CHAPTER 8

WATER RESOURCE OF THE BALASON BASIN

8.1 Introduction

The river Balason, originating from Lepchajagat at an elevation of 2416 m, flows through the district of Darjeeling, is noteworthy for its erosional and depositional hazards, causing occasional flood in its lower catchment. The discharge of the river at Matigara, varies from a negligible amount of 0.409 cumecs during the dry season (March – April) to a high of over 940 m^3/second during the rainy season (July-August). The mean annual sediment discharge is very high and it was estimated to be 87365 metric tons. The mean annual rainfall in the catchment area is 3359.81 mm, based on long-term average data of 22 rainfall recording stations situated within the catchment area.

The Balason basin is unable to hold back water due to excessive deforestation, overgrazing and extensive unscientific agricultural use of land in its catchment area. As a result, most of the precipitated water goes down the slope, giving rise to severe soil erosion and landslips.

The amount of load transported not only provides an indication of the rate of mechanical denudation in a basin, but also has wider implications for the economic management of the fluvial system. The river is incompetent to cope with the enormous amount of debris load that is transported to its lower course during the monsoon months (June-September). All these processes themselves generate certain responses within the river channel. Flooding is thus, the result of the continuous set of possible responses within the fluvial system.

On the other hand, during the non-monsoon months (November to April) negligible amount of water flows through the narrow braided channel and this paucity of water hinders the local people from reaping any benefit out of the soil in conjunction to the river itself. The overall economic situation has become very grim and is deteriorating day by day. Effective ways to control the situation are

necessary. Thus, there is a growing and perceived need for the assessment of water resource of the drainage basin and suggestion for its sustainable effective management.

The **aim** of this chapter is to assess the annual water resource of the basin, its seasonal distribution, its present utilization and conservation. The emphasis has been given on the estimation of the annual water resource of the basin on the following aspects:

- the study of rainfall and runoff,
- the study of evaporation,
- estimation of total water resource,
- the problems of the conservation of water resource.

8.2 Study of Rainfall - Runoff

Runoff is that balance of rain water which flows or runs over natural ground surface other than water losses by evaporation, interception and infiltration. Several empirical formulae, curves and tables relating to the rainfall and runoff have been developed, Khosla (1950); Ghatwar and Basu (1984); Ghatwar, 1986; Sarkar (1989 & 1998). However the present investigator has chosen the formula of Khosla (1950) due to its wide applicability in the Indian context. According to Khosla (1950), runoff is the function of precipitation and temperature i.e.

$$R = \propto P/T \quad \text{.....8.1}$$

where R = runoff, P = precipitation after the deduction of losses and T= temperature.

The common loss due to evaporation and transpiration, generally known as evapo-transpiration is the function of temperature of the area concerned. Thus Khosla's formula reads as follows:

$$R_m = \propto P_m/L_m \quad \text{.....8.2}$$

where R_m= monthly runoff, P_m =monthly precipitation and L_m = monthly evaporation.

Again the amount of monthly evaporation (L_m) is given as:

$$L_m = T_m{}^\circ C / 0.274 \quad \text{.....8.3}$$

For determining the loss by evaporation and the resultant runoff, following Khosla's formula, the average monthly rainfall data was collected from various recording stations, mainly tea gardens. As the temperature data was not available for all the stations, it was computed by interpolation and extrapolation methods. Distribution of average monthly rainfall and evaporation loss for some selected recording station were calculated. (appendix 8.1).

After carefully studying the calculated figures as well as the map, (figure 8.1) it is interesting to note that in the upper catchment areas as well as in the central hilly parts, some pre-monsoon rainstorms during March to May, yield a considerable amount of run-off. The tea gardens like Margaret's Hope, Gopaldhara, Dooteriah, Selimbong, Tumsong and Chamong record a higher amount of run-off as to the percentage of total annual rainfall during April and May, due to low temperature and low of evaporation loss.

The stations located just below the upper catchment i.e. in the central, south, eastern parts of the basin like Sungma, Manjwa, Pubong and Pankhabari show comparatively lower amount of runoff as percentage to the total rainfall in May. The entire foothills and plains display almost the similar higher trend regarding run-off as percentage to total rainfall e.g. Panighatta (68.68%), Longview (69.86%), Marionbari (67.63%) and Matigara (57.03%).

The amount of runoff as percentage to the total rainfall increases with the onset of the monsoon season and the month of June the runoff exceeds to over 70% in all the stations of the study area, with very high being recorded over Longview (87.65%), Sungma (84.34%), Nagri farm (82.42%), Selimbong (81.53%), Nagri (82.55%), Thurbo (82.75%), Balason (88.27%, Manjwa (86.25%, Panighatta (85.43%, Ambootia (88.54%), Chamong (84.18%), Marionbari (86.5%) and Matigara (82.9%). The amount increases with the establishment of the southwest

PRECIPITATION AND EVAPORATION LOSS OF SOME SELECTED STATIONS OF THE BALASON BASIN

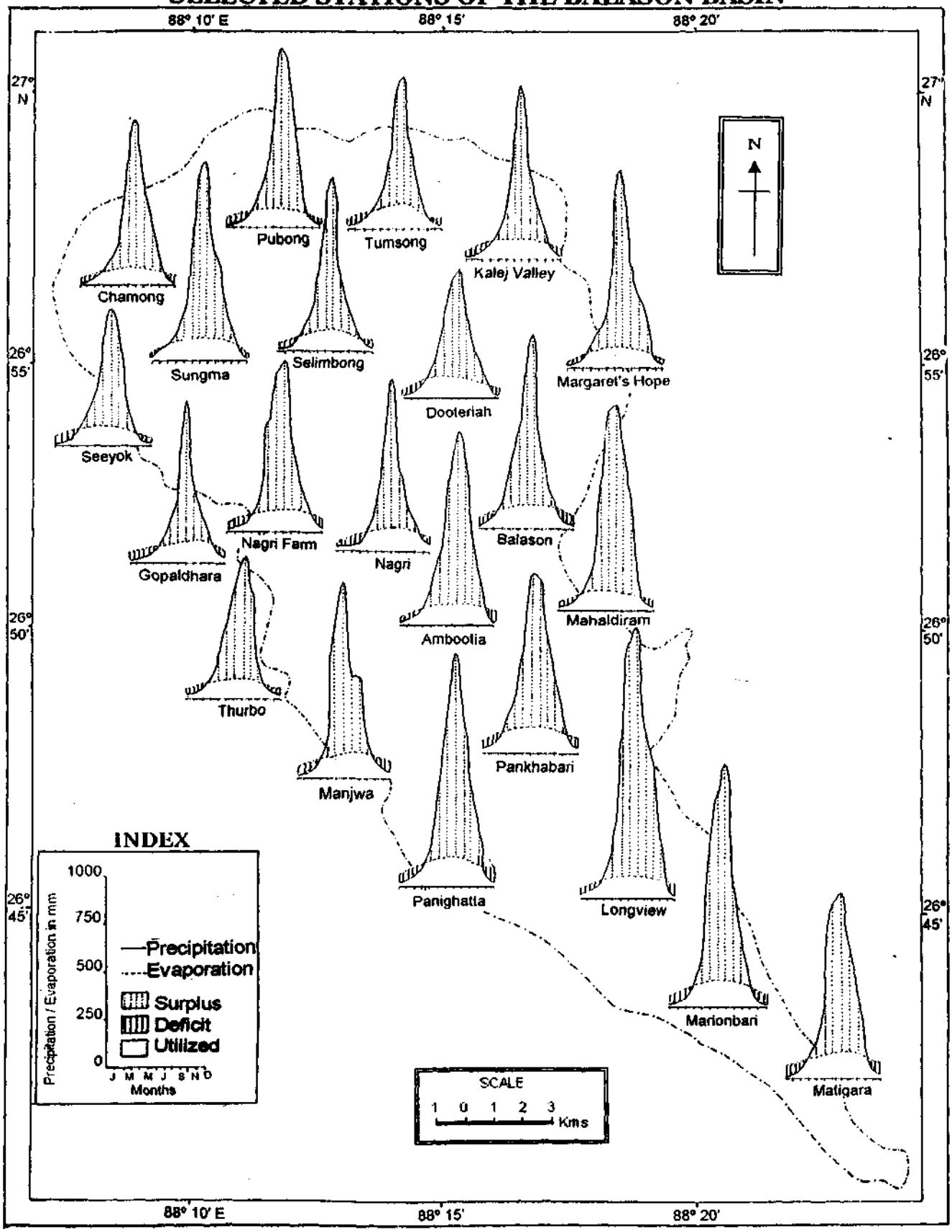


Figure 8.1.

monsoon to a remarkable extent and goes above 80% in all the stations during the month of July, which is the rainiest month in the study area.

Table 8.1

Mean annual rainfall in mm, temperature in °C, evaporation in mm and runoff in mm of selected stations in Balason basin*

Stations	Altitude in m.	Rainfall	Temperature	Evaporation loss	% of evaporation loss to rainfall	Runoff	Run off as % of rainfall
Ambootia	948	3922.51	20.27	1172.94	29.90	2749.57	70.10
Balasun	1127	2842.80	19.33	1118.66	39.35	1724.14	60.65
Chamong	1520	2961.80	16.52	955.74	32.27	2006.06	67.73
Dooteriah	1380	2597.80	18.74	1084.28	41.74	1513.52	58.26
Gopaldhara	1560	2324.70	16.23	938.75	40.38	1385.95	59.62
Kalej Valley	1400	2502.30	18.54	1072.52	42.86	1429.78	57.14
Longview	610	5116.50	21.29	1231.53	24.07	3884.97	75.93
Mahaldiram	1676	4060.00	15.58	895.52	22.06	3164.48	77.94
Manjwa	690	3430.30	20.77	1201.46	35.02	2228.84	64.98
Margret's Hope	1403	3009.10	18.54	1072.50	35.64	1936.60	64.36
Marionbari	249	4335.80	23.66	1368.80	31.57	2967.00	68.43
Matigara	121	3734.10	24.19	1399.09	37.47	2335.01	62.53
Nagri	1348	2631.70	18.64	1090.31	41.43	1541.39	58.57
Nagri farm	1342	2832.00	18.89	1092.86	38.59	1739.14	61.41
Panighatta	255	4018.40	22.38	1294.61	32.22	2723.79	67.78
Pankhabari	1030	3564.60	24.96	1239.25	34.77	2325.35	65.23
Pubong	1644	2848.90	15.68	907.29	31.85	1941.61	68.15
Seeyok	1520	2296.80	16.52	955.90	41.62	1340.90	58.38
Selimbong	1700	2440.70	15.24	881.49	36.12	1559.21	63.88
Sungma	1727	2589.40	15.06	871.60	33.66	1717.80	66.34
Thurbo	1451	2680.60	17.34	1003.37	37.43	1677.23	62.57
Tumsong	1533	2396.82	19.99	950.00	39.64	1446.82	60.36

*Data collected from tea gardens and other sources.

Such high trend of runoff as percentage to the rainfall exists upto the month of September. Runoff as percentage to precipitation starts to decrease from the month of October and reaches below 40% in most of the areas, e.g. Matigara (27.61%), Panighatta (24.57%), Pubong (27.16%), Balason (30.39%), Thurbo (5.61%), Pankhabari (22.54%), Sungma (5.01%), Seeyok (17.15%) during October. The lowest runoff during this month is however recorded over Nagri farm with the percentage amounting to 8.35% and at Nagri with just 0.29%. Such variation in runoff percentage is generally due to the uneven spatial distribution of monsoon rainfall.

The winter season (November to February) receives an insignificant amount of rainfall which cannot flow as runoff due to evaporation, transpiration and infiltration through the soil and due to this, during these months on an average only 0.41 cumecs discharge has been recorded in the river Balason during the year 1998 to 2001.

Table 8.2

Monsoon rainfall in mm, temperature (°C), evaporation (mm) and runoff (mm) of selected stations in Balason bBasin*

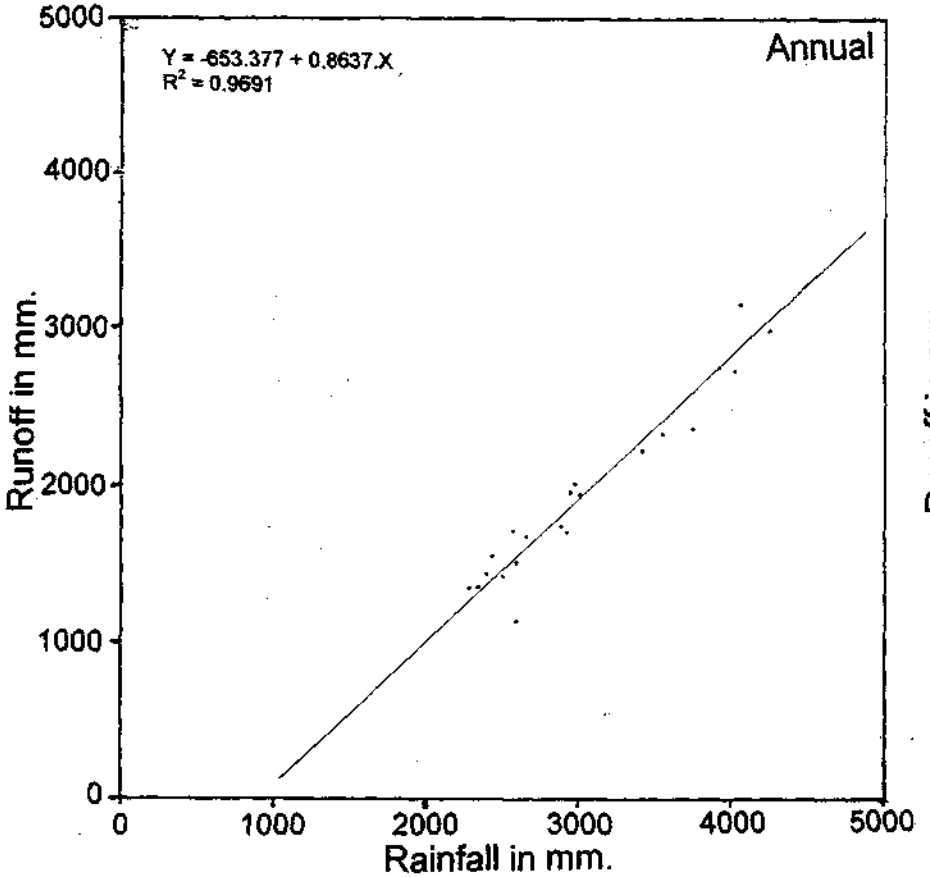
Recording stations	Altitude in m.	Rainfall	Temperature	Evaporation loss	Evaporation loss in % to rainfall	Runoff	Runoff as % of rainfall
Ambootia	948	3123.70	23.90	576.17	18.45	2547.53	81.55
Balasun	1127	2318.00	23.14	557.96	24.07	1760.04	75.93
Chamong	1520	2501.70	20.08	484.09	19.35	2017.61	80.65
Dooteriah	1380	2117.50	22.29	537.34	25.38	1580.16	74.62
Gopaldhara	1560	1968.40	19.78	476.81	24.22	1491.59	75.78
Kalej Valley	1400	2112.80	22.16	534.28	25.29	1578.52	74.71
Longview	610	4380.30	24.83	598.70	13.67	3781.60	86.33
Mahaldiram	1676	3817.08	18.84	545.08	14.28	3272.00	85.72
Manjwa	690	3020.00	24.31	586.17	19.41	2433.83	80.59
Margret's Hope	1403	2488.40	22.16	534.28	21.47	1954.12	78.53
Marionbari	249	3660.90	27.20	655.70	17.91	3005.20	82.09
Matigara	121	3245.60	27.70	667.03	20.55	2578.57	79.45
Nagri	1348	2242.4	22.50	542.48	24.19	1699.92	75.81
Nagri farm	1342	2407.20	22.54	543.45	22.58	1863.75	77.42
Panighatta	255	3386.70	25.94	625.36	18.47	2761.34	81.53
Pankhabari	1030	3114.60	25.01	602.94	19.36	2511.66	80.64
Pubong	1644	2513.70	19.23	463.70	18.45	2050.00	81.55
Seeyok	1520	1861.10	20.09	484.33	26.02	1376.77	73.98
Selimbong	1700	2077.70	18.67	450.19	21.67	1627.51	78.33
Sungma	1727	2313.90	18.50	445.94	19.27	1867.96	80.73
Thurbo	1451	2084.20	20.71	499.42	23.96	1584.78	76.04
Tumsong	1533	2023.87	19.99	482.12	23.82	1541.75	76.18

*Data collected from tea gardens and other sources.

8.2.1 Rainfall runoff correlation.

There is often a very close relationship between the rainfall and runoff. An effort has been make to analyse the nature of relationship between the rainfall and runoff for both annual and monsoonal through linear regression (figure 8.2). The

RAINFALL AND RUNOFF CORRELATION



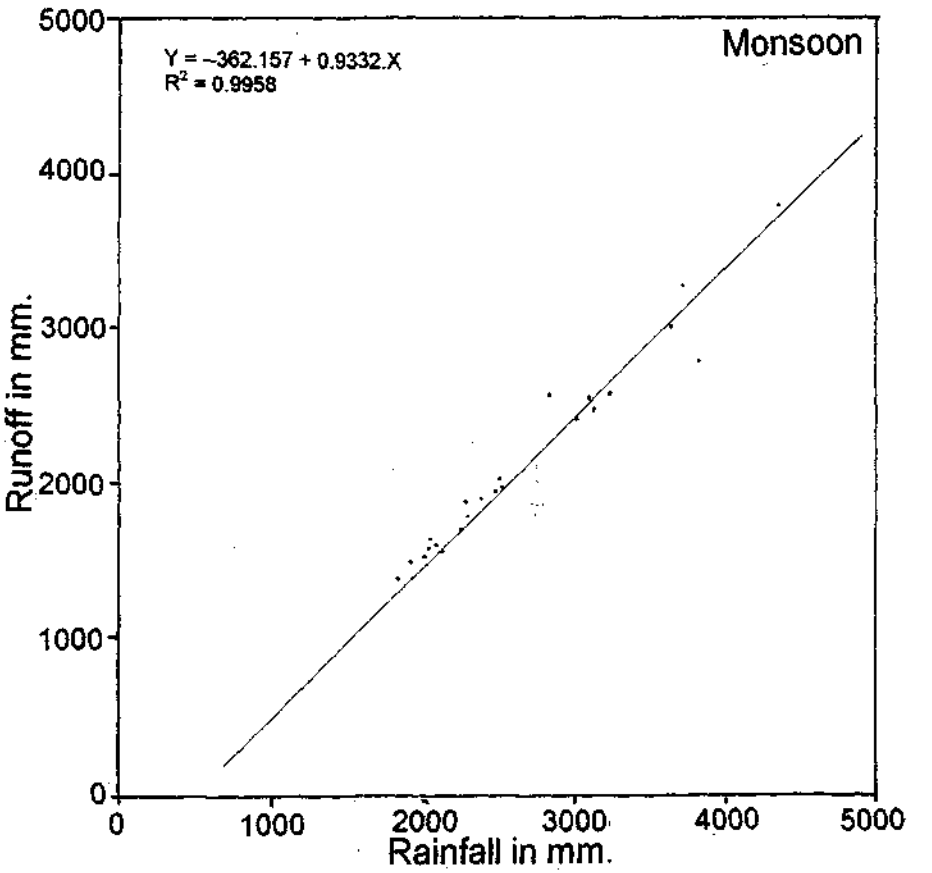


Figure 8.2

data required for such analysis has been obtained from 22 stations (table 8.1 & 8.2).

8.2.1.1 Annual rainfall-runoff correlation:

The correlation co-efficient between mean annual rainfall (X) and mean runoff (Y) is very high (r=0.9844) and have a 't' value of 25.0968 which is significant at the level of 99.9%. This indicates a very close relationship between these two attributes. The regression equation between the mean annual rainfall (X) and mean annual runoff (Y) is as follows:

$$Y = -653.377 + 0.8637\ x$$

In the above equation, the slope of the regression line (b = 0.8637) is of some value if comparison is to be made between this relationship and that which exists in other areas. Moreover, the coefficient of determination ($r^2 = 0.9691$) indicates that 96.91% of the total variation in Y has been explained by the respective X values and only 3.09 %.remain unexplained (table 8.1).

8.2.1.2 Monsoon rainfall runoff correlation:

The same situation is prevalent also in the relationship between mean monsoon rainfall (X) and the respective runoff (Y), where r = 0.9976. The linear regression equation in this case is:

$$Y = -362.157 + 0.9332\ x$$

Here the value 'b' or the slope of the regression line (i.e. 0.9332) is also important to make comparison between this and the other areas of established relationships. Moreover, the coefficient of determination ($r^2 = 0.9958$) shows that 99.58% of the total variation in Y has been explained by the respective X (table 8.2).

8.3 Study of Evaporation

Evaporation is another important factor in determining the surface runoff. An effort has been made to calculate the amount of monthly evaporation loss on the basis of the equation 8.3. A detailed station wise amount of evaporation loss has been tabulated (appendix 8.1.) and diagrammatically represented in the figure 8.1.

From the appendix 8.1. as well as from figure 8.1 it is seen that the foothills of the study area i.e. around Longview tea garden experiences minimum amount of evaporation loss (i.e.24.07% to the total annual rainfall). The highest amount of evaporation loss has been estimated in and around the north-western part of the basin that ranges from 40.38% to 42.86% to the annual rainfall. In the remaining stations the loss ranges between 30% to 40%. Though the region loses a considerable amount of valuable water through evaporation, this amount, on an average does not exceed 30% of the total amount of water received through rainfall.

In the monsoon period, although the trend is almost the same, the amount of monsoon evaporation loss in respect of total rainfall is low. The lowest amount of evaporation loss with respect to mean monsoon precipitation is noticed in and around the Longview area (13.67%), while the highest value of 25.38% is found around Dooteriah. On an average, the amount of monsoon evaporation does not exceed 20% of the total monsoon rainfall.

8.4 Estimation of Runoff of the Basin

The water resource of the Balason basin has been estimated in two different ways: (i) the empirical estimation of runoff based on long term average rainfall and temperature data of the catchment area (Khosla, 1950) and (ii) the estimation of runoff based on discharge data of 4 consecutive years (1998 - 2001) at Matigara (NH 31 bridge).

The empirical estimation of the runoff for the basin has been determined for both the rainy months and for the whole year. These two estimates will provide us with the basic information about the long term average available surface water resource of the study area. Although it is possible to estimate the runoff of the basin from the discharge data recorded near Matigara, but these do not seem to be enough for the purpose of water conservation plan of the study area. In fact, the water resource of a basin cannot be determined only from the discharge data because, water inputs through precipitation are exchanged through a complex 'process – response' system.

8.4.1 The mean monsoon (June to October) runoff:

Based on the calculated value of the total monsoon runoff of different recording stations (table 8.2), a monsoon runoff map has been prepared (figure 8.3.). Six major runoff classes have been identified and the corresponding area coverage of each class has been determined and tabulated in table 8.3. The estimated water resource of each class has been estimated by multiplying the area with respective mean runoff. The total water resource has been estimated by summing up all the calculated values, which is 8,53,421 million cubic metre.

Table 8.3

Monsoon (June - September) Runoff of the Balason basin

Sl. No.	Runoff classes (in mm)	Area in sq. km.	% of area to the total area	Estimated runoff in million m^3	% to total run off.
1	Below 1500	41.20	11.21	51.500	6.03
2.	1500-2000	109.22	29.73	191.135	22.4
3	2000-2500	54.70	14.89	123.075	14.42
4	2500-3000	103.46	28.16	284.515	33.34
5	3000-3500	34.91	9.50	113.458	13.29
6	3000 and above	23.93	6.51	89.738	10.52
	Total	367.42	100	853.421	100

Among the monsoon runoff classes 2500 – 3000 mm runoff class contributes the maximum monsoon water resource of the basin i.e., 284.515 $m.m^3$ (33.34 %) which covers an area of 103.46 sq. km. (28.16 %) of the total area of the basin identified along the entire south central part of the study area.

On the other hand, the lowest runoff class i.e. (<1500 mm), accounts for only 51.50 mm^3 (6.03 %) of the total water resource covering an area of 41.20 sq. km. (11.21 % of the total study area) identified in the extreme north eastern and north western part of the basin. The very high run-off class of above 3000 mm, covers the lowest area of 23.93 sq. km. (6.51 % of the total study area) and contributes 89.738 mm^3 (10.52 %) of the water resource of the basin, identified in the east central part of the study area i.e. southern slope of the Selim Hill..

The monsoon runoff of the Balason basin, as estimated by empirical methods, seems to be higher than other part of the country. It is most probably due to a very

MONSOON RUNOFF OF THE BALASON BASIN

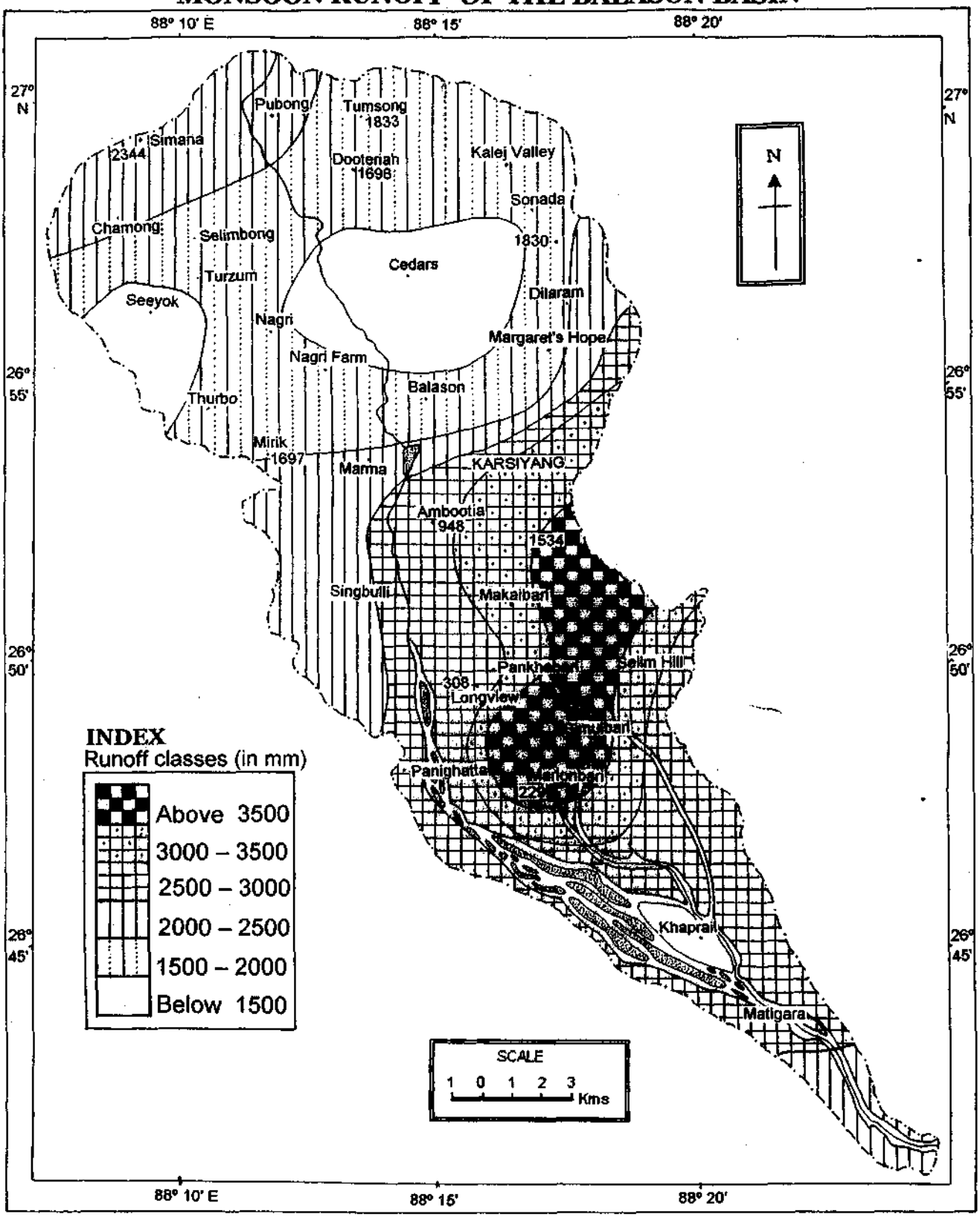


Figure 8.3

high amount of rainfall on a deforested steep slope, which permits quick runoff generation and minimum infiltration and / or retention within the catchment area.

8.4.2 The total water resource

The nature and amount of annual runoff of the basin has been estimated from the figure 8.4 which was drawn on the basis of the collected data from 22 .recording stations (table 8.4). Six classes have been identified to calculate the total annual runoff of the basin and the contribution of each class to the total annual water resource.

Table 8.4.
Mean annual water resource of the Balason basin.

Sl. No.	Runoff classes (in mm)	Area in sq. km.	% of area to the total area	Total runoff in million m^3	% to total water run off.
1	Below 1500	66.57	18.12	83.21	10.59
2	1500-2000	112.45	30.61	196.79	25.04
3	2000-2500	71.79	19.54	161.53	20.55
4	2500-3000	78.27	21.30	215.24	27.38
5	3000-3500	28.08	7.64	91.26	11.61
6	3500 and above	10.26	2.79	37.96	4.83
	Total	367.42	100	785.99	100

Out of the total annual surface water resource of the basin (785.99 $m.m^3$), the runoff class 2500-3000 mm contributes to the highest amount i.e., 215.243 $m.m^3$ or 27.38 % of the total. The highest area falls in the 1500-2000 mm runoff class, covering 112.45 sq. km. and contributing to 196.788 (25.04 %) million m^3, which is 25.04 % of the total. The very high runoff class (above 3500 mm) covers only 2.79 % of the total area and contributes about 4.83 % of the total annual water resource of the basin. The very low runoff class (< 1500 mm) shares 66.57 % of the total area but contributes only 10.59 % of the total runoff. The total annual runoff of the basin has been estimated to be 67.477 $m.m^3$ less than that of the monsoon runoff which indicates that the non-monsoon rainfall have negative influence on run-off.

8.4.3. Estimation of run-off from the discharge record at Matigara

The estimation of runoff has also been carried out based on the daily average discharge data of the river at Matigara for 4 consecutive years (1998 - 2001). The

ANNUAL RUNOFF OF THE BALASON BASIN

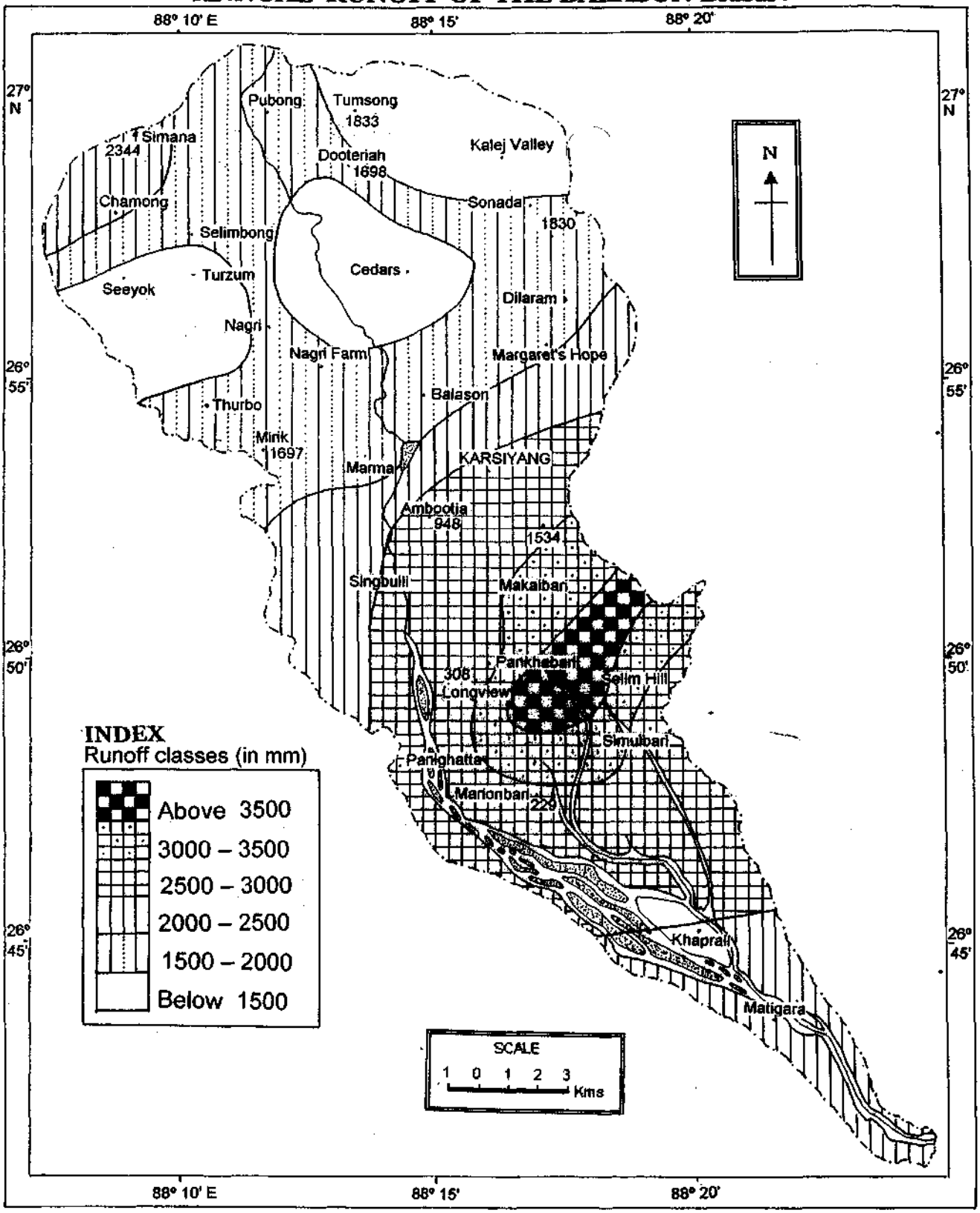


Figure 8.4

total annual runoff has been calculated using the equation 8.4 and based on the data tabulated in table 8.5.

$$Tr = Td \times 86400 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8.4$$

where, Tr = total annual runoff, Td = daily average discharge in cubic meter / second.

Table 8.5.

Runoff of different years based on discharge run-off model.*

Year	Annual water resource (million m^3		Monsoon water resource m^3 million m		Non-monsoon water resource in million m^3	
	Total	per Km^2	Total	per Km^2	Total	per Km^2
1998	1343.715	3.66	1263.126	3.44	80.589	0.22
1999	671.068	1.83	592.549	1.61	78.519	0.21
2000	849.692	2.31	722.214	1.97	127.478	0.35
2001	655.077	1.78	587.589	1.60	67.488	0.18
Average	879.89	2.39	791.369	2.15	88.519	0.24

*Based on data compiled from CWC records.

8.5. Estimation of Surface Water Resource of the Balason Basin

The estimation of water resource of the Balason basin has been attempted based on (a) long term mean rainfall of the basin using empirical model and (b) estimation of daily discharge record of the river at down stream near Matigara. The Table 8.6 depicts the salient feature of surface water resource of the basin and also offer an unique opportunity to make a comparative analysis of different estimates of surface water resource of the study area.

Table 8.6
Surface water resource of the Balason basin

Methods	Mean annual		Mean of monsoon months (June to September)		Mean of non monsoon months (October to May)	
	Total	Per km^2	Total	Per km^2	Total	Per km^2
30-60 years average*	785.994	2.139	853.421	2.323	- 67.427	-0.184
Based on discharge (1998 ~ 2001)	879.89	2.39	791.369	2.15	88.519	0.24
Range	93.896	0.251	-62.052	-0.173	155.946	0.424
Mean	832.942	2.265	822.395	2.2365	10.546	0.028

*Long term water resource based on empirical formula.

From the estimated values it is noticed that the total annual water resource in the year 1998 was 1343.715 million m^3 out of which 1263.126 million m^3 belongs to monsoon period. In 1999, the total annual water resource was estimated to be 671.068 million m^3 of which 592.549 million m^3 belongs to the monsoon period.

In the years 2000 and 2001 the annual water resource was estimated to be 849.692 million m^3 and 655.077 million m^3 respectively, while in the monsoon the amount were estimated to be 722.214 million m^3 and 587.589 million m^3 respectively.

It is interesting to note that the long term average estimates of water resource is considerably less than that of the 4 years (1998 – 2001) mean discharge of the river. In case of non-monsoon months, the empirical model yields a negative value of - 67.427 while, the estimation based on discharge shows a value of 88.519 $m.m^3$. Such difference may be due to the following reasons:

i). The empirical estimation of the water resource of the basin has been carried out on the basis of rainfall and temperature data of some selected stations and thereby, they are reliable for their respective stations only, while the actual estimation has been based on the daily average discharge of the river Balason near Matigara, for the 4 consecutive years (1998 to 2001).

ii). Subterranean water flows as springs (locally known as 'jhora') even in the non-monsoon months contribute considerable runoff and this may account for the positive value of 88.519 million m^3 during non – monsoon months.

iii). The recharge of water through sewage disposal may also play an important role in the overall estimation of surface water resource.

8.6. Conclusion

The high intensity rainfall on steep degraded slopes of the Balason basin of lower Darjeeling Himalaya causes high runoff and thereby, less amount of water becomes available to saturate soil and recharge aquifers, inducing phenomenal degradation along the hill slopes. While, moderately dense forest cover along the foothills reduces the run-off as well as the soil erosion and keeps some water available to form good ground water reserve.

Out of the total surface water yield of 832.942 $m.m^3$ (mean of empirical and discharge method), nothing has yet been utilized commercially. Similarly, its vast

sub-surface water reserve remains commercially untapped. It is thus, imperative to find out suitable ways and means to conserve such huge unutilized water resource both surface and sub-surface.

The construction of a number of check-dams across the river at suitable sites to preserve the monsoon supply for re-distribution during the non-monsoon months would serve the immediate purpose adequately. Construction of mini-hydel projects, tapping the mountain torrents at suitable sites, such as Rinchintong Khola, may provide with the vital energy for domestic and industrial activities in the sub-Himalayan West Bengal. Such a comprehensive approach would require taking more than a theoretical interest in the protection of forest resource and needing serious involvement in the task of soil and water conservation measures in the catchment area.

Hence the problem of water management of the region under study by their very nature, are not such as can be tackled by any single discipline. All disciplines concerned with good land and water management should be brought together. This systematic approach to water management should be brought together for the maximization of regional welfare.

References

Ghatwar,L and Basu, S.R. 1984 ; The Lish - Gish basin – a study of its water resources. *Indian Journal of Power and River Valley Development,* February, 1984 : 50-54.

Ghatwar L. 1986; A study of fluvial dynamics of the twin basins of the river Lish and Gish : *Unpublished Ph.D. Thesis*, University of North Bengal.

Khosla, A.N. 1950 ; The Water Resources : Analysis and utilization of data. *Indian Service of Engineering* (Duplicated).

Sarkar S., 1989 ; A Geo-environmental appraisal of the Upper Mahananda Basin of the Darjeeling Himalaya, West Bengal. *Unpublished Ph.D. Thesis,* University of North Bengal, 37-159.

Sarkar, S. 1998 ; The water resource of the Upper Mahananda basin : Problems & Prospects; *National Geographical Journal of India,* Vol. 44 Z(1-4) p. 105-112.