July 1979—Flash Flood in the Luni

A Case Study

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FOREWORD

In the context of development and management of water resources in arid Rajasthan, Luni Basin forms a promising area to work upon. Recurrence of floods with attendant wasteful flow of precious water helps to focus our attention only too strongly. Amongst these the July 1979 flash flood was of an unprecedented nature. In course of this, thousands of hectares of prosperous agricutural land together with irrigation infrastructure along the Luni and its tributaries like Mitri-Jojri, Guhiya, Reria and Bandi were severely damaged. Losses on this account together with those on other property and public utility services are estimated by the State administration at well over Rs. 100 crores. Loss of precious human and animal life is besides.

The initiation of the Luni Basin programme coincides with the July 1979 floods. The CAZRI had started investigations including installation of rain guages and stream gauging stations during summer 1979. The flood episode gave further impetus to intensify the scientific studies and data collection besides the information for proper management and utilization of water resources of the basin. I am glad that the scientists of the CAZRI were able to generate considerable data. I congratulate Dr. R. P. Dhir and other scientists associated with this study for their dedicated efforts in collection of data and bringing it out in its present form as a bulletin. Some of the material in this report was found very useful by various central and state agencies including the Central Team which visited Rajasthan in August 1979 to assess the situation and finalise their report for flood relief work. On the recommendation of the Central Team studies on ecological aspects and on cost of reclamation of lands damaged by floods were initiated and results of the same have been incorporated in this bulletin.

Besides serving as a record of the flood, I hope the material in this bulletin will be of interest to various agencies and individuals concerned with the development of the natural resources of Western Rajasthan, particularly the Luni Basin.

22 December 1979.

H. S. MANN
DIRECTOR

PREFACE

As part of the integrated resource survey of the Upper Luni and water balance study of the Luni Basin programme, a net work of rainfall and stream gauging equipment was timely installed and the man-power also engaged to record observation during the ensuing monsoon season. The observation set-up was of a capacity to meet the normally expected situation with some allowance to cope up with the abnormalities. However, even this turned out to be not fully adequate to meet the magnitude of the flash flood that occurred. Coupled with this was the difficulty in communication and access. Notwithstanding this, the observers and the supervisory staff could obtain a set of satisfactory hydrological data of this unprecedented flood. However, as the very first intimate contact showed, this flood was not a mere hydrological event. It was much more than this seeing to the loss of human and animal life, ruined settlements, destroyed irrigation wells and productive farm lands turned into wilderness. Initially, our effort was just to observe what had happened. But later in response to specific requirement of various agencies, a series of special investigations were taken up. We had no proven methodology for collection of data on topics like ecological study of the flood to guide us in our endeavour. The team of various subject-matter specialists got together to develop an approach based on its experience on natural resource survey and management. In view of this the reader of this publication may have a number of useful suggestions to give and these will be received by the authors of this publication gratefully.

Heartfelt thanks are due to Dr. H. S. Mann. Director, for his keen interest and advice in the conduct of this study. We are grateful to him and to Dr. K. A. Shankarnarayan, Head of Division of Basic Resources Studies for going through the manuscript and making many a useful suggestions for its improvement. Help rendered by Shri J. S. Choudhari, S-1 (Soil Sci.), A. K. Kalla, T-3 (Hydro.), Ganga Singh, T-3 (Hydro.), V. C. Issac, T-4 (Hydro.), Bhasha Ram, T-3 (Plant Eco.), Vijendra Kumar, T-1 (Photo), P. Joshi, D. M (Carto), S. S. Dave. D. M. (Hydro.), Rameshwar Lal, Sr Steno are thankfully acknowledged.

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Normally, Luni is a lifeless river and any flow of water worth the name becomes a much talked about news. This year the picture appeared no different and in fact people living in the Luni River catchment together with those in the rest of the Western Rajasthan were keenly looking forward to a mere break of the monsoon. There was even an element of desperation since unlike the normal onset of rain towards end of June or first week of July, there was not a patch of cloud even towords mid of July. Then came the welcome news of monsoon having moved into the north eastern part of arid Rajasthan on 14th July. This gave relief giving showers to a sizeable part of the thirsty lands. Thereafter from 11.00 P.M. of Sunday, the 15th of July, started a 70 to 80 hour spell of an almost continuous torrential rain that at times reached the proportion of a virtual down pour. Many places received in just 24 hours an amount of rain which was close to the mean annual rainfall for whole of the year. The total rainfall of 700 to 850 mm that a number of stations got in just 5 days has surpassed all previous records in the area affected. The down pour was confined to major part of Upper Luni basin only and therefore the massive run-off got quickly concentrated into the streams to give a most unusual fury to the river.

In Mitri-Jojri, one of the tributaries of Luni, the water level at Pipar at 9.00 A. M. on the 16th July was only 25-30 cm and in another couple of hours it rose to 500 cm mark. *In Luni proper at Bhavi, the water level rose from 75 cm to 400 cm in just five hours, and* in Bandi river at Jetpur from 60 cm to 392 cm in six hours. The ultimate flood level attained by the streams has also been a record. The railway bridge over the Luni near Luni Jn. has the highest flood mark at 179.52 m above mean sea level recorded in the year 1944. This is 3.35 m above the base level. *This year the flood level rose to nearly 2 metres above the previous highest.* The flood water level would have risen even higher but for the fact that a side of the bridge gave way to release pressure on the bridge. This shows the enormity of the flow.

The magnitude of flood and the speed with which it happened was far beyond the imagination of the people. Even the older generation of people had no experience of such a phenomenon. And so hardly any one could foresee what was to happen, leave apart making contingent arrangements for the same. So it was only when they saw water rising everywhere that people made efforts to save themselves and their movable belongings. But in many situations it was already too late. This explains the unheard-off loss of the precious human and animal lives. Nearly 350 people lost their lives and 119 were declared missing. Over a lac of livestock perished.

Besides above, a colossal damage has taken place to dwellings, agricultural lands, irrigation infrastructure, standing crops, means of communication, power supply and other public property. The total damage as per the State Government report is estimated at over Rs. 100 crore.

JULY 1979, FLASH FLOOD IN THE LUNI

The following section gives a description of the wet spell that caused the flood and an account of the flood event in respect of peak discharge and volume of flow in the Luni and its tributaries. The particular wet spell was confined to the south-eastern part of the Western Rajasthan i.e. the whole of the Luni Basin and some area further north comprising Nagaur. However, Barmer, Jaisalmer, Bikaner as well as the Sikar-Churu area received little rain during the period. Within this, the area of maximum concentration (over 400 mm rainfall) was restricted to a much smaller area of about 14550 km^2 (see fig. 1) identified by Ajmer in the east, Jodhpur in the west and roughly Pali in the south. *This area of concentration of wet spell almost coincided with the* Upper Luni basin.

Description of the rainfall spell

The intense spell of rainfall started on 15th July and continued up to 19th July 1979. Fortunately, the CAZRI had installed nearly 241 rain-gauge stations in an area of 33,000 km^2 under its Luni Basin survey programme. Data from most of these stations located in the area of maximum concentration i. e. Upper Luni Basin and some selected spots in the rest of the Luni Basin including some IMD stations are given in Table 1. These show that even on the day of start i.e. 15th July quite a few stations received 150 to over 250 mm rainfall. The wettest days, however, were 16th and 17th when almost all the stations in the Upper Luni recorded this amount of rain. Kosana (near Pipar) and Borunda are reported to have received respectively 507 and 415 mm in a single day i.e. on 17-7-79. On 18th and 19th the number of stations getting heavy rainfall progressively declined. *Total rainfall of the spell record at various stations in Upper Luni ranged between 400 to over*

Table 1 : Daily rainfall (mm) at different stations in Upper Luni Basin duing the July, 1979, wet spell

Name of station	Dates					Total
	15	16	17	18	19	
1. Nand	—	190.5	130.0	10.0	190.5	521.0
2. Nagelao	—	187.5	162.5	42.5	175.0	567.5
3. Banseli	12.7	177.8	66.0	12.7	134.6	403.8
4. Lotiana	12.5	150.0	60.5	61.3	107.5	391.8
5. Shyamgarh	38.1	50.8	38.1	38.1	111.7	276.8
6. Dhundra	28.4	221.0	134.6	60.6	—	444.6
7. Mogra	58.8	157.5	150.0	50.0	—	416.3
8. Olwi	171.3	197.5	183.0	31.3	—	583.1
9. Bhavi	25.0	150.0	200.8	175.0	118.8	583.1
10. Khejarla	15.3	78.8	214.3	112.3	43.3	464.0
11. Udliawas	20.0	190.0	160.0	210.0	30.0	610.0
12. Kosana	12.5	103.0	507.6	50.0	100,0	773.1
13. Bhanwari	101.0	215.9	157.5	55.9	—	530.9
14. Gundoj	159.0	235.0	165.0	63.0	—	622.0
15. Sonei Lakha	—	150.0	150.0	200.0	100.0	600.0
16. Bhakriwala	12.5	206.3	200.0	87.5	25.0	531.3
17. Jetpur	155.0	220.0	150.0	82.8	—	607.8

18.	Nimbol	50.0	175.0	300.0	200.0	112.6	837.5
19.	Gorawar	262.5	212.5	225.0	150.0	75.0	925.0
20.	Nimaj	65.0	225.0	227.5	156.3	121.3	795.1
21.	Borunda	34.5	210.0	414.8	67.4	99.8	826.5
22.	Bilara	28.0	336.0	282.0	180.0	27.0	773.0
23.	Pali	9.0	136.0	155.0	150.0	64.5	514.5
24.	Jodhpur	4.2	222.8	148.2	146.4	120.6	642.2
25.	Jalore, C. L.*	—	22.3	80.5	62.6	8.2	173.6
26.	Bithia C. L.	133.4	146.1	101.6	12.7	—	393.8
27.	Bisalpur C. L.	56.3	125.0	93.8	12.5	—	287.6
28.	Kusib C. L.	4.5	19.5	50.0	20.1	16.3	110.4
29.	Sindri L. L.**	—	25.0	68.8	—	—	93.5
30.	Ronodar L. L.	18.0	36.3	3.8	—	—	58.1
31.	Bhakarpura L. L.	18.8	58.8	35.0	3.8	—	116.4

*Central Luni Basin, **Lower Luni Basin.

900 mm which is one to two times the mean rainfall received during a whole year. What is more the individual days were characterised by exceptionally heavy rain of 150 to 250 mm each day. An isohyetal map based on the data from various rain-gauge stations is given in fig. 2.

Looking to the arid zone setting the total amount of rainfall received during a span of just five days is extraordinary. Fortunately, past data is available for quite a few stations located in the area. A comparative statement is given in Table 2. This clearly shows that the rainfall received in the July, 79 spell has been well above the previous highest. For example the maximum rainfall of a spell in Bilara was 545.6 mm received over 13 days in the year 1908. This year in just five days, it received 773 mm. *This speaks volumes for the unprecedented character of this year's wet spell for the area concerned.*

Table 2 : Rainfall of July, 1979, wet spell in comparison to the previous highest spell

Station	Present spell of rainfall (mm)	Previous highest spell (mm.)	Remarks
Bilara	773	545.6 (13 days) 1908	Record
Borunda	843	374.7 (7 days) August 1976	Record
Pali	514.5	492.9 (9 days) August 1944	Record
Ajmer	432	373.6 (6 days) Sept. 1944	-do-
Jodhpur	442	450.6 (9 days) Aug. 1944	—

Though the rainfall has been a record for this part of the Luni Basin, the phenomenon is not unusual for the Basin as a whole since there have been many occasions in the past when some or the other part has witnessed such spells. For instance Pindwara received a rainfall of 476 mm in one day i.e. on 31-8-73. Erinpura received a rainfall of 350 mm each day on two consecutive days in 1973, and Bali recorded a total of 583 mm in four days in that year. Likewise Sanchor recorded a rainfall of 693 mm in 5 days and Desuri 660 mm in 8 days in the year 1952. Desuri had 475 mm in five days also in August 1944. Kharchi received 356 mm in a two days spell in the year 1926.

An account of July 1979, flash flood

The area that experienced current down-pour almost coincided with the upper catchment of the Luni basin. Torrential character of rainfall, moderate intake rate of catchment soils (contrary to the highly permeable soils of the rest of the Western Rajasthan), gentle slopes, part of which has hilly topography, and existence of a well organised drainage system—all combined for a quick concentration of water into the streams. The tributaries of the Luni which came into severe flood were the Mitri-Jojri, Guhiya, Reria and Bandi (fig. 3). This together with the flood flow in the Upper Luni created an unprecedented flood situation all along the course of the Luni river right up to it's exit in the Rann of Kutch. The wave of flood travelled very fast. Whereas the peak flood level in the Upper reaches occurred on 16th, the same happened in Lower Luni on the evening of 18th to early morning of 19th July. An account of the flood in the Luni and some of its tributaries is as follows:—

Mitri-Jojri: On 16th July, at gauging point Bisalpur, the river was flowing at 70 cm. It gradually rose to 1.89 m at 4.00 P.M. and shot up to 3.77 m by 5.00 P.M. This rapid rise continued whole evening to reach a peak level of 5.66 m by midnight. This level stayed for about 3 hours and then started declining at a fairly uniform rate of 5 to 8 cm/hour to come down to a level of 1.89 m in the early hours of 20th. In the upper reaches the rate of rise was even faster.

Bandi: The river at Jetpur, a point about 3 km upstream of its confluence with the Luni was flowing at a level of 70 cm at 4.30 A.M on the 16th July. In six hours it rose to a peak level of 3.92 m. It flowed around this level for 3 hours and then started declining gradually to a level of 1.0 m at 5.30 A.M. on the 20th.

Luni: The Samdari gauging station on the Luni river is located in the Middle Luni sector. Up to 8.00 A. M. on 17th July there was no flow in the river. But in just one hour it rose to 1.35 m. Thereafter the level went on rising with only slight fluctuations of rate to 4.6 m by 12 noon of the 18th--thus giving a mean rise of 17 cm per hour. A very rapid rise indeed. The river remained at this level for a couple of hours and then declined sharply to 3.4 m by 9.0 A.M. on 19th. Thereafter the rate of decline was gradual to reach a level of 1 m on the afternoon of 22nd. Further downstream at Gandav, a point 50 km upstream before the Luni debouches into the Rann, the picture was the same. Only the initial wave of flood waters reached here 24 hours later.

Volume of flow and peak discharge: Hydrographs showing stream discharge against time for some of the streams is given in figs. 4 and 5.

Total volume of flow, peak discharge and H.F.L. of the various streams is given in Table 3. It is clear from this Table that major contribution to the total flood water came from Mitri-Jojri, the Upper Luni, Reria-Guhiya, and Bandi. Contribution from Sukri, Jawai and many other streams south of Bandi was very small to negligible. The proportion of rainfall water which ran-off into the streams varied considerably in different

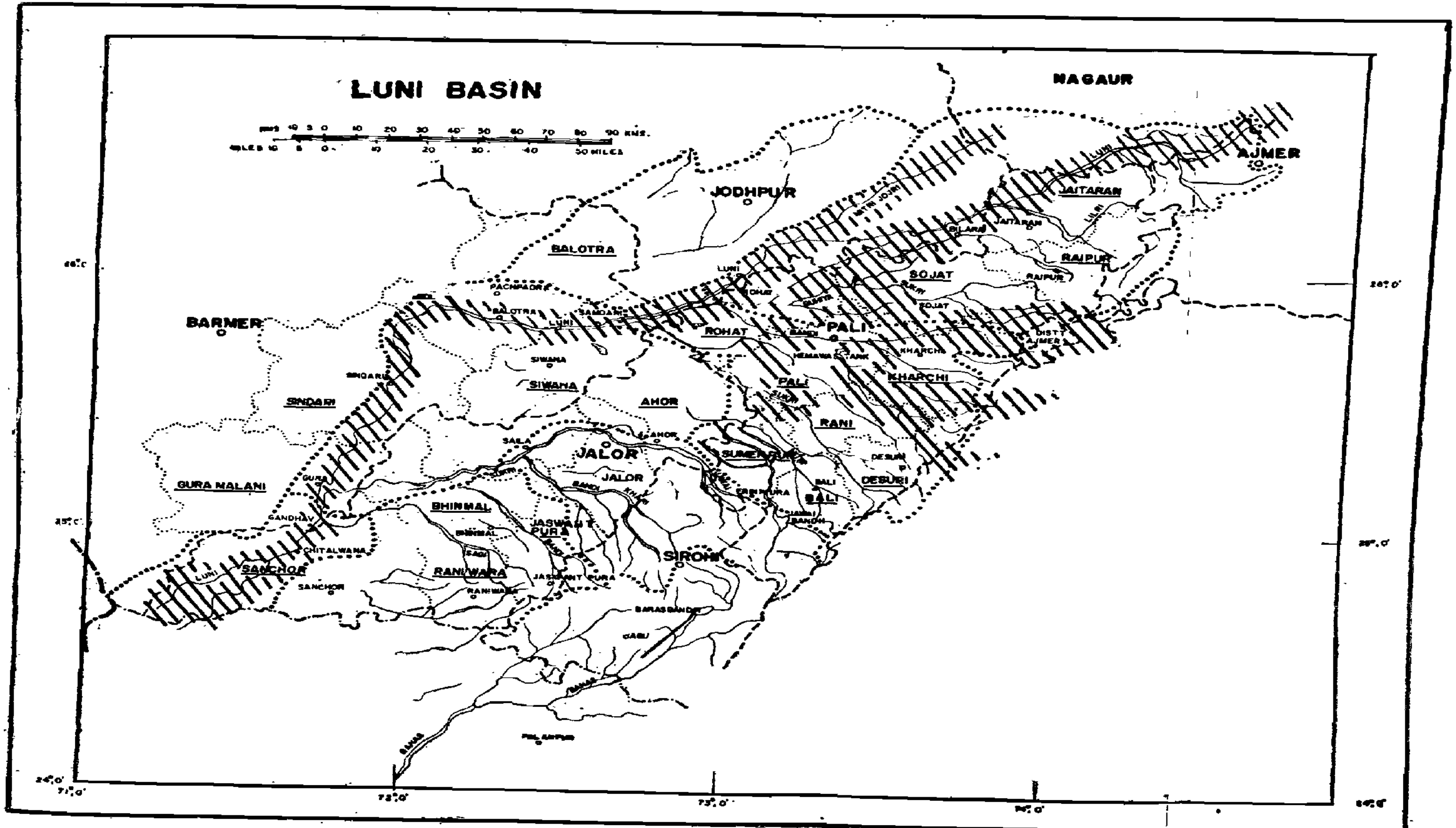

Fig. 3 The streams that came in flood.

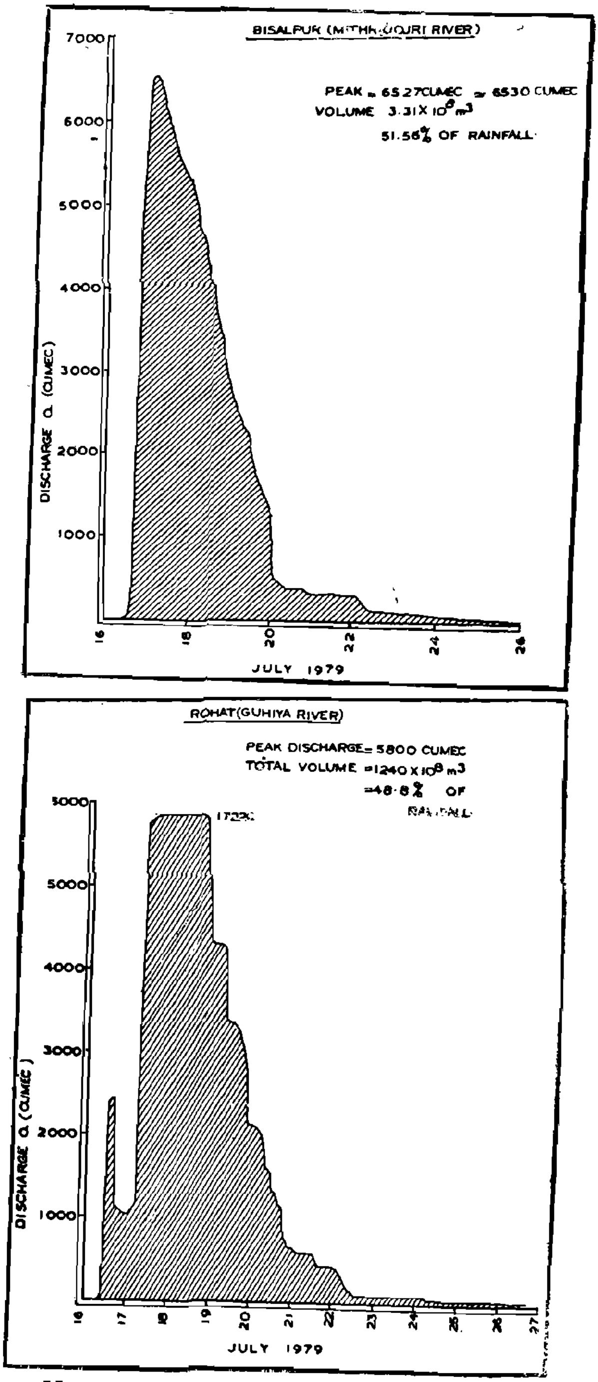

Fig. 4 : Hydrographs of the streams for the flood period; (a) Mitri—Jojri at Bisalpur, (b) Guhjya at Rohat.

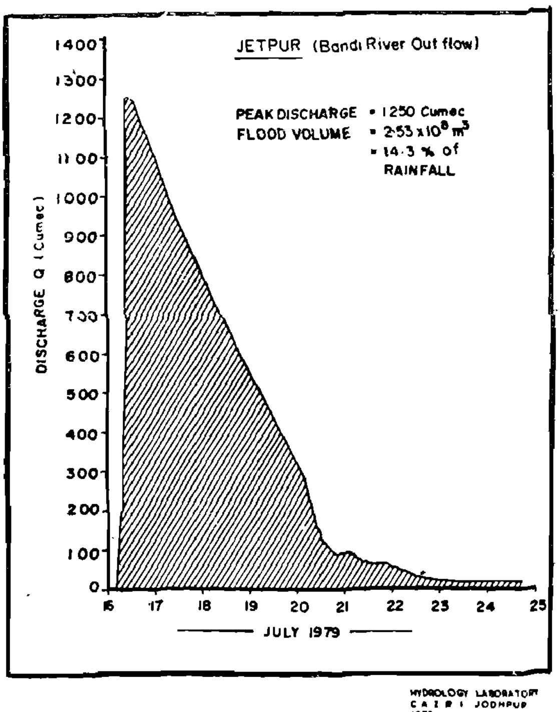

Fig. 4 (*Contd.*) (c) Bandi at Jetpur.

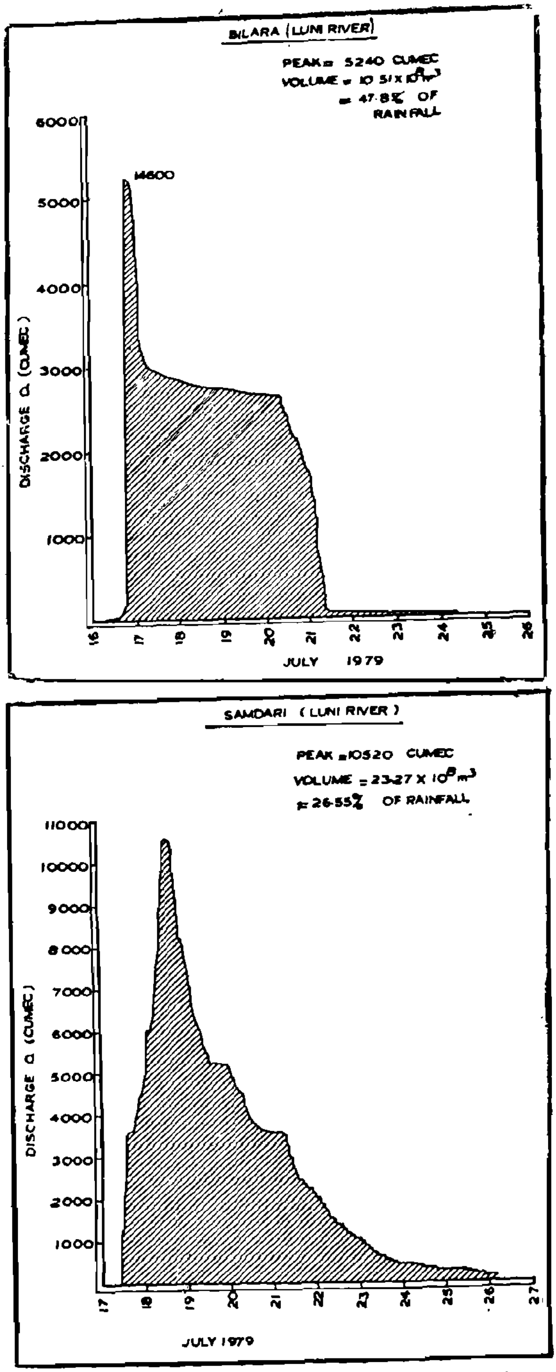

Fig. 5 : Hydrographs of the Luni proper for the flood period; (a) at Bilara, (b) at Samdari.

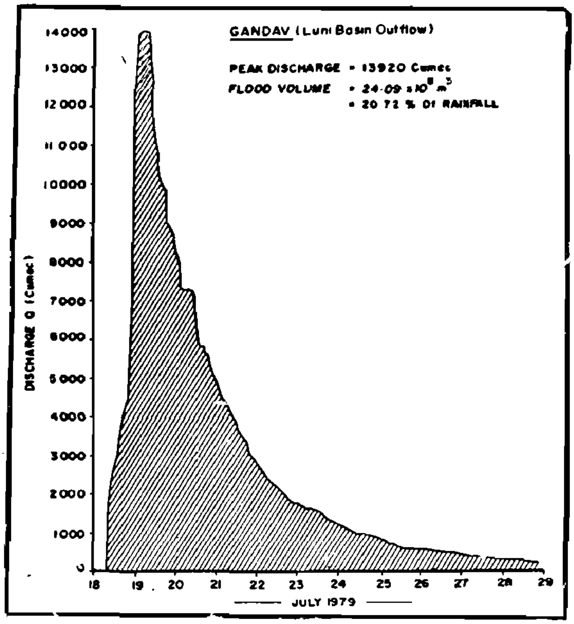

Fig. 5 (*Contd.*) (c) Gandav (Basin out flow).

Table 3 : Peak discharge and volume of flow of Luni and its tributaries

S. No.	Station	River	Location	H.F.L. (m.)	Peak discharge (cu. m.)	Total flood volume (cu.m.)	Remarks
1.	Bisalpur	Mitri/ Jojri	Lower 1/3 length	6.60	6527	3.31×10^8	In flood
2.	Jasnagar	Luni	Upper 1/3	1.52	1303	1.60×10^8	—do—
3.	Bhavi	—do—	—do—	4.00	5240	10.51×10^8	—do—
4.	Samdari	—do—	Middle	4.60	10520	28.27×10^8	—do—
5.	Gandav	—do—	Lower	4.49	13920	24.09×10^8	—do—
6.	Rohat	Gunhiya	Lower	4.00	5800	12.04×10^8	—do—
7.	Jetpur	Bandi	Lower	3.92	1250	2.53×10^8	—do—
8.	Rani	Sukri	Upper	0.50	89.5	9.49×10^6	Not in flood
9.	Sanderao	Mitri	Middle	2.45	81.5	$9{\cdot}28 \times 10^6$	—do—
10.	Nawakhera	Jawai	Lower	2.00	187.5	12.56×10^6	—do—
11.	Komta	Khari	Lower	0.15	21.5	0.79×10^6	—do—
12.	Madgaon	Bandi Khari	Lower	0.87	172.5	7.35×10^6	—do—
13.	Sewari	Sagi	Lower	0.52	95.2	0.75×10^6	—do—

sub-catchments as can be seen from data below:

Stream	Gauging piont	Runoff as per cent of rainfall received above the gauging station
Mitri-Jojri	Bisalpur	51.6
Guhiya	Rohat	48.8
Bandi	Jetpur	14.3
Luni	Bhavi	47.8
,,	Samdari	26.6
,,	Gandav	20.7

The volume of run-off that concentrated into the stream courses was much beyond the carrying capacity of the channel. The HFL attained by the streams, except in case of Bandi, was much above the level of stream banks. So, as the level of water rose, it also spread laterally.

Lateral spread of flood wave in different streams:

Mitri/Jojri:

In upstream at Kosana, the flood waters spread to a distance of 0.5 km on village side and 0.75 km on the other, thus the spread was 1.25 km. Downstream at Pipar, the lateral spread of flood water was abou ½ km, because of change in river course. Further down at Benan, the water had flown to width of 1.50 km, and at Dantiwada (d/s of Benan) it was 2 to 2.25 km wide. Thus an average lateral spread of Mitri/Jojri river along its course was 1.75 km.

Luni:

The cross section of river at Bhavi during flood was 700 m and water has spread to both sides about 1 km. Downstream at Kakani and Luni the lateral spread of flood water was 2.5 to 3.0 km. At Samdari flood cross-section of the stream was 1200 m. and water spread to 2 to 3 km. Between Sindari and Guda, lateral spread of the Luni river was 3 to 5 km and after Gandav water has flown to a width of 20 to 25 km. Thus up to Gandav mean lateral spread can be taken as 2.5 to 3.5 km

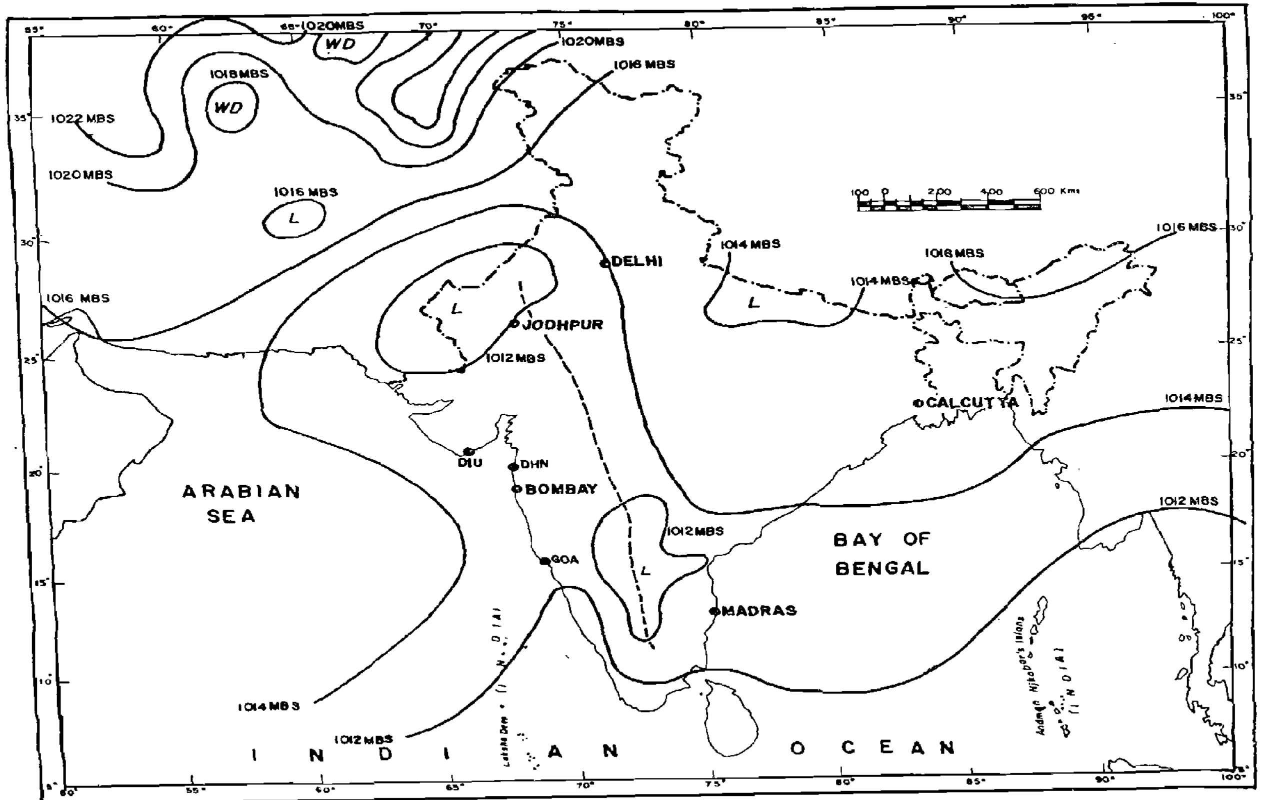

Fig. 6 : Surface synoptic conditions associated with the monsoon depression (July 16, 79.00 GMT)

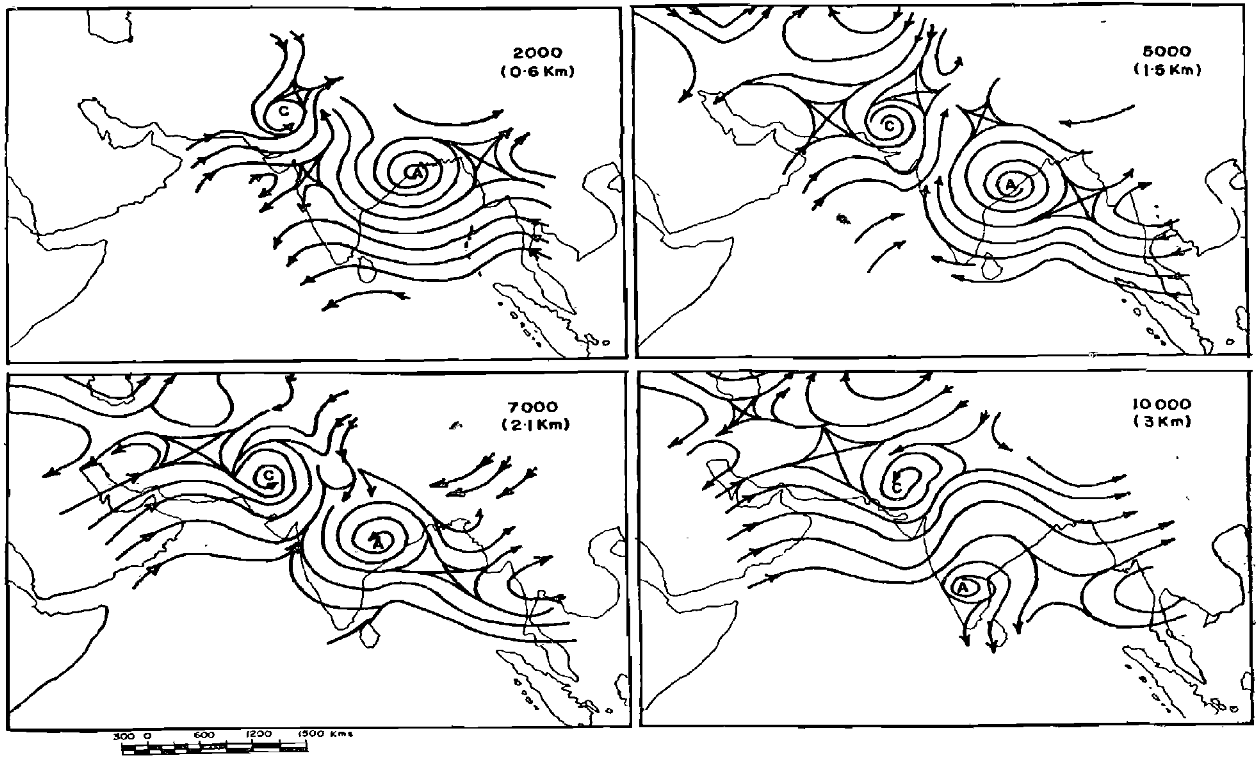

Fig. 7 : Upper air circulation associated with the *monsoon depression* (July 16, 79, 00 GMT).

Guhiya:

At Sheopura, before entering Sardar Samand, lateral spread of Guhiya was 0.50 to 0.75 km. At Rohat railway bridge, the cross-section of flow was 1300 m and water spread after this point, on road to Jalor was 2 to 2.5 km. Thus an average lateral spread of Guhiya can be taken as 1.50 to 1.75 km.

Bandi:

The cross section of flow of Bandi at Pali during peak flood was 0.6 to 0.8 km. Also at Jetpur (d/s of Pali) lateral spread was of the same order. Thus 0.75 km can be taken as width of flow of Bandi flood water.

Synoptic conditions associated with the wet spell:

The monsoon moved into western Rajasthan on the 14th July '79 i.e. two weeks behind its normal onset date. However, it was fairly active, being associated with a well marked low pressure area over Western Rajasthan with its centre at Churu (fig. 6). It created a strong cyclonic circulation extending up to mid troposhere level (Fig. 7). During this period a western disturbance also persisted in north Pakistan and in adjoining Jammu and Kashmir region as an upper air system in the lower troposphere. By 16th July the monsoon through over W. Rajasthan moved slightly south-westward and the low pressure system imbeded in the monsoon trough had intensified and lay just north of Jodhpur. Under the influence of the cyclonic circulation associated with this system strong south westerly winds varying between 40 to 60 knots were blowing into the system from the Gujarat coast (Jamnagar, Veraval, Bhuj) while winds north of Jodhpur remained very low and were north-easterly to northerly in direction. This sharp drop in the wind circulation seems to have resulted in strong convergence in the Ajmer-Pali-Jodhpur region. It was this strong inflow of moisture laden winds from the Arbian sea coupled with the convergence conditions that resulted in heavy downpour in the region.

PAST FLOODS IN THE LUNI AND FREQUENCY OF WET SPELLS IN THE BASIN

Flood in Luni is not an unusal phenomenon, though certainly infrequent. Under favourable conditions i.e. when monsoon depressions or low pressure system directly pass over the western Rajasthan, they strengthen immensely the monsoon current and induce heavy rainfall in the region. People in the area recall that a flood in the Luni of as much a severity as the year 1979 had occurred 117 years back. But floods of lesser magnitude are more frequent. Unfortunately no systematic record is available. The Rajasthan State Irrigation Department had maintained a stream gauging station on Luni near Balotra. Some data on maximum discharge, volume of flow are available for the period 1962 to 1968 and for the flood year of 1973. However, the time span is too short. In view of this an indirect approach was followed based on the quantum of rainfall received. Rainfall data for the period 1903 to 1979 of 18 stations located in or in immediate vicinity of the Luni Basin was tabulated. Spells with concentration of rainfall i.e. those received 200 mm or more in four days were identified. In situations where such rainfall occurred in a common period at 2-3 stations, these have been considered as localised, at 3 to 5 stations as fairly wide-spread and more than five as wide spread flood. An average rainfall of over 350 mm for the wet spell was assumed to be associated with severe flood situation. Results of this analysis are reported in Table 4. Admittedly, the approach used is rather rough, but the results are quite suggestive of the situation.

Table 4 : Past occurrence of likely floods in the Basin for the period 1903-1979.

	Magnitude	
Extent	Moderate	Severe
Localised	1919, 1931, 1937, 1938, 1940, 1947, 1956, 1958, 1961, 1962 (10)	1903, 1905, 1910, 1912, 1916 1917, 1921, 1924, 1929, 1931, 1945, 1946, 1960, 1967 (14)

1	2	3
Fairly wide-spread	1926, 1927, 1972, 1977 (4)	1928, 1941, 1943, 1952 (4)
Wide-spread	*1975 (1)	1907, 1908, 1944, 1973, 1979 (5)

* Localised severs.

It will be seen from the results that wide spread, severe floods in the Luni seem to have occurred five times in a period of 77 years, and fairly widespread severe four times. However, localised severe floods appear to be much more common (14 events). Ramaswamy (1971) while describing the 1967 flood in the Luni has reported, based on rainfall distribution analysis, a heavy to very heavy rainfall over Luni Basin for September, 1924; August, 1927; August, 1931; July, 1935; July, 1943; September, 1961; September, 1967 and July, 1968. We have found slight variation from these. The reason for this variation appears to be the difference in the approaches adopted.

Frequency of wetspells at various stations in the Luni Basin and western Rajasthan:

As stated above there have been a few occasions in the past when a large stretch of Luni Basin and even the western Rajasthan, as a whole has experienced above normal rains. Taking all the stations in the western Rajasthan together, there have been 12 years in the past 104 years when the rainfall has been more than 150% of the mean annual normal rainfall. Such years together with the per cent departure of more than 50% are as follows: 1876 (98%), 1878 (54%), 1893 (106%), 1908 (102%), 1917 (72%), 1926 (60%), 1944 (67%), 1973 (59%), 1975 (101%), 1976 (57%) 1977 (73%) and 1978 (58%). It is interesting to *see that of these twelve years, four have occurred in the present decade alone.*

However, occasions when individual stations have recorded very heavy spells are much more frequent.

Table 5 gives frequency distribution of wet-spells of intensities more than 250 mm at the 18 stations located in the Luni Basins. It will be observed that in the past 79 years, Desuri has recorded 26 wet-spells and Jaswantpura 17 such spells i.e. when rainfall received has been 250 mm or more. Another characteristic feature worth noting from Table 5 is that Desuri is characterised also by a greater frequency of wet-spells of over 400 mm. In comparison with other stations, particularly those located to the north and west of Desuri, wet spells of above 400 mm intensity are conspicuously dominant here.

Table 5 : Frequency of wet-spells at individual stations in the Luni Basin for the period 1901-1979.

Station	Intensity of wet-spells (mm)					
	250-300	300-350	350-40	400-450	More than 450	Total number of spells
Jodhpur	3	1	0	1	1	6
Merta city	3	1	0	0	1	5
Pali	1	3	2	0	2	8
Kharchi	5	1	2	0	0	8
Erinpura Road +	0	1	0	0	0	1
Jalore	5	2	1	0	2	10
Ahore+	2	1	0	1	0	4
Jaswant-pura	7	5	2	1	2	17
Bhinmal	4	2	1	1	1	9
Desuri	9	3	3	5	6	26
Bali	3	4	2	0	4	13
Sojat	3	1	4	0	1	9
Bilara	2	2	1	0	3	8
Jaitaran	0	2	0	0	0	2
Pachpadra	0	1	1	0	0	2
Balotra (1929-79)	0	1	1	0	1	3
Jasol	1	2	0	0	0	3
Sanchore	3	3	3	0	3	12

+1960-79.

ECONOMIC LOSSES DUE TO FLOODS

The unprecedented July 1979 flood and the heavy rains caused an unheard-off loss of human and animal life, immense misery all around and a colossal damage to property. agricultural lands, means of communication and other public utilities in the districts of Pali, Jodhpur, Barmer, Jalore and Nagaur. In all 939 villages besides important towns were seriously hit. Twenty five thousand people were marooned and had to be rescued by the army or sustained through air-dropping of food. Three passenger trains and many goods were stranded. An important town like Jodhpur remained cut-off for five days. Disruption of power supply for over 15 days paralysed the life in various ways. A precise account of the economic loss is impossible. The district authorities and various state departments of Rajasthan Government have made an assessment of the major flood damages. Based on these, the Relief Department has issued a report (August 1979). Data from this together with that from the Railways is summarised below:—

A. *Damages to life and private property—*

1. *Loss of life and damages to the houses:*

a) Loss of human life due to flood including that from house collapse etc. is reported to be 337. 119 persons are declared missing.

b) In all 99686 heads of livestock including cattle, camel, sheep and goat have perished. Of these, 61,435 heads totalling a loss of Rs. 300 lacs, were in Jodhpur district alone.

c) 63,464 houses (both pucca as well as kachha) were either completely destroyed or seriously damaged. In district of Pali alone the damage caused on this account amounts to Rs. 221.02 lacs while it is still higher i.e. 1103.0 lacs in Barmer district.

2. *Damages to agricultural crops, land and wells:*

In the districts of Pali, Barmer and Jalore standing crops over an area of 67481, 4800 and 14905 ha respectively have been completely damaged. A loss of Rs. 118.25 lacs is reported in Pali and Barmer alone. Figures for other districts are not available. Flood has also caused damage of permanent nature in large agricultural lands. It is estimated that 10,8799 ha. have been affected very badly in the three districts of Pali Jodhpur and Barmer. Similarly 2,482 wells are reported to be destroyed or seriously damaged in the districts of Pali, Jodhpur and Barmer incurring a loss of Rs. 93.29 lakhs.

B. *Damages to Government and Public Departments—*

a) *Public Works Departments (P.W.D.)*

The network of roads and bridges, causeways and culverts also could not stand the onslaught of heavy rains as well as the unpredictable force of flood water. Thus the road communication was completely paralysed, causing widespread and extensive damages to roads and cross drainage works. Many Government buildings were also submerged in water some collapsed while others need major repairs. Considerable mileage of State roads as well as Community Development roads in interior need quick restoration. The estimated amount required for these purposes in these five districts is Rs. 628.50 lacs while amount estimated for repair of buildings is Rs. 20 lacs, thus total amount required is Rs. 648.0 lakhs.

b) *Losses and damages to Rajasthan State Electricity Board:*

The flood caused not only a disruption of power supply but also severe damage to permanent installations. More conspicuous amongst these is that to the extra high voltage transmission lines between Bilara and Jodhpur and between Pali and Jodhpur. Repair charges of these alone are estimated at Rs. 40 lacs. Damages to 33 KV sub-transmission systems is more extensive. About 600 poles with a circuit length of approximately 60 km length have either been tilted or damaged. For about 2½ km. line supports and conductors are reported to have been washed away. Damages to 11 KV sub-transmission systems have been described by the State Electricity Board as beyond description. According to the estimates line supports for about 250 kms have been tilted or have fallen and about 150 transformers have been damaged or washed away. Further, 160 kms of low tension lines have been completely washed away while 100 km has suffered repairable losses. Damage on the sub-transmission system is estimated at Rs. 140 lacs. Including the loss of revenue and expenditure on stop-gap arrangements, the total losses are estimated at Rs. 300 lakhs.

c) *Losses and damages to the water supply schemes and drainage works:*

A large number of water supply schemes mostly located on the banks of various rivers in these districts suffered heavily, although there were losses of those located at other places also. The estimated amount required by the PHED for restoration of damages is a fair indication to collosal damages caused. For all the 5 districts 120 lakhs are required for restoration of water supply both in towns and villages.

d) *Damages to irrigation work:*

In these five districts, total of 71 tanks and associated infrastructure were damaged. Of these 11 got seriously breached. The estimated losses incurred on this account are Rs. 132.27 lakhs.

C. *Damages to the Industrial Sector*

Excessive rains and resultant floods in these five districts caused much damage to industrial establishments also. Rajasthan Industrial & Mineral Development Corporation, Jodhpur has estimated a sum of Rs. 7.76 lakhs is needed to restore power and water supplies; drainage and repairs of roads in these areas. Nagaur district suffered an estimated damage of Rs. 3.3 lakhs, in this way while in Pali town these damages in the Mandia Road Industrial area of RIMDC amount to about Rs. 6.43 lakhs.

As regards the damages to industrial units proper in the form of damage to buildings, machinery foundations etc., Barmer district suffered the most. It was estimated that the loss to the industrial units of Balotra was of the order of Rs. 135 lakhs, while in Pali it was Rs. 27.45 lakhs. It was rather minor (Rs. 13,000) in Nagaur. However, in Merta city stock of groundnut worth Rs. 3.92 lakhs was washed away from the local oil mills. In Jodhpur the minor damages were caused to industrial units but units remained closed for 10 to 11 days for want of power. In Pipar town 13 leather tanning units situated near the banks of river Luni suffered a loss of Rs. 1.00 lakhs.

Mining of salt is well established industry in Pachpadra in Barmer district. Due to the damage of salt-pits and washing away of the manufactured salt lying at the spot, damage to the extent of Rs. 185 lakh has been caused at the salt work. Besides, 500 families were rendered unemployed on account of the damages.

A consolidated statement of damages under various heads is given in Table 6.

Table 6 : Losses due to floods

A-Private property		(Lacs of rupees)
(a)	Fully and partly damaged houses.	4700.00
(b)	Cattle deaths	750.00
(c)	Agriculture crops	960.00
(d)	Damages to land being rendered unproductive	1403.00
(e)	Damages to private irrigation wells	318.00
(f)	Industries	500.00
	TOTAL ..	8631.00

B. Public property

(a) Damages to certain dams, tanks and canals for irrigation	330.95
(b) Damages to. water mains and other estimates of P.H.E.D.	368.13
(c) Damages to P.W.D. roads and buildings etc.	764.00
(d) Damages to R.S.E.B. installation	300.00
(e) Damages to U.I.T. Municipalities and other Community Development Works.	125.00
(f) Damages to schools and other Government buildings	106.00
(g) Flood protection works	1000.00
Total ..	2994.08

The above table contains a provision of Rs. 1000 lacs on flood protection works and about Rs. 500 lacs for damages in Ajmer, Bhilwara, Tonk, Sawaimadhopur and Sikar districts. Therefore deducting *this the damage due* to flood in the Luni comes to Rs. 10,125 lacs or 1012.5 million rupees.

ECOLOGICAL STUDY OF FLOOD DAMAGED AGRICULTURAL LANDS

Because of pressure on land, cultivation in the area extends close to and in many situations right up to the bank of the stream courses. The younger alluvial plains along many of these streams, notably the Mitri-Jojri, Luni up to Bhavi, parts of Guhiya, Reria, Bandi and Jawai, are gifted with good ground-water potential. This good quality water is being exploited for generations for irrigation. Recent years have seen a big spurt in utilisation. For example, the Mitri-Jojri in its 85 km course before joining the Luni has all along a ½ to 3¼ km wide strip of irrigated belt. So the picture here is one of an almost continuous stretch of well developed, highly prized farms irrigated with mechanised dugwells. Besides the conventional crops, a variety of cash crops like chillies, cumin, corriander are grown under a rather intensive soil management including use of manure and fertilizers. Thus, a large quantity of labour and cash inputs have gone into development of these lands.

Further, in some situations as in Bisalpur, Kolia, Benan, costly infrastructure had been built over time to command the lands. In Bisalpur the lands slope gradually towards the Mitri-Jojri which is ½ to 3¼ km from the village settlement. To carry water from the wells located on the bank of the stream, the farmers had made high-level water courses to command the farthest end in vicinity of the settlement. Most of these are 2-3 m above-ground at their off-take point from the well. All these installations were damaged. To revive and repair these channels will cost Rs. 3,000/- to Rs. 10,000/- each.

Manifestation of flood phenomenon

The massive flow of water charged with sediments that passed through the streams affected the land situated in the vicinity in various ways. One of these was through stream bed widening and bank-cutting which caused damage both to the irrigation wells and the agricultural lands. The other was through flood waters which, not getting contained in the channel, swept through the adjoining lands. In the villages located downstream of Pipar water current of 0.5 to 2.5 m depth moved over the fields. This caused scouring and sheet erosion at some places and massive deposition of nearly inert sand and river gravel at others. Thus in the process not only the level of lands was destroyed but the fields also got covered with unproductive sand. Damage to irrigation courses and field channels is besides. It is no exaggeration to say that in comparison to the prosperous, well managed irrigated farms before the floods, the lands today are nothing but wilderness. Efforts of generations have got turned into nothingness in lands along Mitri-Jojri as well as in extensive stretches along the Luni.

(a) *Increase in channel width and bank cutting.*—Observations on this aspect are limited and confined to certain points along the Mitri-Jojri and the Luni. At Pipar the channel width of Mitri increased from the original 70 m to 110 m; whereas downstream at Benan from 70 m to 140 m and at Jaspali from 85 to 160 m. The Luni at Kankani village increased its width from 398 m to nearly 1500 m. At Silor the river has eroded its right bank to an extent of 500 to 700 m.

(b) *Inert sand deposition with some scouring of agricultural lands.*—This has been the most extensive phenomenon affecting large stretches of land on either side of the banks particularly of the Luni and the Mitri-Jojri. Observations and, measurement made at few points are as follows:

Lateral spread of sand deposit

Mitri :	1.	Pipar	150-250 m.	from bank (Present Bank
	2.	Buchakla	300-350 m.	,,
	3.	Benon	450-750 m.	,,
Luni up-	4.	Bhavi	500-600 m.	,,
stream	5.	Bala	800-1250 m.	,,
Luni midstream	6.	Nimla	500-600 m.	,,

				from bank (Present Bank)
	7.	Shikarpura	2.5 km	(current had diverted on right bank)
	8.	Luni	1000. m.	
Lower stream Luni	9.	Karmawas		3 km. on left bank. A flood current got diverted from right bank and invaded 4.5 km distance.
	10.	Silor		
	11.	Jethantri		,,
	12.	Kanon		,,

Often the depth of deposition is variable even within a single field, thus giving it an undulating relief. Though a maximum deposition of up to 3 m had been seen, the deposition at most places (Table 7) is 20 to 60 cm.

Table 7 : Frequency distribution of total sand sediment spots examined under different thickness classes.

Village	Total spots examined in sector	No. of spots under various thickness classes				
		20 cm	20-40 cm	40-60 cm	60-100 cm	More than 100 cm
1. Pipar	8	2	4	2	—	—
2. Benon-I Buchkala	3	2	5	4	1	1
3. Binawas-Dantiwada	9	2	6	—	1	—
4. Bhawi-Bala	8	2	5	1	—	—
5. Kankani-Satlana	11	4	1	3	3	—
6. Samdari-Silore	8	1	3	2	—	2
7. Jethantri	7	—	1	2	4	—
8. Parlu-Kanon Balotra	6	—	1	2	3	—
TOTAL ..	70	13	26	16	12	3

At places where a strong current of water had passed, masses of river gravel are seen as side deposits immediately downstream.

(c) *Soil scouring and sheet erosion in association with slight river sand deposition.*—This process is most common just downstream of the breaches of embankments etc., but the process occurs in localised manner all along. The strong current of overflowing water or an off-shoot from the stream has gullied or scoured soil to depths of mostly 0.5 to 1 m to expose underlying gravelly strata. As deep as 3 m scoured spots were seen along Mitri. In Benan, Buchkala and Jaspali 30 to 50% lands in 300 m wide strip on the left bank and about 80 m on the right have been so affected.

Physical and Fertility Characteristics of Fresh Sediments in Comparison to Buried Soil

A study of physical and other characterestics of soil was made at 60 sites out of which 21 were along Mitri-Jojri and the rest 39 along the Luni. The fresh sediments are very light coloured, loose, structureless sand and gravel. In comparison the original buried soil is light to dark grey, and somewhat aggregated. This contrast afforded a good opportunity to separately sample the two and compare their properties. The fresh sediments had just 3-4% clay and less than one per cent silt. Their moisture retention capacity (moisture equivalent) was around 3.5%. In case of gravels picture was even worse. The original soil underneath was loamy sand to sandy loam containing mostly 6-10% clay and 4 to 7% silt. Its water retention capacity varied from 5 to 20%. The fresh mantle therefore is too coarse and highly droughty. This attribute becomes serious handicap particularly under irrigation. This will necessitate frequent irrigations with attendant heavy deep percolation losses.

A study was made on the available nutrient status of fresh sediments and original soil. Results are presented in Table 8.

Table 8 : Available nutrient status of fresh sand over-laden and original soil.

Location	Fresh sand			Original soil		
	Organic carbon	P_2O_5	K_2O	Organic carbon	P_2O_5	K_2O
Pipar to Benon on Mitri	0.05	15	147	0.23	28	342
Bhavi to Bala on Luni	0.07	66	104	0.15	12	317
Luni-Kankani on Luni	0.10	14	219	0.21	35	456
Samdari to Balotra on Luni	0.06	13	182	0.17	25	495

N. B. (1) Based on analysis of over 60 spots in all.

(2) P_2O_5 & K_2O values in kg/ha and organic carbon in %.

It will be seen that organic carbon (humus) content of fresh sediments is only one-half to one-fifth of that contained in the original soil. Similarly available phosphorus and potassium in the sediments contained *only half of that in the original soil.* *Thus, not only in* its physical condition but also in fertility, the fresh sediments are an inferior medium for plant growth. Addition of amendments, bulky organic manures including green-manuring and fertilizer application will be necessary for reasonable harvests.

Effect on current biological productivity.

The thick fresh sand crusted fields give the impression of sterile lands. Some farmers did sowings on these lands soon after the flood with bajra and other common crops. However, observations showed that the crop stand in sand covered fields was 75 to 90% lower in comparison to the neighbouring original soil. What is more, the growth and vigour of plants was also poor. Normally, during this part of the year there is a good growth of natural vegetation both on the cropped and fallow lands. This provides considerable grazing to livestock. In the current year the severely sand-cast lands were almost barren. A systematic study was made at 13 locations where observations on number of plant species and their density and above-ground biomass were recorded. Each location had varied thickness of sand deposition and their sampling was done to cover this variation. Table 9 summarise the result obtained.

Table 9 : Mean value and range of number of species, plant density and biomass production in flood effected areas

Particulars	No sand deposition	Sand deposition up to 15 cm	Sand deposition up-to 30 cm	Sand deposition above 30 cm
1. No. of species	8.7	5.2	4.6	Nil
Range	1-15	1-11	2-9	Nil
2. Plant density/m2	69.7	32.7	4.7	Nil
Range	30	6-108	4-5	Nil
	128			Nil
3. Above ground forage biomas g/m2	34.1	17.7	3.2	Nil
Range	4.5-134.6	0.5-56.6	0.5-9.7	Nil

The data in the above table indicate that with increase in thickness of sand-cast, there was a progressive decrease in number of plant species as also in their density and biomass.

OBSERVATIONS ON DIFFRENTIAL DAMAGE TO TREES, SHRUBS AND GRASSES IN THE FLOOD AFFECTED AREA

Nearly 30-40 plants of each species were observed along the devasted banks of the Luni and Mitri-Jojri. The up-rooted or partially up-rooted root system of various trees were examined. A few observations are as follows:—

Trees: Salvadora oleoides and *Salvadora persica* (Jal) were found to have very shallow horizontal root system and without any vertical tap root anchoring. Thus they were the first to be washed away and, therefore, they failed to provide any resistance.

Acaica nilotica (Babool), *Azadirachta indica* (Neem) and *Prosopis cineraria* (Khejri) are the trees which bear superficial as well as vertically downward penetrating roots. In the shallow groundwater condition of younger alluvial plains were seen to have more horizontal root spread than verticals. Most of them were partially (2/3) up-rooted and whole trunk had come down to the ground but were not washed. Few *Ficus* species (Pipal) which had more net work of horizontal roots all around the tree were up-rooted.

Zizyphus mauritiana trees, were found to withstand the flood damage very strongly. The trees have more vertical penetrating roots along with a very high net work of horizontals which at places on the river bank site provided resistance to flowing water in cutting the bank. In one case this tree provided perch to as many as 12 persons, for 72 hours.

Prosopis juliflora (Vilayti Babool), was more common along the bank of Luni river. The tree tops are cut every year. New growth of shoots make when bushy with 3-4 m height. Root system of this this is also very strong. They provided much resistance to flowing water. In most cases the whole body tilted in water flow direction or they lay prostrate on the ground.

Shrubs of *Tamarix ereoicoides* use to be on sand bar in the river bed were not seen at all. They are either completely washed away or buried under huge sand piling.

Grasses

Cynodon dactylon (Dob) and *Desmostachya bipinnata* (Dob) provided good resistance to soil erosion. Most of the irrigation channels with carpet of *Cynodon* were found intact. Roots of Dob grow vertically down up to 1.5 to 2 m depth. At few places the roots of this grass were found coming out of the coarse sand deposition.

Sedges

Cyperus rotundus (Motha) is one of the most common sedge which was found abundant on irrigated field. They are also capable of coming out of the coarse sand up to a depth of 30 cm.

COST OF RECLAMATION OF IRRIGATED LANDS DAMAGED BY THE FLOODS

As stated earlier, the damage to irrigated lands has been very serious. This is for two reasons. Firstly, because the amount of investment in terms of both physical labour and cash inputs in building up infrastructure, land-levelling, soil improvement etc. is incomparably larger than on dry lands. Secondly, partly arising out of above, is the economic contribution and social value of these lands. Therefore treatment of these lands deserves a high priority in dispensation of relief. The State and Central Government have due appreciation of this. However, in order to implement this programme of reclamation, it is necessary to know the type and magnitude of damage and the steps that are necessary to restore the productivity of these lands. As part of its contribution, the CAZRI conducted a survey of some of these sites and the results obtained are discussed as follows:—

Methodology used.—Even in highly damaged irrigated holdings it is possible to sense the original layout and setting. Surviving segments of irrigation infrastructure, exposed patches of original soil surface, soil profile at deeply scoured spots help in establishing the original level, lay out and soil conditions. Even where the original land surface is buried under a blanket of sand, the thickness of fresh sand deposits and the original soil can be established through auger holes. Fresh sand contrasts from underlying soil by its very light, non-coherent loose nature. In most cases soil texture differences are also highly significant. Thus through systematic observations comprising topographic survey and soil augering the magnitude of damage can be established fairly accurate.

Regarding scope and need of reclamation measures solution was not so easy. This has been due to a number of reasons. Firstly, because losses like that of productive top soil are not amenable to easy translation into economic terms. Further, there are no quick ways of restoring the productivity of land to its original level.

Best that one can aim at improvement of whatever is left through a gradual process of land management. Secondly, the reclamation has to take into account the economics of the measure. Questions like: removal of what thickness of sand crust should be considered economically feasible ?; in what situation removal of sand should be preferred vis-a-vis efforts at improving the sand crust itself ?—these are issues, decisions on which are likely to vary from individual to individual. Approach used in the present case is as follows:—

Land levelling needs have been worked out not necessarily to restore the original level or the shape and size of fields. The objective is to level the present undulation while ensuring that the parcels that result after levelling will lend themselves for irrigation command from the source concerned.

The problem arising out of sand casting is a difficult one to solve. Though it is obvious that the sand crust deposition is quite inferior as a medium for crop growth to the original soil that has buried or replaced. Realising that the efforts and problems involved in its removal are colossal, removal of sand has been thought of only in a few specific situations. These are:—

(a) where a sand crust has a thickness of up to 30 cm mean depth a highly productive loamy soil. The basis for this is that the cost of removal which comes to about Rs. 4,000/- to 8,000/- per ha is still worthwhile in comparison to a permanent handicap for ever which the farmer will facing.

(b) where the river gravel has covered up to 30 cm. of depth.

Where the thickness of sand deposit is more than 30 cms or where underlying soils has not been so good i. e. where the original soil itself is also of light texture, the reclamation measure aims at levelling, assuming that through managements farmers will be able to bring back the new surface to required productivity in 3 to 5 years. Where the thickness of river gravel is over 30 cm, its removal becomes too costly. Where the original soil itself has been displaced by river gravel, its removal does not have any meaning. In both of these situations, the only conceivable situation is amendment of soil with tank silt and fine soil. This measure is also very costly but still it is considered more feasible than removal of gravel or simply abandoning the land.

The land loss due to bank cutting has been taken as total loss.

Assessment of magnitude of damage and cost of reclamation of surveyed sites

Table 10 gives area affected by various degrees of severity for the major categories of damage at each of the surveyed sites. The term severity as used here is purely to express the magnitude of manifestation of the particular process of damage to the irrigated holding. It is not necessarily related to the volume of efforts involved in reclamation of the land. Just to illustrate a mean sand deposition of 30 cm on the soil surface though severe as a manifestation of the process, can have a varying significance for land levelling depending upon the size of undulations. Similarly, the severity of damage to infrastructure is defined here by the percentage damage to the system as it existed before the floods. It does not speak of the volume of effort involved in repair since the same will depend upon the massiveness of the infrastructure. Translation of the nature of damage in terms of magnitude of effort involved in reclamation has been attempted in Table 11. The criteria used in deciding upon the severity of reclamation measure is as following. Moderate land-levelling category corresponds to levelling of a hectare of land having 0.3 to 0.5 m. high undulations in 50% of the area or an equivalent earth work. Severe category has such undulations of 0.5 to 1 metre high. Very severe category has one to two metre high undulations in 50% of the area. The measure transfer of soil or such amendment has been recommended in a situation of severe sheet erosion so that a concretionary strata has been exposed or where the deposits are of coarse gravel. The aim of the measure is to make the lands workable though not very good soils. The term moderate means a quantity of transported soil that will give 2 cm thickness on soil. Severe means a quantity required to give 1 cm of such thickness. Repair of infrastructure means the magnitude of efforts involved in labour and material. Moderate category comprise that effort which is the range of Rs. 500/- to Rs. 1,000/- the severe is Rs. 1,000/- to 2,000/- and very severe more than this.

Translation of this effort in terms of money for various measures is given in table 12. It will be seen that total cost on land reclamation using tractor for the entire holding varies between Rs. 3,035/- to Rs. 40,227/- depending upon the size of the holding on the one hand and severity of damage on the other. Cost of land reclamation of these individual holdings is given in Table 12. In arriving at the cost value, it has been assumed that family's own resources of manpower and transport will be available to supplement the total requirement. The levelling operation aims at simply making the lands fit for irrigation and not necessarily restoration of original level and size and shape of plots. The cost of removal of these individual holdings is given in Table 12. In the scrapped material along the boundary of the fields and in reconstruction of infrastructure have been kept in view.

Even after the lands have been levelled and infra-structure re-built, the farmer can at best hope to realise in the first few years only a fraction of the productivity that was being realised from the lands before the floods. This is because the physical condition and fertility level of the newly deposited sands are low. In order to have any reasonable return, the farmers will be required to make extraordinary effort in form of soil amendment, manure and fertilizer This effort has been roughly valued at Rs. 600/- per hectare.

TABLE 10

Magnitude and severity of different categories of damage at the surveyed sites

Site No.	Area of holding (ha)	Area (ha) damaged by									Damage to infrastructure	Area not significantly damaged (ha)
		Sand casting		River gravel deposition			Scouring	Exposure of gravelly strata	Severe rill erosion	Bank cutting		
		Moderate	Severe	Moderate	Severe	Very servere						
1.	1.30	0.32	0.89	0.03	—	—	0.15	—	—	—	Moderate	Nil
2.	3.24	0.81	1.02	0.03	0.08	—	0.16	0.16	—	0.32	Severe	Nil
3.	0.97	0.32	—	0.08	—	—	—	0.49	—	—	Moderate	Nil
4.	8.10	2.43	4.05	0.16	0.16	—	0.32	—	—	0.16	Severe	0.65
5.	1.62	—	0.65	0.32	0.32	0.32	—	—	—	—	Moderate	Nil
6.	1.30	0.32	—	—	—	—	0.16	—	0.65	0.16	Moderate	Nil
7.	1.94	0.32	0.49	0.08	0.21	0.08	0.08	—	—	—	Severe	0.65
8.	4.05	0.49	0.81	0.24	0.16	—	0.16	—	—	0.40	Severe	1.78
9.	3.24	0.32	0.49	0.49	0.32	0.49	—	—	—	—	Moderate	1.13
10.	5.67	0.81	1.13	0.16	—	—	0.24	—	—	—	Moderate	3.32
11.	15.55	5.67	2.59	0.81	0.49	0.49	—	1.30	1.30	0.16	Severe	Nil
12.	0.97	0.97	—	—	—	—	—	—	—	—	Moderate	Nil
13.	1.62	1.62	—	—	—	—	—	—	—	—	Moderate	Nil
14.	3.24	0.81	0.97	0.32	—	—	—	—	—	—	Severe	Nil

TABLE 11

Nature and magnitude of different reclamation measures

Site No	Total holding (ha)	Area (ha) requiring: Land Levelling			Removal of sand/gravel		Transfer of tank silt soil from outside for amendment		Repair of infra-structure		
		Mode-rate	Severe	Very Severe	Moderate 10-30 cm	Severe 15-30 cm	Mode-rate	Severe	Mode-rate	Severe	Very-severe
1	2	3	4	5	6	7	8	9	10	11	12
1.	1.30	0.16	0.24	0.89	—	—	—	—	Yes	—	—
2.	3.24	0.49	1.62	0.65	—	—	0.16	—	—	Yes	—
3.	6.97	0.32	—	—	—	0.10	—	9.49	Yes	—	—
4.	8.10	4.05	2.48	0.49	—	—	0.32	—	—	Yes	—
5.	1.62	—	0.65	—	0.32	0.32	—	0.32	Yes	—	—
6.	1.30	1.13	0.10	—	—	—	—	—	—	Yes	—
7.	1.94	0.49	0.40	—	0.08	0.34	—	0.08	—	Yes	—
8.	4.05	0.97	0.89	—	—	—	—	—	—	—	Yes

1	2	3	4	5	6	7	8	9	10	11	12
9.	3.24	0.65	0.32	—	—	—	0.97	0.32	—	Yes	—
10.	5.67	1.62	0.73	—	—	—	—	—	—	—	Yes
11.	15.55	10.17	1.94	0.52	0.81	0.49	1.44	0.16	—	Yes	—
12.	0.97	—	0.65	0.32	—	—	—	—	Yes	—	—
13.	1.62	—	—	—	—	1.65	—	—	—	Yes	—
14.	3.24	10.49	1.30	1.65	0.32	0.49	—	—	—	—	Yes

Notes to Tables 11:

Land levelling Moderate	—	Undulations of	0.3 to 0.5 m affecting 50% of the area or equivalent.
Severe	—	″	0.5 to 1.0 m ″ ″ ″ ″ ″
Very severe	—	**	1.0 to 2.0 m ″ ″ ″ ″ ″

— ** — Based on magnitude of effort involved in rebuilding the infrastructure.

TABLE 12

Cost of reclamation of damaged area of individual holdings (In rupees)

Site No.	Area of the holding (ha)	Area damaged (ha)	Cost of land levelling		Cost of removal of sand/gravel		Cost of transport of soil amendment material	Cost of re-building irrigation infrastructure ****	Cost of other soil improving inputs	Total Rs.	
			With Tractor	Manually	With Tractor	Manually				with Tractor	Manually
1	1.30	1.20	3780	5670	—	—	—	750	780	5310	7209
2	3.24	3.92	2697	8546	—	—	800	1900	1750	8347	11196
3	0.97	0.97	288	432	640	960	4900	550	600	6978	7442
4	8.10	7.09	9783	14675	—	—	1600	1900	4330	17663	25555
5	1.62	1.32	1170	1755	1920	2380	3200	750	1000	8040	9585
6	1.30	1.30	1305	1958	—	—	—	950	780	3035	3628
7	1.24	1.20	1161	1742	1120	1680	800	800	790	4661	5842
8	4.05	1.86	2475	3713	—	—	—	3500	1130	7105	8343
9	3.24	2,26	1161	1752	—	—	8050	1900	1350	12464	12042
10	5.67	2.35	2772	4158	—	—	—	3500	1400	7672	9058
11	15.55	15.55	14517	21776	3560	5370	8900	3900	9330	40227	49276
12	0 27	0.87	2322	3483	—	—	—	950	540	3812	4773
13	1.62	1.62	—	—	6480	9720	—	1900	970	9350	12500
14	3.24	3.24	5121	7682	2600	3900	—	8500	2000	13221	17662

**** Excluding the expenditure on repair of wells and lift mechanism.

SOME RELEVANT BIBLIOGRAPHY

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3. Central Water Commission, New Delhi, Report of Shri Pritam Singh, Member (Flood), an aerial survey of the flood affected areas along Luni River in July 1979.

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6. Dhir, R. D. and Krishnamurthy, K. V. (1952). Hydrology of the Rajasthan desert, *Bull. Natn. Inst. Sci.* India, *1:* 211—216.

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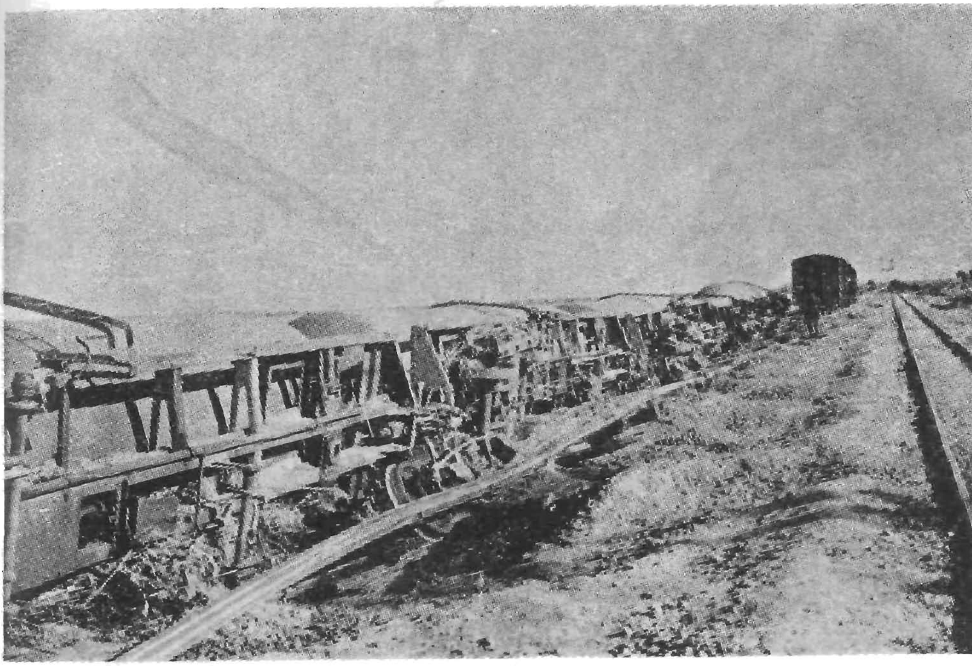
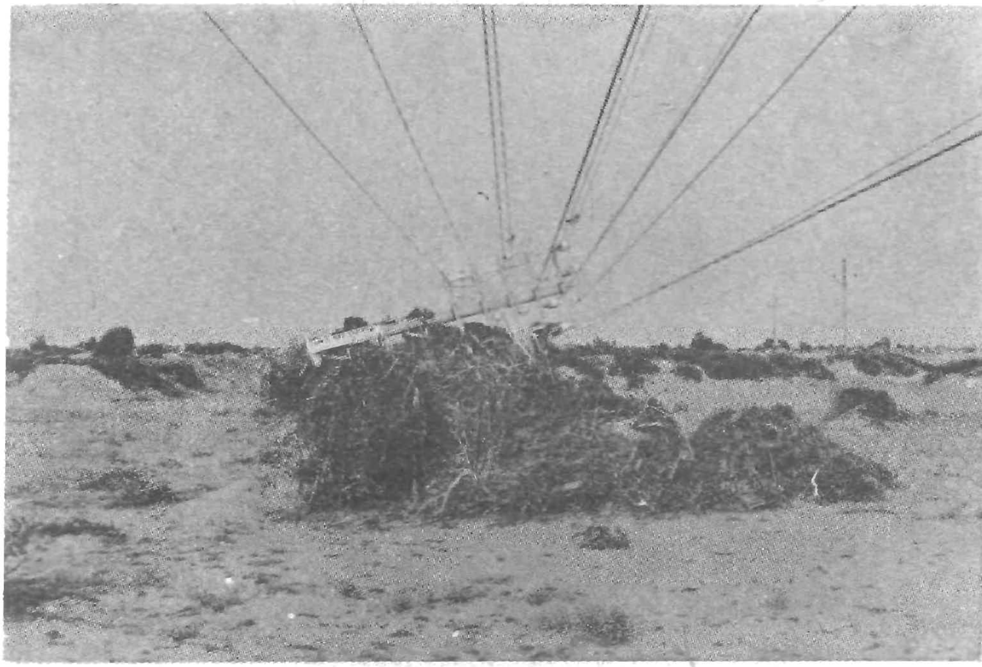
Glimpses of flood havoc

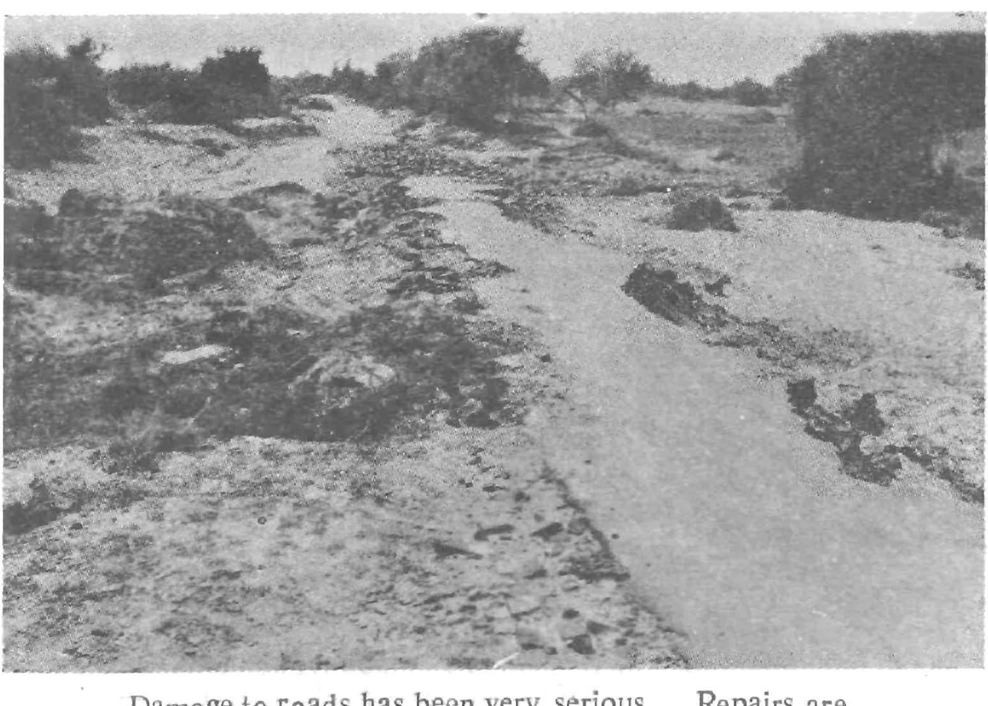


An upturned goods train on the Luni-Samdari Section after the rail track caved in.

Scene over the railway bridge on the Luni. The track was washed away by the overflowing flood water.

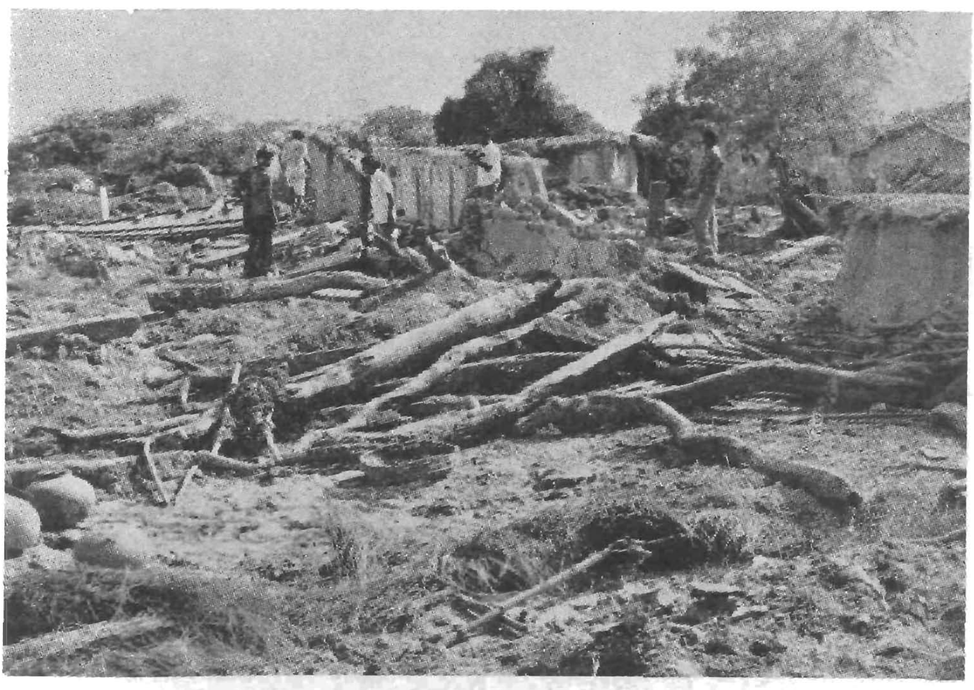


Uprooted shrubs and trees floating in the flood. Water got trapped in telephone and power lines structures to cause dramatic damage.



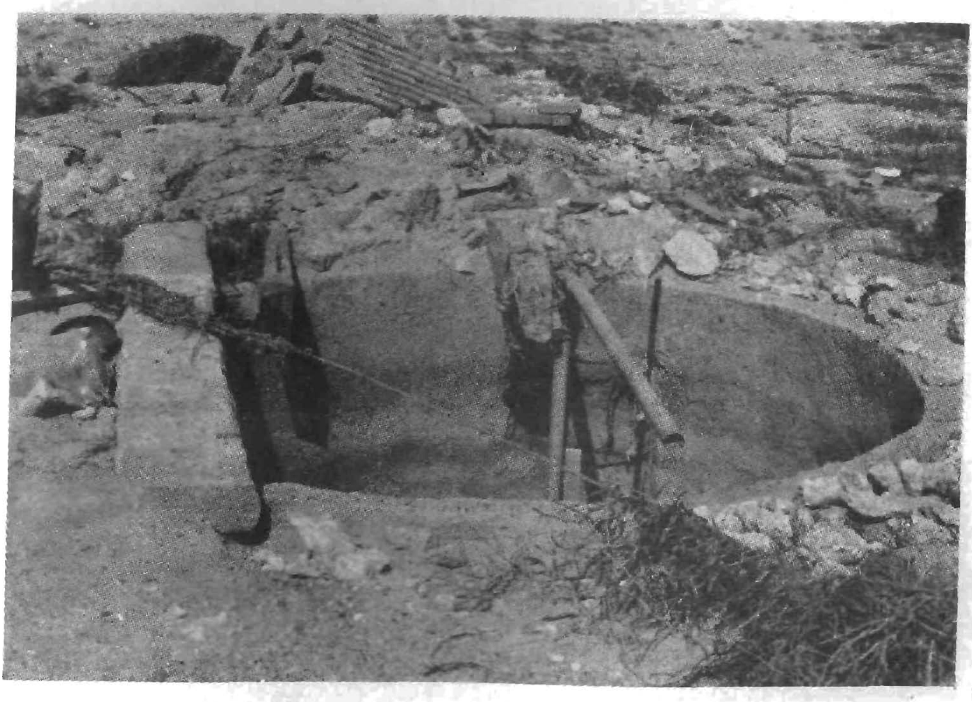
Damage to roads has been very serious. Repairs are estimated to cost over Rupees 60 million.

Scene at the Luni causeway on the Jodhpur-Pali highway. The sand and gravel had piled up as high as 3 metres.

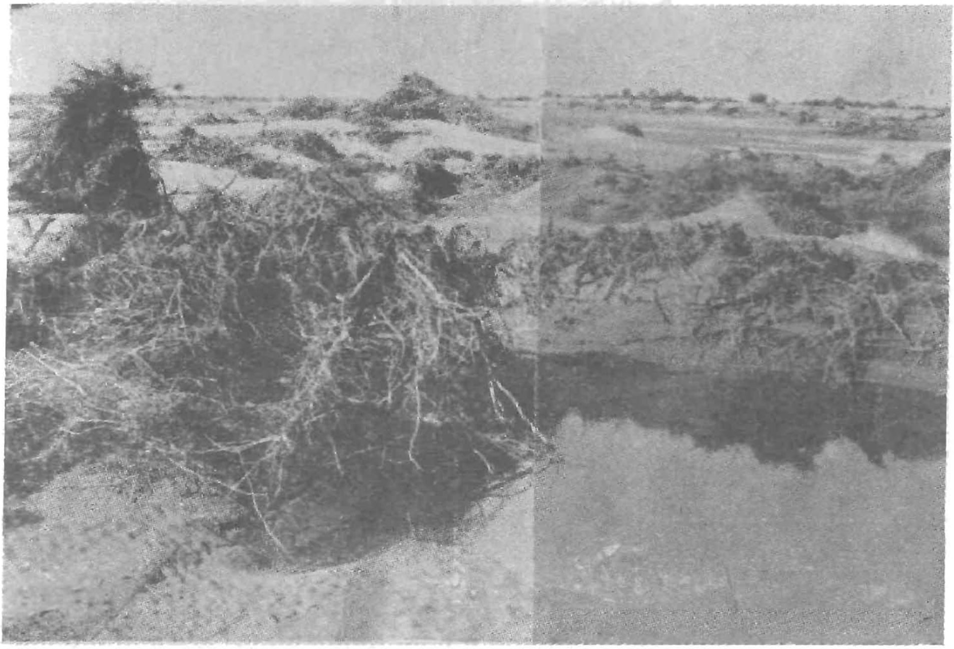


The scene of flood havoc at Satlana village after the deluge. Such sights could be seen all along the Mitri and the Luni. As per the Government report, the damage to houses and dwellings total Rupees 470 million.

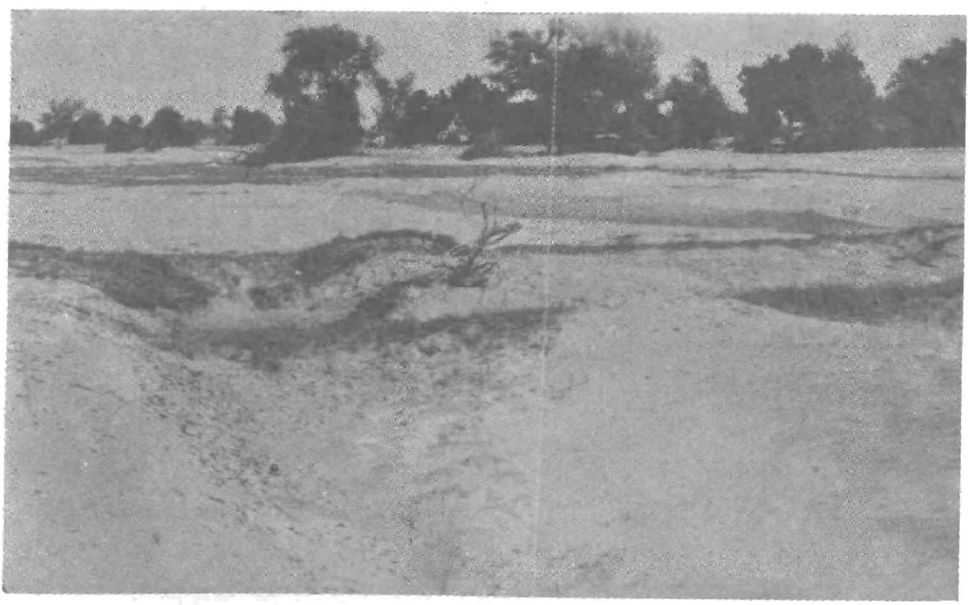
Retrieving whatever is possible.



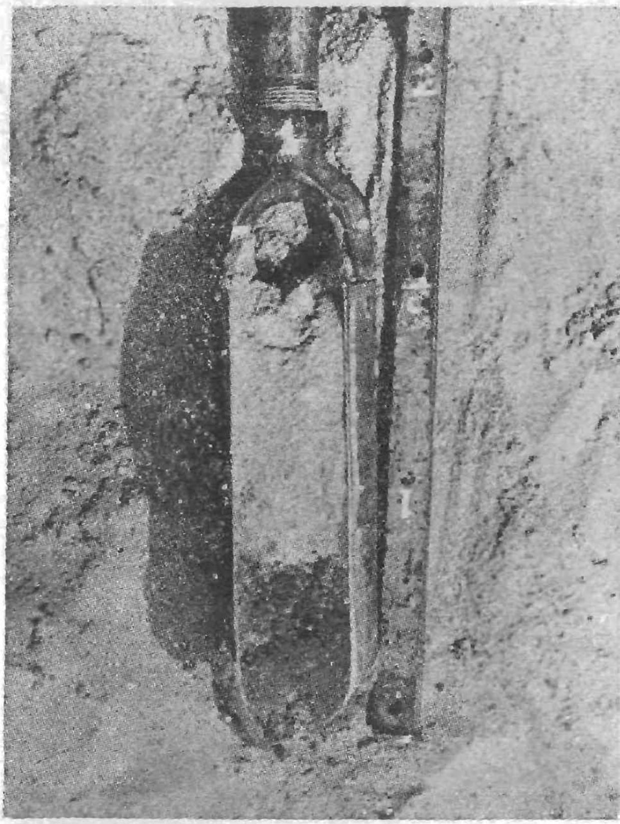
Collapsed structure of an irrigation well. Nearly two thousand five hundred wells together with the irrigation infrastructure are reported to have been seriously damaged.



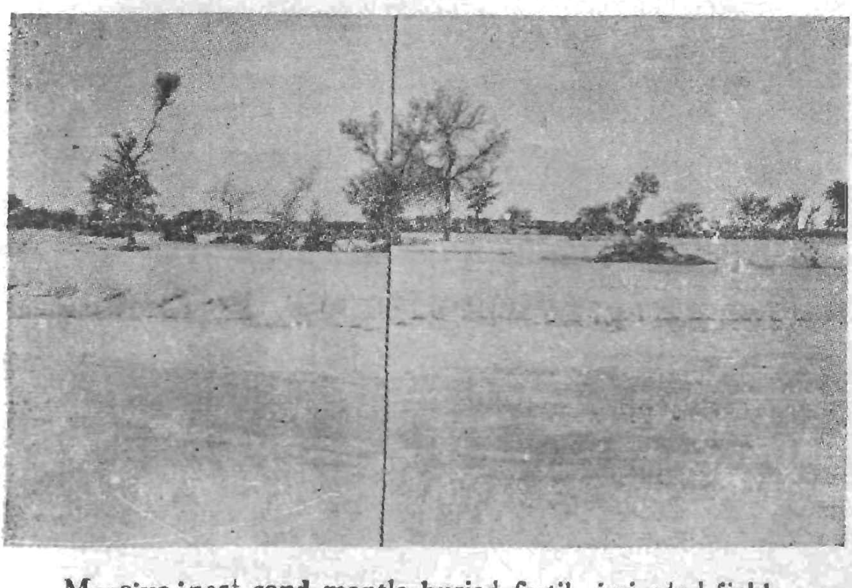
Irrigated lands in the immediate vicinity of the streams have been damaged almost beyond recognition.



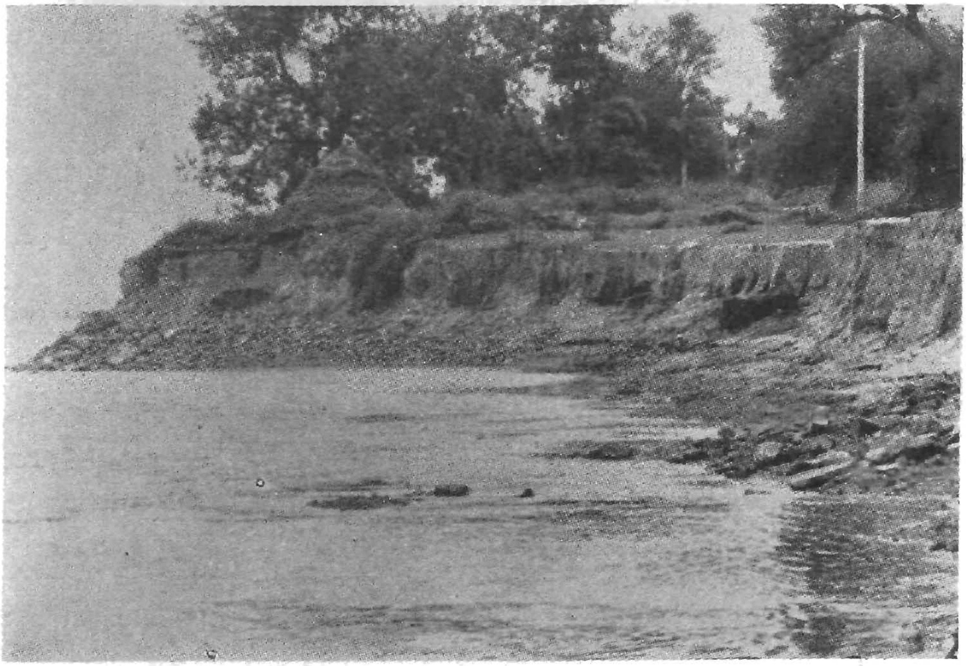
Scouring and sand deposition have together spoiled the ground level.



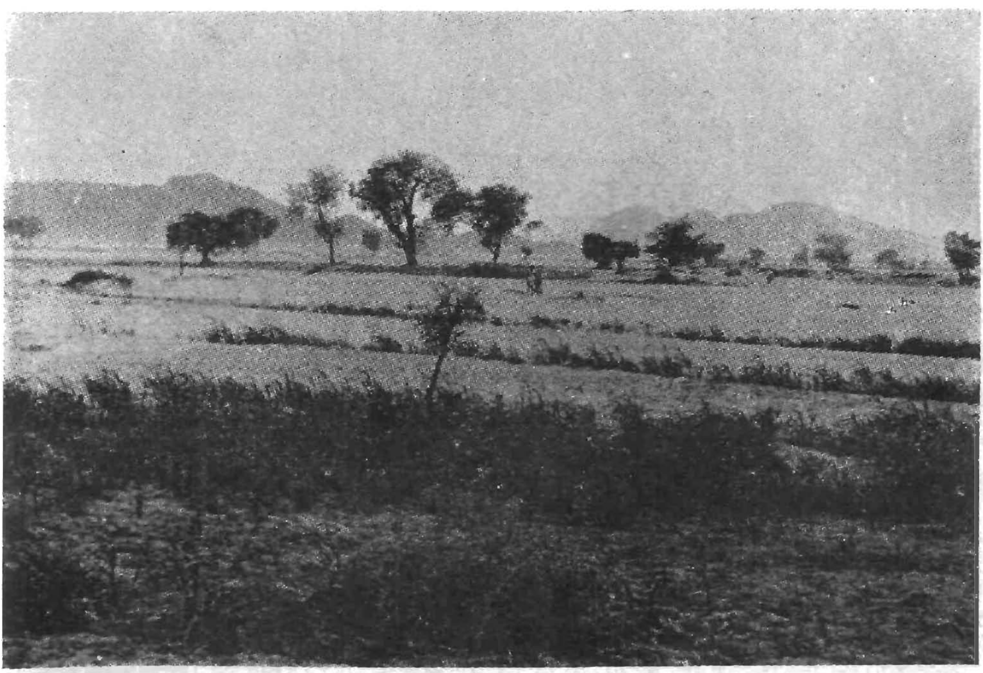
Contrast between original soil and deposit stand.



Massive inert sand mantle buried fertile irrigated fields.



At this point the Luni has shifted about half a kilometre from its original course and annihilated the agricultural land (Village Silor)



Comparative growth performance of bajra sown after floods. In the fore-ground with good stand, the sand deposition has been thin.