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WATER LOGGING INUNDATION PROBLEMS OF GREATER GUWAHATI
A Geographical Study

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Introduction

(a) *Study Area*

Guwahati is the premier urban centre of Northeast Region of India known as the 'Gateway of north-east'. It lies at the point of intersection of 26° 10'45" north latitude and 90° 45'00" east longitude. The total area of Greater Guwahati is 243.2 sq. km. including a small area of 23 sq. km. in the north of the river Brahmaputra, known by the name North Guwahati.

(b) *Drainage*

The master drain Brahmaputra river has been aligned longitudinally and it flows east to west direction segmenting Greater Guwahati into North Guwahati in the north and the core city in the south.

On the north bank of the river Brahmaputra the river Ghorajan and Barnadi maintaining their natural courses and discharge into Brahmaputra. These two rivers are not harmful to the dwellers of the North Guwahati.

On the south bank of river Brahmaputra there are as many as five tributaries such as Bharalu, Mora Bharalu, Barapani, Khanajan and Bondaijan. Bharalu is the most harmful tributary to the city dwellers, which flows through the alluvial depression of Guwahati Municipal Corporation area to meet at Bharalumukh. Bondajan in the east and Khanajan in the west both rivers originate from Silsako Beel and Dipar Beel respectively. Backflow of water from the river Brahmaputra through Bharalu, Khanajan and Bondajan cause floods frequently in every summer.

(c) *Relief*

The original city is located within a crescent shaped basin, surrounded by a number of hillocks. The hills are outliers of the Meghalaya Plateau, predominantly residual in character. They are composed of granites and gneissic rocks with the outer surface fairly weathered and contain red soil. The hills have steep slope but from the base, the slopes become gradual up to the riverbank of the north. As a result, an undulating topography has emerged with swamps and low-lying areas in between. The original settlements were mostly located on the elevated plains and the foot hill zone. Thus, the low-lying areas, smooth terrain and some hillocks of different elevations present a peculiar relief to the area.

The benchmark of the G.T.S. (Great Trigonometrical Survey) near Deputy Commissioner Office is 54.75 m. While 52.20m is recorded near Railway Station above M.S.L. with an average elevation of 51.3m for the southern bank of Brahmaputra and it rises up towards Kharghuli and Chittrachal (Navagraha) hill in the east (216 m) and Nilachal hill (303 m) in the central part. The average elevation of the low-lying areas is 49m and the lowest is 41.16m above the M.S.L. This land gradually rises to Khasi and Jaintia hills to a maximum elevation of 575m, which ends in the southern boundary of Guwahati. Again, there are areas near Chittrachal hills with a general elevation 182m towards the east and to the southern plains of 49m elevation. In between the Khasi hills and the

Brahmaputra river lies the Sarania hills (250 m), the Fastasil hill range (358 m) and the Kalapahar Narakasur hills (200-300 m). A vast low-lying area of Dipar Beel occupies more than 54 sq. km. on the western part of the city.[1] Moreover, there are low-lying plains intervened by scattered swamps and marshes in between the hills, extending from east to west. These low-lying areas are inundated often at the time of heavy rainfall.

Data Base and Methodology

For geographical location of study area, Survey of India topographical sheet No. 78 N/12 and 78 N/16, of R.F. 1: 63360 (scale 1 inch to a mile) are used and prepared a map of Greater Guwahati. It depicts various features of topography, characteristics of rivers, tributaries, settlement pattern and transport network etc. To find out the average slope of the area, the C.K. Wentworth formula has been applied on a contour map of above mentioned sheets. The formula is given below:

$$\tan\theta = \frac{N \times I}{3361 \text{ (constant)}}$$

where,

$\tan\theta$ = average angle of slope
N = average number of contour crossings per mile
I = contour interval in feet

For rainfall analysis hourly data of seven years has been collected from Indian Meteorological Department. Average hourly variation of rainfall during monsoon period (May to September) of a few consecutive years has been tabulated and calculated by the following formula:

$$R = \frac{r}{n}$$

where, R= average rainfall per hour

r = total rainfall of the hour of the month

and n = total number of rainfall occurrence of the hour of the month

In order to adopt a pragmatic approach, standard deviation and co-efficient of variations of hourly data have been calculated on the basis of the following formula :

$$\sigma = \sqrt{\frac{\Sigma(x-\overline{x})^2}{n}}$$

Where, σ = standard deviation

$\overline{x}$ = hourly rainfall

x = mean hourly rainfall

(i) n = number of observation

and (ii)

$$cv = \frac{\sigma}{\overline{x}} \times 100$$

where, cv = coefficient of variation of mean hourly rainfall

σ = standard deviation

$\overline{x}$ = mean hourly rainfall.

The data regarding various levels of water in Brahmaputra has been collected from Brahmaputra Flood Control Department for the monsoon period of 150 days (May to September), the average water level percentage of 150 days and cumulative percentage of 150 days has also been calculated.

This way most of the parameters have been analysed and presented with the help of suitable diagrams and other cartographic aids. A few secondary data relevant to the problems have also been collected from Town and Country Planning Department and Guwahati Municipal Corporation.

Results and Analysis

(a) *Average Slope Analysis*

The term slope is used for the land surface, which is inclined from the horizontal. The average slope of Greater Guwahati has been studied with the help of average slope determination of C.K. Wentworth.[2]

It is found that the average slope of Greater Guwahati varies from zero degree to 18 degrees. The maximum slope is 18 degrees and is noticed in the Nilachal Hill (6° to 18°), Kalapahar-Narakasur Hill (9° to 18°) and the Khanapara Hill side (6° to 18°) areas (Figure 7.1). In the same way Hengerabari N.C., Modgharia N.C., Ramcha Hill Grant, Sunsali Grant, Clearance Garden, Noonmati Garden, all are in the North-Eastern part of the Greater Guwahati, where the average slope varies from 9° to 18° or above. Both Kalapahar-Narakasur hill and Hengerabari-Modgharia hill area, the slope declines to 3 degrees near Ganeshguri. Beyond these areas the plains extend from Saukuchi, Sijubari, Hatigaon to Satgaon. A corridor of less than 3 degrees of average slope has been found between the westward slope of Nilachal Hills and the eastward slope of Jalukbari hill area. Further, it is noticed that the 3 degrees isopleth encircles the Dipar Beel and extends along the Pub-Bora Gaon to Borjhar-Azara area, here the western limit of the greater Guwahati ends. It is also observed that the Mora-Bharalu plains extend south to north between the Fatasil and Kalapahar hills. An isolated spot near Mikirpara, where slope increases for 3 to 6 degrees and another spot near Kakatipara where slope increases from 3 to 12 degrees, are found in the south west limit of Guwahati. These isolated hills are actually outliers of the Meghalaya Plateau.

The three tributary basins of Greater Guwahati are of contrasting characters. The Bondajan basin is found at higher altitude, having a 9 degree slope; Bharalu basin on 6 degree slope, while the Khanajan basin lies below 3 degree slope. Thus, it has been observed that the average slope of the urban complex gradually falls towards west, with exceptional inter-basin separation.

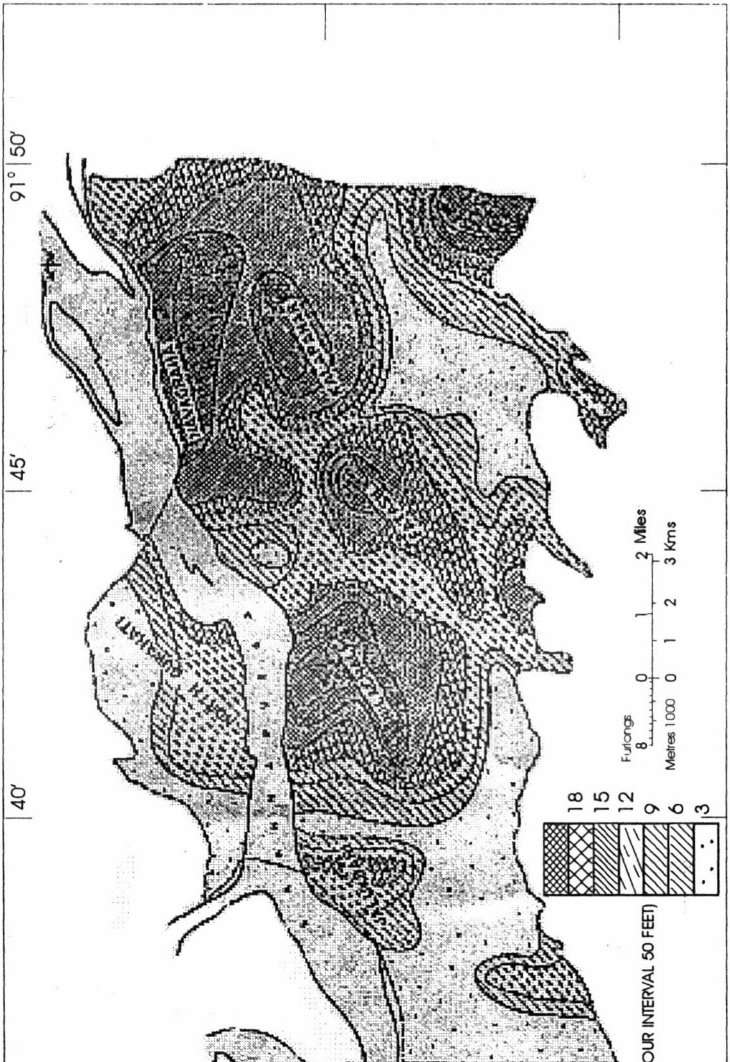

Fig. 7.1 : Guwahati: Average land Slope

The intervening hills, dividing the basins, are the residual outliers of the Maghalaya Plateau. These have been considerably eroded and demonstrate only relict monadnocks. The relief and slope characteristics of Greater Guwahati region indicate that while the natural inclination of the relief is from east to west, the drainage of the three tributaries to Brahmaputra has been at right angle to the natural inclination. Moreover, the orientation of the city is axial, along the Brahmaputra in east-west direction and the natural drainage courses again intersect the city at right angle and therefore, the natural courses have been intersected by roads, bridges, culverts and such other man-made hindrances.

(b) *Rainfall Analysis*

The water logging and inundation problems may be looked into from the point of view of rainfall intensity and rainfall regime of the city. Rainfall data for each hour for 7 years (1980-86) of 5 monsoon months (i.e. May to September) has been used and analysed. The average rainfall per hour for each monsoon months and for the season has been plotted in the graphs. The graphs are not smooth and show many primary and secondary peaks. To make the curve smooth three points moving average (Table 7.1) has been used. Yet some of the smoothed curves have shown oscillatory character (Fig. 7.2).

The May curve indicates few peaks, out of which, two are greater than the mean rainfall of 24 hours. May, June and July curves show prominent peaks. The characteristic feature of high peak of May 2300 hour IST corresponds to afternoon peak of July 1400 hour IST and then to early hour peak to July 0200 hour IST. The peaks are conspicuously smooth in the month of August. Significantly both early peak 0300 hour IST and late peaks 2000 to 2300 hour IST occur in September. During the monsoon season as a whole the rainfall curve shows three prominent peaks each at 2300 hour IST, 1400 hour IST and 0200 hour IST. Along with these three prominent peaks, there are five other mild peaks which are above mean rainfall. From the above analysis it is apparent that

Table 7.1 : Average Variation of Rainfall per hour for the Monsoon Season 1980-86*

(Rainfall in mm)

Hours	May	June	July	August	September	Seasonal (monsoon)
1	2	3	4	5	6	7
1	3.9	3.7	3.4	3.2	3.6	3.6
2	5.0	3.0	6.5	2.9	2.0	3.9
3	3.1	2.7	3.4	3.4	5.5	3.6
4	3.3	2.1	1.3	1.2	3.0	2.2
5	2.9	1.9	1.7	4.0	1.7	2.4
6	1.7	1.5	1.9	4.4	1.1	2.1
7	3.0	1.2	2.1	3.3	1.0	2.1
8	1.2	1.0	2.1	3.1	2.7	2.0
9	2.5	2.1	2.9	3.4	1.6	2.5
10	1.5	2.6	2.6	3.0	1.5	2.2
11	1.8	3.0	3.1	2.3	2.0	2.4
12	1.6	4.3	1.9	2.5	2.3	2.5
13	1.7	3.4	1.1	2.6	1.5	2.0
14	1.2	10.0	1.2	1.4	1.1	3.0
15	2.9	1.7	1.6	1.8	1.9	2.0
16	1.0	5.8	1.3	2.5	1.7	2.5
17	1.2	5.0	4.6	2.4	3.3	3.3
18	2.1	1.4	1.5	3.7	1.4	2.0
19	2.6	1.3	2.3	1.9	2.2	2.0
20	2.8	2.0	2.4	2.1	4.1	2.7
21	1.4	2.0	5.1	4.1	4.5	3.4
22	3.0	5.1	2.4	3.2	3.0	3.3
23	8.8	1.8	3.3	2.2	4.0	4.0
24	4.8	2.2	2.7	2.5	2.0	2.8

* Computed by the author from the data of Indian Meteorological Department, Guwahati.

Guwahati experiences about eight peaks hours of high intensity rainfall periods in one monsoon season. The rainfall curve clearly depicts (Fig. 7.2) that most the rainfall occurred in afternoon and during night, whereas it is less between 0400 hour to 1300 hour IST.

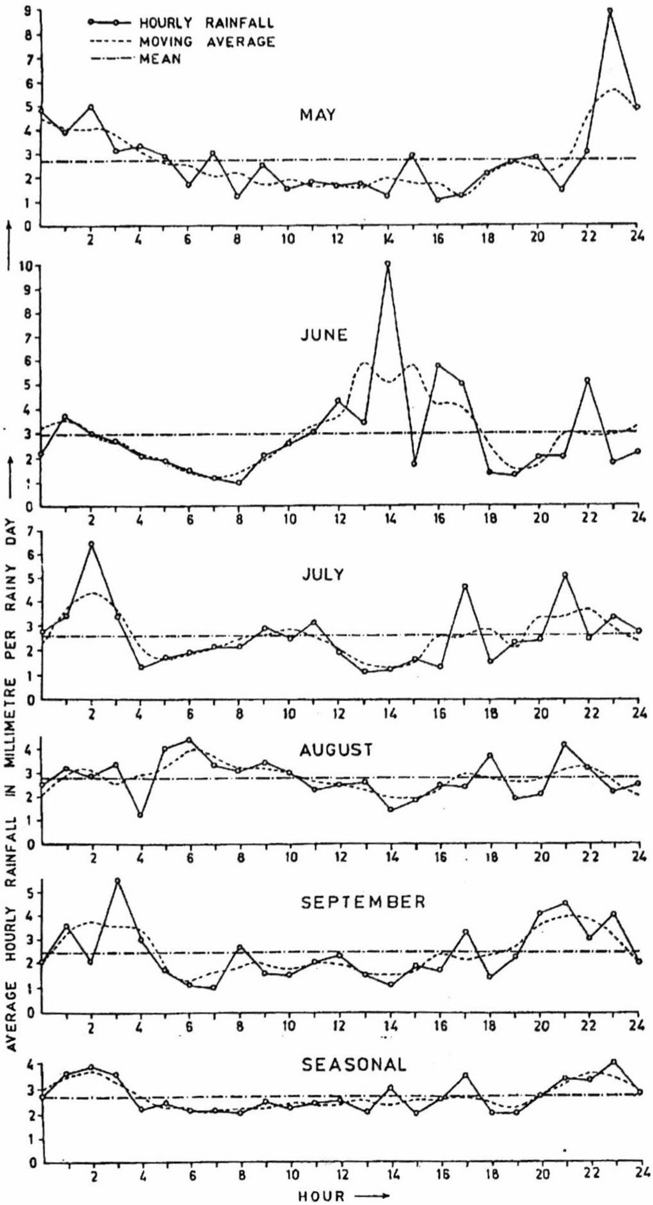

Fig. 7.2 : Hourly Variation of Rainfall of Guwahati

Table 7.2 : Three-Point Moving Average of Rainfall per hour for the Monsoon Season 1980-86*

(Rainfall in mm)

Three point moving average of the hours			May	June	July	Aug	Sep	Seasonal monsoon
1	2	3	4.0	3.1	4.4	3.1	3.7	3.7
2	3	4	3.8	2.6	3.7	2.5	3.5	3.2
3	4	5	3.1	2.2	2.1	2.9	3.4	2.7
4	5	6	2.6	1.8	1.6	3.2	1.9	2.2
5	6	7	2.5	1.5	1.9	3.9	1.3	2.2
6	7	8	2.0	1.2	2.0	3.6	1.6	2.1
7	8	9	2.2	1.4	2.4	3.2	1.8	2.2
8	9	10	1.7	1.9	2.5	3.1	1.9	2.2
9	10	11	1.9	2.6	2.8	2.9	1.7	2.4
10	11	12	1.6	3.3	2.5	2.6	1.9	2.3
11	12	13	1.7	3.5	2.0	2.5	1.9	2.5
12	13	14	1.5	5.9	1.4	2.2	1.6	2.3
13	14	15	1.9	5.0	1.3	1.9	1.5	2.5
14	15	16	1.7	5.8	1.4	1.3	1.6	2.6
15	16	17	1.7	4.1	2.5	2.2	2.3	2.6
16	17	18	1.1	4.0	2.5	2.9	2.1	2.4
17	18	19	2.0	2.5	2.8	2.7	2.3	2.2
18	19	20	2.5	1.5	2.0	2.6	2.6	2.7
19	20	21	2.3	1.7	3.3	2.7	3.6	3.1
20	21	22	2.4	3.0	3.3	3.1	3.9	3.6
21	22	23	4.4	2.9	3.6	3.2	3.8	3.4
22	23	24	5.5	3.0	2.8	2.6	3.0	3.4

*Computed by the author.

The means hourly rainfall per rainy day is maximum and becomes incessant in June and the minimum in September (Table 7.3). The co-efficient of variation of mean hourly rainfall is also maximum in June. Hence, June rainfall always alarming as soils absorbs by the rain water into the saturated point. The other peaks (primary and secondary maxima) from June to September, is a sensitive period with full of potential of flooding the city through runoff water.

Table 7.3 : Mean, Standard Deviation and Co-efficient of Variation of Rainfall per hour per Rainy Day for the Months of May to September and for the Season 1980-1986*

Months	Average hourly rainfall in mm ($\bar{x}$)	Standard Deviation of $\bar{x}$ (in mm)	Co-efficient of Variation of $\bar{x}$ in %
May	2.70	1.69	62.59
June	2.95	1.99	67.45
July	2.59	1.31	50.57
August	2.79	0.82	29.39
September	2.44	1.19	48.77
Seasonal (Monsoon)	2.68	0.66	24.62

* Computer by Author.

(c) *Behaviour of River water inside Greater Guwahati*

The tributaries of Brahmaputra inside Greater Guwahati are rendered inactive in discharging their water load because of the higher water level in the 'master drain'. On the contrary, backflow from the river Brahmaputra enters through the outlets of natural drainage and increases both the level and volume of water in these tributaries. Normally, backflow through Bondajan on the east, Khanajan on the west and Bharalu in the central part, causes flood inside Greater Guwahati almost at every spate of high water in Brahmaputra.

From the 10 years observations of the water level of Brahmaputra at D.C. Court site shows that the water level of Brahmaputra rises above the danger level (49.68 m.) seven times in ten years duration. It means that hardly one year was free from flood out of every three years.

Monthly water level of the Brahmaputra for D.C. court has been studied and it is plotted in the graph (Fig. 7.3). From this curve it is observed that the water level crossed the danger mark twice in 1980, once in 1981, thrice in 1987, and twice in 1985. In the year 1982,1983 and 1986 the water level did not cross the red mark (49.68 m) at all. The water level that crossing the danger level generally, in between July, August and September only.

An observation has been made on the daily water level of Brahmaputra at D.C.Court site for seven years and tabulated in

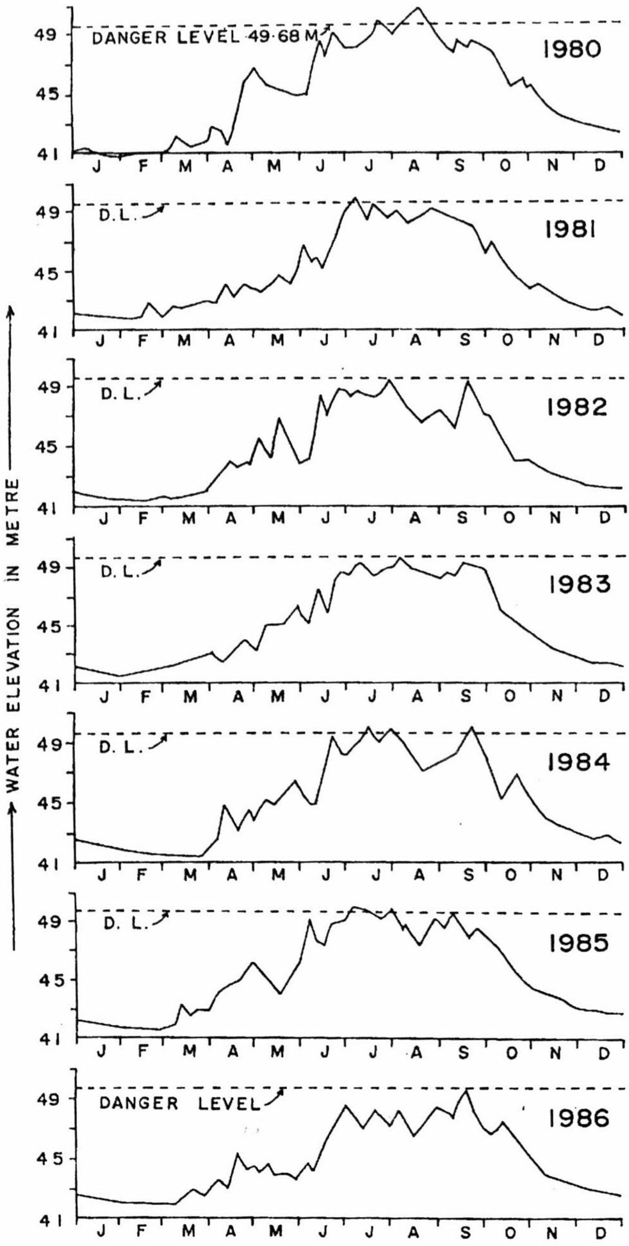

Figure 7.3 : Water Elevation of the Brahmaputra at D.C. Court Site

percentage (Table 7.4) for 150 days (May to September) and represented cumulative graph (Fig. 7.4) . It shows that for about 7 per cent of 150 days (10.5 days) the water level of Brahmaputra equals the danger level or exceeds it during the monsoon period. During this period when water level exceeds or equals the danger level, the sluice of Bharalu is to be closed to stop the back flow from the Brahmaputra in order to avoid inundation of the city area.

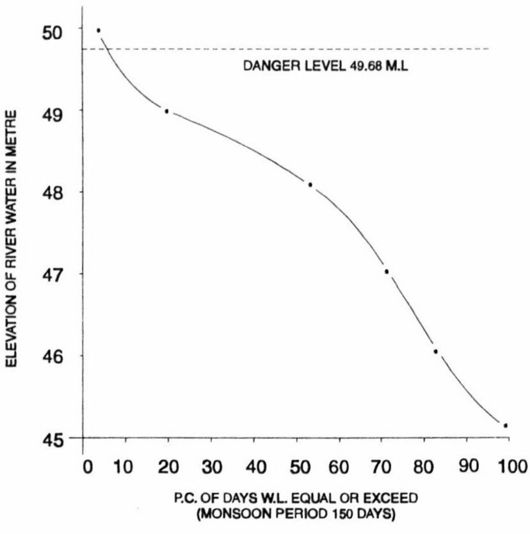

Fig. 7.4 : Water Level Duration Curve of the Brahmaputra at D.C. Court, 1980-86

"Gradient or slope of the stream channel is the angle between the water surface and the horizontal plane."[3] In general, a stream's gradient decreases from its source towards the month. But in case of the Bharalu river, the gradient of the river bed does fall progressively, but at certain meanders, the river bed is found to be of higher elevation than the upper course. This is mainly due to the sluggish movement of the water in the lean season and deposition of silt of the bed. This is another reason for rapid rise of water level in the river.

Table 7.4 : Number of Days the Water Level was above Mean Sea Level

Year	50m	49m	48m	47m	46m	45m
1980	8 days	27 days	65 days	13 days	5 days	32 days
1981	0 days	27 days	60 days	4 days	18 days	16 days
1982	0 days	14 days	50 days	25 days	27 days	10 days
1983	0 days	22 days	65 days	22 days	15 days	39 days
1984	10 days	37 days	35 days	31 days	28 days	40 days
1985	0 days	44 days	50 days	36 days	6 days	17 days
1986	0 days	6 days	33 days	59 days	32 days	7 days
Total	18 days	117 days	258 days	190 days	131 days	161 days
Average days	2.6	25.3	51.1	27.1	18.7	23.0
% of 150 days	1.7	16.8	34.1	18.1	12.5	15.3
Cumulative	1.7	18.5	52.6	70.7	82.2	100

Source : Above data computed by the author from Brahmaputra Flood Control Commission, Guwahati.

Note : At D.C. Court danger level is 49.68 m.

The closure of the sluice gate near the Pragjyotish College results in accumulation of the rainwater from the catchment area in the drain. As this water cannot flow out through its mouth at the time of high water in Brahmaputra, the accumulated water takes a reverse course and slowly drains out through the Mora-Bharalu (dead river) to Dipar Beel. Unfortunately, the shallow and narrow channel of Mora-Bharalu fails to clear off the accumulated water with any great speed. This keeps the water level of the Bharalu river high for weeks together and causes water logging in the entire low-lying areas of the basin.

(d) *Waterlogging and Inundation Problems*

Waterlogging is a colossal and continuous problem of Guwahati. In order to locate and verify the vulnerable waterlogging spots, constant personal observation was made by the researcher in the last few consecutive monsoons. Empirically speaking, few causes may be attributed to this phenomenon:

(i) Topography of Guwahati is singnificantly undulating.
(ii) Both natural and artificial drains are not capable of carrying the storm water due to their shallowness and narrowness.
(iii) Encroachments over the low-lying areas by new settlers on either side of the natural drains have blocked the natural flow of flood water to the drains.
(iv) Construction of building and roads over the man-made drains are also responsible for bottlenecking the drainage.
(v) Indiscriminate cutting of hill sides for filling up low-lying areas are also responsible for sheet wash and blockage of channels. The hills are exposed to heavy rain which supply enormous loose soil and silt up the drains rapidly.
(vi) The filled-up areas possess high seepage capacity because of lower compactness and saturate at a faster rate and therefore, do not allow flow of flood water.
(vii) Most of the original swamps and natural water reservoirs are filled up for residential, official, industrial and institutional purposes. Consequently, the rain water spread over the built-up areas causing flash flood.
(viii) Rising of the ground water table with the rise of Brahmaputra level saturates the entire plain area and reduces the rate of percolation.

The topography of Guwahati controls the natural drainage. As mentioned earlier. The relief of the city gradually slopes from east to west. Two major natural drains of Greater Guwahati originate in the hills and other two major drains originate from lakes. Mushrooming of settlements on either sides of the perennials drains in and around Guwahati restrict easy flow of water. In between the natural drains, the presence of depressed area usually prompt the tendency of collection of water in scattered areas after every heavy shower.

The cultural morphology of the city has undergone tremendous change and new settlements particularly, the unplanned ones have created many bottlenecks to the system of natural drainage. Within the busy functional areas of the city, drain-cum-footpaths are not adequate to carry all the storm waters. Besides, most of the drains are relentlessly constructed against the natural direction of flow.

In addition, the broad gauge railway line has been constructed through the heart of the city, which constrains the existing inadequate drainage system of the city. Ignoring the Master Plan of the city and construction of broad gauge line across the natural courses have added to the problem.

Enormous sheet wash from Navagraha hill slopes constantly fill up the existing drains and flood the road from Silpukhuri to the Flood Control Commission Office at Chandmari. Similar situations are also seen over the road near Assam Engineering Institute to Bamunimaidan area.

In matters of water logging, the composition of the soil in the city area has a major role to play. At one hand, the depressed area are composed of transported soil from the hilly areas and at the other, much of the built-up areas have come up over the newly field soils. The rain-water, in absence of effective soil conserving cover, erode the high land and deposit the materials over the low-lying areas. The water percolation rate reached the lowest point during the monsoon period. Two specific reasons may be attributed to this phenomenon :

(i) The low-lying areas are composed of transported soil or silt,

(ii) Widespread saturation of the soil takes place as noted earlier, due to rise of Brahmaputra level and due to the nature of its soil composition. Consequently, the surface flow progressively increases with the advance of monsoon season, resulting in the collection of rain-water in the depressed regions. The best example of such a situation may be cited from Kumarpara area. The elevation of this area is comparatively low (49 m above MSL, whereas, danger level of Brahmaputra is 49.68 m at D.C. Court site). Being nearer to the Brahmaputra and the Bharalu, soil of the area gets rapidly saturated with the advent of monsoon. The sub-soil of this region hardly gets time for complete desiccation in between the wet seasons and the monsoon, coupled with high water in the Brahmaputra, completely stops percolation. Hence, the entire Kumarpara area is submerged during heavy showers.

Illegal encroachers fill up most of the natural water reservoirs of Greater Guwahati. The swampy areas in between Fatasil and Lakhra road are packed with settlements. The Bishnupur area, and the low-lying areas of Gopinath Nagar are also filled up for construction of residential quarters, resulting in permanent blockade of rain-water. The areas in between the Rajgarh Road and R.G. Baruah Road significantly, lies below 49 m contour. This part of the city is also subjected to continuous earth filling for new constructions of residential houses. In the absence of effective outlets, the water in unfilled areas remains stagnant causing water-logging for weeks together.

Looking into the growth momentum of the city, establishment of industrial areas and capital complex in and around the city, various government agencies have offered suggestion for alleviation of this problem. The notable suggestions offered by the Town Planning Organisation, Assam, and the Brahmaputra Flood Control Board perhaps, would ease the situation to a certain extent, provided these schemes are effectively implemented. Nevertheless, it seems that the problem will persist for a long time to come without a long run plan of drainage of the city to be undertaken in a war footing.

Conclusions

The above analysis of various aspects of the city environs boils down to the following issues: These are– (a) the natural drainage problems, (b) the artificial drainage problems, and (c) the silting problems.

(a) *The Natural Drainage Problems*

The main natural drainage of the city is the Bharalu river. Prolonged silting and encroachment upon its banks have reduced the load discharge capacity of the drain, especially in the lower part from

R.G. Baruah Road bridge (Zoo Road bridge) to Lakhra Road bridge point.

Bed of the middle part of Mora-Bharalu is at a higher elevation, which fails to carry off the normal discharge. At the time of high water level of the Brahmaputra, the water back-flows into the city through the existing channels and open culverts. Dipar Beel needs to be excavated to enable it to absorb the city runoff through the existing drain. Barchala Beel connected through open drains cannot accommodate all the water received at the time of peak discharge. There is also no practical use of Chala Beel (Chatribari swamp) due to its shallowness. Hence, both the beels needs to be excavated to enable them to reserve the excess storm water.

(b) *The Artificial Drainage Problems*

Existing drainage facilities of Guwahati are not a adequate to carry all storm water from each of the localities. Hence, some more new drains could be constructed along the natural slope of the area. Moreover, existing drains can be renovated for easy flow of rainwater with provision of annual clearance.

As most of the roads, inside the city are very narrow, underground drains are desirable. These roads should not be utilised for drain-cum-footpath indiscriminately.

Existing manholes of drain-cum-footpaths are not adequate. More manholes and inlet holes are require for the quick disposal of silt and stagnated water. The size of the inlet holes and their position need to be re-oriented.

(c) *The Silting Problems*

The problem of silting is very serious, especially in high rainfall intensity areas, as it is related with the hill cutting and earth filling. Even, well-designed drainage systems may not cope up with the huge volume of silt load carried along with the runoff, unless some remedial measures are undertaken.

It is seen that clearing silt from the existing drains do not help as the high intensity of rainfall from surrounding hills with silt overflow towards the city dwellers. For this, deep drain may be constructed along foothills of all the hills located in and around Guwahati. Tunnel like drains should be constructed through Nilachal, Navagraha hills connecting drains of foothills to outlet it to the master drain Brahmaputra so that runoff with silt would be released immediately. Same way a few more 'silt traps' may be constructed important site along foothills of Sarania hills, Kalapahar, Narakasur, Fatasil, Sonaighul and Ramcha hills etc. These silt traps need to be cleaned after each storm. For this special labour force should be employed therein.

Before making any remedial measures for construction of drain, tunnel and silt traps, aerial photographs of two seasons of Greater Guwahati should be obtained. An aerial photograph covering water logging area of summer season and another aerial photograph of winter season should be obtained so that construction work could be aligned as per need in plan manner.

This work cannot be claimed to be all-pervading and complete in all aspects. There are ample scopes for further investigation in this field by experts. However, the contribution made through this humble work might be helpful in tackling this age-old problem.

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