CHAPTER 7
Discussion and Conclusion

Drainage basin provides an ideal unit of the landscape to understand the landform evolution in humid environment through information of tectonics and surface geomorphic processes. In areas of active tectonism drainage development provide the much needed change to the evolving tectonic processes. However, the control of climate on the landform development in such an environment of tectonism also need to be taken into account and often decoupling of these two variables viz., climate and tectonics became very important for meaningful geomorphic model. Signatures of tectonism and climate proxies are embedded in different components of a drainage basin. As such geomorphological study through a drainage basin approach in areas of active tectonism is expected to contribute significantly towards understanding the intricate relationship between landform evolution and climate and/or tectonics.

The Jia Bharali is a major north bank tributary of the Brahmaputra with its catchment spread into Eastern Himalaya and Brahmaputra plain covering ~11280 sq km (91°55'E - 93°25'E and 26°35'N - 28°00'N). Apart from the Sonitpur district in central Assam, East and West Kameng, Tawang districts of Arunachal Pradesh, the basin also covers small part of Bhutan in the west and China in the north. It has a very high ratio of upland source area to plains area with ~ 11% of the catchment developed within the Brahmaputra alluvial plain. Within the upland source area the precursor stream of Jia Bharali is known as Kameng which originates from Higher Himalaya and drains through the Dafla hills in Lesser Himalaya before debouching into the Brahmaputra plains south of Bhalukpong, downstream of which it takes the name Jia Bharali. The present Jia Bharali river within the alluvial segment is a highly braided, bedload channel with high width/depth ratio and restricted floodplain mostly covered by the channel system itself. It debouches into the Brahmaputra east of Tezpur town after flowing for about 38 km taking a nearly straight course downstream of Potasali. The basin area is influenced by south west monsoon that brings in substantial precipitation.
(2000-4000ml per annum) most of which are experienced in June to September. In general the catchment area shows an increasing rainfall from plains to lesser Himalayan range followed by a declining trend further north of Rupa-Bomdila area. The average discharge, sediment yield and suspended sediment load of Jia Bharali measured at the mountain exit are ~349,487 m$^3$/s, 4721 ton/km$^2$/year and 2013 ha.m respectively. However, both the discharge and sediment load show strong seasonality influenced by the monsoonal rain. Except the plain segments of the Jia Bharali catchment is very sparsely populated and accessibility to most part of the regions severely limited.

In view of the Jia Bharali basin’s trans Himalaya nature, spreading into different tectonic and lithologic domain, the river system provide a unique opportunity to study the evolution of fluvial landscape in a Himalayan domain and a foreland basin domain represented by the present day Brahmaputra valley. Perceived active tectonism resulting in weathering and unroofing in the Himalayan upland has resulted in high rate of sediment dispersal along the Jia Bharali river system which is manifested in high rate of aggradation in the alluvial plain. The basin thus provides a mosaic of structurally controlled fluvial landform in the upland Himalayan domain and largely depositional fluvial landform features within the valley segment. The present work is primarily aimed at study of the fluvial landscape within Jia Bharali river catchment and to work out the mutual control of lithology and tectonics on the geomorphic elements. For the purpose, an integrated approach is made through a combination of laboratory analysis of the drainage network vis-à-vis tectonic framework and limited field traverses. A detail geospatial database was generated based on Survey of India topomaps in 1:50000 scale, satellite images (Landsat ETM+, IRS-1D FCC), digital elevation model (DEM: SRTM) and available published works. However, unavailability of topographic maps for the areas adjacent to the international border imposed limitation in covering the entire catchment area since satellite data of spatial resolution 23.5 and 30m were not adequate to generate the drainage network in 1:50000 scale. As such a few representative 5th order sub basins with all available data and covering different lithotectonic domains were selected for detail analysis. The entire database was brought into same datum and projection system (UTM, WGS84) so that errors can be minimized in spatial analysis. Drainage basin morphometry and indices of active tectonics were used to establish the relation between drainage
development vis-à-vis., tectonics. The results are produced in the form of tables and various bivariate plots. Data capture and analysis was carried out in GIS environment using ArcGIS 9.1 while a handheld GPS (eTrex Garmin Vista) with ~5-10m spatial resolution was used for field documentation.

Geologically the Jia Bharali basin is characterized by a wide spectrum of lithostratigraphic units ranging from Quaternary Alluvium in the south to Precambrian crystallines in the north. The alluvial segment of the basin is occupied by Quaternary sediments composed of gravel, sand, silt and clay and found in the form of different terrace levels. The Quaternary sequence is more than 1000m thick within Brahmaputra valley and they bear signatures of Quaternary tectonics and/or climatic fluctuations resulting in various phases of river rejuvenation. The Neogene clastics, juxtaposed with the Quaternary Alluvium across the Himalayan Frontal Thrust (HFT) are considered equivalent of the Siwaliks, and divided into Kimin, Subansiri, and Dafla Formation. While the Kimin is predominantly a conglomerate-sandstone association, the Subansiri and Dafla represent a predominantly fluviatile deposit of sandstone, shale and clay. Further north sandstone, shale and thin coal beds of Gondwana affinity are found exposed along a narrow zone following the Arunachal Himalayan trend. Good Gondwana exposures are found in and around Sessa (92°31’52.3”E 27°06’16.2”N) where the sequence is characterized by thick sandstone beds alternating with thin shale beds and intervening coal seams. The coal bear imprints of various flora of Gondwana affinity. Gondwana is further divide into Bhareli Formation, Bichom Formation, Miri Formation. Northward towards Bomdila and beyond metamorphic rocks with general increase in grade and composed of mainly phylite, quartzite, schist and gneisses, and intruded granite are encountered. These metamorphics are variously grouped under different lithostratigraphic names viz., Bomdila Group, Dirang Formation and Sela Group. The Bomdila Group is further subdivided in to four division viz., Khetabari, Tenga, Chilliepam (Dedza) Formations, and Bomdila/Ziro/Daporijo Gneiss whereas the Sela group is divided into two distinct formations on the basis of lithology and their metamorphic grade, viz., the Taliha Formation and the Galensiniak Formation. Late phase granitic intrusive are also recorded from within the Bomdila Group. The Dirang Formation lies unconformably over the Bomdila Group and truncated towards north by the MCT beyond which the Sela Group outcrops till the northernmost boundary of the basin. In
general rocks in the upland terrain show a regional trend of E-W to ENE-WSW in conformity with the eastern Himalayan trend. Three major structural and tectonic elements viz., HFT (Himalayan Frontal Thrust) separates the Siwalik from the alluvial plain of Brahmaputra, MBT (Main Boundary Thrust), separates the Siwalik rocks from the Lesser Himalayan rocks and MCT (Main Central Thrust) separates the Lesser Himalayan rocks from the higher Himalayan crystalline rocks are encountered from south to north. Apart from these prominent structural lineaments, a number of transverse structures are also found to affect the catchment area.

Broadly the Jia Bharali catchment can be classified into three distinct geomorphic domains viz., the dissected hills in the Arunachal Himalaya, and the piedmont plains in the foot hills zone and the alluvial plain (11%, 1191 sq km) north of the Brahmaputra River. Numerous fluvial geomorphic features such as alluvial fan, active channels, abandoned channels, meander scars, static water bodies, sandbars, alluvial terraces, active floodplain etc. are identified within the alluvial plain. A number of Precambrian inselbergs (90-140m amsl) interspersed with narrow valley fills are found dotting the alluvial terrain in and around Tezpur town and adjacent to the Brahmaputra river. Fluvial terraces occupying different topographic levels are ubiquitous features in the alluvial plain showing signatures of various phases of river rejuvenation in the area. These terraces are in general characterised by higher degree of dissection, induration and oxidation in comparison to the present day floodplain deposits. Fluvial terraces are also developed around Bhalukpong due to incision of the Kameng river. Within the alluvial domain spatio temporal variation (1979 - 2004) of the Jia Bharali river shows that it is subjected to frequent changes of course between Bhalukpong and Tezpur. The Bor Dikrai, a eastern tributary of Jia Bharali with its confluence near Silonighat, shows consistent northward shift while around this area the Jia Bharali shows a trend of consistent westward shift. Increase in braiding index from 2.3 in 1979 to 5.8 in 2004 suggests increasing sediment load in the trunk channel. During this period on the other hand, the Brahmaputra followed a consistent southward migration. It is perceived that subtle vertical tectonics has been responsible for many phases of incision and river rejuvenation in the alluvial terrane as suggested by the changes in planform geometry and spatio temporal variability of the present river regime.
Topographic analysis based on Digital Elevation Model (DEM) shows that ~83% of the total basin areas are above 500 m amsl. In general the topographic gradient is towards south, merging into the Brahmaputra plain. However, differential erosion has resulted in local topographic gradient which are followed by the tributary drainage networks. A pronounced break in slope is observed where there is juxtaposition of the Alluvium and Siwaliks across the HFT. About 60% of the total area shows a slope of >20° while less than 2% area shows slope of >45°. Slope distributions within the structural hills are controlled by the erosional dissections together with structural elements. Differential erosion resulting in higher dissection is found more pronounced in the western part of the basin. It is observed that longitudinal profiles of the major tributaries show development of knick points where the rivers cut across the major structural elements like the MCT, MBT and HFT. The longitudinal profile of Jia Bharali river show an average gradient of ~22 m/km. However, in its upstream course north of the MCT the gradient is ~112 m/km changing to 8.3 m/km between MCT and MBT and 2.1 m/km between MBT and HFT. The alluvial segment shows a substantially lower gradient of ~0.4 m/km.

It is observed that although average drainage frequency for the whole basin is ~3.8 km⁻², there marked differences between drainage development in the alluvial plain (0.7 km⁻²) and in the upland Himalayan domain where the frequency is as high as 4.5 km⁻² north of the MBT. The drainage density also varies accordingly with values ranging from ~1 km⁻¹ within the alluvial domain to ~3 km⁻¹ north of MBT. The drainage north of MBT have comparatively higher mean bifurcation ratio of ~4.8. Further, the sub basins in the north of MBT and western part of Jia Bharali basin also have higher bifurcation ratio with mean value of 3.1-5.2. The bivariate plot of stream order against bifurcation ratio reflects that the basins within Himalayan terrain have a rugged topography. Bivariate analysis of stream order against stream number and total stream length in general show negative correlation while stream order versus mean stream length shows positive correlation. Exceptions to these trend of mean stream length variation is observed in case of 10 sub basins (basin index 2, 4, 12, 13, 16, 18, 24, 29 33, 35). These sub basins with variable lithology, show high relative uplift value (0.6-0.9) together with basin asymmetry. The sub basins around and north of MBT (12, 13, 16, 18, 24, 29, 33, 35) shows high circularity ratio (0.6-0.7) and high hypsometric integral value (0.5-0.6). It is observed that the sub basins in central part
of Jia Bharali catchment are comparatively more circular than those of alluvial and piedmont zone. The relief ratio, computed for the fifth-order drainage basins, varies between <0.1 to 0.3. Sub basins within alluvial terrain show low relief ratio (0.002-0.012) whereas the basins of hilly part shows high relief ratio (0.04-0.28). However, higher relief ratio is found in the western part of Kameng river than the eastern part. The moderate to high value of ruggedness number (2.7-10.3) indicate more steepness in the basins of within Himalayan domain than the alluvial plain.

Geomorphic indices viz., longitudinal profile, hypsometric integral, stream-length gradient index (SL Index), basin asymmetry etc. were studied to assess the influence of active tectonics in the area. Longitudinal profiles of the fifth order basins show development of knick points in different section which are correlatable with the major structural elements. Around the MBT and north of MBT, sub basins show convex upward nature with high average gradient index (367 to 1179). The SL index values for each of the basins are also highly variable from source to mouth. The high relative tectonic uplift value (0.6 -0.9) of the sub basins around the MCT, MBT, HFT further suggest active deformation along these major tectonic elements. While the basins of western part of Kameng and north and around MBT shows consistently high value (0.7-0.9) of relative upliftment. The basin asymmetry factor is found to range between 19.1 and 79.6 and it is perceived that around MBT and south of MCT the sub basins are more tilted. The tilting of the sub basins in the west of Kameng and between MBT and MCT shows a radially outward pattern suggesting centralized uplift in the area while the basins in the eastern side (having index 16, 17, 18, 19) show a relative tilting towards north and east. The Jia Bharali basin as a whole has a basin asymmetry factor of 66.3. These observations suggest a possible eastward tilt of the catchment area. The hypsometric integral values for all basins are in the range from 0.1 to 0.6. In the north of MBT the basins with high integral value represents deep incision in the basins as well as a younger stage of evolution. Comparatively the sub basins in western part of Kameng has high hypsometric integral (0.5-0.6) than the eastern part (0.4-0.5), suggesting differential rate of incision.

The present study brings out the geomorphic setup of the Jia Bharali river catchment and distribution of various geomorphic elements within different lithotectonic domains. Drainage development in the area has been studied in terms of the
morphometric parameters and the relation between the lithotectonic setup vis-à-vis drainage characteristics of selected sub basins have been worked out through computation of geomorphic indices. River profile analysis, stream offsets along major structural lineaments and transverse structures, evidence of incision and strath terrace development, conformable trend of both major lineaments and drainage etc. suggest significant structural control on the drainage development in the study area while lithology seems to be the controlling factor in drainage development within the alluvial segment. The geomorphic indices of active tectonics viz., hypsometric integral, relief ratio, relative uplift value, drainage basin asymmetry and differential incision in west and eastern part of the basin suggests a plausible scenario of comparatively higher deformation and rapid upliftment in the western part of Kameng river and north of MBT. Analysis of tilt direction of the selected sub basins further indicates a zone of uplift around Nafra, between the MBT and MCT. As such this study contributes towards a meaningful interpretation of drainage behaviour vis-à-vis the NE Himalayan Evolution. The perceived differential tectonic activity as reflected in the river regime however needs to be further corroborated through detail structural data.