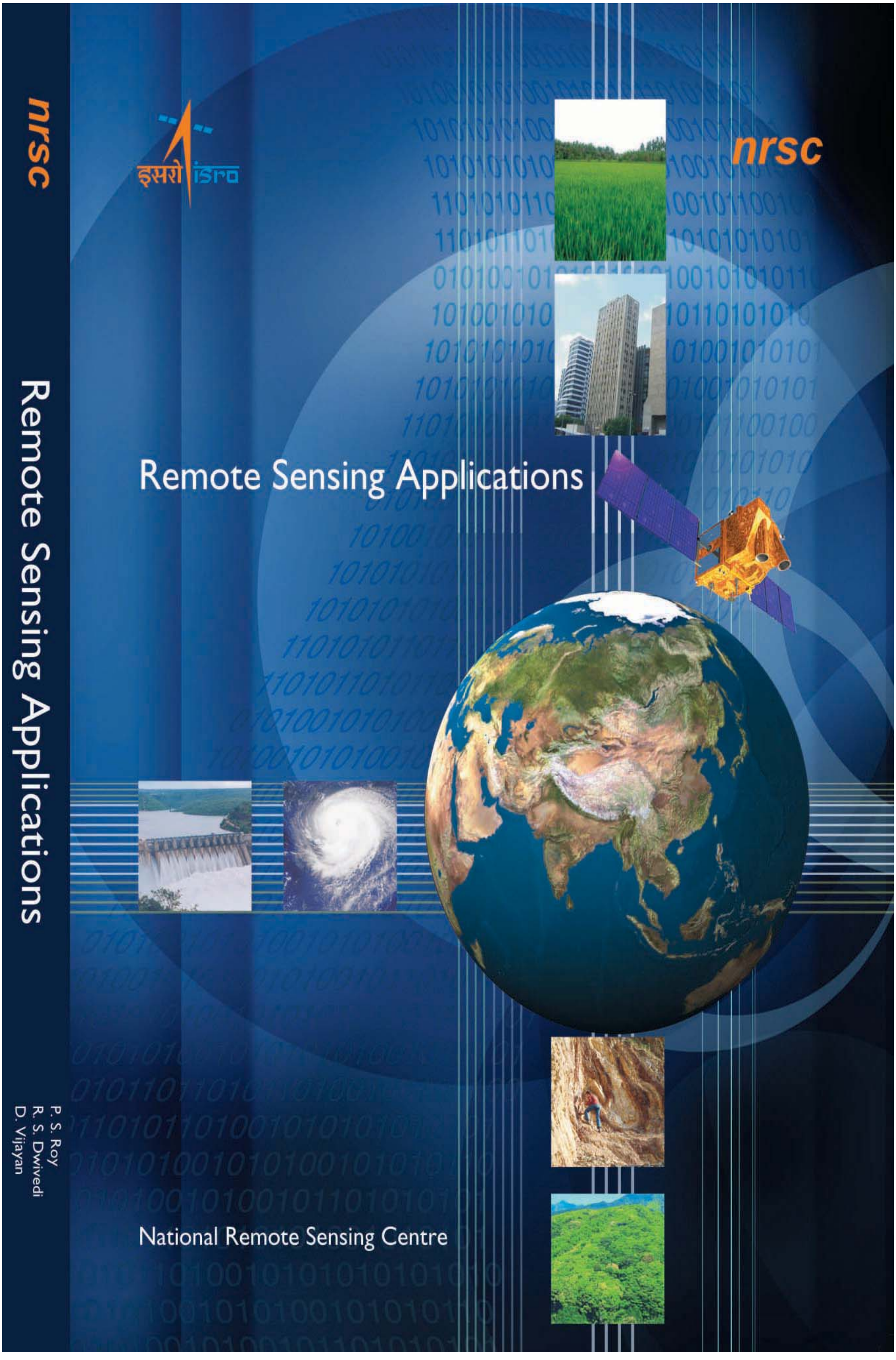
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R. S. Dwivedi
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National Remote Sensing Centre

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Flood Disaster Management

12.1. Introduction

12.1.1. Floods in India

India, on account of its geographical position, climate and geological setting, is the worst affected centre of disaster in the South Asian region, making it vulnerable to natural hazards such as cyclone, drought, floods, earthquakes, fire, landslides and avalanches. India is the worst flood-affected country in the world after Bangladesh and accounts for one fifth of global death count due to floods. Around 40 million hectares of land in the country are subject to floods according to National Flood Commission, and an average of 18.6 million hectares of land is affected annually. The annual average cropped area affected is approximately 3.7 million hectares. The most flood-prone areas in India are the Brahmaputra and Ganga River basins in the Indo-Gangetic-Brahmaputra plains in North and Northeast India, which carry 60 per cent of the nation's total river flow. The other flood prone areas are the north-west region of west flowing rivers such as the Narmada and Tapti, Central India and the Deccan region with major east flowing rivers like Mahanadi, Krishna and Cauvery.

Nearly 75 per cent of the total Indian rainfall is concentrated over a short monsoon season of four months (June-September). As a result the rivers witness a heavy discharge during these months, leading to widespread floods in Uttar Pradesh, Bihar, West Bengal and Assam. The Himalayan Rivers also carry a large amount of sediment, causing erosion of the banks in the upper reaches and over-topping in the lower segments. Drainage problems also arise concurrently if floods are prolonged and the outfalls of major drainage arteries are blocked. One of the major reasons for the floods is the massive indiscriminate deforestation, which leads to large amounts of topsoil coming loose in the rains. Thus, the soil, instead of soaking up the rainfall, flows down into the river and in turn causes the riverbeds and its tributaries to rise.

12.1.2. Flood Management

Though floods cannot be stopped, its damages can be minimized by proper management measures. Flood disaster management demands efficient planning measures, implementation and policy making decisions, application of modern scientific and communication tools for smooth functioning of the system. For effective flood management, the concerned flood control departments require information at different phases of the flood disaster cycle as shown in Table 12.1. Relief and rescue operations need to be carried out immediately during the flood to provide emergency help to the affected people and reduce the likelihood of secondary damage. One of the most important elements in Flood Management is the availability of timely information on the spatial extent of the affected area for taking decisions and actions in the form of a map. A flood inundation map helps the decision-maker to make a scientific assessment for better management of relief activities. This spatial information about the flood situation needs to be continuously updated for the successful execution of the operations. Hence an identified system has to be developed to address the various information needs and to provide an operational service with its framework.

Table 12.1: Information requirements for a disaster manager

S.No	Phase	Required Information
1	Flood preparedness (Before Flood)	– Chronically flood prone areas – Prior information on probable flood affected areas with considerable lead time – Optimum evacuation plans
2	Relief and Rescue (During flood)	– Flood affected areas – Flood damage statistics – Updation of the flood condition in terms of flood recedence and persistence etc.
3	Flood Mitigation (After Flood)	– Changes in the river course – The status of flood control works – River bank erosion – Drainage congestion – Flood Risk zones

12.1.3. Role of Space Technology

Role of space applications in disaster management lies in its criticality to produce as well as disseminate the information on real/near real time basis. The developments in space technology offer tremendous technological potential to address the crucial information needs during mitigation and preparedness, response and recovery/ relief phases of a disaster. Earth observation satellites enable continuous monitoring of atmospheric as well as surface parameters attributing to the phenomena. The operational role of satellite communications viz., satellite phones, point-to-point networking solutions routed through the arrays of Very Small Aperture Terminals (VSATs) deployment in remote and inaccessible areas, Cyclone Warning and Dissemination Systems (CWDS), Data Collection Platforms (DCP) and Satellite Aided Search & Rescue (SAS&R) are very critical during a disaster.

Satellite remote sensing data provides information on spatial flood extent, flood damage statistics and also in river engineering studies in a cost effective manner as discussed below. The utilization of each product is shown in Table 12.2.

Table 12.2: Utilization of the flood products

S.No	Deliverables	Utilization
1	Flood map	To map inundated areas for organizing relief operations
2	Flood damages – Extent of inundation – Crop area submerged – Number of Villages marooned – Length of Road/ railway network affected/submerged	Quick assessment of flood damages, for providing relief & Rehabilitation
3	Flood control works and River configuration	Strengthening of existing & planning of future flood control works
4	River Bank erosion	Planning anti erosion works
5	Identification of chronic flood prone areas and Floodplain zoning	Hazard zonation & floodplain regulation, planning flood control works

During preparation phase,

- Using historic satellite remote sensing data acquired during floods, it is possible to provide the chronically flood prone areas in the form of a map showing severely affected, occasionally affected, etc.
- Prior information on probable flood affected areas using hydrological models can be provided
- Using flood inundation models in GIS environment, optimum evacuation plans can be generated for carrying out rescue operations

During floods,

- A flood map showing the spatial extent of the flood affected areas
- Flood damage statistics like district-wise flood affected area, submerged crop, marooned villages and length of submerged road/rail can be provided
- Satellite data can be used at regular intervals for updation of the flood condition on the ground in terms of flood progression, recedence and persistence

During mitigation phase,

- Using high resolution historic and present satellite data, mapping of river configuration and flood control works, changes in the river configuration, and studies on bank erosion/deposition can be carried out
- Using multi-date satellite data it is possible to demarcate the drainage congestion areas in the chronic flood prone areas
- Flood hazard and risk zone maps can be generated using multi-year satellite data acquired during floods

12.1.4. Initiatives of Department of Space

In order to provide vital inputs and support in the event of a flood disaster, Department Of Space (DOS) has been developing techniques and methodology by integrating space based systems and services for disaster management. DOS had executed a Disaster Management Support Programme (DMSP) for integrating operationally the space technology inputs and services on a reliable and timely basis for strengthening India's resolve towards disaster management. DMS Programme addresses five issues mainly (i) creation of digital databases at appropriate scales for facilitating hazard zonation, damage assessment etc., in perennially disaster prone areas, (ii) development of appropriate Remote Sensing & Geographical Information System (GIS) based decision support tools and techniques and demonstrations catering to the information needs at different levels, (iii) acquisition of close contour information for priority areas, (iv) strengthening the communications backbone for addressing the real time / near real time information transfer needs and (v) networking of scientific institutions for exchange of data, information and knowledge. Towards enabling the operational services, a Decision Support Centre (DSC) is established at National Remote Sensing Centre, (NRSC) as a single window provider, interfacing with the National / State disaster management agencies. The important components of the DSC include satellite/ aerial data acquisition strategy, user required information and formats, output generation, dissemination of information generated to the users through networking, support functions such as digital database, hazard zonation, network modelling, query shells, etc.

For the last one and half decade, NRSC has been extensively using satellite remote sensing data for flood mapping and monitoring activity operationally in near real-time besides in other river mapping studies. Optical satellite data from the series of Indian Remote Sensing satellites (IRS) and microwave data from Canadian satellite RADARSAT are used to map the flood-inundated areas in near real-time and estimate the flood damages. The flood maps and damage statistics are disseminated to central and concerned state government departments by digital and surface means. A flood map provides the spatial extent of flood inundation in the entire state, at an instant of time and helps to identify the worst flood affected areas and acts like a guide for better planning of rescue operations and allocation of resources for relief (Bhanumurthy *et al*., 2003). It can also be used as an information layer to integrate with other related available ground information. It can be used to validate / crosscheck with the information collected from other sources and helps as evidence in explaining the flood impact. This type of information is quite difficult to generate by conventional means since some of the areas may not be accessible (Srinivasa Rao *et al.*, 2006). The flood damages are based on scientific assessment and hence reliable and accurate.

12.2. Approach

The main components of flood mapping and monitoring are shown in Figure 12.1. They are

- Flood watch
- Satellite data planning and acquisition
- Satellite data analysis
- Product Dissemination

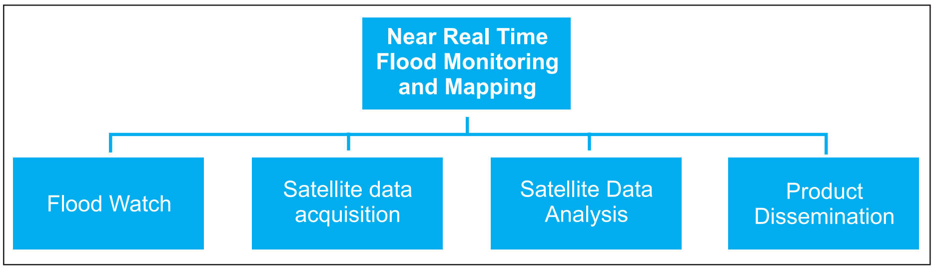

Figure 12.1: Components of the Near Real Time Flood Mapping and Monitoring Activity

12.2.1. Flood Watch

Flood watch is one of the preparedness activities where a constant watch is kept on the flood situation in the country through different sources of information. It is the most important activity and is a triggering tool for the next chain of activities.

12.2.1.1. Flood News

The flood related information is collected daily from web news/television/ newspapers/state ground departments. The local web news sites of the respective states are scanned for the latest information on the flood condition.

12.2.1.2. Meteorological Satellite Data

Meteorological satellite KALPANA-1 images over the country were collected to understand the cloud cover pattern. The cloud cover over the country from 18-21 August, 2008 through a series of INSAT images, is shown in Figure 12.2. Persistence of thick cloud cover over the country can be observed from the images during 18-21 August, which led to heavy rains and subsequent flooding in some parts of the country.

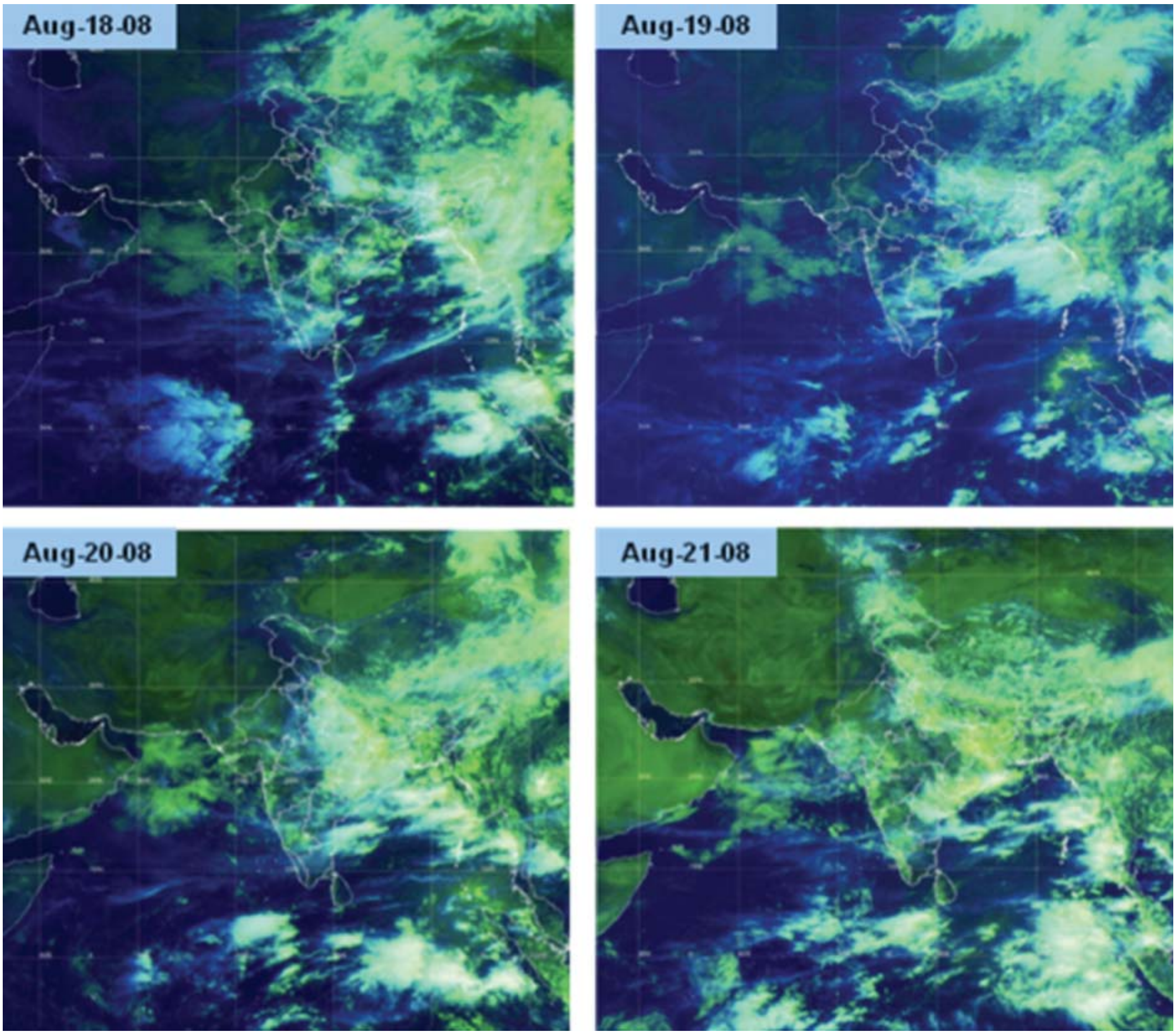

Figure 12.2: KALPANA-1 images showing cloud cover during 18-21 August 2008 (Source: www.imd.ernet.in)

12.2.1.3. Rainfall Data

The rainfall data measured at various rain gauge stations across the country by Indian Meteorological Department (IMD) and Central Water Commission (CWC) is collected and related to the cloud pattern in Kalpana-1 images. The rainfall distribution from Tropical Rainfall Measuring Mission (TRMM) merged products which are available on their website are also downloaded. Figure 12.3a shows the rainfall distribution as on 15th and 20th September 2006 from IMD and Figure 12.3b shows TRMM image showing the accumulated rain over India during September 2006. It is observed that during 15th and 20th September 2006, vigorous

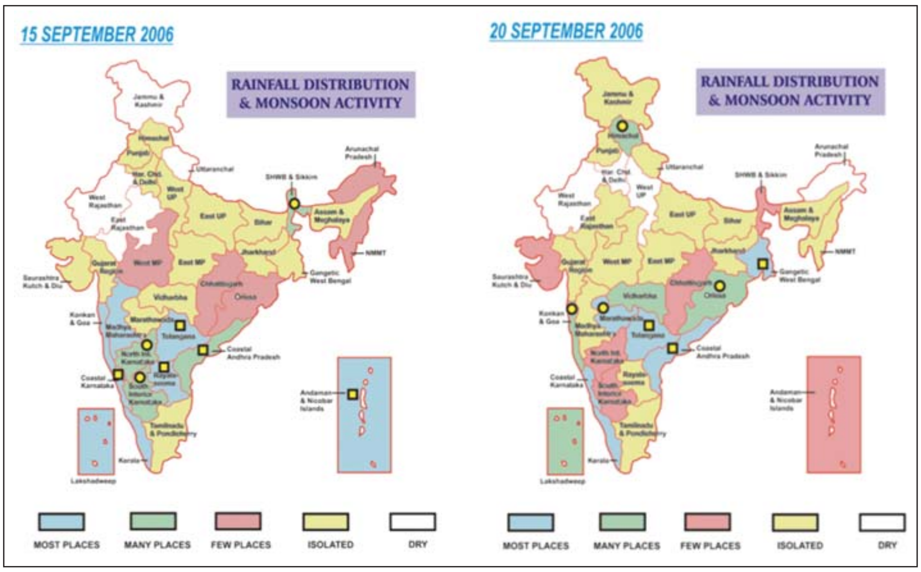

Figure 12.3a: Rainfall distribution as on 15th and 20th September 2006 (source: www.imd.ernet.in)

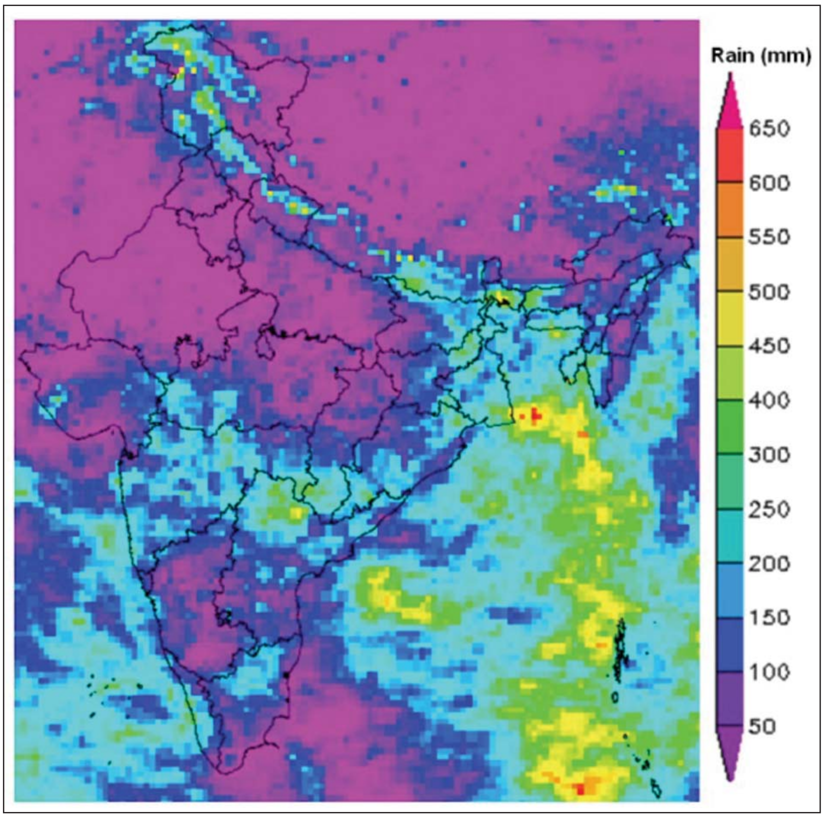

Figure 12.3b: Rainfall distribution maps from TRMM merged product (source:http://disc2.nascom.nasa.gov/Giovanni/tovas/realtime.3B42RT.2.shtml#description)

rainfall activity was over South and South East India respectively. The TRMM accumulated rainfall map shows that about 300-450 mm of rainfall occurred during September 2006 on this region.

12.2.1.4. Water Level Data

The water level data of rivers and its tributaries at various gauge recording stations is obtained from CWC on daily basis. The water levels of Ganga River and their tributaries in part of Bihar, the water levels of Brahmaputra, Barak Rivers and their tributaries in Assam are received from CWC. River gauge hydrographs are prepared using the water level data. The trend of the flood wave is monitored through these hydrographs.

Figure 12.4 shows the location of six rain gauge stations along river Brahmaputra for which the water level data is supplied by CWC. The gauge hydrograph prepared for river Brahmaputra along Dibrugarh shows that the river was flowing above the danger level mark throughout the month, whereas at Dhubri it crossed the danger level during the third week of August 2008 (Figures 12.5 a&b).

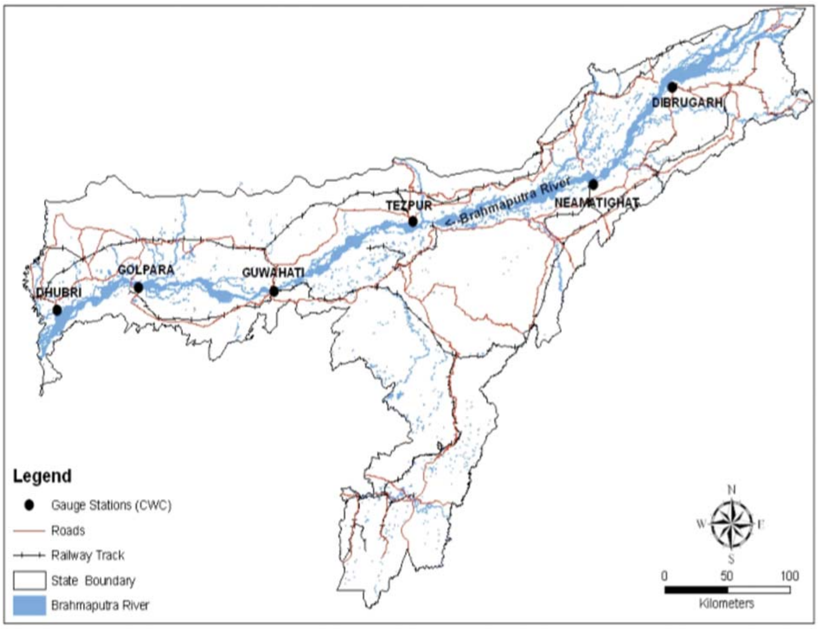

Figure 12.4: Location of gauge stations along river Brahmaputra in Assam

12.2.2. Satellite Data Acquisition

After the flood watch, the affected regions are identified and all the available satellites onboard covering the affected area are earmarked and coverage charts are prepared. Continuous meticulous planning is required to acquire satellite data during rising of flood wave, at the peak and falling of the flood wave to help the flood disaster manager for successful relief and rescue operations.

Presently, optical satellite data from IRS-P6, IRS-P4, NOAA and TERRA/AQUA satellites is being used. Based on the trend of the flood wave, microwave data from RADARSAT/ERS SAR/ENVISAT satellites are programmed. RADARSAT-1 operates at C-band with HH polarisation and has the flexibility to acquire images at different incidence angles, resolutions and swath modes. Figure 12.6 shows the different beam modes of Radarsat satellite. ERS operates at C-band with VV polarization with a resolution of 25 m and a swath of 100 km. Presently, RSI/Canada requires minimum 48 hrs advance intimation for programming the RADARSAT-1 satellite to acquire data over any area. Emergency Programming mode with 'near real time' data supply option is selected so that the acquired raw Radarsat data will be placed on the *ftp site* of RADARSAT. Table 12.3 shows the satellites and sensors that are used for flood mapping activity.

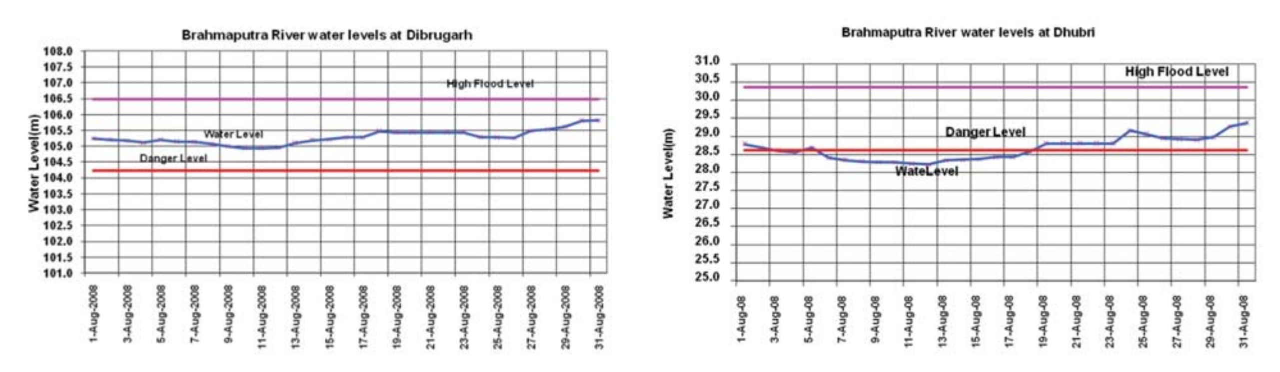

Figure 12.5: Gauge hydrograph of river Brahmaputra at (a) Dibrugarh in Assam and (b) at Dhubri in Assam

Table 12.3: Satellites and their Sensors used for flood mapping

S.No	Satellite	Sensor/ Mode	Spatial Res(m)	Spectral Res (μm)	Swath (km)	Used For
1	IRS-P6	AWiFS	56	B2: 0.52-0.59 B3: 0.62-0.68 B4:0.77-0.86 B5: 1.55-1.70	740	Regional level flood mapping
2	IRS-P6	LISS-III	23.5	B2: 0.52-0.59 B3: 0.62-0.68 B4:0.77-0.86 B5: 1.55-1.70	141	District-level flood mapping
3	IRS-P6	LISS-IV	5.8 at nadir	B2: 0.52-0.59 B3: 0.62-0.68 B4:0.77-0.86	23.9	Detailed level Mapping
4	IRS-1D	WiFS	188	B3: 0.62-0.68 B4:0.77-0.86	810	Regional level flood mapping
5	IRS-1D	LISS-III	23.5	B2: 0.52-0.59 B3: 0.62-0.68 B4:0.77-0.86 B5: 1.55-1.70	141	Detailed level Mapping
6	Aqua/ Terra	MODIS	250	36 in visible, NIR & thermal	2330	Regional level Mapping
7	IRS-P4	OCM	360	Eight narrow bands in visible & NIR	1420	Regional level Mapping
8	Cartosat-1	PAN	2.5	0.5- 0.85	30	Detailed level Mapping
9	Cartosat-2	PAN	1	0.45-0.85	9.6	Detailed level Mapping
10	Radarsat-1	SAR/ ScanSAR Wide	100	C-band (5.3 cm) HH Polarization	500	Regional level mapping
11	Radarsat-1	SAR/ ScanSAR Narrow	50	C-band (5.3 cm)	300	District-level mapping
12	Radarsat-1	Standard	25	C-band	100	District-level mapping
13	Radarsat-1	Fine beam	8	C-band (5.3 cm)	50	Detailed level mapping
14	ERS	SAR	25	C-band VV Polarization	100	District-level mapping

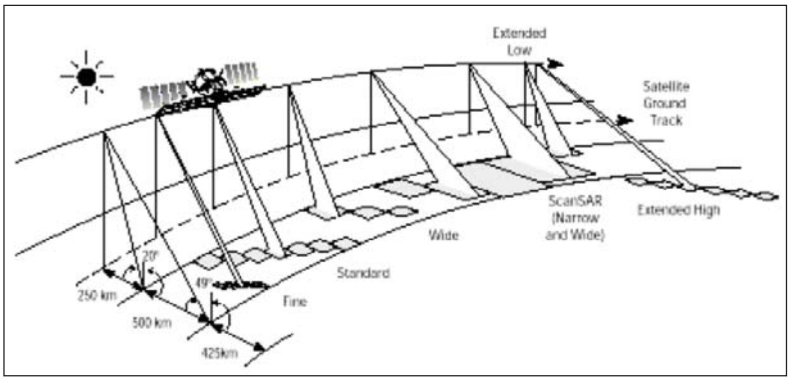

Figure 12.6: Beam modes of Radarsat satellite (Source:http://gs.mdacorporation.com/products/sensor/radarsat/radarsat1.asp)

"Data acquisition planner" application tool which is developed by ADRIN, DOS is used for determining the ideal sensor of IRS series that cover the flood affected region in a specific period of time. This software has a user-friendly GUI and is developed with Visual Basic 6.0 and MapObjects 2.0 in the front end and C-program in the backend.

In this tool, satellite and sensor characteristics are maintained in a database. Existing satellite sensor properties can be edited and new satellites and sensors can be added, as and when required. Satellite orbits are predicted using the satellites' Two Line Element sets (TLE) and the ground coverage is predicted using the viewing geometry parameters of the respective sensors. With this application, all possible coverages of the user-defined area by satellites of our interest during the specified time period can be determined. Figure 12.7a shows the path coverage of IRS-P6 AWiFS sensor over Assam region on 5th June 2006.

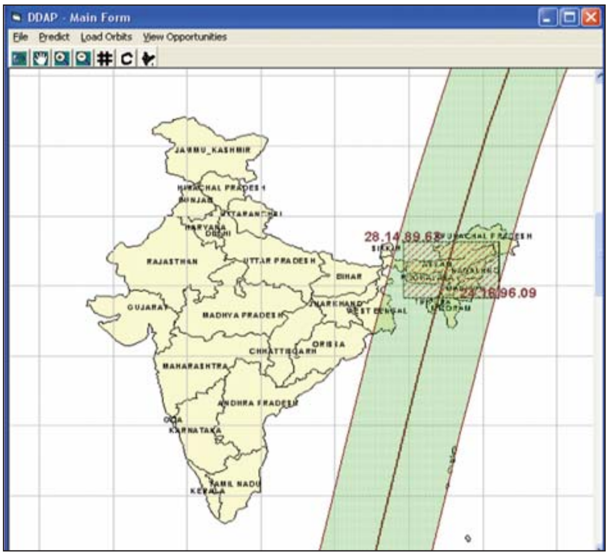

Figure 12.7a: Path coverage of IRS-P6 AWiFS over Assam region on 5th June, 2006

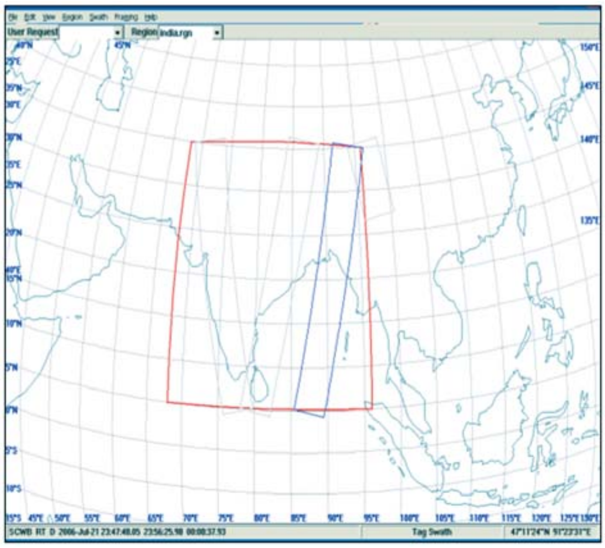

Figure 12.7b: Scan SAR Wide Beam coverage over Assam on 21 Jul., 2006 at 23:47:48.05

For Radarsat SAR data, "Swath Planner" application tool which is provided by RSI, Canada is used to identify the possible coverages over the affected area for different beam modes. Figure 12.7b shows the Scan SAR Wide Beam coverage over Assam on 21-Jul-2006. All the above information are compiled and a consolidated flood disaster watch report is prepared on daily basis, highlighting the incidence of the flood event, its trend, damages reported, along with details of satellite data planning and status of acquisition. Figure 12.8 show the elements of disaster watch report activity.

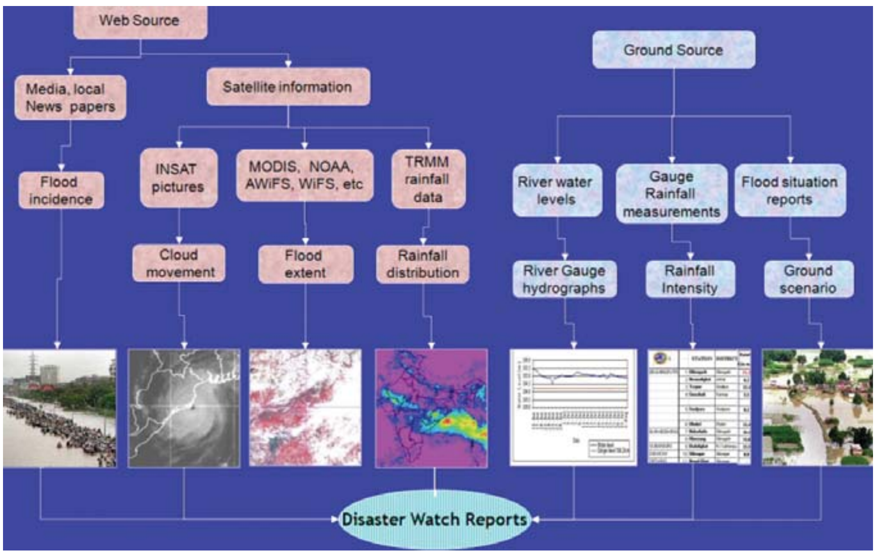

Figure 12.8: Elements for satellite data planning and acquisition

12.2.3. Satellite Data Analysis

12.2.3.1. Optical Data

Optical remote sensors measure the reflectance from objects on the ground. Pure and deep-water bodies absorb most of the electro-magnetic energy and reflect very little energy. Flood water, because of different sediment concentrations, reflects considerable energy in different bands, including near infra red (NIR) region. Figure 12.9 shows IRS-P6 image of 30-Aug-2005 with variations in flood signatures.

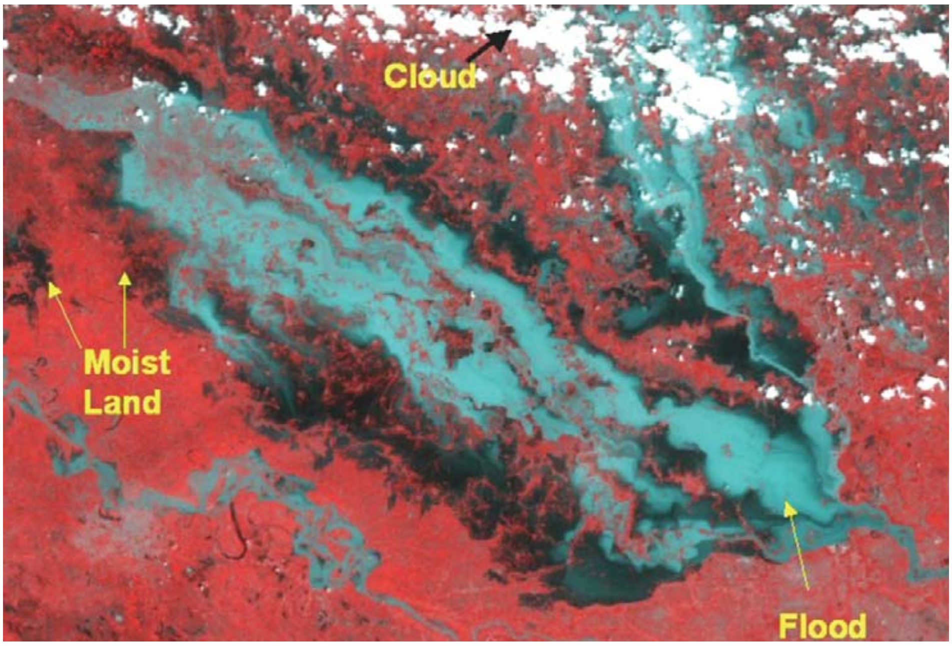

Figure 12.9: IRS-P6 AWiFS image of 30 Aug., 2005

Red Band

	Minimum	Maximum	Mean	S D
	5.81	6.367	6.191	0.153
	6.128	6.845	6.634	0.126
	6.248	6.487	6.419	0.054
	6.805	8.954	8.275	0.421

Infra Red Band

	Minimum	Maximum	Mean	S D
	4.608	5.135	4.826	0.118
	3.026	4.192	3.672	0.239
	2.665	2.804	2.748	0.036
	3.47	5.496	4.246	0.306

Table 12.4: (a) Radiance values of flood waters in (a) red band and (b) infra red band

Tables 12.4a & 4b shows the variations in radiance values of flooded areas derived from IRS-P6 AWiFS image, both in Red and Infra red bands. It is possible to delineate the flood extent from optical data even with two bands, i.e., red and infra-red bands. Figure 12.10 shows the scatter-plot between Red and Infrared bands which provides a fair view of the separation of various classes for delineating flood extent. Though delineation of flood extent is not a trivial exercise, the presence of cloud cover makes the classification process very difficult.

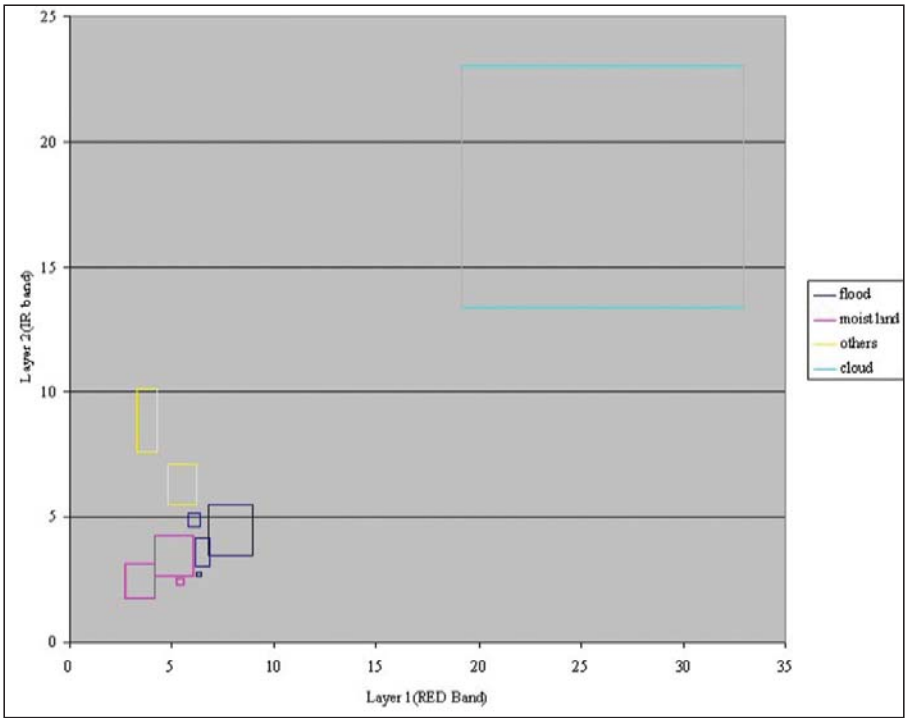

Figure 12.10: Scatter plot of Red and Infra red bands (IRS-P6 AWiFS image)

The flood water signature generally mixes with cloud shadow and also with mixed pixels of cloud and cloud shadow. In some cases, it mixes with large urban areas / built-up lands.

12.2.3.2. Microwave Data

The advantage of using radar data over the optical data is its ability to penetrate cloud cover and also data acquisition during day and night. Water surfaces are generally smooth at radar wavelengths and can be regarded as specular reflectors which yield small backscatter. The surrounding terrain is assumed to be rough at radar wavelengths which exhibits diffuse scattering with moderate backscatter, as shown in Figure 12.11. Hence, water is regarded as low intensity areas whereas the surrounding terrain corresponds to brighter intensities.

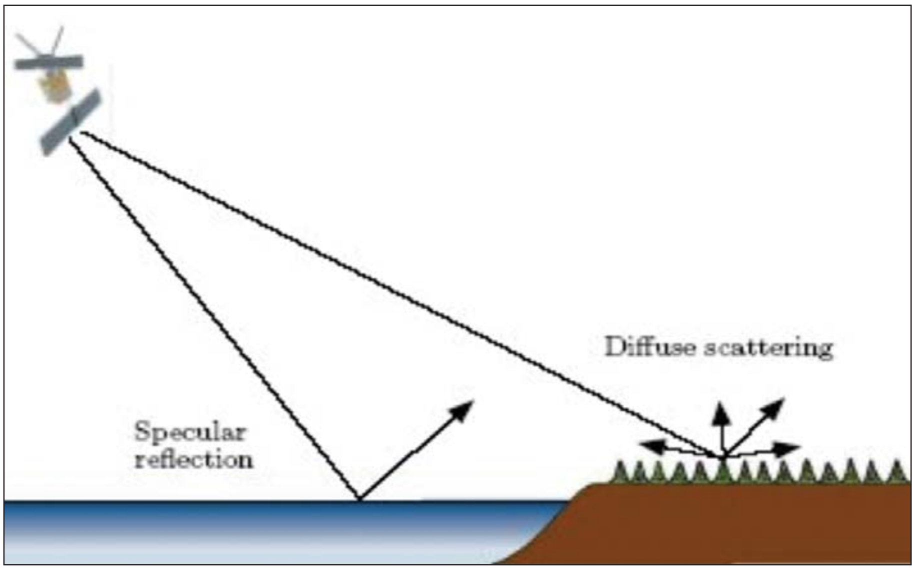

Figure 12.11: Scattering mechanisms of water bodies and dry land (source: Stian and Inger,2004)

The backscatter depends on the frequency, incidence angle, polarization and is sensitive to the ripples on the water surface induced by wind waves. Thresholding is the traditional method of detecting flooding in open areas. Intensities below the threshold are regarded as flood or open water, whereas pixels with intensities above the threshold are regarded as dry land. The threshold will depend on the contrast between the land and water classes, and generally needs to be set for each SAR scene.

Example:

We observe that for the 45º incidence angle case the water and land modes are easily separable with the proposed threshold, whereas the proposed threshold at 23º incidence angle introduce classification errors (Figure 12.12). This is because the contrast decreases with decreasing incidence angle, and the two modes of the histogram merge together (Stain and Inger, 2004).

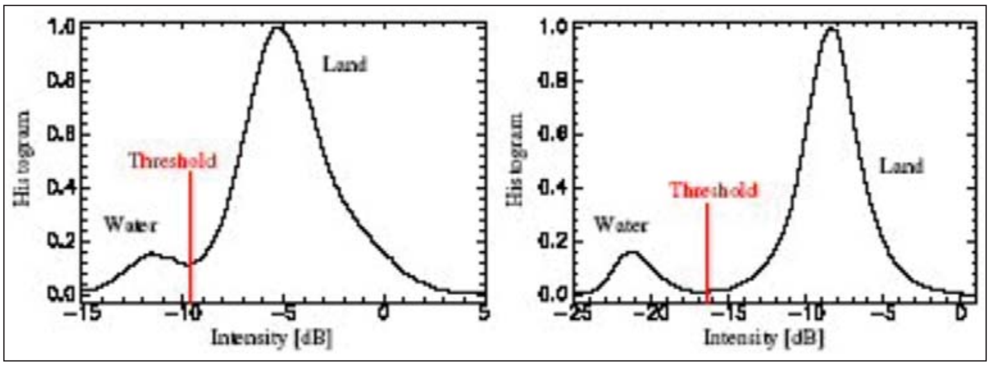

Figure 12.12: Histograms of two SAR images covering same area with different incidence angles (Left: 23^0 & Right: 45^0), (source: Stian and Inger,2004)

12.2.3.3. Methodology

Before the onset of flood season, pre-flood satellite data over flood prone states are acquired and analysed. River banklines, permanent water bodies and active river channel are extracted using digitization tools. These datasets and layers will be used as master data sets for further analysis.

Such pre-flood master layers are prepared every year for all the flood prone rivers in the country. The procedure is shown diagrammatically in Figures 12.13 and 14 for analysis of optical and microwave data respectively. The satellite data acquired during floods is geocoded with the respective master data sets. In case of optical data, supervised classification is performed using the infra red band by providing about 10 training classes in water at

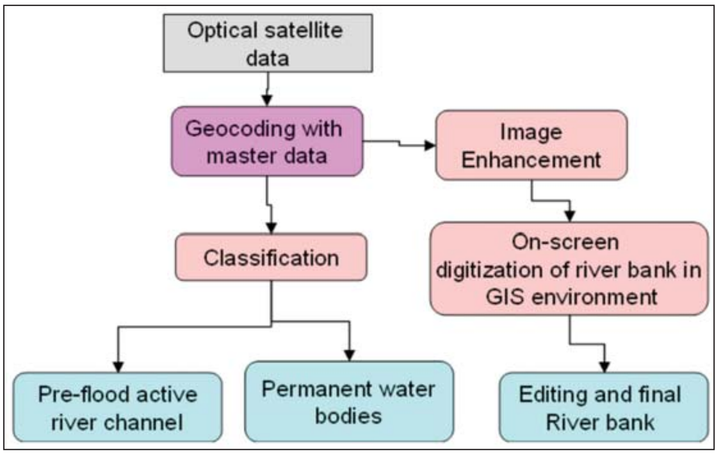

Figure 12.13: Flow chart for pre-flood analysis of optical data

different pockets. A cloud mask and a cloud shadow mask are also prepared. Since signature of cloud edges mixes with the water signature, a model was developed to classify water and cloud using different spectral bands for AWiFS data. Figure 12.15 shows the steps involved in the analysis of satellite data.

In case of SAR data, sigma nought is generated and using variable threshold model, water is classified (Srinivasulu *et al.*, 2005). Post editing tools are applied and final flood layer is prepared. The flood inundation layer is prepared by integrating the water layer with the pre-flood active river channel, permanent water bodies and river bank. The flood inundation layer is prepared in 2-bit consisting of the pre-flood river bank, permanent water bodies, active river channel as one theme and flood layer as the second theme. A single-bit flood inundation layer is also generated for estimation of damage statistics. The final flood inundation layer is converted from raster to vector format for composition of a flood map and generation of damage statistics.

12.2.4. Flood Inundation Products

The satellite data analysis and extraction of flood inundation layer is carried out using imaging software package and flood products are generated in ARCINFO environment using ARC GIS software.

12.2.4.1. Flood Maps

A database consisting of base layers like administrative boundaries (state, district, taluk, mandal), roads, railways and settlements, airport locations, district headquarters, villages, landuse/landcover are prepared for each state. Flood map templates are created at 1: 1 Million, 1:500,000 1:250,000 and 1:50,000 scale using the above layers. From the satellite data, pre-flood river bank and permanent water bodies layers are prepared before the onset of the flood season, as discussed earlier. During flood season, the flood inundation layer which is generated after the analysis of satellite data, is also stored and updated in the database. Table 12.5 shows the database layers used for generation of flood inundation information. Using flood templates and the inundation layer, flood maps are composed at state / district level and for selected areas at detailed level.

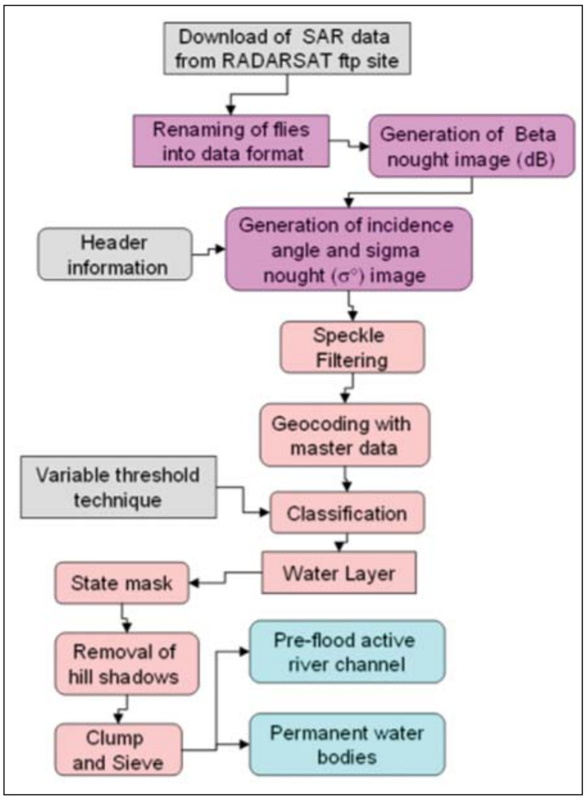

Figure 12.14: Flow chart for pre-flood analysis of microwave SAR data

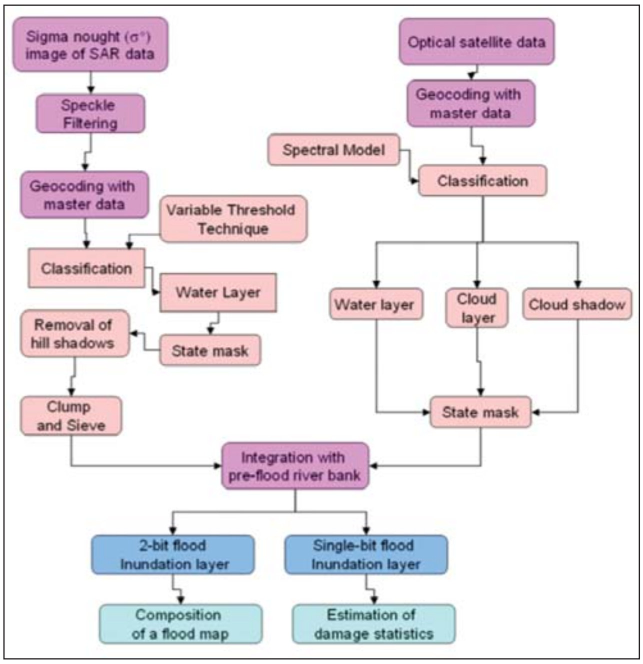

Figure 12.15: Methodology for analysis of satellite data during floods

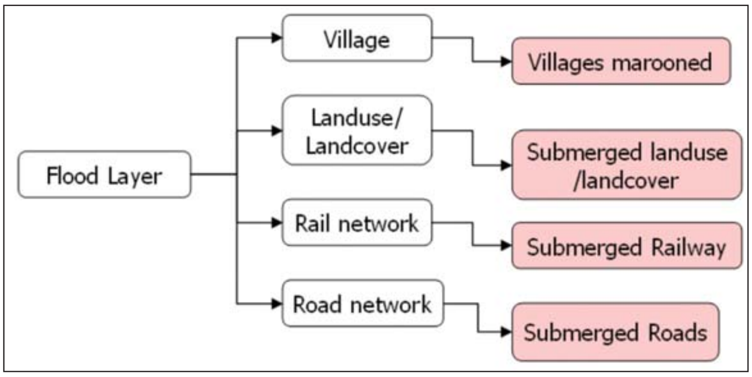

Figure 12.16: Generation of damage statistics

12.2.4.2. Flood Damage Assessment

The flood inundation layer is intersected with the district layer and district-wise flood inundation area statistics are generated. Similarly, for detailed damage assessment, the flood layer is intersected with village boundaries; transport network; landuse/ landcover; and damage statistics such as villages marooned, length of road and rail network submerged are estimated. Figure 12.16 illustrates the steps diagrammatically.

A detailed flood report is prepared describing the flood situation, the actions taken, the observations made from the analysis and the flood damage statistics.

The flood products are disseminated to the concerned user departments by digital means through e-mail system as well as by surface mail.

For effective and fast dissemination of the flood products and to reduce the turn-around-time, the control room at Decision Support Centre (DSC) is equipped with an extended C-band network through EDUSAT satellite linkage. It is connected to 9 primary user nodes (NRSC, PMO, CWC, IMD, SAC, NEOC, knowledge institutes, etc.) with the central hub at New Delhi. Through this VPN network, all the flood products in pdf format are transferred to the data computer system at the user end.

Table 12.5: Database layers

S.No	Layers
1	**Administrative boundaries** – International – State – District – Taluk/Mandal/Block – Village Road – National Highway – Major Roads – State Highway – District Road – Village Road – Other Roads Railway Settlements Landuse/Landcover – Kharif crop – Double crop
2	**Pre-flood/water bodies**
3	Flood Inundation layer
4	Cloud cover

12.3. Case Study – 2006 Floods in Bihar, India

Bihar, the land-locked central Indian state that lies in the Gangetic basin, accounts for 16.5% of the flood-prone area and 22.1% of the flood-affected population in India. Out of 94.16 Lakh ha of geographical area, 68.80 Lakh ha is flood prone and 30 out of 37 districts of Bihar are flood-prone. According to statistics, the flood-prone area of Bihar has nearly tripled from 2.5 million hectares in 1954 to 6.8 million hectares in 1994.

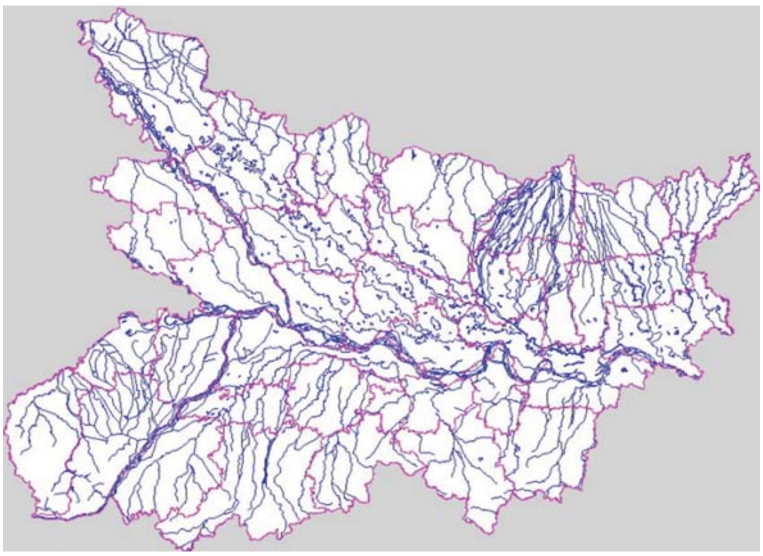

Figure 12.17: River stream network in Bihar

The rivers that regularly inundate the plains are the Ganga, Kosi, Gandak and Son. North Bihar plains are drained by an extensive networks of rivers most of which flow into the Ganga and has their part of catchment in the Nepal, Himalaya. These rivers carry high discharges and large quantities of sediments from the slopes of Himalayas and to the depth of the sediments in the lower flatter areas before their confluence with the Ganga causing reduction in channel capacities. South Bihar also experiences floods due to excess discharges in the tributaries of the Ganga like the Sone, the Punpun, the Kiul and the Harohar which accumulate in the lower natural depressions whose drainage depend on the stages prevailing in the Ganga. Figure 12.17 shows drainage networks in Bihar state with Districts boundaries.

During 2006, Bihar reeled under floods during the months of June, July, and September. The water levels of River Ganga, its tributaries, Kosi, Bagmati and few others were above the danger level. Most of the districts in the state were affected due to floods. DSC has monitored the flood extent by analysing 12 satellite data sets and prepared 16 flood maps at different levels. Flood damage statistics were estimated and the information was disseminated to the concerned user departments.

Figure 12.18a shows the IRS-P6 AWiFS pre-flood image of Bihar, Figure 12.18b shows the extracted river bank and water bodies from this image, Figure 12.18c shows the Radarsat image of 28-29 Sep 2006 acquired during floods and Figure 12.18d shows the extracted flood inundation layer from Radarsat image.

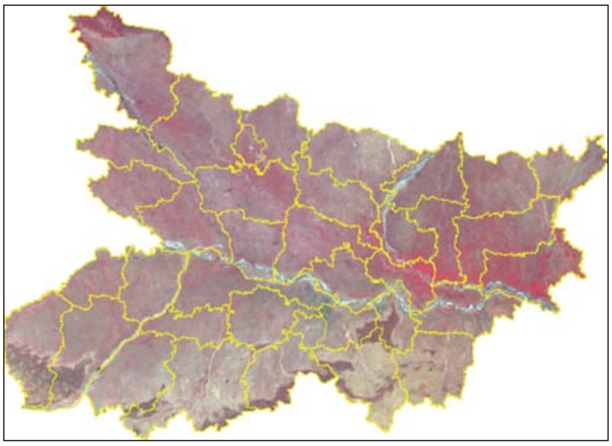

Figure 12.18a: Pre-flood AWiFS image of Bihar state

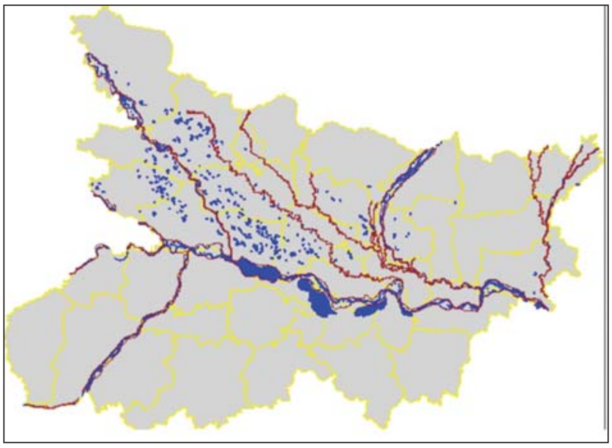

Figure 12.18b: River bank and permanent water bodies

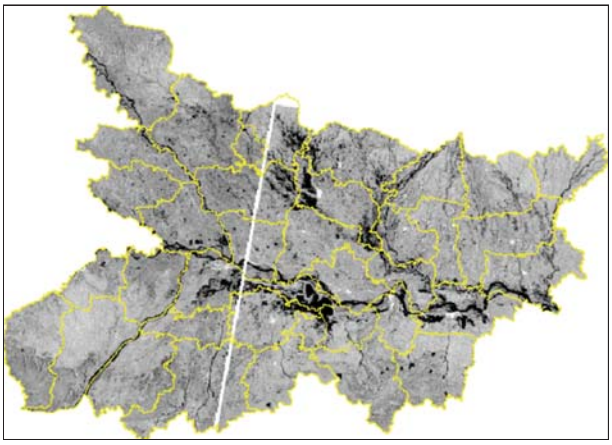

Figure 12.18c: Combined Radarsat image of 28 & 29 Sep., 2006 acquired during flooding

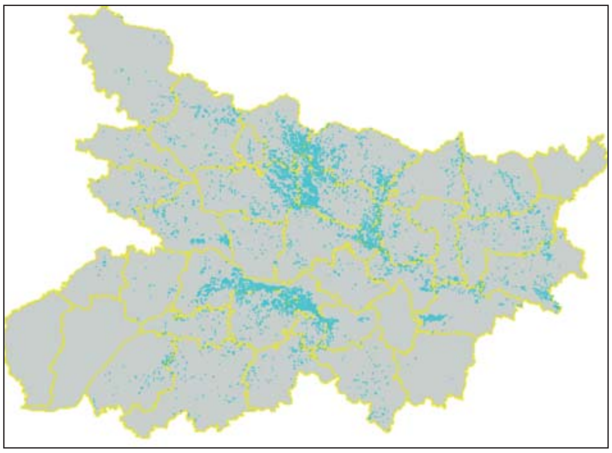

Figure 12.18d: Extracted single-bit flood inundation layer from 28 & 29 Sep., 2006 image

The flood layer of 28th and 29th September 2006 were combined and the map was prepared for the entire state.

Figure 12.19 shows the flood map at state level showing the spatial flood extent in each district overlaid with transport network and pre-flood water bodies layer.

Figure 12.20 shows a district flood map for Nalanda district in Bihar based on the analysis of Radarsat data of 18-July-2006. This map shows the submerged railway and roads with settlements and taluk boundaries.

Figure 12.21 shows the detailed flood map at 1:50,000 scale for part of Darbhanga district showing the inundated villages in the district, based on the analysis of IRS-LISS-IV MX data of 28-Sep-2006. LISS-IV MX sensor aboard IRS-P6 satellite has a spatial resolution of 5.8 m with a swath of 23 Km is suitable for detailed level flood mapping.

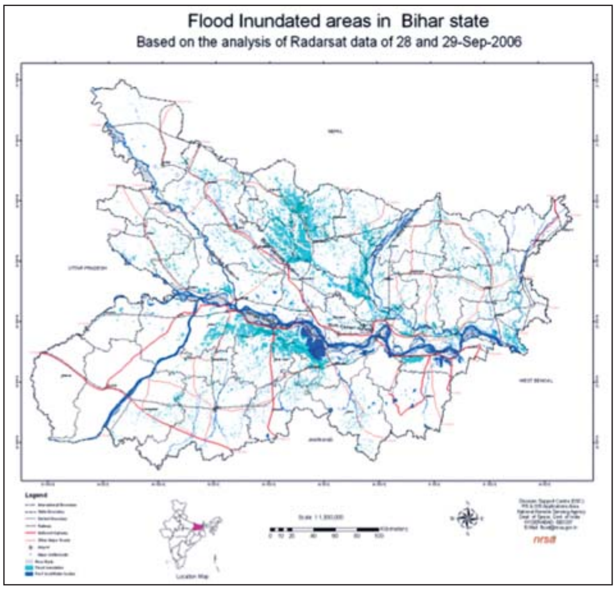

Figure 12.19: Bihar state flood map based on the analysis of Radarsat data of 28 & 29 Sep., 2006

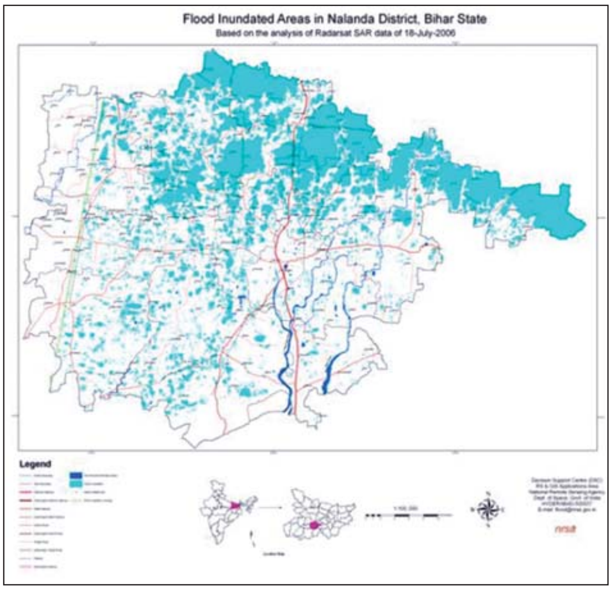

Figure 12.20: A district-wise flood map for Nalanda district based on the analysis of Radarsat data of 18 July., 2006

Figure 12.22 shows the increase in the flooded area in part of Bagmati river basin during June to Oct 2006. This monitoring of floods at regular interval of time was possible through meticulous planning and acquisition of satellite data.

Further, all the flood inundation layers acquired during 2006 were integrated and the maximum extent of flooding observed from these datasets was extracted. During 2006 flood season, about 11, 28,902 hectares of area was inundated in Bihar. Figure 12.23 shows the maximum flood inundation in Bihar during 2006.

12.4. River Configuration and Bank Erosion Aspects in Flood Control Planning

Most of the flood prone rivers in India change their course frequently after every flood wave attacking strategic locations at different times. During floods, bank erosion takes place due to high inflows, excessive sediment charge and channel shift of the river on either side of the river banks takes place. As the discharge of the stream increases, the depth and the mean velocity increases, due to which river banks are subjected to greater erosive action. An increase in the discharge increases high stream power of the flow and would cause more bank erosion. As the severity and effect of hydraulic forces increase manifold during the flood, the rate of erosion increases rapidly. Further physical modelling studies for river flood control planning to study river behaviour needs latest accurate information on river configuration. Hence, it is necessary to understand the behaviour of the river and its latest configuration so as to plan the flood control measures effectively. At the same

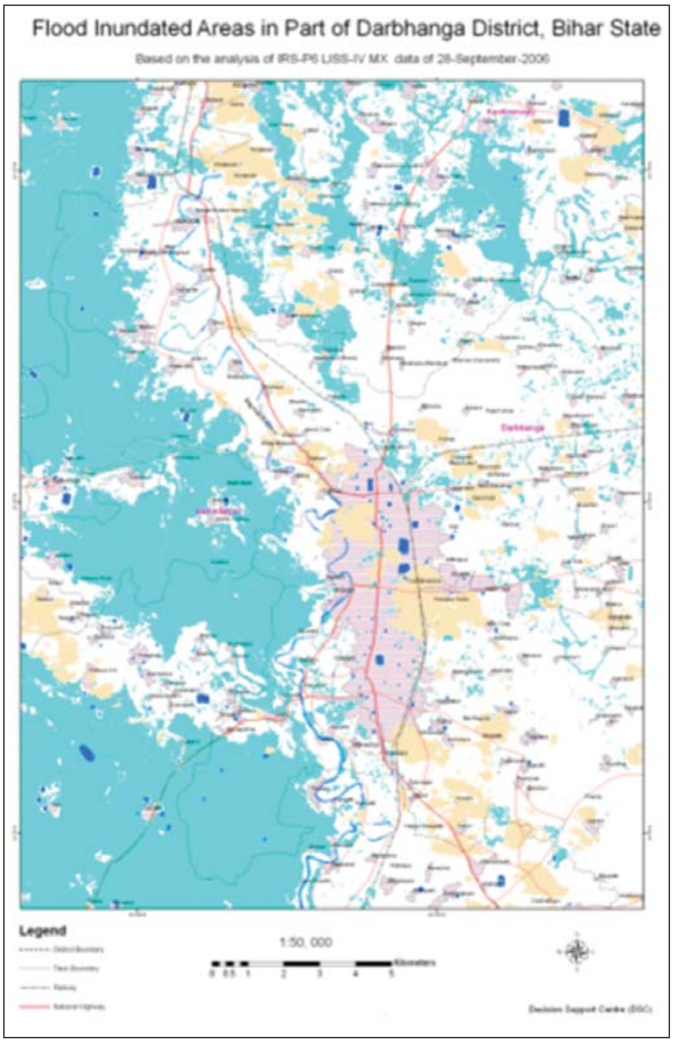

Figure 12.21: Detailed flood map showing the inundation in and around Darbhanga town in Bihar based on the analysis of IRS-P6 LISS-IV MX data

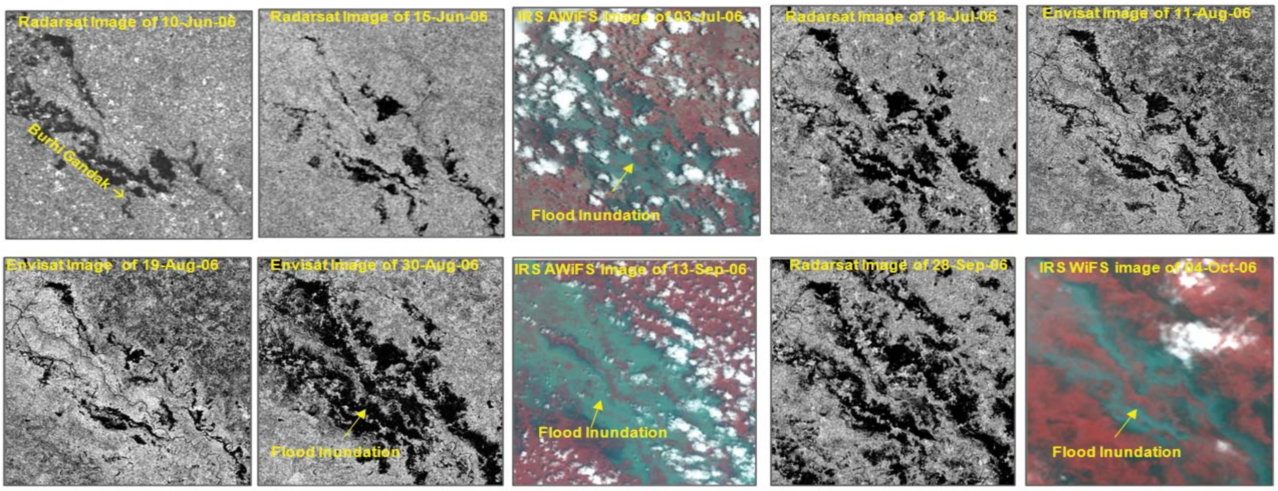

Figure 12.22: Continuous monitoring from June to Oct., 2006

time it is equally important to monitor the existing flood control structures from time to time to avoid breaches in view of the frequent changes in river configuration.

For flood mitigation, major thrust was given for structural measures such as construction of embankments mostly in Assam, Bihar, UP & West Bengal in India. Other measures like channel improvements, raising villages, selective dredging etc., have been tried at some locations. Though embankments have controlled the flood to some extent, but they have inadvertently added severe problems like drainage congestion in the countryside. Greater threat to the people was created in cases of failures of embankments. The building up of the riverbeds because of the high silt content which deposits down is another problem that has been faced. Anti erosion measures that are needed to protect the embankments in vulnerable reaches are found to be very costly and often required more than the original outlay on the embankments they seek to protect. Therefore flood risk zone mapping was found to be one of the non-structured measures.

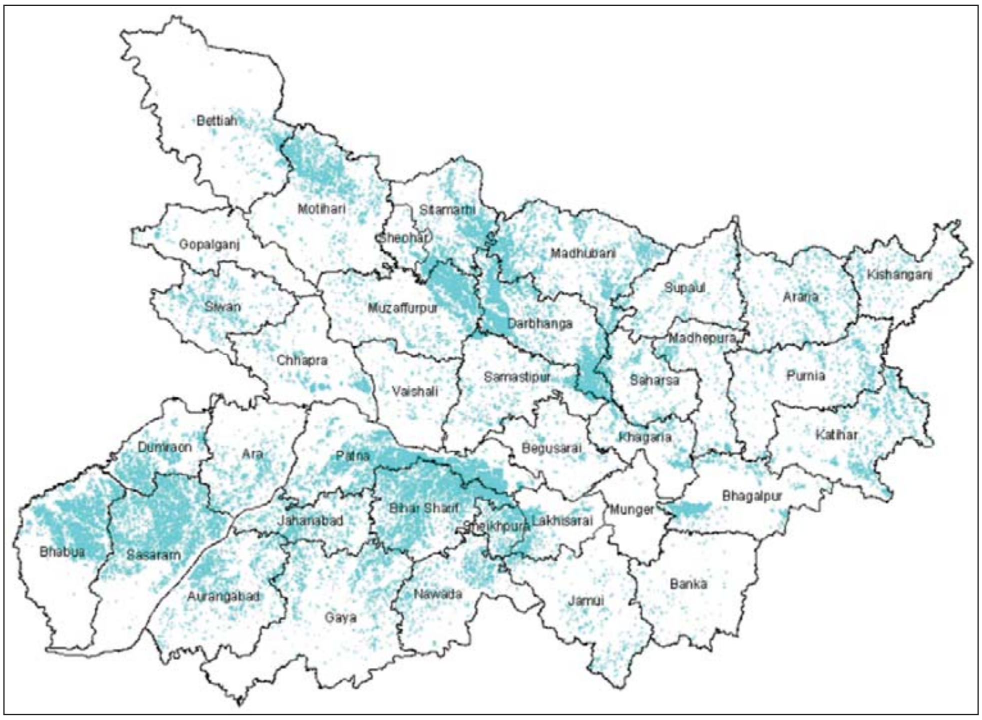

Figure 12.23: Maximum flood inundation map for Bihar during 2006

12.4.1. Potential use of Satellite Data

Conventional method for river configuration mapping is time consuming and expensive. In the recent years, Satellite Remote Sensing Technology has successfully proven itself as a valuable information generator for various river engineering studies. The potential of remote sensing data is that it is highly reliable, accurate and cost effective. Using LISS-III/IVMX and CARTOSAT -1 & 2 PAN data of Indian Remote Sensing (IRS) satellites, the latest river configuration, shift in the river courses, formation of new channels/oxbow lakes, bank erosion/deposition, drainage-congested areas, etc. can be mapped at different scales. Since accurate river configuration is obtained, it can be