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SOME HYDROLOGICAL ASPECTS OF BRAHMAPUTRA RIVER

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PREFACE

The Brahmaputra river in north-eastern states of India is characterised by high seasonal variability in flow, sediment transport and channel configuration. Information of some hydrological aspects of river Brahmaputra is important for hydrologist and field Engineers involved in the various hydrological studies dealing with the flood problem of Assam.

The Brahmaputra is one of the most sediment charged large rivers of the world. Among the largest rivers of the world, it is second only to the yellow river in China in the amount of sediment transported per unit of drainage area. Sedimentation is also an important factor for producing flood in the Brahmaputra valley.

The report on 'some hydrological aspects of Brahmaputra river' provides some informations about flood producing storms & rainfall, river stage, river discharge and sediment discharge of the Brahmaputra.

The scientific teams of north-eastern regional centre of NIH in Guwahati undertook visits to central and state Govt. offices for collecting the required data, maps etc.

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(SATISH CHANDRA)

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ABSTRACT

The Brahmaputra river in north-eastern states of India is characterised by high seasonal variability in flow, sediment transport and channel configuration. Information of such hydrological aspects of river Brahmaputra is of much interest for hydrologist and field engineers involved in the various hydrological studies dealing with the flood problem of Assam.

In this technical note some hydrological aspects of the river Brahmaputra, like flood producing storms & rainfall, river stage, river discharge and sediment discharge have been reviewed with the analysed data obtained from various sources.

1.0 INTRDOUCTION

The Brahmaputra river in north-eastern India is a severe flood prone river. The catchment of the river covers the major parts of north eastern states of India. The river produces major floods in Assam and the river is characterised by high seasonal variability in flow, sediment transport and channel configuration. This report focuses on the Brahmaputra river system in Assam, India with limited references to the adjoining highlands of conterminous India and those of China and Bhutan.

1.1 Physiography of Brahmaputra Valley

The catchment of the Brahmaputra occupies an area of 580,000 sq.km. The break up of the catchment area is as 293000 sq.km. in Tibet (China), 240000 sq.km. in India & Bhutan and 47000 sq.km. in Bangladesh. The Brahamputra valley in Assam is surrounded by an almost continuous chain of high hills and plateaus on the north, east, and south and represents a tectno-sedimentary province 720 km. long and 80-90 km. wide, with elevations ranging from 120 m at Kobo in the extreme east through 50.5 m at Guwahati to 28.45 m at Dhubri in the extreme west (Fig. 1) . The channel of the river itself, with an average width of 8 km, occupies about one tenth of the valley. With over 40% of its area under cultivation, the Brahmaputra valley in Assam is the home of more than 15 million people.

1.1.1 Geology of the eastern Himalayas and the Brahmaputra basin

The Himalayan watershed of the Brahmaputra comprises four topographic units that rise progressively to the north (Fig. 2).

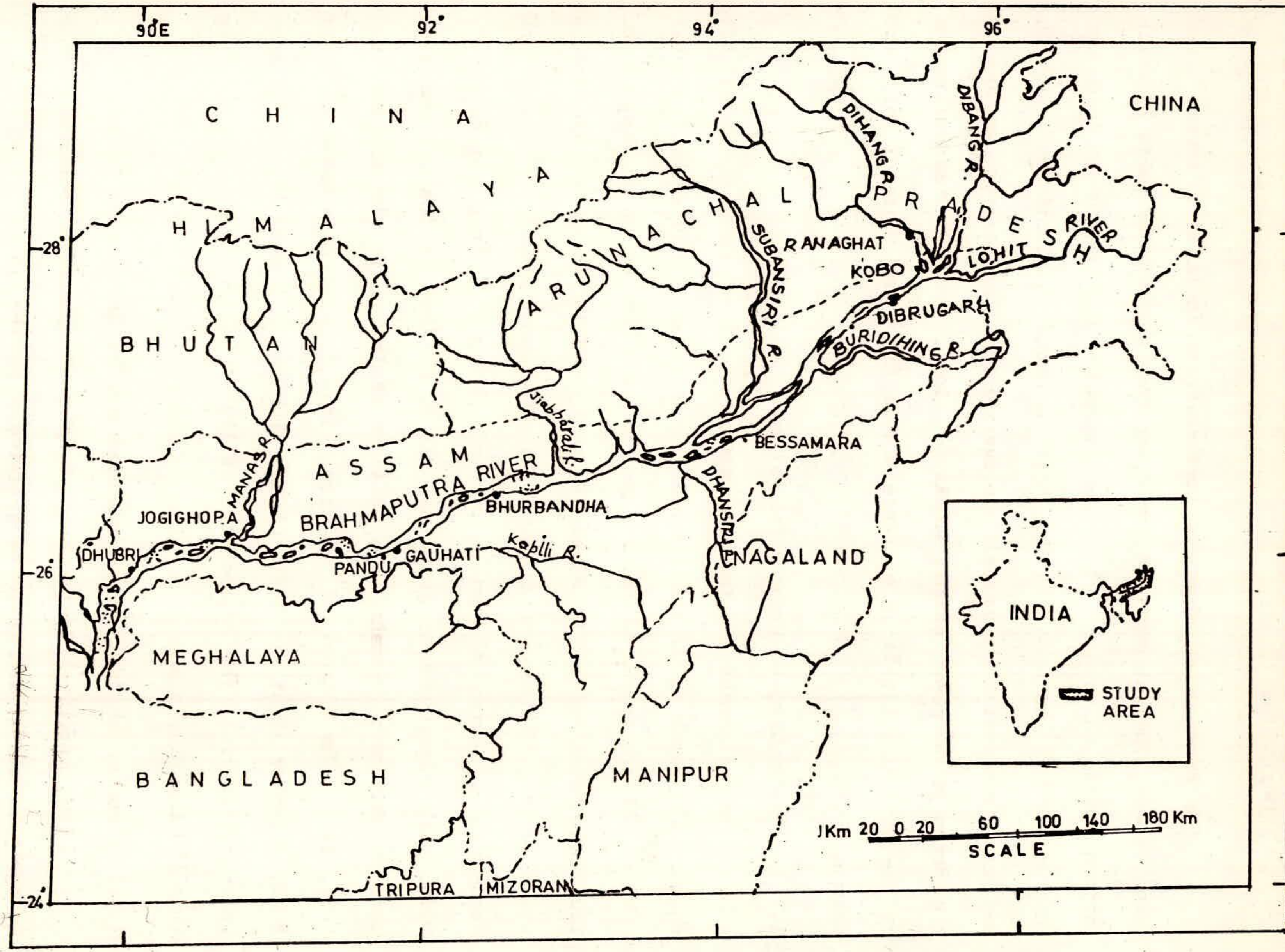

FIG. 1 BRAHMAPUTRA RIVER SYSTEM, ASSAM, INDIA

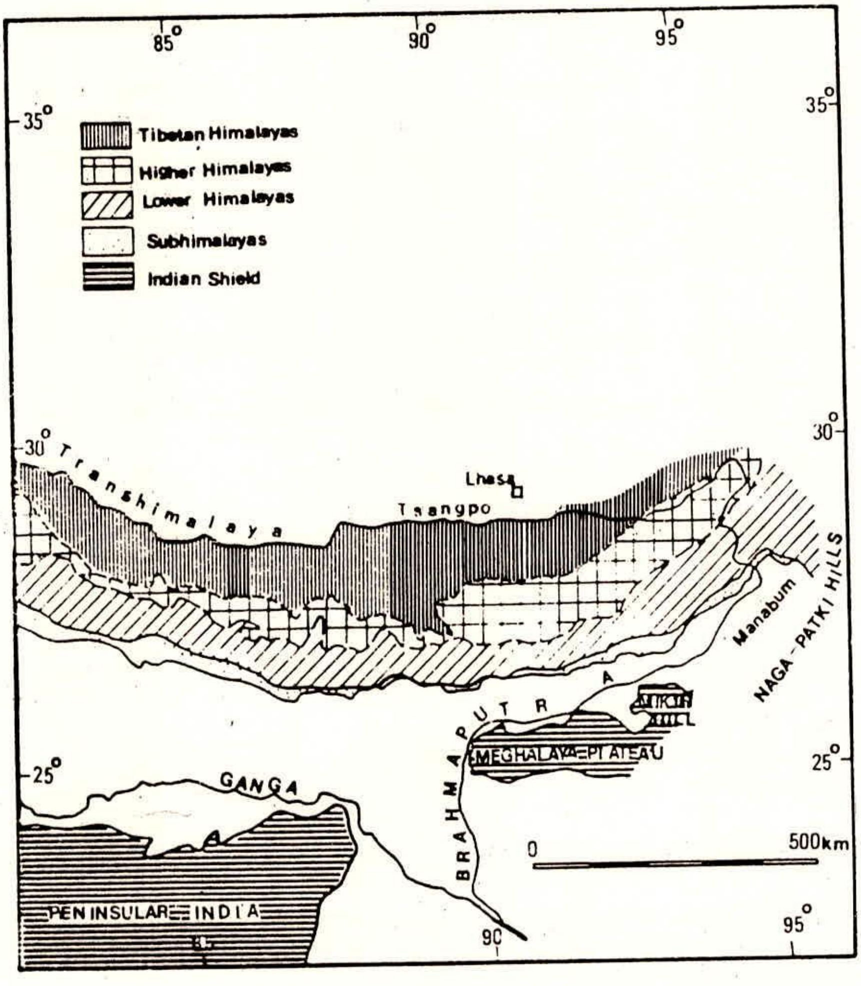

Fig. 2. Geology of the Eastern Himalayas and the Brahmaputra Basin.

The lowermost ranges called sub-Himalayas (average elevation 1000 m) consist mainly of tertiary sand-stones and are conspicuous by the presence of many raised relatively young terraces (Ref.No.6). The middle Himalayas (average elevation 4000 m) are underlain by lower Gondwana (Palaeozoic) deposits comprising shales, slates, and phyllites overlain by a thick horizon of basaltic rocks. The Greater Himalayas (average elevation 6000 m) consist primarily of granites and gneisses. Further to the north the Trans-Himalayas of Tibet (average elevation 4500 m) are made up of sedimentary formations of palaeozoic to Eocene age (Ref.No.13).

The Patkai-naga ranges bordering the Brahmaputra valley on the east and south east (average elevation 1000 m) consist of tertiary formations criss crossed by a large number of active faults. The highland to the south of the valley, comprising the Meghalaya plateau and Mikir hills (elevation 600-1800 m) made up primarily of gneisses and schists, forms a part of the stable Indian peninsular block of precambrian age.

The Brahmaputra valley in Assam is underlain by recent alluvium approximately 200-300 m thick, consisting of clay, silt, sand, and pebbles (Ref. No.7). Its present configuration evolved during 2 million years of pleistocene and recent time (Ref.Nos.9 and 11).

1.1.2 Course and morphology of the Brahmaputra river

The Brahamputra river originates in a great glacier mass in the Kailas range of the Himalayas south of lake Gunkyud in south-west Tibet (elevation 5300 m) and flows through China, India, and Bangladesh for a total distance of 2880 km before ending into the Bay of Bengal through a joint channel with the Ganga. In Tibet, where it is called Tsangpo, the Brahamputra flows eastward for 1100 km along the bottom of a longitudinal graben parallel to and about 160 km north of the Himalayas (Fig. 3). At the extreme eastern end of its course in Tibet, the Tsangpo suddently enters a deep narrow gorge at P_e (3500 m) which skirts around the Namcha Borwa peak (7755 m) and continuous southward across the Himalayan ranges. The gradient of the river in the gorge section ranges from about 4.3 to 16.8 m/km. On entering India, the Tsangpo, now called Dihang, traverses 226 km of mountainous course before debouching onto the Assam plain near Pasighat (elevation 155 m). At the exit of the gorge the slope of the river is only 0.27 m/km. Near Kobo, 52 km south of Pasighat, two rivers (Dibang and Lohit) meet the Dibang, and the combined flow, called the Brahmaputra moves westward through Assam for 720 km until near Dhurbi, where it swerves to the south and enters Bangladesh. The Brahmaputra has a gradient of 0.09-0.17 m/km near Dibrugarh at the head of the valley and is further reduced to about 0.1 m/km near Guwahati.

In Assam the Brahmaputra flows in a highly braided channel characterised by the presence of numerous lateral as well as mid-channel bars and islands (Fig. 4). Braiding indices (Ref.No.5) of the two reaches of the Brahmaputra shown in Fig.4 are 5.3 and 6.7 most of the channel bars in the Brahmaputra are transient in nature, being submerged during summer high flows and changing drastically their geometry and location.

The river Brahmaputra is divided in three parts as upper reach (from its origin to Indo-China boarder), middle reach (from Indo-china boarder to Indo-Bangla boarder) and lower reach (from Indo-Bangla boarder to its outfall in Bay of Bengal).

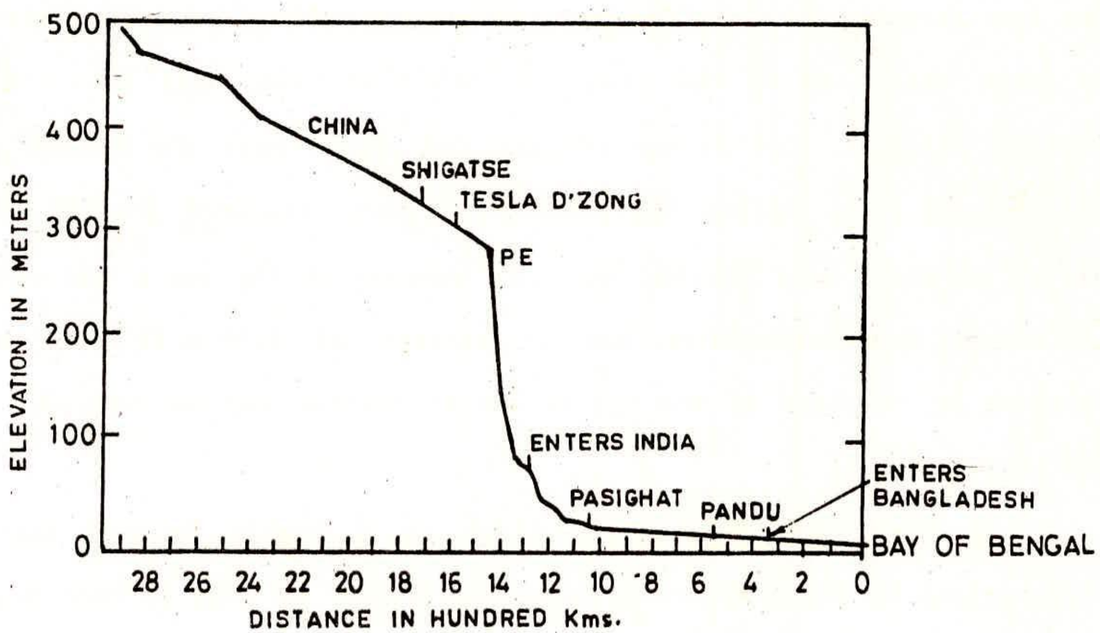

FIG. 3 – LONGITUDINAL BANK PROFILE OF THE BRAHMAPUTRA RIVER

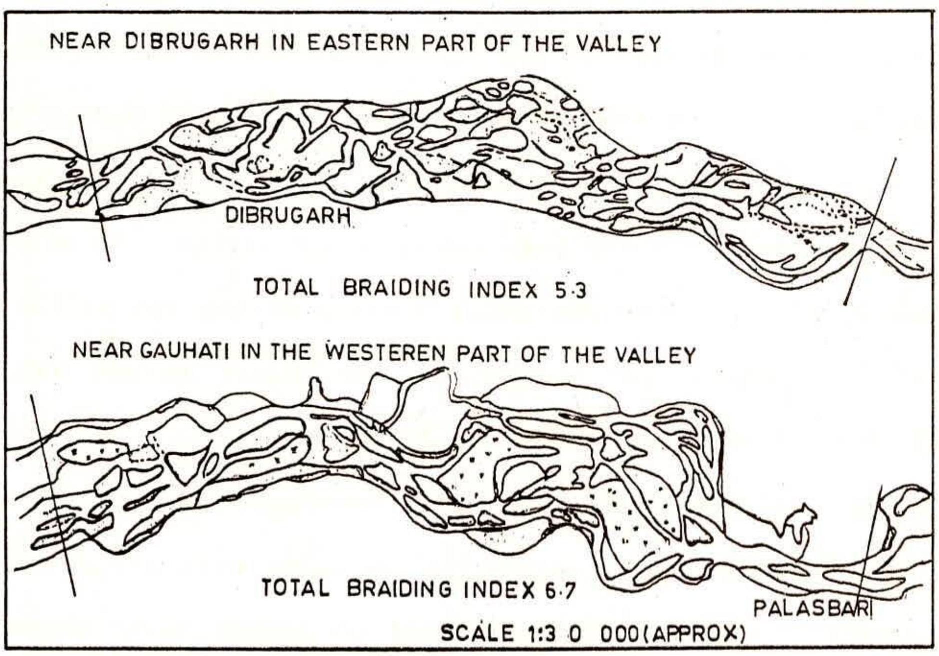

FIG 4 – BRAIDING IN THE BRAHMAPUTRA RIVER ASSAM

1.2 Climate, Vegetation, and Soil of the Brahmaputra Basin

The catchment of the Brahmaputra, excluding the Tibetan portion, forms an integral part of the monsoonal regime of south-east Asia. Rainfall averages 230 cm annually, with a variability of 15-20%. There is a marked spatial variation in the distribution of precipitation over the catchment (Fig. 5). The Himalayan sector receives 500 cm of rainfall per year, the lower ranges receiving more than the higher areas. Monsoonal rains from June to September account for 60-70% of the annual rainfall. The annual average humidity in the plain area of the Brahmaputra valley is 72% ranging from monthly average of 70% in the month of March and 85% in the month of August.

Natural vegetation in the Brahmaputra basin varies with altitude from tropical evergreen and mixed deciduous forests within the valley and foothills, to alpine meadows and steppes in the higher ranges and, in Tibet, about 20% of the Brahmaputra valley is forested.

Soils in the sub-Himalayan region developed on the tertiary sandstones are shallow and consist primarily of sands with admixtures of cobbles and boulders. Alluvial soils, formed on recent river deposits, occur in the Brahmaputra valley. A few isolated pockets of deeply weathered older alluvium occur in upland areas within the valley and in the piedmont region. Borings in the quaternary sediments of the Brahmaputra valley extending down to more than 100 m (Ref.No.8) show repeated sequences of clay, fine sand, coarse sand, coarse sand with cobbles, pebbles, and boulders.

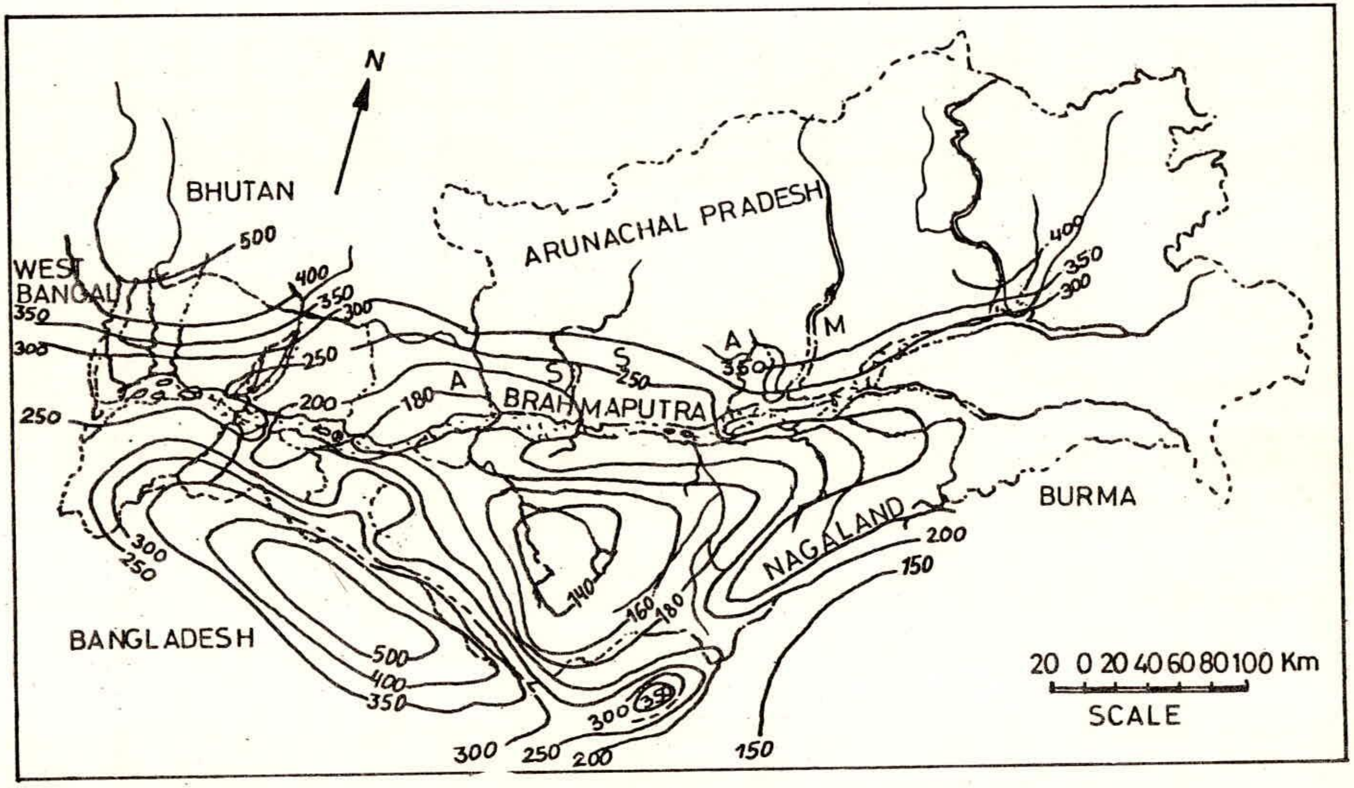

FIG. 5. ISOHYETAL MAP OF BRAHMAPUTRA VALLEY AND ADJOINING HIGH LANDS (Based on Meteorological Department of India data).

2.0 FLOOD PRODUCING STORMS AND RAINFALL IN BRAHMAPUTRA VALLEY

Major floods over the regions of Brahmaputra valley are seen when the major rainfall in the valley takes place during the monsoon season.

2.1 Meteorological situations associated with major floods in the Brahmaputra Catchment in Assam

A study of the meteorological situations associated with major floods in Assam for the period of 1956 to 1963 has been made by experts of IMD (Ref.No.4). Altogether 22 major flood situations have been studies, out of which 10 were due to break monsoon, 6 due to low pressure area, depressions etc. in Bay of Bengal, 3 due to land depressions and 3 due to upper air cyclonic circulations. Break monsoon situations are typical of this regions resulting in exceptionally heavy rainfall. The situation normally occurs when the axis of the seasonal monsoon trough shifts northwards from its normal position and lies close to the foot of the Himalayas with the setting in this situation the easterlies which had a full survey over north India to the north of the axis of the seasonal trough get replaced by the westerlies. This results in marked decrease of the rainfall in the central and northern parts of the country and increase in rainfall activity along the foot hills and sub-mountainous region of the Himalayas. If during a Break period a westerly wave also happens to pass east-wards across Nepal-Assam Himalayas, the Assam hills and plains receive exceptionally heavy rainfall. The study showed that it is mainly during August that floods are caused by the break monsoon conditions. Floods due to moonsoon depressions from the Bay generally occur in the month of June. Floods in September are rather rare and major floods mostly occured in the month of August. Unlike other parts of the country rainfall associated with the monsoon depressions, the month of June itself is sufficieent to cause major floods in this region. This is due to fact that during the premonsoon months of April and May this part receives a fairly good amount of rainfall on account of large scale thunder storms. The saturated ground conditions and bankful river stages help in producing major floods during June.

2.2 Normal annual and seasonal rainfall in Brahmaputra Catchment in Assam

A chart of normal annual and seasonal rainfall in Brahmaputra catchment in Assam, obtained from ref.no.3 is shown in table 1.

Table 1 Normal annual/seasonal rainfall in Brahmaputra Catchment in Assam

	Normal rainfall in cm	
	Period (1901-1950)	Period (1951-1960)
Annual	274.2	264.3
Seasonal (JUne-Sept.)	179.3	152.8
June	62.8	47.70
July	65.0	49.4
August	47.4	40.0
September	41.4	29.0

On the comparison of normal rainfall (annual & seasonal) figures of table 1 for the period 1901-1950 and 1951-60, it is found that the normal (annual & seasonal) rainfall for the period 1901-1950 is more than for the period 1951-1960. From the rainfall figures of monsoon months (June, July, August, September) of both periods (1901-50 & 1951-60),it is also observed that the peak value of monthly rainfall in monsoon season is in the month of July.

2.3 Seasonal rainfall in the Catchments of Dihang, Dibang and Lohit rivers for the years 1958 & 1959

The combined flow of rivers Dihang, Dibang and Lohit forms the Brahmaputra . Actually the name of Brahmaputra in China is Tsangpo but after crossing the Indo-china boarder, the Tsangpo changes its name to Siang-Dihang in Arunachal Pradesh. It traverses the Arunachal Pradesh in a more or less southern direction for 226 km before reaching the Pasighat ending its journey in the mountains. From pasighat Dihang travels another 52 km before joining the Dibang & Lohit, two major tributaries from north-east and east respectively as can be seen from Fig.1.

Informations of seasonal rainfall for the catchments of the rivers Dihang, Dibang and Lohit are important for dealing with the flood studies of the river Brahmaputra. But the seasonal rainfall data for the catchments of Dihang, Dibang & Lohit rivers are available only for the two years 1958 and 1959 which are shown in table 2 below:

Table 2 Seasonal rainfall in the Catchments of Dihang, Dibang & Lohit rivers for the years 1958 & 1959

Catchments	Seasonal rainfall in cm (June to Sept.)	
	1958	1959
Dihang	210.9	142.4
Dibang	173.0	117.0
Lohit	179.8	142.0
Combined Catchment	194.0	135.4

(Source: Ref. No.3)

2.4 Average rainfall for monsoon & non-monsoon periods in different raingauge stations of Dihang Catchment

From avilable raingauge data (Ref.No.3) of the stations of Dihang catchment, the average value of rainfall (monsoon & non-monsoon periods) in the different raingauge stations of the catchment has been shown in table 3. The period of data record for each raingague station is also shown against each station in table 3.

Table 3 Average rainfall (monsoon & non-monsoon periods) in different raingauge stations of Dihang Catchment

Monsoon/ Non-monsoon	Average Rainfall in cm						
	Pasighat 1953-70	Along 1960-70	Kambang 1966-70	Boleng 1969-70	Inkiyong 1968-70	Medhuka 1966-70	Tuting 1966-70
Monsoon (May-Sept.)	421	166	283	223	156	169	275
Non-monsoon	86	59	74	66	98	69	122
Total:	507	225	357	289	254	238	397

(Source: Ref. No.3)

The statement of table 2 shows that the rainfall is heavy at pasighat but to the north of pasighat it reduces as could be seen from average rainfall figures of Along, Boleng and Inkiyong. The rainfall figure of Tuting shows higher, near the international boarder where Dihang enters India, when compared to the stations situated in the middle of the catchment. Medhuka of the north western boarder of the Dihang basin shows low rainfall when compared to pasighat.

3.0 RIVER STAGE OBSERVATIONS AT VARIOUS GAUGING SITES OF RIVER BRAHMAPUTRA

River stages of river Brahmaputra have been observed since 1907-8 at the following sites for the duration noted against each as shown in table no. 4.

Table - 4 River stage observation sites with period of record

Sl.No.	Gauge site	River chainage from Bangladesh Boarder (Km)	Period of record
1	Dibrugarh	580	1907 to 1917 & 1933 onwards
2	Silghat	352	1908 to 1916 & 1955 onwards
3	Tezpur	335	1907 onwards
4	Guwahati	205	1908 onwards
5	Goalpara	95	1908 onwards
6	Dhubri	20	1907 onwards
7	Morkongselek	627	1955 onwards
8	Neamatighat	465	1955 onwards
9	Pandu	198	1955 onwards
10	Jogighopa	85	Sept. 1955 onwards
11	Bessamara	495	June 1955 onwards

(Source: Ref. No.3)

Where Morkongselek, Dibrugarh, Neamatighat, Silghat, Tezpur, Guwahati Pandu, Goalpara, Joghigopa and Dhubri are now permanently the sites for river stage observations.

3.1 Flood Lift

Maximum and average flood lift for the sites Dibrugarh, Neamatighat, Silghat, Tezpur, Guwahati, Pandu, Goalpar a and Dhubri are shown in table 5.

Table 5- Maxm. and average flood lift of river Brahmaputra at various gauging sites for different periods

Site	Maxm. F.L.in meter	Average F.L.in meter	Period
Dibrugarh	6.523	5.681	1909-17
	6.980	5.898	1933-47
	4.668	4.651	1948-50
	4.755	3.655	1951-75
Neamatighat	6.323	5.432	1955-75
Silghat	11.552	9.290	1908-16
	9.040	7.617	1955-75
Tezpur	9.114	8.464	1907-16
	8.772	8.214	1930-34
	8.687	7.721	1939-54
	7.157	5.758	1955-75
Guwahati	9.784	9.330	1908-18
	10.089	9.610	1920-32
	10.851	10.058	1933-42
	10.394	9.906	1943-50
	10.973	9.266	1951-62
	10.333	9.552	1964-73
Pandu	9.178	8.008	1955-75
Goalpara	10.052	9.062	1908-22
	8.169	7.849	1923-42
	9.327	7.961	1954-70
Dhubri	9.190	7.724	1907-27
	6.614	6.227	1933-49
	6.462	5.630	1950-61
	6.599	5.630	1961-75

From the data of maxm. and average flood lift at various gauge site given in table 5, following conclusions can be made.

(a) Gauge levels during the period before the 1950 earthquake, all throughout shows greater flood lift compared with those after 1950.

(b) Flood lift at Guwahati and Goalpara sites shows little variation but for all other sites. the flood lift has reduced after 1950.

(c) The maxm. reduction in the average flood lift is at Dibrugarh, with an approximate reduction of more than 2 m and similarly at Tezpur it is 1.95 m.

(d) The flood lift reduction is more pronounced in the upper reaches from Dibrugarh to Tezpur than in the lower reach.

(e) This reduction of flood lift in the upper reaches has probably resulted in the development of acute erosion problem. On both bank of the river, besides the inundation problem for which continuous embankments had to be constructed subsequently.

(f) The average flood lift on Brahmaputra now varies between a maxm. of 9.55 m at Guwahati to a minimum of 3.65 at Dibrugarh . The average flood lift at Neamatighat, Silghat, Tezpur, Pandu, Goalpara and Dhubri is now 5.43, 7.62, 5.76, 8.07, 7.96, 5.63 metres respectively.

(g) The amount of flood lift at various sites when examined from upstream to downstream is not increasing in a regular manner as should have been the case. The natural features along the river restricting the section of river appears to be responsible for this irregular propagation of flood wave through the wide and narrow reaches all along the valley.

3.2 Variation of high and low water levels

A study on high and low water levels of the Brahmaputra from 1910 to 1965 at different places along the banks of the Brahmaputra was made by CWPRS, Pune (as per informations available in reference no.3) and incorporated in the report of the study group on erosion by Brahmaputra. It was concluded that:-

a. In every places, there is a tendency of increase of H.F.L. & L.W.L. The average rate of increase per year in H.F.L. & L.W.L. during different span of years at different places are given in table 6.

Table 6: Average rate of increase per year in H.F.L.& L.W.L. at different places during different span of years

Place	H.F.L.(in ft.)	L.W.L.(in ft.)	Span of years
Dibrugarh	0.1	0.20	1913 - 1964
		0.084	1920 - 1948
Tezpur	0.025	0.20	1931 - 1964
		0.07	1931 - 1946
Guwahati	0.077	0.1	1908 - 1965
		0.082	1920 - 1952
Dhubri	0.025	0.11	1931 - 1964
		0.085	1931 - 1950

b. There is some cyclic behaviour of such yearly fluctuations in H.F.L. & L.W.L. The extent of amplitude and the length of cyclic time differs much in each cycle and no definite conclusions may be made.

c. The sudden rise of bed at Dibrugarh due to earthquake of 1950 is one of the factors which cause the rise of water levels. The rate of increase of L.W.L. is the highest at Dibrugarh. It then gradually shows low in the down stream reaches. Similarly rate of change of H.W.L. is the highest at Dibrugarh and low at Tezpur and Dhubri. The rate of Guwahati shows a bit higher than that of Tezpur possibly due to restricted section there.

d. The casue of rise of the H.W.L. and L.W.L. at Dibrugarh is due to rapid aggradation after 1950. But below Tezpur, the small aggradation may not alone be responsible for such rise. The causes may be aggradation, change in quantities of discharges depending upon pattern of rainfall, change of river configuration and altribution from the local tributaries.

Data on H.W.L. & L.W.L. from the year 1967 to 1975 were also examined for places Dibrugarh, Neamati, Tezpur, Guwahati, Goalpara and Dhibri. Here also, except at Goalpara and Dhubri some cyclic behaviour in fluctuations are observed. But the amplitude is very small and ranges in between 3 ft. However the cyclic period is very long say 4 to 5 years. The Goalpara and Dhubri, the average rate of change of L.W.L. and H.W.L. in between 1967 to 1975 may be accepted as nil.

The table 7 shows the rate of such changes. The trends given by the table are very rough indirection as the duration considered is only about 8 years.

Table 7 :- Average rate of change of H.W.L.& L.W.L. per year at different places in between 1967 to 1975

Place	H.F.L.(in ft.)	L.W.L.(in ft.)	Span of years
Dibrugarh	-0.11	+0.11	1967 - 1975
Neamati	+0.15	-0.11	-do-
Tezpur	+0.05	-0.08	1967 - 68 & 1971-74
Guwahati	+0.10	+0.15	1967-68, 70-71 & 1973 to 1975
Goalpara	Negligible	Negligible	1967 - 1975
Dhubri	Negligible	Negligible	-do

From the table 7 , the Dibrugarh and the Neamati gauges show a decreasing value in H.W.L. and L.W.L. respectively. The overall position from Neamati to Guwahati shows on increasing trend. To find out the actual causes of such trend of rise, a rigorous study on rainfall, gauge, discharge and change of river configuration of the Brahmaputra as well as all the tributaries for a pretty long period will be required. The correlation study of all these data may help in finding out actual cause of this problem.

3.3 Number of occurances and duration of floods above danger level

For evaluating the number of occurances and duration of high floods, the floods of 1910, 1911, 1915, 1916, 1931, 1938, 1948, 1954, 1960, 1962, 1966, 1969, 1970, and 1973 have been considered. Number of occurances and duration of floods above danger level at various stages for selected years for gauging sites Dibrugarh, Guwahati, Goalpara and Dhubri have been shown in table 8, 9, 10 and 11 respectively.

3.4 Time lag of flood peaks

Time lag of flood peaks for various stations have been calculated by flood forecasting circle of the C.W.C. Time lag calculated on the basis of 1976 flood gave the following time lag between different stations.

Dibrugarh with respect to Pasighat	= 12 hrs.
Neamati with respect to Dibrugarh	= 24 hrs.
Tezpur with respect to Neamati	= 24 hrs.
Guwahati with respect to Tezpur	= 24 hrs.
Goalpara with respect to Guwahati	= 24 hrs.
Dhubri with respect to Goalpara	= 24 hrs.

The time lag of peaks is dependent on many factors like stage of the river, contributation of the major tributaries and that of the intermittent catchment area,valley storage available at various states of the river both on the main as well in tributary basins and the flood wave preceeding the once under consideration. The above values will, however, give a fair indication of the time lag between the main stations.

Table 8: Number of occurances and duration of floods above danger level for selected years, Dibrugarh gauge site, Danger level =

Year	Stage ⩾ 345 ft.			Stage ⩾ 344 ft.			Stage ⩾ 343 ft.			Stage ⩾ 342 ft.		
	No.of occurance	Duration (days)		No.of occurance	Duration (days)		No. of occurance	Duration (days)		No. of occurance	Duration (days)	
		Total	Max.		Total	Max.		Total	Max.		Total	Max.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1938	X	X	X	X	X	X	X	X	X	1	1	1
1948	X	X	X	X	X	X	X	X	X	1	1	1
1954	X	X	X	X	X	X	1	2	2	2	3	2
1960	X	X	X	1	1	1	3	4	2	8	14	3
1962	2	2	2	2	4	2	4	10	3	7	17	8
1966	X	X	X	X	X	X	X	X	X	2	5	3
1969	1	3	3	1	5	5	5	11	6	10	27	12
1970	X	X	X	1	1	1	5	8	3	8	22	6
1973	X	X	X	2	2	1	6	12	3	4	24	11

Table 9: Number of occurance and duration of floods above danger level for selected years, Guwahati gauge site,

Danger level = 163 ft.

Year	Stage ≥ 161 ft.			Stage ≥ 163 ft.			Stage ≥ 162 ft.		
	No. of	Duration (days) Total	Max	No.of	Duration (days) Total	Max.	No. of	Duration (days) Total	Max.
1910	2	64	51	2	81	79	2	91	82
1911	4	57	47	3	79	63	3	84	65
1915	2	71	60	1	80	80	1	82	82
1916	4	46	20	2	69	54	3	75	56
1931	2	11	10	1	20	20	2	47	44
1938	2	11	10	1	20	20	2	47	44
1948	1	3	3	1	4	4	1	8	8
1954	4	35	24	2	47	42	4	53	43
1960	2	15	10	3	47	26	2	55	47
1962	1	4	4	6	23	8	5	35	9
1966	2	20	15	6	37	25	3	58	41
1970	5	27	10	4	31	19	4	31	22
1973	3	18	9	3	21	9	4	37	18

Table 10: Number of occurances and duration of floods above danger level for selected years, Goalpara gauge site

Danger level = 119 ft.

Year	Stage $\geq$ 122 ft.			Stage $\geq$ 121 ft.			Stage $\geq$ 120 ft.			Stage $\geq$ 119 ft.			Stage $\geq$ 118ft		
	No.of occurance	Duration (days)		No.of occurance	Duration (days)		No.of occurance	Duration (days)		No.of occurance	Duration (days)		No.of occurance	Duration (days)	
		Total	Max.		Total	Max.		Total	Max.		Total	Max.		Total	Max.
1910	1	6	6	1	18	18	2	33	27	1	48	48	2	59	53
1911	1	7	7	2	28	16	1	41	41	1	47	47	3	73	63
1915	1	2	2	2	14	11	2	24	17	2	66	55	1	78	78
1916	X	X	X	1	3	3	2	14	7	3	41	16	2	50	48
1931	X	X	X	X	X	X	X	X	X	X	X	X	1	7	7
1938	X	X	X	X	X	X	X	X	X	1	9	9	2	21	14
1948				Data	not		available								
1954	1	9	9	2	21	13	4	46	26	1	73	73	1	78	78
1960	X	X	X	X	X	X	X	X	X	1	4	4	2	8	5
1962	X	X	X	1	4	4	1	6	6	2	19	15	2	28	22
1966	X	X	X	X	X	X	1	1	1	1	2	2	2	8	5
1970	X	X	X	X	X	X	1	2	2	1	14	14	2	23	21
1973	X	X	X	X	X	X	X	X	X	X	X	X	2	8	5

Table 11: Number of occurances and duration oif floods above danger level for selected years, Dhubri gauge site,

Danger level = 94 ft.

Year	Stage ≥ 97 ft.			Stage≥96 ft.			Stage ≥95 ft.			Stage≥94 ft.			Stage≥93 ft.		
	No.of occurance	Duration (days) Total	Max.	No. of occurance	Duration (days) Total	Max.	No.of occurance	Duration (days) Total	Max.	No.of occurance	Duration (days) Total	Max.	No.of occurance	Duration (days) Total	Max.
1910	1	3	3	1	15	15	1	24	24	2	39	28	1	75	75
1911	1	3	3	1	7	7	2	17	14	1	42	42	1	60	60
1915	X	X	X	2	10	8	2	41	34	1	78	78	1	82	82
1916	X	X	X	X	X	X	2	10	5	2	43	29	2	56	51
1931				Data		not		available							
1938				Data		not		available							
1948	X	X	X	1	14	14	4	27	19	4	51	26	3	77	67
1954	2	18	12	3	38	22	1	72	72	1	74	74	3	85	81
1960	X	X	X	X	X	X	2	6	4	2	14	7	4	46	19
1962	2	4	3	2	22	15	2	35	24	2	57	41	3	71	47
1966	X	X	X	1	3	3	2	6	5	2	8	3	3	40	18
1970	X	X		1	13	13	3	30	28	2	38	33	3	48	37

4.0 DISCHARGE OBSERVATIONS AT VARIOUS GAUGING SITES OF RIVER BRAHMAPUTRA

The discharge of river Brahmaputra has been observed at the sites and the period as given in table 12.

Table 12: Discharge measurement sites with period

River mileage from Indian boarder with Bangladesh in km.	Location	Period
	Shigastse (Tibet)	1955-61 (July to August)
1596	Chuchul D'zong(Tibet)	1955-61 (July to Sept.)
1178	Tsela D'zong(Tibet)	1955-61 (July to Oct.)
692	Pasighat (India)	1949-62
495	Besamara (India)	1975
198	Pandu (India)	1955-76
85	Jogighopa (India)	1955-57 and from 1971 onwards

(Source: Ref. No.3)

The discharge observations at Pasighat and Jogighopa which were discontinued earlier have again been started since 1976 and inaddition one new site at Bessamara between Pasighat and Pandu has been opened since 1976.

Besides the above, discharge in Brahmaputra are measured in Bangladesh at Chilmari (near the Indian Boarder), Bahadurabad, Sirajganj and Nagarbari (before confluence with ganges AT Bahadurabad, the discharge observations were started in 1966 and on the other three sites from 1965 onwards.

4.1 Discharge observations at various sites in Tibet (China)

The diischarges of the sites Shigatse, Chuehul -D'zong and Tsela-D'zong are obtained from the reference no.3 for the flood period 1955 to 1961. Monthly mean for the period 1955-61 for July-Oct. alongwith maximum instantaneous discharges during the period at the sites Shigatse, Chuehul-D'zong and Tsela-D'zong are shown in tables 13, 14 and 15 respectively.

Table 13: Monthly mean and maximum instantaneous discharges at the sites Sigatse (Tibet)

Period		Maximum monthly mean and year (Cumecs)	Average montly mean (Cumecs)	Max. observed discharge with date (Cumecs)
July	55-61	1435, 1958	1123	3380
Aug.	55-61	2463, 1961	1727	on 18.8.61
Sept.	55-61	1835, 1960	1359	
Oct.	56-61	1040, 1961	741	

Table 14: Monthly mean and maximum instantaneous discharges at the site Chuehul D'zong (Tibet)

Period		Maximum monthly mean and year (Cumecs)	Average monthly mean (Cumecs)	Max. observed discharge with date Cumecs)
July	55-61	2860, 1955	2141	6230
Aug.	55-61	3912, 1961	3010	on 29.8.60
Sept.	55-61	3370, 1960	2344	
Oct.	56- 61	1582, 1961	1219	

Table 15: Monthly mean and maximum instantaneous discharges at the site Tsela D'zong (Tibet)

Period		Maximum monthly mean & year (Cumecs)	Average monthly mean (Cumecs)	Maximum observed discharge with date (Cumecs)
July	55-61	4830,1955	3539	
August	55-61	6165,1961	5325	10200 on 11/12 August 1959
Sept.	55-61	5177,1960	3992	
Oct. (Excluding 59)	55-61	2669,1961	2411	

The maximum discharge at Tsela D'zong during August 1962 is not available.

Studying the average monthly mean of the three sites, the following trends, can be observed.

1. The average monthly mean discharge at Shigatse and chuehul D'zong for the month of May is quite low when compared to the discharge for the month of Tsela D'zong. This is probably due to discharge of river Giandachu meeting Tsangpo at Tsela D'zong.

2. The average monthly discharges, for July, Aug. and Sept. are less than double at Chuehul D'zong and more three times at Tsela D'zong of the discharge at Shigatse.

3. The maximum discharge at three sites is in August and the dominent discharge at Shigatse, Chuehul D'zong and Tsela Dzong can be taken as 1727, 3010 and 5325 cumecs respectively.

4. The maximum discharge at all the three sites has been observed in August.

4.2 Discharge observed at various sites in India

Discharge of river Brahmaputra in India are observed at the sites Pasighat, Pandu, Jogighopa and Bessamara. The maxm. and minimum instantaneous discharges with date at the various sites have been shown in table 16.

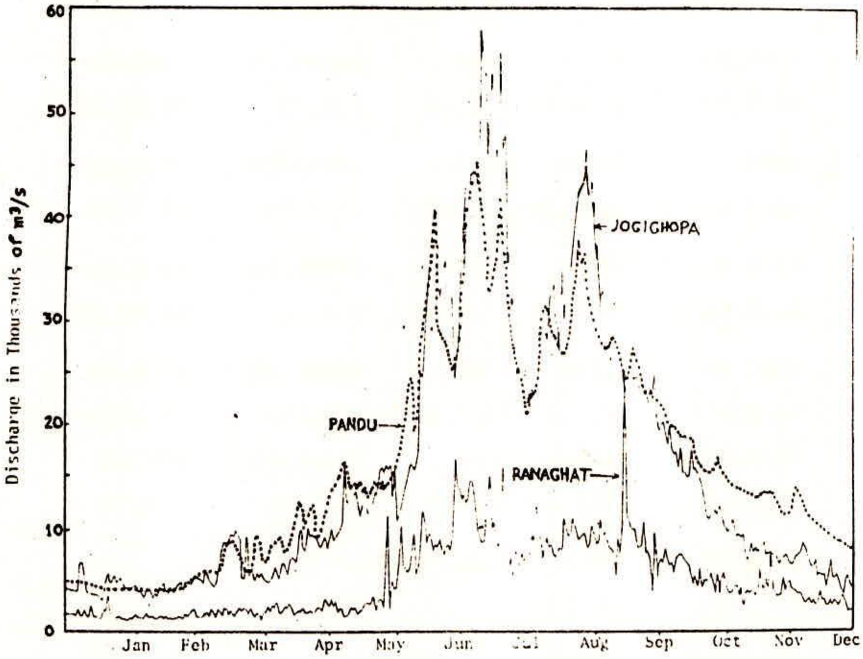

Fig. 6. Discharge hydrographs of the Brahmaputra River at Ranaghat, Pandu, and Jogighopa for 1976.

Table - 16: Maximum and Minimum instantaneous discharges at various sites in India

Discharge at Pasighat (Cumecs)		Discharge at Pandu		Discharge at Jogighapa (Cum.)		Discharge at Bessamara (Cumecs)	
Maximum Date (1)	Minimum Date (2)	Maximum Date (3)	Minium Date (4)	Maximum Date (5)	Minimum Date (6)	Maximum Date (7)	Minimum Date (8)
11354.55	1194.06	52600	3914	40916.05	4174.70	24781.14	4044.36
20.8.49	22.10.49	29.7.55	28.12.56	23.7.56	11.4.56	28.7.75	31.12.75
24526.68	1082.84	44100	3200	54364.30	5575.10	17779.96	1807.71
7.7.50	23.2.50	16.9.56	14.1.56	24.6.57	31.1.57	7.7.76	16.1.76
18494.84	1279.10	58500	3288	42490.10	7463.80		
29.6.51	29.12.51	10.8.57	24.2.57	27.8.71	31.12.71		
9470.62	1106.39	62000	3288	64186.20	3887.20		
7.9.52	27.1.52	29.8.58	8.1.58	1.8.72	29.12.72		
6000.14	1665.57	41200	2057	53843.70	2969.70		
22.7.53	20.1.53	14.8.59	1.2.59	19.9.73	18.2.73		
26468.99	1074.92	58600	2857	56906.80	4656.20		
28.7.54	28.1.54	18.9.60	17.2.60	3.9.74	30.12.74		
14489.60	1248.82	51700	3325	58034.40	2165.00		
9.8.55	30.1.55	17.7.61	27.2.61	4.8.75	24.1.75		
14270.64	1939.15	71900	2662	58180.90	3407.90		
27.8.56	21.12.56	23.8.62	19.2.62	8.7.76	6.2.76		
16480.79	1144.45	47610	N.A.(1963)				
18.7.57	13.2.57	25.8.63					
14070.28	1416.10	33000	N.A.(1964)				
27.8.58	3.4.58	16.9.65					
13627.75	1679.38	58244	N.A.(1965)				
21.6.59	30.1.59	29.8.66					
19123.44	1078.71	45620	2605				
15.9.60	9.2.60	11.7.67	11.2.66				
21996.49	1177.37	36196	2222				
14.7.61	21.2.61	25.7.68	15.1.67				
29630.10	N.A.	40480	1757				
18.8.62		21.7.69	5.2.68				
		49386	2343				
		26.7.70	27.1.69				
		35009	2239				
		27.8.71	7.2.70				
		47734	2763				
		31.7.72	31.12.72				
		51100	2604				
		8.8.73	16.1.73				

C_3	C_4
53286 3.9.74	2786 29.1.75
49479 27.6.75	

Continue - C_3 C_4

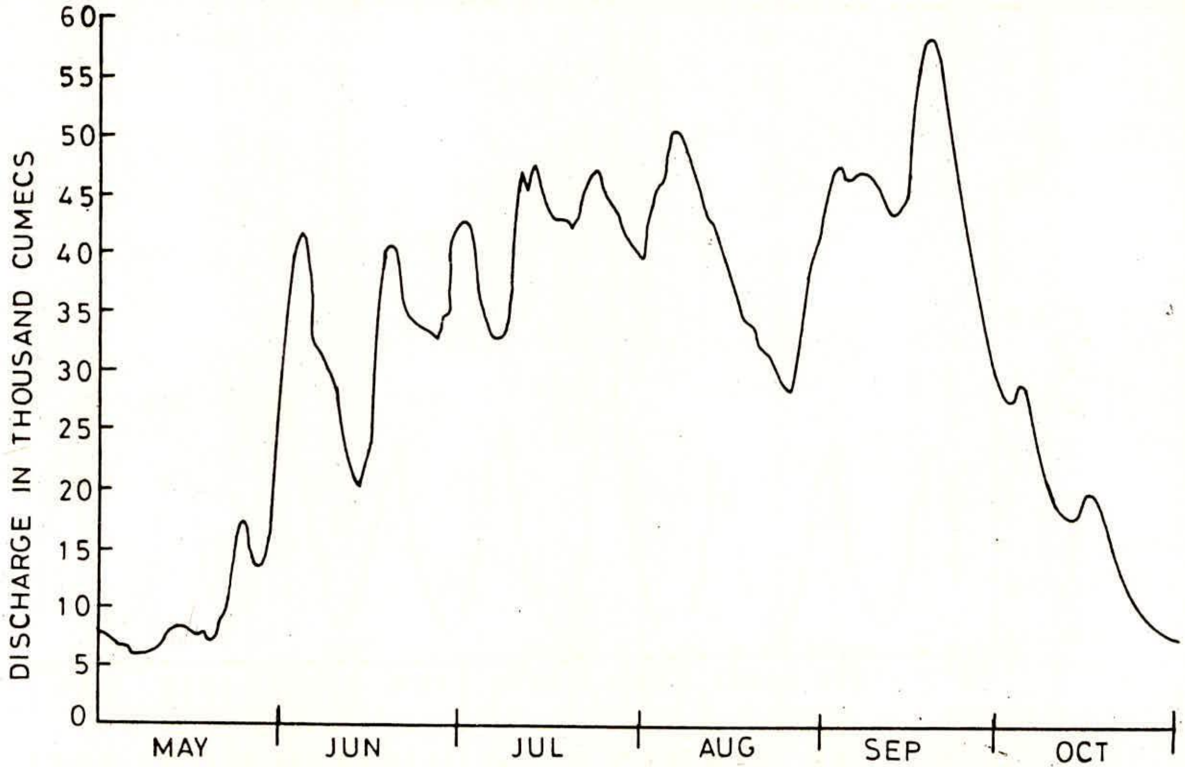

FIG. 7 - DAILY FLOW IN THE BRAHMAPUTRA RIVER AT PANDU DURING RAINY SEASON (MAY TO OCT. 1960)

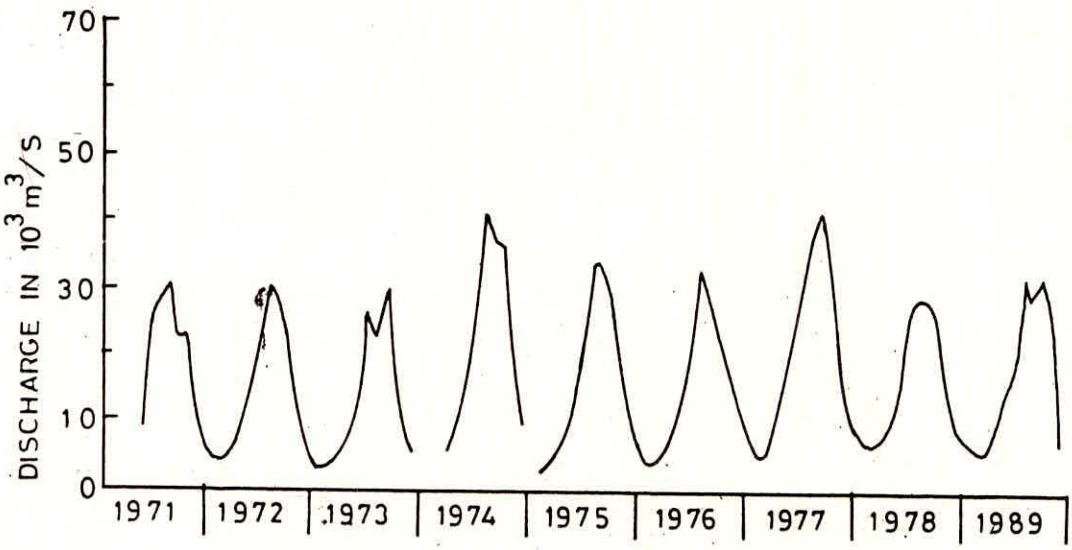

FIG. 8 - MEAN MONTHLY FLOW IN BRAHMAPUTRA RIVER AT PANDU (1971 - 1979)

The Brahmaputra is the fourth largest river in the world (Ref.No.5) in terms of average discharge at mouth, with a flow of 19,830 m^3/S. The rainy season (May to October) accounts for 82% of the mean annual flow at Pandu. Discharge hydrographs of the Brahmaputra river (obtained from Ref. No.5) at Ranaghat, Pandu, and Jogighopa for 1976 have been shown in Fig.6. The daily flow for the year 1960 and mean monthly flow for the years 1971-79 in Brahmaputra river during rainy season (May to October) at gauging site Pandu have been shown in Fig. nos. 7 & 8 respectively.

The hydrographs of the Brahmaputra at Ranaghat, Pandu, and Jogighopa for 1976, shown in Fig.6, show the high fluctuations in daily discharge of the river.

4.3. Discharge observations at various sites in Bangladesh

Discharge of river Brahmaputra in Bangladesh are observed at the sites Chilmari, Bahadurabad, Sirajganj and Nagarbari. The maximum and minimum instantaneous discharges at these sites for the years 1965, 1966 and 1967 are shown in table 17.

Table - 17: Maximum and Minimum instantaneous discharges at various sites in Bangladesh

(Unit:Cumecs)

Years	Discharges at Chilmari		Discharges at Bahadurabad		Discharges at Sirajganj		Discharges at Nagarbari	
	Maxm. Date	Minimum Date	Max. Date	Minimum Date	Max. Date	Minimum Date	Max. Date	Minimum Date
1965	-	-	-	-	1906800 23.8.65	-	1962200 22.8.65	-
1966	298300 30.8.66	1173000 26.3.66	2440000 31.8.66	123596 1.3.66	2019000 2.9.66	126900 16.2.66	1779400 28.8.66	102800 21.7.66
1967	2275800 12,7,67	105900 8.2.67	2426900 17.7.67	196640 13.2.67	2068600 14.7.67	115100 16.2.67	1513300 20.7.67	132500 6.2.67

(Source: Ref.No.3)

Few informations of the discharge data at the station Bahadurabad in Bangladesh for the period 1956 - 1962 have been obtained from the ref. no. 3 which are as follows:

a)	Maximum recorded flood	=	68200 cumecs
b)	Average annual discharge	=	19200 cumecs
c)	Average discharge in dry season (Nov. to April)	=	6510 cumecs
d)	Average discharge in monsoon season (May to Oct.)	=	31850 cumecs
e)	Average discharge in high period (July-Sept.)	=	39900 cumecs.
f)	Minimum discharge	=	3120 cumecs

5.0 SEDIMENT DISCHARGE OBSERVATIONS AT VARIOUS SITES OF RIVER BRAHMAPUTRA

The Brahmaputra is one of the most sediment-charged large rivers of the world (Ref.No.5) . Among the largest rivers of the world, it is second only to the yellow river in China in the amount of sediment transported per unit of drainage area. D.C. Goswami (Ref.no.5) in his study has reported that the Himalayan catchment in Bhutan that receives about 500 cm of rainfall in the wet outer hills seems to be highly productive of sediment due to the combined effect of damaging land use practice (mainly deforestation) and friable soils.

A detail study on the sediment load in the Brahmaputra valley has been carried out by Central Water and Power Research Station, Pune for report of the study group on erosion by Brahmaputra (Ref.no.3).

5.1 Sediment discharge observations at the sites Pasighat and Pandu in India

Sediment discharge observations at the sites Pasighat and Pandu were started in 1958 and 1955 respectively by CWC. The monthly suspended sediment yield at Pasighat for the year 1958 has been shown in table 18 and the monthly discharge and silt load at Pandu for the years 1955 and 1956 has been shown in table 19.

The data of surface sediment load collected at Pandu site for the years 1965, 1967, 1962 and 1973 are available in ref. no.3 . The particulars of the surface sediment load at Pandu for the years 1965, 1967, 1972 & 1973 are shown in table 20.

Table 18: Monthly suspended sediment yield at Pasighat for the year 1958

Month	Suspended sediment in Acreft.
January	–
February	–
March	157
April	3976
May	7551
June	6632
July	8041
August	17412
September	5891
October	2684
November	394
December	
Total =	52738 Acreft. = 6500 H.m.

(Source: Ref.No.3)

Table 19: Monthly discharge and silt load at Pandu for the years 1955 and 1956

Months	1955			1956		
	Sediment load Acre ft.	Discharge volume in Cumecs day	% of silt by volume discharge	Sediment load Acre ft.	Discharge volume in cumecs. day	% of silt by vol. discharge
Jan.	800	4.33	0.0093	500	4.60	0.0055
Feb.	500	3.40	0.0074	600	3.67	0.0082
March	1200	4.97	0.012	2000	6.13	0.0163
April	1600	6.80	0.012	2400	8.27	0.0145
May	6800	14.80	0.023	45800	29.57	0.077
June	37500	37.30	0.05	61300	34.50	0.089
July	95800	48.33	0.099	4300	29.53	0.073
Aug.	80500	45.50	0.09	34800	24.83	0.070
Sept.	29000	24.00	0.062	47400	28.50	0.083
October	8000	16.00	0.025	14000	18.00	0.039
Nov.	2300	9.00	0.013	1900	8.33	0.011
December	900	5.67	0.008	800	4.87	0.0082
Total in Acre ft.	264900			254500		
Total in Hactase meter	32675			31393		

(Source: Ref. No.3)

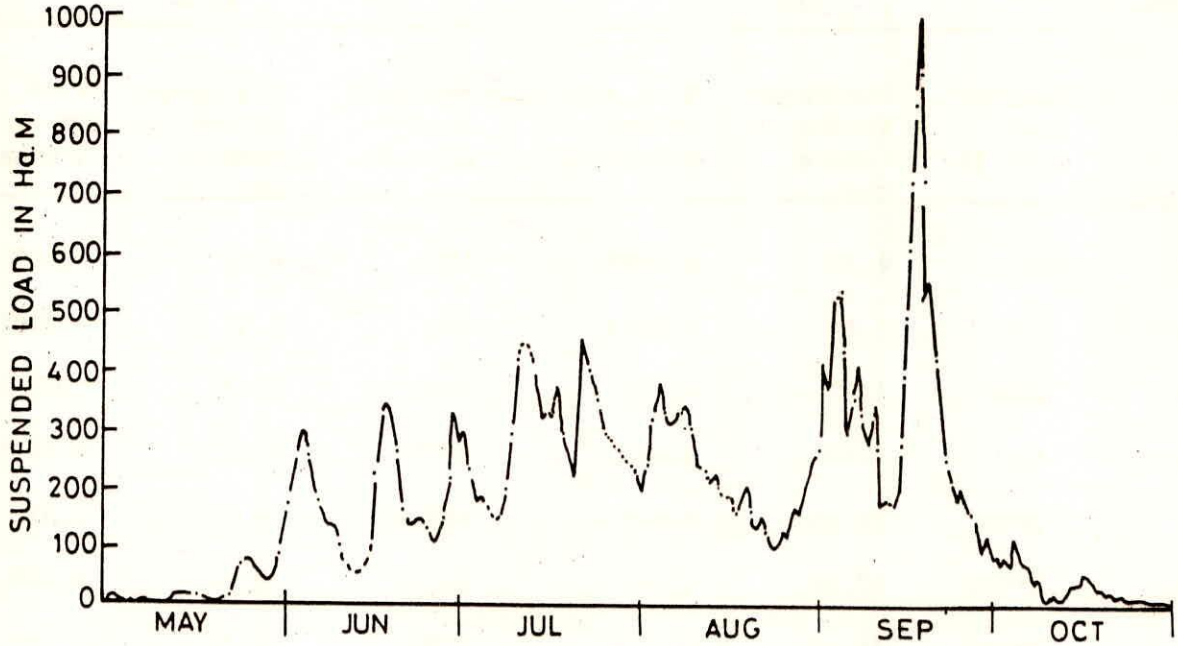

FIG.9 - DAILY SEDIMENT DISCHARGE IN BRAHMAPUTRA RIVER AT PANDU DURING RAINY SEASON (MAY TO OCT. 1960)

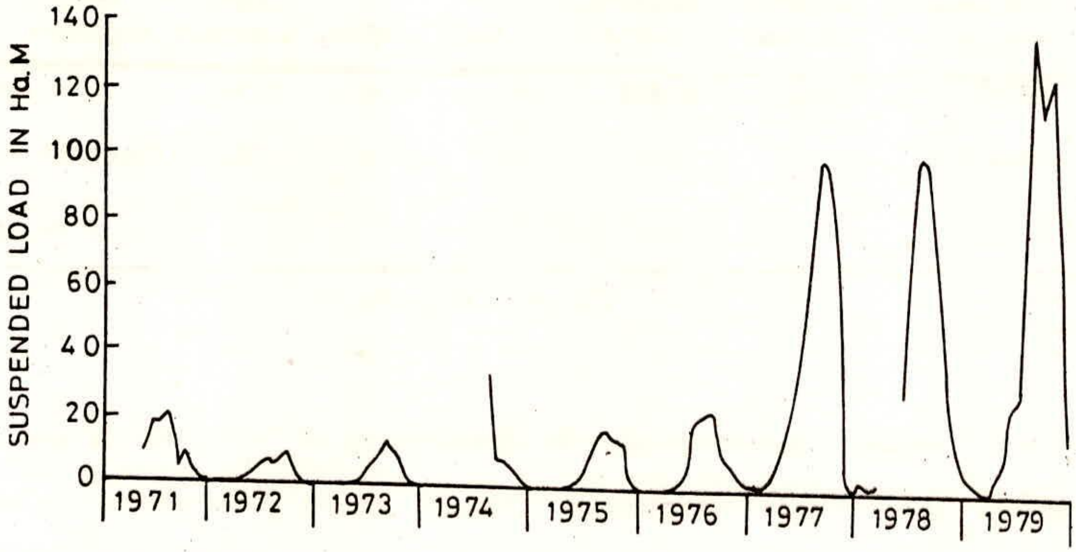

FIG.10 - MEAN MONTHLY SEDIMENT DISCHARGE IN BRAHMAPUTRA RIVER AT PANDU (1971 – 1979)

Table 20: Particulars of the surface sediment load at Pandu for the years 1965, 67, 72 & 1973

Max^m .sediment load (H.M.)		Minm.sediment load (H.M.)		The annual sediment Load(H.M.)		~~% break up of the max.~~ sediment load during monsoon period in 1967		
Monsoon Period	Non-monsoon Period	Monsoon Period	Non-mon. Period	Max.	Minn.	Coarse sediment	Medium sediment	Fine sedime
63681	5778	7.852	0.868	545	7074	7.960	9.024	46.647
1967	1965	1972	1973	1965	1972	(12.5%)	(14.18%)	(73.33%)
						Total = 63.68		

(Source: Ref. No.3)

The daily sediment discharge for the Brahmaputra at Pandu during the monsoon season, 1960, is illustrated in fig. 9. It is interesting to note that the major fluctuations occur in sediment load dur ing the monsoon period. Sediment transport in the Brahmaputra is more variable than flow (Ref. no.5) . The mean monthly sediment discharge in Brahmaputra river at Pandu (1971-1979) is shown in Fig. 10. The sediment discharge at Pandu for 1971-79 indicates a modest very much larger increase in sediment discharge, particularly since 1977

5.2 Sediment discharge observations in Bangladesh

We have the little informations of the sediment data in Bangladesh from the ref. no.3 which is written below:

The average maximum sediment concentration on river Brahmaputra observed at Bahadurabad was 1180 p.p.m or 0.12% maximum silt content at

Bahadurabad at surface and near river bed has been found to be 1408 p.p.m. and 4544 p.p.m. The annual suspended sediment load has been estimated at 735 million metric tons. Average annual silt runoff per sq.km. (1956-62) = 1370 metric tons. The composition of the suspended sediment load ranged from a minimum of 70% to a maximum of 90% silt and clay. Only traces of fine and very fine sand with a maximum sand of 0.355 mm were found. The bed material is 95% fine and very fine sand with minor traces of coarse sand, silt and clay. The maximum size of bed material was 0.83 m.m.

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