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Hydrological Studies on Zhob River and Streams of the Kachhi Plain

By

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Introduction.

In November, 1957 the Government by publication in the Gazette notified the setting up of a Flood Commission for West Pakistan. One of the terms of reference of the Commission was to assess the adequacy of existing data regarding precipitation, river discharges, river regimes, etc., and the agencies engaged on its collection and to prepare a comprehensive programme for further survey and investigations, collection of further data as may be required for formulation of flood control projects with full utilization of the multipurpose benefits of such projects.

For the efficient discharge of its duties it was envisaged that the Commission would need basic data in regard to river discharges, rainfall, run-off and silt loads etc. The existing hydrological data available in the Irrigation Department being inadequate in certain respects and no data being available for regions like Baluchistan, it was decided to create a Directorate of Hydrology within the Irrigation Department with the following objectives :—

(a) To co-ordinate the activities previously being carried out by the various branches of the department with a view to compiling consolidated data regarding water potential of West Pakistan according to internationally accepted standards.

(b) To extend the coverage of the data currently being collected in areas like the ex-Punjab and Sind to the whole of the West Pakistan.

(c) To supply the gaps in the existing data and to remove deficiencies with a view to making the data more reliable for the purpose of formulation of policies for the conservation and optimum use of the water resources of West Pakistan.

Subsequently the Government of West Pakistan through a memorandum clarified, that the aim of the Government was to develop the

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Directorate into a repository of information concerning all aspects of hydrology so that in due course not only the Irrigation Department, WAPDA, and the Flood Commission but also any other agency engaged in the development or utilization of water resources looked upto it for supply of up-to-date and unbiased data.

For this purpose a Hydrology Division was opened within this Directorate at Quetta in October, 1958 by the author to undertake hydrological studies for the assessment of surface water potential of the former Baluchistan, henceforth to be called "Baluchistan".

As has been stated above, practically no data existed for Baluchistan when operations in this connection were started by us in this region. This involved pioneering work including reconnaissance of the interior parts of the region for selecting suitable sites for the purpose of establishing hydrological stations. Before mentioning the details of investigations conducted in this region, it would be proper to give a brief description of the economic and topo-graphic conditions of Baluchistan which is quite different from the regions like the ex-Punjab and Sind.

Baluchistan or what is also known as Quetta and Kalat Region is an oblong stretch of land situated at the extreme Western part of West Pakistan. It is included within the parallels 31° to 25° North and the meridians 61° to 69° East. It does not however include the Sind area from 29° to 24° North and 67°·30′ to 69° East. Its area is approximately 1,34,200 square miles which is equal to the total area of ex-Sind, ex-Punjab, ex-Khairpur and Bahawalpur States. Its population according to 1951 census was 11,74,036 or about 8·5 persons per square mile. The 1961 figures have recorded a population of 13,94,000 in this area; but excluding Nasirabad Sub-Division which has now been transferred out of Quetta Division under the recent administrative reorganization its population comes to 12,93,000. Thus there is an overall increase of about 19 per cent in Baluchistan over a period of 10 years. In addition there has been the annual migration of nomad powindas from Afghanistan and further north through the region down to the sea and back. The country divides itself into four tracts :—

1. Upper high lands.
2. Lower high lands.
3. Plains.
4. Deserts.

The upper high lands occupy the central and east central portions of the country. The lower high lands include the slopes of the Suleman range on the East and Pab, and Kirthar ranges on the south. The ranges of Mekran, Kharan and Chagai lie on the west. The plains of Baluchistan include the flat triangular strip known as the Kachhi plain, the whole of the Western part of Lasbela and the valley of Dasht river in Mekran. The deserts are situated in the North-Western part.

The whole region is sparsely populated and at first sight would offer great development potential excepting, of course, the arid inland

regions. Whilst development is certainly possible, there are considerable limitations which need to be looked into before taking any steps in this direction. However, the region has an importance to West Pakistan that cannot be denied. Its total area is a little less than half that of West Pakistan and it is very largely the only remaining part of the country capable of accepting fresh population and virtually undeveloped. Hydrologically the region drains into 3 distinct basins :—

(i) The inland basin of North Baluchistan very arid with Salt pans and huge area of boulder strewn sections.

(ii) The coastal area, much better water with a high rainfall and comprising the major rivers namely Dasht, Hingol, Poral and Hub.

(iii) The area east and south of Quetta commencing at the Zhob river which drains into river Indus beyond Dera Ismail Khan after joining with Gomal and the streams of the Kachhi plain of which the biggest is the Nari and other streams namely Bolan, Talli, Lehri, Chhatar, Mula, Sukhleji draining the high ground north of Karachi and ultimately the Western bank of Indus.

It is third basin which forms the subject of this paper. An Index map showing this basin is enclosed as Fig. 1. By far the biggest potential area is the Kachhi plain which receives the waters of Nari, Chhatar, Talli, Lehri, Bolan, Sukhleji and Mula rivers and has probably a million to a million and a half acres of valuable lands which can be controlled if their catchment is properly protected. This without doubt is the area which will give the highest return of the works.

The Importance of Hydrologic Data.

There are 3 broad problems in Hydrology :—

(i) The measurement, recording and publication of basic data.

(ii) The analysis of these data to develop and expand the fundamental concepts.

(iii) The application of these data to multitude of practical problems.

The practical problems can range from the fields of flood control, irrigation, water supply down to highway construction, rail road construction, water power engineering projects; in short all major branches of civil engineering where the collection of hydrological data is a fundamental pre-requisite to the formulation of any development projects.

The hydrologist, therefore, plays a role of the utmost importance in national development studying and measuring water resources of the country so as to present to the Government a complete picture of any catchment area showing :—

(i) Where is the water?

(ii) How much is there?

(iii) What use is made of it?

(iv) What use can be made of it?

(v) What is the source of water?

(vi) Where water be stored for utilization?

(vii) What relations exist between the known surface water resources to the natural precipitation of the area?

With that background Government is provided with a clear factual picture of what can be done in any river catchment. The importance of hydrological data can be well illustrated by giving an example in each of the major fields of engineering:—

(a) *Irrigation and Flood Control.* — Before the construction of a dam is taken up it is essential to ascertain the quantity of perennial supplies and flood flows of the river and the sediment load which it carries. If a dam constructed is so small that it does not have the capacity to retain the peak flood flows of the river or to safely pass it over its spillway, it will obviously be washed away or damaged resulting in colossal loss of public funds. On the other hand if so large a dam is constructed that the river has not enough supplies to fill it up this will not again be an economical use of Government funds. The silt load plays an equally important role in the construction of a dam or any multipurpose storage project. If the river flow contains excessive sediment it is obvious that the storage reservoir will not last for its intended life but will be filled up in a short time. In such a case, therefore, a thorough examination of the sediment load as also the quality of water to ensure its suitability for irrigation purposes would be necessary before hand. Likewise in the design of new barrages and canals and the remodelling of existing structures with which our country is faced today, the measurements of river discharges, sediment loads and the forecasting of floods in relation to the rainfall pattern of various regions is the first and the foremost need of the irrigation engineers.

(b) *Hydro-Electric Power*:—In constructing a hydroelectric project the perennial supplies of a stream play an important role in designing the primary or firm power of a project. The mean and flood flows are also of importance in fixing the secondary power of a proposed scheme so that capacities of power channels and generating sets could be determined accordingly. Since a hydroelectric project is generally combined with irrigation and flood control in a multipurpose scheme, the narration given in para (a) becomes equally applicable in this case as well. In fact the entire operation

of the reservoir viz. inflow, outflow, its depletion and replenishment depends upon a sound collection of the daily river discharges so that the storage requirements as against availability, can be studied in detail on a mass curve.

(c) *Water Supply.*—The basic information regarding the availability, the place of availability and its quantity are essential pre-requisites for taking up any water supply scheme all of which fall within the scope of the subject of hydrology. Quality testing of water is also important so that the presence of any excessive salts in the water rendering it unsuitable for drinking purposes can be pre-determined and treated accordingly before any water supply scheme is taken up.

(d) *Highway and Rail road Construction.*—In the construction of a national highway or rail road particularly in areas like Baluchistan, a number of hill torrents and rivers will have to be crossed over, where bridges or causeways might have to be provided. Most of the rivers particularly in Quetta and Kalat region generally appear to be very deceptive from their looks. A nullah or stream standing high and dry today might be discharging quite a few thousands of cusecs of water the next day and might again revert to its dry state the day after. Therefore in designing bridges and causeways etc., it is very essential to assess the minimum and mean flows of our streams. If a bridge is under-provided for these conditions it is likely to be damaged but if on the contrary it is over-provided it will mean uneconomic construction.

The work of hydrological survey is not a short term affair, though it can and has provided answers, wherever possible, enabling development to take place but basically it is concerned with the provision of long term projects which must be based on authentic data.

Physical and Geological Features of the Zhob Valley and Kachhi Plain.

The Zhob valley is surrounded by a hilly region extending to the Afghan Frontier on the North, Quetta to the North-East which is composed of a variety of igneous and sedimentary rocks. Numerous nallahs join the Zhob valley from the North and South. The area besides the Zhob valley region is composed of steep hills and cliffs. Vegetation in the area is scanty and the Zhob District is thinly populated and small villages are scattered all over where springs occur. In many localities of the Zhob valley excellent soil is available for irrigation and agriculture. The 1961 census figures have shown a rise of 33·9% in the population of Zhob District which is the maximum rise in Baluchistan and is a proof of the promises of development that the valley offers. Although no detailed geological investigations have been carried out in the Zhob but according to Dr. Coulson the valley is said to have very coarse shingly deposits with few fine grained agrillaccous deposits that would form an impervious cover for water contained in the lower beds. Dr. Coulson goes on to add that one can not expect any continuity of alluvial deposits along the

course of the Zhob which is to all intents and purposes in a state of geological youth.

The principal towns situated in the Zhob valley are Hindubagh, Qilla Saifullah and Fortsandeman. Hindubagh is situated about 75 miles from Quetta on the Northern side of main Zhob river. Killa Saifullah is situated at 115 miles from Quetta on the Quetta-Fortsandeman road. The hill ranges to the south of it are composed of jurassic and cretaceous lime stones showing strikingly steep dips to the South. These rocks are well jointed. Unconformably overlying these formations are the recent and sub-recent alluvial deposits which include gravels forming terraces and fan deposits and extend from the foot of outer stone hills northward to a mile or so and give place to alluviams of finer texture in the plains to the north. Fortsandeman is situated at 206 miles from Quetta at the North-East end of the valley in a plain surrounded by a circle of hills with the drainage coming down from all sides and hence seems to be favourably situated for tapping water from underground alluvial formations.

Other towns in the valley are Meena Bazar and Badinzai situated about 25 miles and 16 miles south-west of Fortsandeman respectively where sites for hydrological investigations have been selected as would be revealed from the chapters that follow. The average annual rainfall in the Zhob valley varies from 7 45 inches at Killa Saifullah to 10·36 inches and 10·95 inches at Hindubagh and Fortsandeman respectively. The minimum and maximum annual rainfall ever recorded in the valley since 1935 was 3·55 inches and 21·8 inches at Hindubagh and Fortsademan respectively.

Kachhi Plain :—All the nullahs and torrents draining Loralai, Sibi, eastern part of Sarawan of District Kalat, Murri and Bugti country after forming into sizeable tributaries join the main rivers namely Nari, Bolan, Talli, Lehri and Chhatar which all debouch into the Kachhi plain. From the Jhalawan country comes the Mula and flowing in north-eastwardly direction emerges into the Kachhi plain near Gandhava a few miles from Pir Chhatar. The area is composed of alluvial flood plains of the Indus consisting of loose or partly consolidated fine silt, sandy clay with occasional thin gravel beds etc. In other words the Kachhi plain may be described as an inland delta which the rivers around are attempting to build up so as to once more produce a free drainage towards the Indus.

The outlet capacity from the Kachhi plain into the western bank of Indus is far less than the inflow into the Kachhi plain when all the Kachhi streams are in spate, more particularly when floods in all the streams happen to synchronize. The heavy sediment laden waters of the rivers of the Kachhi deposit huge quantities of sediment on the plain thus causing a gradual but continuous rise of level. Vast areas of fertile alluvial soil therefore exist in the Kachhi which affords bright opportunities for the development of this plain if the flood waters of the Kachhi streams can be controlled.

Zhob River and Streams of the Kachhi Plain.

None of these rivers carry any large flows of water except after heavy rains. During the greater part of the year there are shallow streams

some of which run dry during continuous spells of drought. A brief description of the Zhob river and the Kachhi streams is given below :—

Zhob :—The Zhob river rises at the Tsari Mehtarzai pass on the eastern watershed of the Pishin valley, and has a total length to its junction with the Gomel river of about 240 miles. In its course, it is distinguished by various local names. The first affluent of importance is the Kamchughai stream which rises in the Kand mountain and runs through the narrow winding glen of the same name. The stream is perennial as far as the Ragha Bakalzai village at the mouth of the glen, but during the rains, the water flows further eastward and at the village of Karezgai merges into the main stream. The Kamchughai stream receives the drainage of the surrounding hills and affords a considerable amount of cultivation. The Zhob river flows about the center of the valley as far as Kazha. A permanent perennial stream first appears in it about 45 miles from the source upto which the dry hill torrent is generally known by the name of Lahar. For the rest of its course it has a perennial stream. After Kazha it gradually begins to cross the valley still continuing eastward, till near Haiderzai it infringes on the spurs of the hills to the south which turn its course north-eastward into the valley. It then flows about the centre of the valley again and is known throughout its course hence by the name of the Lora. At about 12¼ miles from Haiderzai it is joined from the south by the Landai and Ghazlai rivers and about two miles further the Kandil river falls into it from the North. The Sawar Rud which contains a good stream of excellent water throughout, falls into the Zhob river from the east, about 13 miles from the Kandil junction. The Zhob river still flowing a north-easterly course passes about 2 miles to the West of Fortsandeman and near Dera (about 29 miles from the Sawar junction) enters the hills. About 30 miles further on, and about 2 miles to the south of Mir Ali Khel it is joined by the Sri Toi river from the West. Passing through the north of Moghal Kot Fort (about 40 miles from Mir Ali Khel), it finally falls into the Gomel near Khajuri Kach. Owing to the height of its scraped banks, the water of the Zhob river cannot be utilized for irrigation till near the Sama Khwal hill, north-west of Meena Bazar, where the first channel for irrigation is taken off, for the Sandiar lands of Badinzai. The Zhob is a sluggish turbid river flowing in a channel varying from 40 to about 80 yards in breadth between the scarped clay banks, about 15 feet in height and quite disappropriate to the volume of water usually flowing in it. It is a shallow stream seldom exceeding 2 feet in depth in the largest pools, and at many places not more than about 6 inches, and about 20 feet in breadth but there are evidences and now also records to show that floods quite a few feet higher than the present level of the water sometimes sweep down the channel. Though they are of a short duration, they offer an impassable obstacle while they last. From its source upto Kazha, the bed can be crossed at all times of the year, but the course of the river between this place and the point where the Sawar Rud joins it is difficult to cross except at the regular fording places which exist at short intervals along it. Great care is necessary when crossing, as the bed of the river is very soft and in many places somewhat resembling a quick sand. The banks on both sides are intersected by innumerable fissures and ravines among which it is difficult to find the way to the fords without a guide. The exposed parts of the

channel are frequently covered with a white efflorescence but the water is sweet. Tamarisk and rushes grow along the channel in many places. The southern watershed dividing the drainage of the Zhob from that of the Bori valley is at an average distance of about 12 miles only, south of the Zhob river. The northern watershed dividing the Zhob from the Kundar drainage is about 40 miles distant.

Kachhi Streams.

Nari. Nari river one of the largest in Baluchistan rises at Tsri Momanrgai in longitude 67°-42′ at the watershed between the Shahrig and the Bori tehsils, 4 miles to the east of Sperargha. Here the river or hill torrent, which has no perennial supply of water is known as Babai. It flows in an eastenly direction for about 32 miles upto the China village then turns to a south-easterly direction, and about 58 miles from China is joined by the Mara River from the north, and about 2½ miles further on the north-east by the Sehan and Watagan rivers which have permanent water. Here the river is known as the Loralai. It then takes an abrupt turn to the south, and passes through the Zati Tangi, a gorge which is about 4 miles long and lies between the Kru and Gadabar ranges, and the river is henceforth known as Anambar. Flowing for about 10 miles in the Luni country, it is joined from the north-east by the Lakhi stream and 8 miles below by the Narechi stream which has perennial water and is now known as Beji river. A little below its junction with the Narechi river and about 4 miles from Chotiali the river is crossed at "Ghatti Pul" by a masonry bridge. It flows in a south westerly direction for about 48 miles, and is joined near the village of Quat by the Dada stream from Harnai which also has perennial water. Following the same course for another 9 miles, the Sangan stream, which has permanent water, falls into the Beji about a mile below the Babar Kach railway station. Hence it turns to the south and through the Nari gorge debouches into the Sibi plain.

The total length of the river from its source at Tsri Momanrgai to its exit into the Sibi plain is about 190 miles.

The river having to carry off the drainage of the enormous catchment area of the Anambar and Narechi rivers besides contribution from several mountain torrents, is between Chotiali and the Nari gorge subject to very sudden and high floods when it becomes a roaring torrent 50 feet deep rushing in places between precipitous banks. A railway line now runs through this part which has six bridges between Sibi and Babar Kach, a distance of 23 miles.

The bed of the river for the greater part of its length is covered with shingle, but from the Zati Tangi to Ghatti Pul it passes through soft soil. At its exit from the Nari gorge, the water is led by means of a weir and a canal to a masonry regulator where it is distributed into 4 small branches which supply the irrigation water for Sibi and the neigbouring villages.

Tamarisk, rushes, and tall reeds grow in many places along the bed and banks of the river and *shisham* and *sufeda* are also found in that part of the river which lies in the luni country.

Nari Catchment Area.—The Nari river occupies roughly a rectangular area of some 8338 square miles enclosed within the part of West Pakistan lying between 67° east to 70° east and 29° and 31° north. It drains an area varied both as regards its topography and its climatic conditions. It varies from the high ground of 10,000 feet and over around Ziarat and Murghakibzai to the low plains area of the Kachhi lying at some 500 feet of elevation or even less. The upper area has a reasonable rainfall and is moderately well covered by Juniper and other forests and the central section through which the Anambar flows, is a good agricultural area suitable for intensive development. To the West around Harnai and Sharig the tributaries of Nari drain areas rich in coal fields. The country is more broken and steeper and also more denuded. The river that is known as the Nari really only forms the latter part of the Anambar, Narechi and the Beji complex. These three streams are the main perennial rivers feeding Nari and giving the bulk of its water. The western tributaries whilst perennial in their upper reaches lose their water in the broad rubble valleys. Throughout the course of Nari and its tributaries these shingle and rubble beds form a distinctive feature. They are a break down product of the geological formations and much of the river flow disappears in these deep deposits. During flood periods great movement of the bed takes place and these shingle areas form a destructive item when dealing with the development of the streams. The soil losses are high as much of the catchment is sadly overgrazed and denuded. Agricultural practices leave much to be desired and protective forests that once are reported to have existed are no longer in evidence. According to the old district gazetteers the upper areas of Baluchistan of which the Nari catchement forms part, were well closed with trees. Some of the authorities consider that this forest cover existed as short time ago as 200 to 250 years ; thus in the 17th and 18th century. Since then dynastic wars and the periodic movements of nomads from the high Himalyan plains and a complete disregard for the value of tree cover, has reduced this to a pitiful minimum. Even the comparatively well covered area around Ziarat can only best be termed as sparse forest cover. Climatically the variations over the catchment are great. Ziarat and the high ground being cool with moderate to heavy winters and snowfall whereas the lower section towards Babar Kachh and the point of entry in the plains at Nari bank are dry and extremely hot. The topography of the lower part of the catchment is extremely rugged and broken and a good idea is gained when flying over it when the barren aspect of the area is seen in greater detail. It is generally accepted that the formations are soft and easily denuded and broken up by even moderate rainfall.

Bolan :—The Bolan rises near Kolpur. Perennial supply first appears at Sar-i-Bolan and disappears again near Abe-i-gum. At Bibi Nani it is joined from the west by the Sarawan river which is known as the Morro River near Bibi Nani. From this point it possesses a perennial stream. The river is joined at Kundlani from west by the perennial waters of the Garmab stream and emerges into the Dhadar plain near Pirchauki. Lower down near Allah Yar Shah an earthen dam has been constructed on the Bolan for irrigation. Below it, the river eventually dissipates into the vast Kachhi plain.

Talli :—The Talli stream which is known also as the Sundimari, Chakar, Karmari, Manjra and Rurk in different localities, rises in the hills bordering Kohlu near Kui, and flows due west through the centre of the Murri country to Talli on the boarders of the Sibi Tehsil, whence it turns south-west and leaves the district near Gurej. Its perennial water is either all drawn off for irrigation or loses itself in the sandy bed of the stream soon after passing Talli.

The Chakar Tangi, just below the junction of the Manjara and Khattan streams is a formidable pass, and the immense boulders which obstruct it are traditionally supposed to be the buffaloes belonging to the Baloch hero Mir Chakar Khan, which were changed into stones at his prayer and obstructed the passage of Turkoman horsemen, who were pursuing him.

Lehri :—Lehri River which is known as the Nal or Gandhar in the Marri country carries off the drainage of the Makhmar, Sori Kaur and Kahan valleys, besides receiving other affluents of less importance. It is a fine stream at Tratani, but is lost before it reaches Lehri except during floods.

Chhatar :—The Chhatar is known in the Bugti country as the Siahaf, which with its affluent, the Pathar, drains the north and north centre of the Bugti territory. These two streams join at Sangsila, and the course of the river then proceeds in westerly direction until it strikes the Kachhi border below Phuleji, the stream being now known as the Chhatar.

Mula :—180 miles long, rising in the Harboi hills, it drains the whole of the north-east of the Jhalawan country and also the south-west corner of Kachhi. The Mula river flows from south to north-east *i.e.* in a direction opposite to other Kachhi streams in the upper catchment with high mountainous banks on both sides like other streams of the Kachhi but after emerging into the plain takes a 180° turn and starts flowing southwards parallel to other rivers of the plain. Some of its perennial supply irrigates flats along the course. Flood water is partly utilized for cultivation in Kachhi.

Sukhleji. The Sukhleji collects the drainage of eastern part of Sarawan and Western part of Kachhi Kalat and emerges into the alluvial plain near Shoran. In the upper reaches it is also known as the Kachhi Jhal. It is relatively a small stream and has a catchment area of 744 square miles at the site when it emerges into the plains.

Hydrological Investigations.

Although investigations were started in most parts of Baluchistan but description given below confines only to Zhob and Kachhi streams which form the subject of this paper.

A thorough reconnaissance of the main rivers and their tributaries mentioned in the foregoing paragraphs was carried out with a view to select suitable sites for installing stream gauging stations, evaporation

stations, rainfall stations and sediment sampling stations so that a true picture of the lower and upper catchments of each main river could be assessed in a reasonably accurate manner. For this purpose each catchment was divided as follows:—

(1) Firstly and primarily the main river itself should be adequately covered for making measurements all the year round.

(2) The sites should be selected keeping in view the conditions in the upper catchments and lower catchments separately.

(3) Sites on the main rivers having been selected other sites of priority No. II should be so fixed that the main tributaries of each catchment are adequately covered.

Sites in Zhob Valley :—For this purpose a site on the main Zhob river under priority No. I was selected at Badinzai. This site had once been considered suitable for a dam site by the Irrigation Department which scheme was subsequently shelved. Gauges were erected at this site for stream gauging and it was also earmarked for regular sampling of the sediments in suspension carried by Zhob river.

The 2nd site was selected lower down about 15 miles below Fortsandeman at Brunj Weir only to serve as a check station for the measurements carried out at Badinzai. The main tributaries viz. Rud Faqirzai, Kapip Lora, and Sowar Nallah were coverd by selecting second priority stations as shown in the list attached as appendix I. In addition an evaporation station together with a rain gauge was installed at Meena Bazar to serve as a representative station for the assessment of evaporation in the Zhob valley.

Sites on the Kachhi Streams :—The largest of Kachhi rivers namely the Nari was first taken up and a stream gauging site selected at Nari bank road bridge 5½ miles from Sibi which was to serve as priority No. I station on the main Nari river where bridge measurements with a current meter could be carried out during floods. Gauges were also erected at Nari Headworks a few miles upstream of Nari bank only to serve as a check station for the measurements carried out at Nari bank. Nari bank was also selected as a site for carrying out regular sediment sampling of the waters of Nari river. The upper catchment of the Nari was well covered by installing gauging stations covering all important tributaries of the Nari including the Anambar and Narechi complex, the Khost river and the Harnai streams. A list of all the stations erected on the Kachhi streams and the Zhob is attached as appendix I.

On the Bolan river 2 sites were selected one at Bibi Nani where Moro river joins the Bolan wherefrom the river possesses a perennial stream. The river at this site is fairly wide and the bed is variable with a shifting control. The floods in the Bolan like other streams of the Kachhi being of torrential nature, accurate measurements of flood flows and development of gauge discharge curve would not have been possible at this

site. Bibi Nani was, therefore, selected only as a check station for making use of the bridge which existed there and for making occasional measurements. The second site which by far is the most important site was selected on the Bolan at Kundlani where a road bridge also exists; the river is comparatively quite narrow and the conditions of control far better than those at Bibi Nani. This site was selected as a priority No. I station for the Bolan river. An Overseer was posted at Dhadar 12 miles away specifically for making regular measurements of the Bolan river and also for making sediment sampling.

On Chakar river a gauge site was selected and erected near Talli village at Talli Tangi where the river emerges out of the narrow gorge into the Kachhi plain. This site was once investigated by the MES long time ago for constructing a dam and is still under investigation by WAPDA. On the Lehri river a gauging station was selected and erected at Gorakh Tangi about12 miles from Lehri village, where the river debouches from a tight gorge from the Murri area into the Kachhi plain.

On the Chhatar a site was selected about 7 miles from Phuleji village at the Phuleji Tangi where the Chhatar river after flowing through the Dera Bugti area emerges on the flat terrain of the Kachhi.

On the Mula river a site was selected at about 20 miles from Gandhava in District Kalat near a small hillock called Sundh some distance above which the Mula emerges into the level country.

On the Sukhleji a gauging station was erected a few miles from a place called Shoran in District Kalat where Sukhleji going south eastwards debouches out of a gorge into the plains. All these sites were also selected for sediment sampling for these respective rivers.

The Kachhi is an area climatically quite different from the places of high altitudes like Quetta. In the Kachhi temprature rises to 120° F or more under shade. Humidity is very low, rainfall is rare but some times it gets sudden and heavy down pours which have unusually high intensities that result in colossal floods. To assess all these factors a representative station was set up at Nari Headworks where an automatic rain recorder was installed together with an evaporation station to assess evaporation and rainfall intensities in the Kachhi. Ordinary raingauge stations being operated by the Metereological Department through the political agencies exist in the Kachhi at Lehri, Gandhava, Dhadar, Sibi etc. Normally more rain recorders and Weather Bureau type standard evaporation pans should have been installed in the Kachhi but due to a miserable shortage of equipment we had to be content with one evaporation station and rain recorder at Nari Headworks and the other at Anambar Headworks in Loralai District to have a separate assessment of conditions in the upper catchment of the streams like the Nari. The automatic rain recorder cum evaporation station at Anambar Headworks was also provided with dry bulb wet bulb maximum and minimum thermometers. A map showing the position of sites narrated above is attached as Figure I which also shows the number of rainfall stations operated by various agencies and departments in the area.

Before starting to make our own investigations it was imperative to have taken an inventory of the data that were already available for this area. It was revealed that except for rainfall figures lying scattered in various offices no other studies had been conducted in this area ; at least no record of it was available. We first therefore visited various offices *e.g.* the Political Agents, the Forest Department, the Health Department, Irrigation Department, Railways and also the Meteorological office at Karachi and dug all rainfall records that were of importance to the hydrological survey. These data were then sifted, compared, checked and processed after which it was recorded in special rainfall registers of each station, opened and maintained for this purpose. In many cases data of one and the same station as received from various agencies differed from one another and had to be reverified before finally accepting it to be correct. The results derived from these investigations are briefly discussed in the following paragraphs.

Rainfall.

The first and foremost requirement of a hydrologist for starting his hydrological analysis is the basic information regarding natutal precipitation over a specific area or river basin with which he may be concerned. The most important component of natural precipitation is the rainfall. A list of rainfall stations that are under operation in the Zhob river basin and the catchment of the Kachhi streams is given in the statement attached as appendix II. This statement gives the annual rainfall of all the Kachhi streams since 1935. These figures would show that the average annual rainfall in this basin varies from 3″ to 14″. It would further be observed that in the Kachhi plain itself where tempratures are high, humidity is relatively very low, the rainfall is less while in the upper reaches in places like Harnai, Sharig, Nakus etc. the rainfall is particularly more going upto a maximum annual figure of 30.27″ as recorded in 1944.

The intensity of rainfall has a direct bearing on the run off or flood flows. A rainfall occuring at a very low rate although for a longer duration would perhaps yield practically no run off as against a sudden cloud burst which brings downpour at a great intensity.

A perusal of the figures given in appendix II would show that 1944 was a year of rains. These rains were wide spread and were recorded over the entire catchment at a rate greater than the average. For instance Khost, Sharig, Harnai, Nakus, Nari Headwork, Dhadar, Loralai, Mach, Kalat, Khuzdar recorded an annual rainfall of 17·27, 21·32, 22·43, 30·27, 8·72, 10·90, 16·85, 27·92, 18·50, 21·86 against their average annual figures of 9·17, 13·15, 14·25, 13·27, 5·39, 4·45, 9·95, 9.50, 8·29, 7.94, inches respectively. Further more Mach which lies in the centre of Bolan river catchment recorded a rainfall of 11·43 inches in the month of August alone in 1944. This heavy rainfall resulted in the highest stage of flood that ever arrived in the Bolan. The highest flood mark is noted quite a few feet above the road level of Kundlani bridge where we have erected a site now. The rainfall of the Zhob and the Kachhi plain has followed a set of pattern in

the past excepting a few deviations. There are the winter rains which generally start in December and continue consecutively for quite a few days but the intensity of rainfall is relatively low thus yielding a relatively low percentage of run off. On the other hand the summer rainfalls are the result of sudden storms which bring heavy downpours, last for comparatively a short duration but have a very high intensity. It is this high intensity of rainfall in the summer which causes heavy floods to arrive in the summers in streams which otherwise have practically little or no flow. This pattern of the flood flows in the rivers of this basin in particular and the whole of Baluchistan in general is depicted by the hydrographs, a detailed discussion of which follows in the chapters to come. As an illustration the highest rainfall intensity recorded on our Automatic rain recorder station at Nari Headworks during 1961 occuring on 19-7-61 is reproduced as Fig ; II. This shows that 3·8″ of rainfall was recorded in a period of only 55 minutes as against a total rainfall of 3·82 inches during the day and 5·96 inches during the month. It is such like intensities of rainfall which bring floods of a flashy nature in the streams of the Kachhi and the Zhob. In the table attached as Appendix III is given a summarized record of rainfall and characteristics of the representative stations in this basin.

Evaporation.

Evaporation which forms an important component of the hydrologic cycle had not been given the due attention particularly in Baluchistan where although a number of rainfall stations had been erected, no evaporation station existed. Measurement of evaporation is of the utmost importance in formulating projects particularly storage projects in areas like the Kachhi where there are extreme variations of temperature and humidity being low, the evaporation rates are high. Therefore adequate allowance has to be kept for evaporation losses in assessing supplies from storage reservoirs. As has been stated before Weather Bureau type class A pans were set up at Nari Headworks in Sibi District *i.e.* within the Kachhi plain itself, at Anambar Headworks in Loralai District to represent the upper catchment of the Kachhi streams and Meena Bazar in District Zhob to represent conditions in the Zhob valley. The record of evaporation rates as observed, collected and analysed is produced in a summarised form in a statement attached as appendix IV. This statement also gives record of Quetta town only to afford a comparison with the figures of the Zhob and Kachhi basins. It would be noticed that the average annual evaporation at Sibi, Loralai, Zhob, Quetta stations was recorded as 89·77, 101·68, 58·98, and 48·44 respectively.

It would further be noticed that the monthly evaporation ranged from a minimum of 3·36 inches to a maximum of 14·95 inches for Nari Headworks, 2·92 to 16·84 inches for Anambar Headworks, 2·38 to 7·64 inches for Meena Bazar and 1·09 to 7·84 for Quetta. This means that any storage project in this area has to cater for a loss of 8 to 9 feet depth of water annually through evaporation. Plate I gives a view of an automatic rain recorder/evaporation station set up by the hydrological survey.

Run off.

As has been stated before, stream gauging operations were started at the sites already mentioned on the Zhob and rivers of the Kachhi. Generally sites with a permanent control are difficult to find in actual practice. Most of the sites erected have semi permanent control or a shifting control. This meant that periodical observation of river flows was necessary at these sites. A gauge discharge curve once developed could not hold for an indefinite period but had to be revised at least on a year to year basis. The hydrographic overseers were given instructions to observe fresh river cross sections after the passage of each major flood and if there was a significant change of section a new cross section be plotted and submitted to Divisional Office. for record. Changes in the configuration of river beds at our discharge sites were kept under vigilant observations. Any significant change in the river cross section meant preparation of a new gauge discharge relation henceforth. In some cases more than one gauge discharge curve had to be established in one year, each applicable to a different period of the year depending how and when a change in the river conditions was reported. It was also ensured that the zero R. L. of a gauging site once fixed was not disturbed unil and unless in a rare case the river conditions made it necessary in which case it meant opening of a new history sheet and preparing gauge discharge relations afresh from then onwards. From these studies hydrographs of Zhob, Nari, Bolan, Talli, Lehri, Mula, Sukhleji, Chhatar showing mean daily flows have been prepared and are reproduced as Fig. III (a) to (h).

The peak discharges of each flood have been shown separately in a table given on each hydrograph. These hydrographs depict the typical flashy nature of floods in these rivers where the peaks shoot up to thousands of cusecs for a few hours and revert to their base flow of just a few cusecs leaving no evidence as if a flood had ever arrived.

Plate 2 shows a general view of Nari river in flood. Plate 3 shows measurements on the Nari in progress at Nari bank. Plate 4 shows the Khost river a tributary of the Nari emerging out of the gorges, just a few minutes before a flood arrived. Plate 5 shows measurements on a cable way in progress.

Relation of rainfall with run off.

Just as no two rain storms are alike in all details, so are conditions of run off divergent from month to month; from season to season, from period of drought to periods of abundant rainfall, from dry parched earth to loose textured soil approaching saturation etc. etc. from thickly afforested area to denuded rocky mountains in the catchment. With such uncertainties to deal with regarding probable stream flows resulting from given rate, duration and total depth of rainfall characteristic of the region under study it appears advisable to rely mainly upon average response and limiting rates of run off, as either observed or derived from physical data and found applicable to the respective seasons and existing or assumed conditions. Therefore had an attempt been made to establish general rainfall run off relations on an annual rainfall and annual run off basis this

would have been of no value due to many uncertainties involved. For instance rainfall which is of the nature of a drizzle or a low intensity and yields no run off would have unnecessarily been taken into account on the one hand and the ground water flow which sometimes appears as spring flow in the streams of this area and again disappears some distance above or below depending upon the river slope, on the other. This would have caused in addition errors that can be avoided if each individual storm is analysed on a season wise basis for each and every river catchment individually. For this purpose a rainfall run off analysis for individual storm period was carried out on a season to season basis separately for all the rivers at the following sites :—

Zhob river at Badinzai,

Bolan river at Kundlani,

Nari river at Nari bank,

Lehri river at Gorakh Tangi,

Mula river at Sundh.

The net results arrived at are reproduced in a summarized form as appendix V (a) to (e), Run off percentage was not worked out for the Talli and Chhatar streams which flow in most of their length through Murri-Bugti territory where no raingauge stations exist due to practical difficulties. Likewise Sukhleji has no rain gauge station in its catchment.

The raingauge measurements of representative stations of each river catchment were converted into areal averages by the Thiessen's method and the weighted mean precipitation over every catchment during each and every storm period was worked out. The run off figures and the peak discharges etc. were taken from the actual measurements or from the gauge discharge curves prepared from actual measurements. The maximum daily rainfall intensity has also been shown to afford a comparison with the peak run off attained during a particular period.

The average run off percentage yielded by a storm from season to season have been shown for each of the river sites in appendix V (a) to (e).

In making this analysis, of course, there is the limitation that the number of representative rainfall stations covering each river catchment is far short of what it should be, particularly for the Lehri stream in which case the raingauge stations adjoining its catchment had to be taken for working out run off percentage as no raingauge exists within the catchment. Nevertheless this analysis comparatively gives a fair idea of the local conditions keeping in view that in advanced countries like the U.S.A. till not many years ago there were 211 automatic rain recording stations to serve an area of 3 millions square miles which comes to about one automatic rain recording station for about every 15,000 square miles.

Sedimentation.

The studies regarding the transport of sediments by flowing water have assumed increased importance now because of the increased rate of construction of river control works in West Pakistan. Now that more and bigger projects will be built, sediment calculations will form an integral part of the design phase for hydraulic structures. In addition, the studies of sedimentation processes are important in initiating soil conservation programmes. These studies include an assessment of the bed loads which may be broadly defined as the coarse material moving on or near the bed and the suspended load which is the material moving in suspension in a fluid being kept up by the upward component of the turbulent current or by the colloidal suspensions. In this area however studies for suspended load only were carried out. At all those sites where discharge measurements were made silt sampling was also conducted. These samples were got analysed at the soil conservation laboratory at Quetta where a Research Assistant was posted by the Hydrological Directorate for this purpose. The perennial waters of all these rivers are generally clear and free of suspended sediment. It is only the flood waters which bring down heavy quantities of sediment load due to the denuded nature of catchments of all these rivers and also contain some dissolved salts. Results of flood samples taken at various sites were analysed both for silt load and salt contents and are given in statement shown as appendix VI.

Soil Erosion.

Evidence is available that termendous soil erosion has taken place in this area over the past few years. Much of the area is bare and sadly overgrazed and virtually the only vegetation in some quantities is to be found in the cultivated valleys. The main reason for this is that bulk of the people of this area, in fact the whole of Baluchistan either lead a nomadic life or engage themselves in cattle grazing. Forests which are reported to have once existed in the past and of which there is mention in the old District Gazetteers seem to have been destroyed over most of the area two to three hundred years ago. Some thin forests of junipers exist around the Ziarat area but even these cannot be called good protective forests. Soil erosion even continues today as a regular process ; the main havoc is created in the Kachhi plain itself which acts as a recepticle for all the sediment laden flood waters of the Kachhi rivers. From the analysis of silt sampling a soil loss map for Kachhi and Zhob basins has been prepared and is attached as Figure IV.

It will be noted that the annual soil losses in the Zhob and Bolan catchments are considerably less while those in the Chakar, Lehri and Chhatar catchments are very high ranging from over 10,000 to about 17,000 tons per square mile. These results are in conformity with what should have been expected by a person who has flown over the catchments of these rivers or has made a reconnaissance himself. The catchments of the Chakar, Lehri, Chhatar being completely devoid of vegetation and consisting of loose disintegrated rocks of the Marri-Bugti area obviously wash away far greater sediments into the streams as compared with the Bolan and Zhob. These figures have been arrived at by taking into account only the suspended load.

No attempt has been made to measure the bed loads due to considerable difficulties involved. Much of the area is covered with sedimentary rocks which break down into fine clay fractions, a proportion of silt and sand, the remainder into shingle and boulder material. The river beds give evidence of the enormous quantities of this rolling load and it is possible that this bed load might at least be as great as the suspended load.

Water Development Inventory.

Development in the Zhob :—The hydrographs for the year 1960 and 1961 show that the Zhob river has a perennial supply of about 35 to 45 cusecs. Below is given a proforma which shows the various schemes proposed, under construction or already constructed on the Zhob river by the Irrigation Department :—

Serial No.	Name of work	Type of weir surface or sub-surface	Flood flow Cs.	Perennial Flow Cs.	Date from which channel started functioning or will start	Cost of Project Rs.
1	2	3	4	5	6	7
1.	Brunj Weir and channel.	Surface	...	10	Channel running upto Killi Brunj only since April, 1961.	5,00,000
2.	Saliaza Irrigation Scheme.	Sub-surface	...	20	Since early days of British rule, supplies not yet released through regulator.	5,00,000
3.	Meena Bazar weir and channel.	Surface	...	10	Will start after about 2 months.	2,95,000
4.	Kibzai Irrigation Scheme.	Surface	100	10	Will start during 1961-62.	6,66,000
5.	Badinzai Irrigation Scheme.	Sub-surface	60	15	Perennial channel will provide irrigation for Rabi and the flood channel for Kharif 1962.	7,90,000
6.	Killa Sharik Weir.	Surface	...	15	Will start functioning after about a month.	2,85,000
7.	Rud Faqirzai Weir and channel.	Sub-surface	...	15	31st December, 1961.	2,65,000

Brunj Weir, Kibzai Irrigation Scheme, Killa Sharik weir are situated downstream of the guage and discharge station at Badinzai while the Badinzai irrigation scheme and the Rud Faqirzai weir are located upstream of it. A weir with a channel has also been constructed at Meena Bazar on the Sawar Nullah which outfalls into the Zhob river upstream of the gauge site at Badinzai. Another weir has been constructed at Kapip on the Kapip or Saliaza river as a part of the Saliaza irrigation scheme. From the proforma it would be seen that none of the channels envisaged in these schemes have started functioning now *i.e.* October, 1961. The total perennial discharge including sub surface discharge to be tapped from the Zhob river comes to 95 cusecs out of which 55 cusces is to be utilized below and 40 cusecs above the present gauge and discharge site. Further more a flood discharge of 160 cusecs is proposed to be utilized in the Kibzai and Badinzai schemes on the hope that this discharge would be available for a good many days in the year. This means that with the completion of all these schemes not only the entire perennial flow of the Zhob river would be utilized but it has also been assumed that perennial sub-surface discharge to the extent of 50 cusecs exists which will be brought to the surface as a result of the construction of sub-surface weirs. All this goesto show that the development from the Zhob river has reached a stage of optimum consumption if not over development so far as the perennial supplies of the Zhob river are concerned. However considerable water potential is available in the flood flows of the river. The annual river run off of Zhob including both perennial and flood flows from October, 1960 to September, 1961 have been worked out as 1,22,246 acre feet only. Therefore more schemes should be taken in hand for flood irrigation in the Zhob valley only after giving due consideration to the requirements of the Zhob component of flood discharges for the proposed dam at Khajuri Kachh. Hithertofore the daily flows of the Zhob river had remained un-assessed and un-measured. The production of hydrographs of the Zhob river should be of assistance and value for undertaking design studies for fhe dam at Khajuri Kachh and other projects contemplated on the Zhob.

The evaporation measured in the Zhob valley at Meena Bazar shows an annual loss of about 5 feet depth from water surface for which due allowance be made for all storage projects contemplated in the Zhob basin.

Development in the Kachhi.

Bolan River :—The supplies of the Bolan river are first utilized at Bibi Nani and by villages in its neighbourhood till the river reaches Kundlani. Below Kundlani a diversion weir is under construction near Dhadar to protect existing irrigation in the area and to provide additional irrigation of 1,000 acres at a cost of 6,02,710. Lower down at Allah Yar Shah stands the Allah Yar Shah Dam also known as the Nari Bolan Dam. This is an earthen dam and without a spill way section. It has only an escape channel to permit releases of excessive flow whenever necessary. From the Bolan Dam offtakes a canal for irrigating the Dhadar plain. Thus excepting some flood spill below Dhadar weir till the flow reaches Bolan dam, all the supply of Bolan river is utilized for irrigation. A scheme for providing a spill-way section for the Bolan Dam is under con-

sideration to provide escape for excessive floods and to irrigate 34,000 acres of land through a net work of canals. A statement showing the total annual run off in acre feet from October 1960 to September 1961 of the Zhob river and all the streams of the Kachhi plain is given below :—

Name of River	Site	Approximate drainage area sq. miles	Annual flow in cusecs days	Annual run off October, 1960 to September, 1961, acre feet
Zhob	Badinzai	4448	61,123	1,22,246
Kachhi Streams				
Nari	Nari Bank	8338	3,85,638	7,71,276
Bolan	Kundlani bridge	1424	58,700	1,17,400
Lehri	Lehri Tangi	1340	1,88,500	3,77,000
Chhatar	Phuleji	995	99,030	1,98,060
Chakkar	Talli Tangi	575	54,182	1,08,364
Mula	Sundh	2880	14,96,66	2,99,332
Sukhleji	Sukhleji Tangi	744	38,535 (9 months)	77,070
		Total ...		19,48,502 acre feet.
			say	19,48,500

It will be noticed that the annual run off of Bolan river as measured at Kundlani bridge for 1960-61 is 58,700 cusecs days or 1,17,400 acre feet and the maximum monthly run off is not more than 50,000 acre feet in any month of the year. These figures are for an abnormal year according to the Meteorological office forecast when the rains in this area were greater than normal. On the other hand the total run off for the calendar year 1960 was only 33,638 cusecs days or 67,276 acre feet which are the figures of a normal year of rains. As against this actual position of supplies, the maximum storage capacity of the Bolan Dam at Allah Yar Shah is a little over 80,000 acre feet. This means that even in the month of maximum supply, the dam cannot receive more than 50,000 acre feet in one month from a river, the annual supplies of which in a normal year are less than the storage capacity of the dam and in an abnormal year exceed it by only about 50%.

That is why we have seen in the past that the dam has never been filled up even during the flood days of Bolan river. The design of spill-

way is based on the quantity of flow of maximum consecutive flood days which occured this year from 20/7/61 to 29/7/61. It shows that even if the flow yielded by consecutive maximum flood days was to increase more than two times, the provision of a spill-way would not become necessary. Bolan river is a river with meagre supplies and the figures show that if the Bolan canal from the dam with an A. F. S, discharge of 210 cusecs was to run regularly for 365 days in a year, it would require about 1,53,000 acre feet of water from the Bolan river the annual run off of which does not exceed 1,17,400 acre feet, even neglecting the withdrawls from the channel to be taken out from the Bolan weir near Dhadar presently under construction. Therefore unless the intention is to cater for the unprecedented requirements of a 50 year flood, or a 100 year flood, the proposal for providing a spill way in the Bolan dam is unnecessary and needs reconsideration. Further more it is proposed to tap perennial supplies to the extent of 125 cusecs from the Dhadar weir for purpose of irrigation. The annual hydrographs for 1959, 1960, 1961 produced as a result of measurments at Kundlani bridge a few miles upstream of the weir site, however reveal that discharge of the Bolan river above Dhadar weir is of the order of 70 cusecs only, rising to 80 cusecs and sometimes falling to even 50 cusecs in periods of drought. The channels at Dhadar should, therefore not be constructed for a capacity of more than 75 to 80 cusecs, as against 125 cusecs now proposed by the authorities.

In short the analysis of data for the Bolan river shows that there is no further scope of development from the Bolan itself when its supulies are not even sufficient to cater for the full requirements of the present two structures namely ; Dhadar weir and the Bolan Dam.

The silt sampling figures of Bolan river show that the silting problem is not as serious as for other streams of the Kachhi. The water is also free from salinity and good for irrigation and drinking purposes. The figures of evaporation show an annual average evaporation of 7½ feet from water surface in the Kachhi plain of which Dhadar and Allah Yar Shah areas form a part. This loss due to evaporation should be taken into account in assessing water usage from storage reservoirs in the Kachhi including the Bolan Dam.

Development on the Nari river.—As has already been stated, Nari is by far, the largest of all the streams and has an annual run off of 7,71,276 acre feet. Most of its flood flows run to waste though a small portion of it is used for irrigation by the zamindars by their own primitive methods. The perennial supplies have been tapped at Nari Headworks where from a Nari canal offtakes with A.F.S. discharge of 130 cusecs. Some perennial supplies still escape down, downstream of the Headworks which can conveniently be utilized by raising the weir crest at Nari and raising the capacity of the existing canal to about 200 cusecs and not more. A few dam sites exist on the Nari namely ; the Gorge at Babar Kachh and the gorge at Chhapar Rift on Khost river a major tributary of Nari. But the high sediment load in the flood water of the Nari is the main deterring factor for undertaking proposals for any high dam on the Nari and for that

matter on other streams of the Kachhi. The answer may lie in thinking on the lines of series of check dams in the upper catchements of these rivers to act as spate breakers for the torrential floods and making limited irrigation for limited periods from such structures. The figures of sediment analysis show that Nari has passed over 4½ million tons of silt load in suspension per day against a flood discharge of 49,000 cusecs.

Chakar River.—The annual run off of Chakar River at Talli Tangi has been measured as 1,08,364 acre feet. This stream has hardly any perennial supplies. Whatever does exist, it is utilized by the local zamindars of Talli by constructing temporary bunds. A suitable dam site exists at 24 miles from Sibi called Talli Tangi. The site was first found out before Independence by the Army Engineers where some geological borings were also carried out to ascertain the quality of rock. The scheme being of a major nature, it is understood has been taken over by the WAPDA. The sediment loads of this river are also very high and the discharge, sediment and evaporation figures as reproduced in this paper should be of help in fixing the capacity of the proposed dam if and when it materializes.

Similarly suitable storage sites exist on other Kachhi streams namely ; the Lehri at Gorakh Tangi about 12 miles from Lehri village, Chhatar river at Chhatar Tangi about 12 miles from Phuleji village, Mula river 6 miles upstream of Sundh and about 30 miles from Gandhava and on Sukhelji river at Sukhelji Tangi about 15 miles from Gajan village. Each one of these sites warrants a detailed geological investigation to ascertain their suitability or otherwise. The hydrological conditions of these streams have individually been assessed and reproduced in this paper.

Conclusions.

Concluding at a glance, the following main factors come to light :—

(i) That the total annual run off of the streams of the Kachhi plain as shown in the statement given above is 19,48,502 acres feet or approximately 2 million acre feet. If all the supplies could be utilized, an area of about 5,50,000 acres and not more could be brought under irrigation assuming a water allowance of 5 cusecs.

(ii) That heavy sediment load in all these rivers rules out the possibility of constructing large storage dams on these rivers. Instead an answer will have to be found out in a series of small spate breaker dams in the higher catchment of each of these rivers.

(iii) The extreme hot climatic conditions warrant that due allowance be given to the evaporation loss in assessing water usage from all schemes on the rivers of this area.

(iv) The formation of irrigation schemes and their proportionate benefits should be limited by the position of available supplies

in various rivers of the Kachhi and Zhob during different seasons of the year.

(v) Over ambitious schemes should be reconsidered in the light of hydrological information made available now.

Acknowledgements.

The job of a hydrologist is important but arduous, interesting but laborious and revealing but dangerous. He has to conduct investigations not on road side or in towns but in river beds and river catchments. He works not in civilization but in hazardous natural geographical conditions. He travels hundreds of miles on poor roads in areas like Baluchistan just to wade through the water of a stream which are sometimes ice cold in areas like Ziarat, simply to make one discharge measurement. He makes himself soaking wet in raining conditions waiting to make a flood measurement. His duties are not bound by time limits ; for instance, he cannot afford to sit at home after office hours or on a gleaming Sunday, if it started raining and floods appeared in the torrential streams such as those of Baluchistan in a matter of few hours. In areas like Baluchistan he has to use his sense to foresee conditions ahead in order to take his position at a particular site before it starts raining heavily for otherwise communications to his gauging stations may be cut off as means of communications are indeed poor and difficult to approach in this region. He sometimes rides 40 miles on camel back to reach his intended spot far away from civilisation and human beings.

It was under such conditions that the staff engaged on hydrological survey in Baluchistan worked to make it possible to collect data on which this paper is based, it required the selfless efforts, good nature and determined minds of the officers and staff of the hydrological survey who were entrusted to undertake this pioneering work of carrying out hydrological survey in Baluchistan. My thanks are due to all those Officers and Subordinate Staff of Hydrology Division, Quetta with whose co-operation and team work, it has been possible for me to complete this paper.

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APPENDIX I

LIST OF GAUGE DISCHARGE STATIONS ON THE ZHOB RIVER AND KACHHI STREAMS

Serial No.	Name of river	Location	Name of tributary	Priorty
1.	Zhob ...	Badinzai ...	Zhob ...	I
2.	Nari ...	Nari bank ...	Nari ...	I
3.	Bolan ...	Kundlani bridge ...	Bolan ...	I
4.	Chakkar ...	Talli tangi ...	Chakkar ...	I
5.	Lehri ...	Gorakh tangi ...	Lehri ...	I
6.	Chhatar ...	Phuleji tangi ...	Chhatar ...	I
7.	Mula ...	Sundh near Gandava.	Mula ...	I
8.	Sukleji ...	Sukleji tangi near Shoran.	Sukleji ...	I
9.	Zhob ...	Brunj weir ...	Zhob ...	II
10.	Zhob ...	Meena Bazar ...	Sawar nullah ...	II
11.	Zhob ...	Rud faquirzai weir Site.	Rud faquirzai ...	II
12.	Zhob ...	Saliaza weir ...	Kapip lora ...	II
13.	Nari ...	Nari headworks ...	Nari ...	II
14.	Nari ...	Anambar headworks	Anambar ...	II
15.	Nari ...	Ghatti bridge ...	Narechi and Anambar.	II
16.	Nari ...	Harnai bridge ...	Ghurmi Rud ...	II
17.	Nari ...	Shahrig ...	Shahrig river ...	II
18.	Nari ...	Khost ...	Khost river ...	II
19.	Nari ...	Nakus ...	Nakus river ...	II
20.	Nari ...	Kahan tangi ...	Kawas lora ...	II
21.	Nari ...	Rehman manda U/S.	Rehman manada ...	II
22.	Nari ...	Mara tangi ...	Mara Rud ...	II
23.	Nari ...	Bag-hao gorge ...	Baghao gorge ...	II
24.	Nari ...	Thaddari ...	Thal rud ...	II
25.	Bolan ...	Bibi nani bridge ...	Bolan river ...	II

APPENDIX

STATEMENT SHOWING RAINFALL STATIONS

Serial No.	Name of rainfall Station	1935	1936	1937	1938	1939
1.	Fortsandeman ...	12·41	17·41	10·75	9·38	11·54
2.	Hindu Bagh ...	11·38	11·54	10·31	9·40	13·44
3.	Killa Saifullah ...	5·44	7·52	5·53	7·12	5·02
4.	Nari Headworks ...	7·26	4·71	13·39	3·77	6·33
5.	Sibi ...	4·68	4·59	3·60	2·81	7·86
6.	Dhadar ...	6·25	4·30	4·81	2·02	5·49
7.	Bhag ...	4·36	1·74	3·19	1·64	4·01
8.	Gandava ...	2·72	4·40	6·62	1·57	4·68
9.	Lehri ...	4·56	3·78	5·09	2·43	5·46
10.	Kalat ...	8·69	9·06	8·71	8·31	10·65
11.	Mach ...	8·40	7·64	4·93	8·93	13·40
12.	Alla Yar Shah ...	...	...	...	...	...
13.	Ziarat ...	5·25	7·50	6·70	4·82	4·08
14.	Murgha Kibzai ...	9·86	17·95	11·86	7·94	14·87
15.	Shahrig ...	12·77	14·72	16·91	14·79	17·39
16.	Harnai ...	10·16	18·20	14·14	11·47	16·78
17.	Babar Kach ...	8·97	6·05	5·92	3·31	10·06
18.	Sinjawi ...	9·03	11·07	5·54	5·57	13·92
19.	Duki ...	11·87	15·42	10·09	7·80	13·28
20.	Anambar Headwork ...	...	...	...	...	...
21.	Loralai ...	6·98	10·44	7·38	7·61	12·34
22.	Jhat Pat ...	4·95	3·36	2·74	1·69	2·88
23.	Talli Tangi ...	...	...	...	...	...
24.	Usta Muhammad ...	5·62	4·94	3·75	0·82	4·68
25.	Mirpur Nasirabad ...	5·48	4·36	5·34	0·71	3·20
26.	Zehri ...	9·63	4·55	9·73	3·85	8·16
27.	Kolpur ...	7·63	7·53	7·48	2·50	7·81
28.	Nakus ...	10·25	14·20	8·55	14·45	14·48

II

THAT FALL IN ZHOB AND KACHHI STREAMS CATCHMENTS

1940	1941	1942	1943	1944	1945	1946	1947	1948
10·55	14·09	10·86	8·98	14·59	9·27	4·12	...	9·64
8·69	6·27	16·22	6·81	21·08	9·56	3·55	...	...
6·24	5·03	8·48	3·85	13·25	7·09	3·66	...	...
4·17	4·08	4·90	5·19	8·72	2·22	1·96	...	3·16
3·83	1·56	4·76	5·96	9·42	5·34	4·11	...	4·58
4·52	2·54	5·07	4·41	10·90	6·24	4·02	...	2·39
3·04	2·61	7·50	1·14	7·15	1·89	1·55	...	3·12
2·59	3·05	5·77	2·60	9·41	1·76	1·55	...	4·60
4·60	1·03	8·11	2·57	4·44	2·17	1·45	...	4·35
6·34	3·05	11·24	7·37	18·50	6·32	4·14	...	11·38
6·91	3·73	10·87	5·79	27·29	4·74	2·76	...	Not
...	...	...	...	...	...	...	...	...
6·34	5·05	7·85	8·60	15·80	9·41	4·76	8·64	1·98
13·62	12·48	10·06	12·85	19·71	10·14	7·19	...	...
10·35	7·75	16·21	9·13	21·32	9·19	8·41	...	8·75
13·54	9·92	24·09	10·88	22·43	7·25	9·92	...	10·36
5·74	1·06	2·15	5·22	10·45	2·57	4·31	...	...
6·43	...	12·33	6·33	14·79	6·69	4·49	...	8·91
7·17	9·77	9·97	8·02	12·59	3·50	4·75	...	11·95
...	...	...	...	...	...	...	...	...
8·48	7·02	8·24	8·10	16·85	3.55	5·19	...	6·20
2·62	0·34	4·80	1·32	8·14	3·87	1·42	...	7·21
4·86	3·33	...	...	...	...	...	...	...
1·56	1·39	2·90	1·33	4·60	0·18	1·78	...	12·95
4·05	1·00	6·45	3·05	8·35	0·98	3·30	...	3·46
4·60	1·51	7·31	6·38	19·43	4·98	0·82	...	4·06
6·62	3·83	5·62	7·74	26·07	5·49	0·71	...	...
11·12	16·06	15·05	13·15	30·27	7·19	4·51	...	(closed)

APPENDIX

Serial No.	Name of rainfall Station	1949	1950	1951	1952	1953
1.	Forssandeman ...	5·63	7·61	10·15	8·29	5·87
2.	Hindu Bagh ...	...	12·84	8·71	...	5·99
3.	Killa Saifullah ...	6·66	6·73	7·99	4·53	6·06
4.	Nari Headworks ...	3·98	15·16	0·48	1·30	2·83
5.	Sibi ...	10·37	4·49	3·30	2·40	5·76
6.	Dhadar ...	2·06	9·45	3·10	3·96	2·62
7.	Bhag ...	4·19	5·45	3·99	0·91	1·52
8.	Gandava ...	2·93	4·36	6·97	4·22	3·53
9.	Lehri ...	7·67	7·68	2·73	...	...
10.	Kalat ...	9·46	5·74	13·48	5·72	6·80
11.	Mach ...	a v a i l a b le				
12.	Alla Yar Shah ...	...	...	...	...	...
13.	Ziarat ...	5·26	6·26	6·86	...	7·46
14.	Murgha Kibzai ...	7·79	14·49	10·50	3·89	12·02
15.	Shahrig ...	16·03	18·09	10·17	11·64 (closed)	
16.	Harnai ...	16·81	21·45	12·98	9·60	13·82
17.	Babar Kach ...	...	4·69	(C L O S E D)		
18.	Sinjawi ...	9·52	15·46	11·11	8·93	10·59
19.	Duki ...	8·93	11·61	7·52	8·32	8·87
20.	Anambar Headwork ...	...	...	...	...	...
21.	Loralai ...	7·55	10·78	11·54	8·38	8·94
22.	Jhat Pat ...	...	2·33	3·56	1·29	1·57
23.	Talli Tangi ...	...	...	2·87	1·75	...
24.	Usta Muhammad ...	7·57	8·40	4·88	0·41	3·48
25.	Mirpur Nasirabad ...	6·80	6·81	4·61	4·60	0·97
26.	Zehri ...	4·23	9·81	4·56	5·86	3.38
27.	Kolpur ...	...	3.91	2·06	...	...
28.	Nakus ...	(CLOSED)				

II—*contd.*

1954	1955	1956	1957	1958	1959	1960	Total	Average
12·31	15·17	14·49	14·94	10·39	14·32	...	262·76	10·95
10·47	9·59	14·83	15·20	6·06	...	5·57	217·51	10·36
4·77	...	15·00	11·56	6·41	15·92	...	163·86	7·45
...	1·90	...	3·75	...	14·01	...	113·27	5·39
4·41	4·58	9·06	8·26	0·88	12·78	...	132·03	5·50
...	...	...	...	...	...	2·20	86·35	4·54
3·49	...	...	...	...	...	...	62·49	3·29
1·66	...	...	...	...	...	...	77·21	3·87
3·30	...	14·21	...	...	...	1·32	90·07	4·74
2·66	4·43	12·98	9·40	6·14	...	...	190·57	8·29
Not available					17·14	...	123·52	9·50
...	...	...	...	...	7·37	0·94	8·31	4·16
...	...	...	...	...	...	...	122·64	6·81
10·37	...	23·31	...	7·34	21·46	...	259·70	12·37
(CLOSED)							223·62	13·15
12·30	13·66	28·93	21·48	10·85	3·72	...	344·74	14·36
...	...	...	...	...	...	...	70·50	5·42
7·85	...	19·92	...	9·91	17·20	6·68	221·87	10·09
8·19	10·46	22·12	...	9·27	14·29	8·43	242·19	10·09
...	...	...	...	...	17·64	8·01	25·65	12·83
7·86	14·67	20·49	12·02	7·75	20·40	...	238·76	9·95
...	2·63	12·56	3·94	0·63	4·47	...	78·32	3·62
...	4·91	...	...	...	...	...	17·72	3·54
...	3·76	11·62	1·72	0·54	Nil	...	88·88	3·86
...	...	...	...	...	...	...	73·52	4·08
3·96	...	...	...	...	...	...	116·81	6·15
...	...	...	...	...	...	...	95·00	6·79
...	...	...	...	...	...	...	159·28	13·27

APPENDIX

SUMMARY AND CHARACTERISTICS IN THE ZHOB AND

Serial No.	Name of rainfall Station	Record of rainfall available	Latitude	Longi-tude	Approx. height A.M.M S.L.
1.	Fortsandeman	1935-46, 48-59	31-21	69-27	4620
2.	Hindubagh	1935-46, 50-51, 53-60	30-50	67-44	5910
3.	Killa Saifullah	1935-46, 49-54, 56-60	30-42	68-32	5080
4.	Nari Headworks	1935-46, 48-53, 55, 57-60	29-40	67-53	500
5.	Sibi	1935-46, 48-60	29-33	67-53	440
6.	Dhadar	1935-46, 48-53, 60	29-28	67-39	496
7.	Bhag	1935-46, 48-54	29-03	67-49	330
8.	Gandhava	1935-46, 48-54, 60	29-56	67-14	288
9.	Lehri	1935-46, 48-51	29-11	68-13	360
10.	Kalat	1935-46, 48-58	29-02	66-35	6620
11.	Mach	1935-46, 59	29-52	67-20	3200
12.	Allah Yar Shah	1959-6/61	29-15	67-45	...
13.	Ziarat	1935-53	30-23	67-43	8000
14.	Murgha Kibzai	1935-46, 49-54, 56, 58-59	30-44	69-26	5010
15.	Shahrig	1935-46, 48-52	30-11	67-43	4012
16.	Harnai	1935-46, 48-59	30-06	67-56	2860
17.	Babar Kech	1835-46, 50	29-48	67-59	800
18.	Sinjawi	1935-46, 48-54, 56, 58-60	30-17	58-21	5200
19.	Duki	1935-46, 48-60	30-11	68-34	3561
20.	Anambar Headwork	1959-9/61	30-10	68-54	3250
21.	Loralai	1935-46, 48-60	30-22	68-36	4700
22.	Jhat pat	1935-46, 48-53, 55-60	28-22	68-25	180
23.	Talli Tangi	1940-41, 51, 52, 55	29-32	68-08	400
24.	Usta Muhammad	1935-46, 48-53, 55-59	28-10	68-03	150
25.	Mirpur Nasirabad	1935-46, 48-53	28-24	68-04	175
26.	Zehri	1935-54,	28-34	66-44	5060
27.	Kolpur	1935-46, 50-51	29-S4	67-08	5900
28.	Nakus	1935-46,	30-07	67-52	3350

III

OF RAINFALL STATIONS

KACHHI BASIN

Mean months Inches	Record of measured rainfall in Inches					
	Maximum daily		Maximum Monthly	Annual		
				Minimum	Mean	Maximum
0·893″	1·29″	(1/59-2/60, 8/60-6/61)	4·06″	4·12″	10·95″	17·41″
0·811	1·10	(1/60-8/61)	6·21	3·55	10·36	21·08
0·592	2·92	(11/58-9/61)	6·00	3·66	7·45	15·92
0·435	3·82	(1/59-9/61)	7·62	0·48	5·39	15·16
0·445	1·92	(1/59-8/61)	7·29	0·88	5·50	12·78
0·424	2·10	(3/59-9/61)	4·77	2·02	4·54	10·90
0·329	2·13	(5/59-8/61)	4·91	0·91	3·29	7·50
0·376	2·00	(5/59-9/61)	3·85	1·55	3·87	9·41
0·440	1·80	(8/59-8/61)	8·12	1·03	4·74	14·21
0·857	1·70	(4/60-6/60-12/60, 1/61, to 9/61).	7·74	2·66	8·29	13·48
0·851	2·00	(1/59-7/60, 1/61-4/61, 7/61-8/61).	11·43	2·76	9·50	27·29
0·419	1·45	(1959-61)	4·73	0·94	4·16	7·37
0·548		Not available	8·57	1·98	6·81	15·80
1·032	1·75	(1959)	7.75	3·89	12·37	23·31
1·062		Not available	9·18	7·75	13·15	21·32
1·454	2·53	(4/59-8/61)	13·00	3·72	14·36	28·93
0·379		Not available	6·53	1·06	5·42	10·45
0·847	2·40	(1/59-3/61)	6·78	4·49	10·09	19·52
0·799	2·20	(1/59-3/61)	9·09	3·50	10·09	22·12
1·086	2·47	(1/59-9/61)	6·23	8·01	12·83	17·64
0·762	1·91	(1/59-9/61)	8·62	3·55	9·95	20·49
0·348	2·30	(7/59-6/61)	7·23	0·63	3·62	12·56
0·444		Not available	1·88	1·75	3·54	4·91
0·285		,, ,,	8·85	Nil	3·86	12·95
0·304		,, ,,	5·50	0·71	4·08	8·35
0·478		,, ,,	7·00	0·82	6·15	19·43
0·578		,, ,,	8·26	0·71	6·79	26·07
1·027		,, ,,	9·49	4·51	13·27	30·27

APPENDIX IV

RECORD OF EVAPORATION RATES FROM WATER SURFACE

(All depths in Inches)

Serial No.	Stations	Years of record	Years	Mean month	Maximum month	Maximum month	Total April to Sept.	Annual
1.	Nari Headworks (Sibi Distt.)	3	1959	7·64	14·95	3·36	63·93	91·70
			1960	7·46	10·84	3·81	57·06	89·57
			1961	7·34	11·53	3·60	56·67	88·05
						Average		89·77
2.	Anambar Headworks (Loralai Distt.)	3	1959	8·11	16·49	2·92	67·03	97·28
			1960	8·75	16·84	2·23	74·16	105·03
			1961	8·56	14·73	3·44	71·08	102·74
						Average		101·68
3.	Quetta (Rani Garden Sariab).	3	1959	3·83	6·76	1·09	33·04	45·96
			1960	4·32	7·50	1·07	38·14	51·79
			1961	3·96	7·84	1·27	35·92	47·56
						Average		48·44
4.	Meena Bazar ff (Zhob Distt.)	1	1961	4·92	7·64	3·38	37·74	58·98

ff Station Started functioning in January 1961.

APPENDIX

ZHOB RIVER

Drainage area = 4448 square miles

Representative Raingauge Stations :—for working out weighted 1. Hindubagh. 2. Loralai

Nature of catchment:—Entire catchment is denuded and without any

Serial No.	Season	Description	Maximum daily rainfall during the period viz. intensity in inches per day	Name of raingauge station recording maximum intensity in the catchment	Total weighted mean precipitation in inches during the priod in the catchment
1	2	3	4	5	6
1.	Spring Showers.	(a) 21-25 April 1959	1·20	Fortsandeman	1·33
		(b) 8-10 March 1960	0·59	Loralai	0·33
		(c) 13-15 March 1960	0·30	Killa Saifullah	0·34
		(d) 18-22 March 1960	0·16	Loralai	0·17
		(e) 16-19 March 1961	0·60	Fortsandeman	0·33
		(f) 2-18 April 1961	1·20	Hindubagh	2·13
				Average run off percentage yielded by a	
2.	Summer Monsoons	(a) 4-6 July 1959	1·27	Loralai	1.01
		(b) 15-31 July 1959	0·84	Killa Saifullah	1·54
		(c) 15-31 August 1959	1·24	Fortsandeman	0·84
		(d) 8-18 July 1960	0·80	Killa Saifullah	0·60
		(e) 18-30 June 1961	1·04	Mina Bazar	0·83
		(f) 1-31 July 1961	1·45	Mina Bazar	2·99
		(g) 1-31 August 1961	1·00	Mina Bazar	0·64
		(h) 1-6 September 1961	0·40	Mina Bazar	0·14
		(i) 7-15 September 1961	0·70	Fortsandeman	0·37
				Average run off percentage yielded by a Summer	
3.	Winter Season	(a) 28-31 December 1960	1·40	Loralai	1.05

V (a)

AT BADINZAI

approximately.

mean rainfall by THIESSONS POLYGON Method :—

3. Killa Saifullah. 4. Fortsandeman. 5. Mina Bazar.

vegetation or afforestation except some patches in the Zhob Valley.

Run off acre feet.	Run off percentage.	Peak run off in cusecs after precipitation.	Date of occurrance of peak run off	REMARKS.
7	8	9	10	11
7030	2.20	3570	21/4/59	
478	0.61*	190	10/3/60	*First rainfall of spring-lesser run off and more absorption.
2414	2.96	1350	15/3/60	
2304	5.80	750	18-19/3/60	
500	0.64 £	275	18/3/61	£ First rainfall of spring-lesser run off and more absorption.
19000	3.76	5755	13/4/61	
Spring storm		2.6%		
5640	2.34*	3460	4/7/59	*This was first rainfall of Summer after a hot spell, hence yielded low run off.
29642	9.15	5630	15/7/59	
23780	11.90	3520	24/8/59	
42400	20.80	6825	10/7/60	
7840	3.96	3215	29/6/61	
48480	6.80	15300*	27/7/61	*Consecutive rain fell on 24, 25, 26 and 27/7/61 at Mina Bazar.
14744	9.65	2115	26/8/61	
4956	14.50	4350	3/9/61	
4890	10.20	3300	7/9/61	
monsoon storm		9.9%		
4750	1.90	3000	30/12/60	

APPENDIX

NARI RIVER CATCHMENT AT NARI BANK ROAD BRIDGE

Drainage Area = 8338 Sq. Miles.

Representative Raingauge Stations :—for working out weighted 1. Loralai. 2. Anambar Headworks,

Nature of catchment :—Entire catchment is denuded except sparse area around Harnai, Loralai and Sanjawi.

Serial No.	Season	Description	Maximum daily rain-fall during the period viz. intensity in inches per day	Name of rain-gauge station recording maximum intensity in the catchment	Total weighted mean pre-cipitation in inches during the period
1	2	3	4	5	6
1.	Summer Monsoons	(a) Storm 28-30 June, 1960	1.52	Sibi	0.97
		(b) Storm 1-15 July, 1960	1.34	Nari Headworks	1.55
		(c) Storm 18-30 June, 1961	1.05	Harnai	1.29
		(d) Storm 1-31 July, 1961	3.82	Nari Headworks	7.76
		(e) Storm 1-31 August, 1961	1.23	Harnai.	1.79
		(f) Storm 3-16 September, 1961	1.08	Harnai.	1.41
				Average runoff percent age yielded by a	
2.	Winter Rains.	(a) 28.31 Dec. 1960	1.40	Loralai	0.97
3.	Sprihg	(a) 1.13 April, 1961.	2.20	Harnai	3.74

V (b)

5. MILES FROM SIBI ON QUETTA ¾ SIBI ROAD.

approximately.

mean rainfall by THIESSONS POLYGON Method :—

3. Sibi. 4. Harnai. 5. Nari Headworks. 6. Dhadar.

afforestation in the Ziarat Area and some vegetation and cultivation in the

Run off acre feet	Run off percent age	Peak run off in cusecs after precipitation	Date of occurr-ance	REMARKS
7	8	9	10	11
36800	8.38	33,800	28.6.60	
75200	10.85	22,600	9.7.60	
34840	6.10	15,650	22.6.61	
379200	11.00	52,000*	26.7.61	*Rain fell daily in the catchment consecutively from 16 to 28/7/61.
180768	22.60	46,850	26.8.61	
110732	17.50	23,600	8.9.61	
summer monsoon storm		12.7 %		
8160	1.9	1,725	30.12.60	
48620	2.9	10.700	11.4.61	

APPENDIX

BOLAN RIVER AT KUNDLANI BRIDGE

Drainage Area = 1424 square miles

Representative Raingauge stations : — for working out weighted
1. Mach. 2. Mastung. 3. Kalat.

Nature of Catchment :—All the mountains in this hilly Catchment River has a single bed from the start to Kundlani.

Serial No.	Season	Description	Maximum daily rainfall during the period viz. intensity in inches per day	Name of raingauge station recording maximum intensity in the catchment	Total weighted mean precipitation in inches during the period in the catchment
1	2	3	4	5	6
1.	Summer storms	(a) Storm 28 June to 2 July 1960	0.75	Mach	0.31
		(b) Storm 6-14 July 1960	0.70	Mach	0.61
		(c) Storm 17-31 July 1961	2.00	Mach	3.21
		(d) Storm 17-31 August 1961	1.30	Mach	0.97
		(e) Storm 4-6 Sept : 1961	1.40	Mach	1.14
					Average run off percentage yielded by a
2.	Winter rains.	29-31 December 1960	1.00	Kalat	0.82

V (c)

73. MILES FROM QUETTA ON QUETTA SIBI ROAD

approximately.

mean rainfall by THIESSON'S Polygon Method :—

4. Dhadar. 5. Allayar Shah.

are denuded and rocky, though sparse vegetation exists in the Valleys. The

Run off acre feet	Run off percentage	Peak run off in cusecs after precipitation	Date of occurrance of peak run off	REMARKS
7	8	9	10	11
1932	8.2	1625	28.6.60	
20794	45.2	18700	9.7.60	
43070	17.7	20600	25.7.61	
9790	13.3	16780	18.8.61	
15022	17.4	15800	4.9.61	
summer storm		20.4%		
2188	3.53	1008	30.12.60	

APPENDIX

LEHRI RIVER AT

Drainage area = 1340 square miles

Representative Raingauge Stations :—For working out mean rainfall.

1. Lehri.

Nature of catchment :—Entire catchment above this site is hilly

Serial No.	Season	Description	Maximum daily rainfall during the period viz. intensity in inches per day	Name of raingauge station recording maximum intensity in the catchment	Total weighted mean precipitation in inches during the period in the catchment
1	2	3	4	5	6
1.	Summer monsoon	(a) 22-30 June, 1961	0.50	Lehri	0.65
		(b) 1-31 July, 1961	2.40	Anambar H/W	4.35
		(c) 1-31 August 1961	1.20	Lehri.	1.53

Average run off percent yielded by a

V (d)

GORAKH TANGI

approximately.

2. Anambar Headworks.

consisting of loose rocks and devoid of any vegetation.

Run off acre feet	Run off percent age	Peak run off in cusecs after precipitation	Date of occurrance of peak run off	REMARKS
7	8	9	10	11
39682	85.00	17800	25.6.61	
201880	64.80	31120	20.7.61	
90930	83.50	16600	29.8.61	

Summer Monsoon Storm 77.8%

APPENDIX

MULA RIVER AT SUNDH ABOUT

Drainage Area = 2880 square miles

Representative Raingauge stations :—for working out weighted
1. Gandhava. 2. Kalat.

Nature of Catchment :—Entire catchment is denuded and without

Serial No.	Season	Description	Maximum daily rainfall during the period viz. intensity in inches per day	Name of raingauge station recording maximum intensity in the catchment	Total weighted mean precipitation in inches during the period in the catchment
1	2	3	4	5	6
1.	Summer Monsoon	(a) Storm 18-30 June, 1961.	0.7	Gandhava	0.51
		(b) Storm 17-31 July, 1961.	2.00	,,	2.72
		(c) Storm 1-31 August, 1961.	1.50	,,	1.42
					Average run off percent age yielded by a
2.	Winter rains.	(a) 29th January to 9th Feb. 1961.	1.7	Kalat	1.88

V (e)

20. MILES FROM CANDHAVA

approximately.

mean rainfall by THIESSON'S Method :—

3. Khuzdar. 4. Surab.

vegetation except some patches under cultivation.

Run off percent age acre fell	Run off percent age	Peak run off in cusecs after precipitation	Date of occurrance of peak run off	REMARKS
7	8	9	10	11
2880	3.7	1800	19.6.61	
95140	22.8	44400	20.7.61	
150894	69.5	65200	28.8.61	
summer storm		32.0%		
1100	0.84	190	8.2.61	

(Sarfraz Khan Malik)
P.S.E. I

Executive Engineer,
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Quetta.

APPENDIX

SEDIMENT DATA OF

S. No.	Name of river	Site	Date	Discharge.
1.	Zhob.	Badinzai	14.3.60	319.00
2.	,,	,,	9.5.60	39.18
3.	,,	,,	13.5.60	34.81
4.	,,	,,	14.5.60	33.96
5.	,,	,,	18.5.60	39.06
6.	,,	,,	15.11.60	32.27
7.	,,	,,	30.12.60	2308.00
3.	,,	,,	12.1.61	60.49
9.	,,	,,	18.1.61	44.92
10,	,,	,,	15.2.61	42.24
11.	,,	,,	10.3.61	41.44
12.	,,	,,	18.3.61	400.00
13.	,,	,,	12.4.61	671.68
14.	,,	,,	14.5.61	40.76
15.	,,	,,	12.7.61	3212.56
16.	,,	,,	16.7.61	984.84
17.	,,	,,	17.7.61	3706.90
18.	,,	,,	17.7.61	13453.38
19.	,,	,,	23.7.61	1479.55
20.	,,	,,	24.7.61	9239.26
21.	,,	,,	9.9.61	92.73
22.	,,	,,	29.9.61	49.92
23.	Nari.	Nari bank.	5.11.60	25.11
24.	,,	,, ,,	13.11.60	15.18
25.	,,	,, ,,	14.12.60	15.90
26.	,,	,, ,,	24.12.60	16.63
27.	,,	,, ,,	28.12.60	24.86
28.	,,	,, ,,	29.12.60	45.96
29.	,,	,, ,,	30.12.60	85.23
30.	,,	,, ,,	30.12.60	201.84
31.	,,	,, ,,	30.12.60	439.01

VI.

FLOOD SAMPLES.

P.P.M.	Load in tons/day.	E.C. x 10^3	Salt content in grms,/1tr.
4466	433.42	0.60	0.384
Nil	Nil	1.20	0.768
Trace	Trace	0.90	0.676
,,	,,	1.00	0.640
13	1.22375	1.95	1.248
Nil	Nil	1.50	0.960
23763	132176.46	2.00	1.280
905	131.832	2.60	1.664
363	39.277	1.90	1.216
277	28.198	1.80	1.152
175	17.477	1.60	1.024
1035	997.720	1.61	1.030
3704	5997.631	0.80	0.512
112	11.002	2.60	1.664
18475	143038.431	2.00	1.280
14376	34120.920	0.80	0.512
190337.504	170337.504	1.50	0.960
21154	685868.653	1.00	0.640
17594	62735.199	0,70	0.448
17352	386370.338	0.80	0.512
31861	7120.274	1.20	0.768
9154	1001.292	2.40	1.536
Nil	Nil	1.40	0.896
,,	,,	1.45	0.928
663	25.505	1.35	0.864
715	28.656	1.50	0.960
932	55.839	1.20	0.768
715	79.196	1.90	1.216
1180	142.377	0.50	0.320
1505	732.084	2.00	1.280
1808	1912.889	1.40	0.896

S. No.	Name of river	Site	Date	Discharge
32.	,,	,, ,,	30.12.60	642.44
33.	,,	,, ,,	30.12.60	1205.73
34.	,,	,, ,,	30.12.60	885.69
35.	,,	,, ,,	4.1.61	189.96
36.	,,	,, ,,	3.4.61	1885.19
37.	,,	,, ,,	4.4.61	564.03
38.	,,	,, ,,	10.4.61	5849.17
39.	,,	,, ,,	11.4.61	10700.29
40.	,,	,, ,,	11.4.61	9470.38
41.	,,	,, ,,	12.4.61	6364.25
42.	,,	,, ,,	12.4.61	5021.63
43.	,,	,, ,,	13.4.61	2290.98
44.	,,	,, ,,	14.4.61	1141.82
45.	,,	,, ,,	16.4.61	263.16
46.	,,	,, ,,	19.4.61	109.67
47.	,,	,, ,,	19.5.61	8.34
48.	,,	,, ,,	25.5.61	477.90
49.	Nari.	Nari bank.	27.5.61	89.72
50.	,,	,, ,,	22.6.61	13800.00
51.	,,	,, ,,	22.6.61	5473.06
52.	,,	,, ,,	24.6.61	2542.15
53.	,,	,, ,,	26.6.61	1200.28
54.	,,	,, ,,	27.6.61	766.36
55.	,,	,, ,,	28.6.61	366.40
56.	,,	,, ,,	1.7.61	4826.03
57.	,,	,, ,,	2,7.61	4429.33
58.	,,	,, ,,	5.7.61	243.44
59.	,,	,, ,,	7.7.61	1680.65
60.	,,	,, ,,	12.7.61	6081.00
61.	,,	,, ,,	12.7.61	4767.54
62.	,,	,, ,,	12.7.61	3182.71
63.	,,	,, ,,	13.7.61	5565.61
64.	,,	,, ,,	13.7.61	3473.75
65.	,,	,, ,,	14.7.61	1036.93
66.	,,	,, ,,	16.7.61	217.26
67.	,,	,, ,,	17.7.61	48503.10

P.P.M.	Load in tons/day.	E.C. x 10^3	Salt content in grms,/ltr.
69589	3103246.090	1.10	0.704
39678	1198754.644	0.51	0.320
32744	746200.572	0.60	0.384
31157	510356.879	0.65	0.416
37795	1047654.201	0.80	0.512
50528	1990110.592	1.00	0.640
53254	2673649.129	0.65	0.416
33887	679656.317	1.20	0.768
15471	150036.028	1.70	1.088
16787	64944.283	0.98	0.627
12666	210304.843	2.00	1.280
35880	1565469.957	2.30	1.409
34139	913856.287	1.00	0.640
24591	225251.197	2.40	1.536
47020	2295307.735	0.95	0.608
22713	424188.120	1.15	0.736
22416	465699.666	1.10	0.704
14907	162845.861	1.00	0.640
84871	4959613.008	1.15	0.736
32823	642883.068	1.10	0.704
32135	1210192.792	0.80	0.512
35515	1242892.198	1.20	0.768
38230	4544652.414	0.63	3.403
22877	4278077.998	0.50	0.320
41889	1339198.380	1.10	0.704
28816	839780.443	0.80	0.512
15465	109815.430	1.10	0.704
3016	5733.222	0.90	0.576
11464	30459.858	1.30	0.832
2792	2802.108	1.50	0.960
725	280.067	1.45	0.928
22909	176870.758	1.75	1.120
51111	2631425.133	0.78	0.499
36167	1240443.976	0.92	0.589

S. No.	Name of river	Site	Date	Discharge
68.	,,	,, ,,	17.7.61	12536.13
69.	,,	,, ,,	17.7.61	9447.33
70.	,,	,, ,,	17.7.61	6796.55
71.	,,	,, ,,	17.7.61	11501.82
72.	,,	,, ,,	18.7.61	16342.86
73.	,,	,, ,,	18.7.61	20832.20
74.	,,	,, ,,	18.7.61	8322.22
75.	,,	,, ,,	19.7.61	4024.02
76.	,,	,, ,,	19.7.61	1605.28
77.	,,	,, ,,	20.7.61	6889.58
78.	,,	,, ,,	21.7.61	18104.03
79.	,,	,, ,,	21.7.61	11107.34
80.	,,	,, ,,	21.7.61	3800.79
81.	,,	,, ,,	22.7.61	20255.42
82.	,,	,, ,,	22.7.61	7749.38
83.	,,	,, ,,	23.7.61	9175.79
84.	,,	,, ,,	23.7.61	4532.83
85.	,,	,, ,,	24.7.61	24242.86
86.	,,	,, ,,	24.7.61	8127.12
87.	,,	,, ,,	25.7.61	15626.41
88.	,,	,, ,,	25.7.61	14521.27
89.	,,	,, ,,	26.7.61	49326.45
90.	,,	,, ,,	26.7.61	41400.66
91.	,,	,, ,,	27.7.61	13265.63
92.	,,	,, ,,	28.7.61	12092.47
93.	,,	,, ,,	29.7.61	2948.71
94.	,,	,, ,,	3.8.61	788.77
95.	,,	,, ,,	12.8.61	1102.49
96.	,,	,, ,,	14.8.61	614.44
97.	,,	,, ,,	16.8.61	160.29
98.	,,	,, ,,	17.8.61	3203.56
99.	,,	,, ,,	18.8.61	21362.87
100.	,,	,, ,,	18.8.61	14231.40
101.	,,	,, ,,	18.8.61	6867.73

P.P.M.	Load in tons/day.	E.C. x 10^3	Salt content in grms./ltr.
12620	208876.614	0.80	0.512
7680	23426.033	1.20	0.768
5022	4794.852	1.19	0.763
6934	9662.266	0.99	0.634
34924	3413734.747	0.87	0.557
26941	1117933.525	0.90	0.576
20105	525334.752	0.85	0.544
15735	211284.463	0.90	0.576
5723	28827.144	1.10	0.704
3174	2718.346	1.20	0.768
35794	1227426.658	0.80	0.512
24687	573776.241	0.93	0.595
42375	1829342.734	1.00	0.640
52119	2986050.219	0.90	0.576
49163	2403424.207	0.50	0.320
31072	1434992.894	0.55	0.352
13231	178533.818	1.16	0.742
7086	13610.576	1.10	0.704
Nil	Nil	0.95	0.608
Nil	Nil	1.00	0.640
Nil	Nil	0.90	0.576
Nil	Nil	1.20	0.768
Nil	Nil	1.00	0.640
305	45.522	0.90	0.576
1165	1789.274	0.60	0.384
403	250.927	0.60	0.384
757	169.958	1.20	0.768
440	657.501	1.20	0.768
183	34.782	1.10	0.704
2230	3776.789	0.55	0.352
175	42.479	1.10	0.704
190	41.641	1.05	0.672
192	31.752	1.10	0.704

S. No.	Name of river	Site	Date	Discharge
102.	,,	,, ,,	20.8.61	1265.67
103.	,,	,, ,,	21.8.61	396.17
104.	,,	,, ,,	23.8.61	578.20
105.	,,	,, ,,	26.8.61	40559.14
106.	,,	,, ,,	26.8.61	17218.10
107.	,,	,, ,,	26.8.61	10842.14
108.	,,	,, ,,	27.8.61	5889.73
109.	,,	,, ,,	28,8.61	2090.07
110.	,,	,, ,,	31.8-61	355.37
111.	,,	,, ,,	3.9.61	14228.80
112.	,,	,, ,,	8.9.61	9644.00
113.	,,	,, ,,	8.9.61	17913.00
114.	,,	,, ,,	8.9.61	23773.00
115.	,,	,, ,,	8.9.61	20285.00
116.	,,	,, ,,	9.9.61	19163.00
117.	,,	,, ,,	13.9.61	5616.84
118.	,,	,, ,,	14.9.61	797.00
119.	Bolan.	Kundalani bridge.	21.11.59	81.48
120.	,,	,, ,,	2.12.59	86.48
121.	,,	,, ,,	11.3.60	54.200
122.	,,	,, ,,	10.11.60	58.88
123.	,,	,, ,,	24.11.60	68.89
124.	,,	,, ,,	29.12.60	610.93
125.	,,	,, ,,	30.12.60	638.14
126.	,,	,, ,,	30.12.60	258.36
127.	,,	,, ,,	4.1.61	93.16
128.	,,	,, ,,	5.5.61	620.05
129.	,,	,, ,,	5.5.61	79.05
130.	,,	,, ,,	2.7.61	702.75
131.	,,	,, ,,	2.7.61	100.72
132.	,,	,, ,,	3.7.61	90.94
133.	,,	,, ,,	12.7.61	61.62
134.	,,	,, ,,	17.7.61	581.77

P.P.M.	Load in tons/day.	E.C. x 10^3	Salt content in grms./ltr.
2168	3039.678	0.45	0.288
651	318.504	0.70	0.448
7895	111430.000	0.49	0.314
650	417.378	0.80	0.512
18783	48409.767	0.70	0.448
22145	392066.923	0.60	0.384
44013	32819.424	0.60	0.384
666	116.303	0.95	0.608
285	47.150	0.94	0.602
23035	601816.079	0.45	0.288
18176	66287.521	0.70	0.448
260	108.089	0.80	0.512
435	122.615	1.35	0.864
139	25.962	1.10	0.704
560	30.150	1.90	1.220
Nil	Nil	1.20	0.770
148	3.567	2.10	1.344
Nil	Nil	7.00	4.480
1153	5.030	5.00	3.200
9000	2303.326	1.65	1.056
11922	4060.984	1.95	1.248
890	122.538	2.60	1.696
13167	31256.166	2.10	1.344
73353	486508.203	2.50	1.600
53599	210674.749	1.90	1.216
7093	2837-967	1.60	1.024
30500	16572.437	3.80	2.432
19637	11064.625	3.20	2.048
8895	3253.057	2.70	1.728
17066	42459.174	2.00	1.280
20740	14564.663	3.20	2.048
21110	3951.970	1.65	1.056

S. No	Name of river	Site	Date	Discharge
135.	,,	,, ,,	17.7.61	203.01
136.	,,	,, ,,	21.7.61	5856.43
137.	,,	,, ,,	24.7.61	266.44
138.	,,	,, ,,	25.7.61	1069.40
140.	,,	,, ,,	26.7.61	7346.28
141.	,,	,, ,,	27.7.61	3093.12
142.	,,	,, ,,	5.8.61	72.46
143.	,,	,, ,,	12.8.61	68.62
144.	,,	,, ,,	18.8.61	10840.73
145.	,,	,, ,,	18.8.61	1513.27
146.	,,	,, ,,	19.8.61	172.50
147.	,,	,, ,,	22.8.61	116.96
148.	,,	,, ,,	27.8.61	77.50
149.	Chakkar.	Talli Tangi.	20.1.60	22.34
150.	,,	,, ,,	6.3.60	2.109
151.	,,	,, ,,	25.3.60	10.00
152.	,,	,, ,,	17.5.60	0.19
153.	,,	,, ,,	9.2.61	86.10
154.	,,	,, ,,	4.4.61	106.19
155.	,,	,, ,,	12.4.61	141.34
156.	,,	,, ,,	13.4.61	57.13
157.	,,	,, ,,	23.6.61	984.99
158.	,,	,, ,,	23.6.61	2751.44
159.	,,	,, ,,	23.6.61	1630.74
160.	,,	,, ,,	24.6.61	166.02
161.	,,	,, ,,	5.7.61	225.46
162.	,,	,, ,,	6.8.61	233.80
163.	,,	,, ,,	12.8.61	151.75
164,	,,	,, ,,	17.8.61	1032.34
165.	,,	,, ,,	22.8.61	291.39
166.	,,	,, ,,	22.8.61	77.68
166.	,,	,, ,,	23.8.61	2239.87

P.P.M.	Load in tons/day.	E.C. x 10^3	Salt content in grms./ltr.
58031	313256.369	1.60	1,024
28866	61317.102	1.12	0.717
23256	14081.799	1.40	0.896
49841	163065.777	1.85	1.184
17719	47907.406	1.70	1.088
17578	47400.786	0.70	0.441
20759	43291.759	0.80	0.512
3355	897.496	2.50	1.600
325	37.126	2.30	1.462
Nil	Nil	3.60	2.304
Nil	Nil	8.20	5.243
1190	25.811	4.90	3.136
17457	9171.557	2.20	1.408
54202	171012.590	1.70	1.088
61479	921098.640	1.50	0.960
1430	460.426	2.20	1.408
72125	543017.585	2.40	1.536
75527	771765.087	2.30	1.472
1341	651.985	2.10	1.344
22328	83513.865	1.35	0.864
21776	156968.150	1.10	0.704
23734	431851.997	0.90	0.573
460	233.249	0.80	0.512
Nil	Nil	2.30	1.380
11965	807.398	1.60	1.024
67992	381631.617	0.90	0.576
352900	175438.740	1.45	0.870
43600	10257.510	1.18	0.660
1000	195.957	1.30	0.832
Nil	Nil	2.05	1.312
227	38.240	1.25	0.800

S. No.	Name of river	Site	Date	Discharge
168.	,,	,, ,,	23.8.61	881.41
169.	,,	,, ,,	23.8.61	251.25
170.	,,	,, ,,	26.8.61	1357.56
171.	,,	,, ,,	26.3.61	1121.88
172.	,,	,, ,,	28.8.61	1118.92
173.	,,	,, ,,	29.8.61	865.33
174,	,,	,, ,,	12.9,61	111.00
175.	,,	,, ,,	25.9.61	47.40
176.	Lehri.	Gorakh Tangi.	15.9.60	10.00
177.	,,	,, ,,	7.10.60	4.00
178.	,,	,, ,,	18.4.61	9.00
179.	,,	,, ,,	10.6.61	218.00
180.	,,	,, ,,	22.6.61	1309.00
181.	,,	,, ,,	28.6.61	6233.00
182.	,,	,, ,,	8.7.61	133.60
183.	,,	,, ,,	11.7.51	3124.00
184.	,,	,, ,,	12.7.61	4240.00
185.	,,	,, ,,	31.7.61	201.74
186.	,,	,, ,,	12.8.61	1552.00
187.	,,	,, ,,	17.8.61	2991.00
188.	,,	,, ,,	23.8.61	7860.00
189.	,,	,, ,,	25.8.61	210.40
190.	Chhatr,	Near Phuleji.	27.8.60	9.48
191.	,,	,, ,,	13.4.61	28.00
192.	,,	,, ,,	20.7.61	2329.00
193.	Mula.	Sund near Gandava.	8.7.60	20521.76
194.	,,	,, ,,	22.7.60	97.62
195.	,,	,, ,,	10.8.60	81.36
196.	,,	,, ,,	2.11.60	68.15
197.	,,	,, ,,	12.12.60	69.90

P.P.M.	Load in tons/day.	E.C. x 10^3	Salt content in grms./ltr.
1575	2438.552	1.25	0.800
2410	7003.000	1.30	0,832
1165	2487.430	1.20	0.768
652	298.483	1.50	0.960
15307	69544.414	0.89	0.570
7884	10717.818	0.83	0.531
31091	438274.272	1.05	0.671
37652	970958.440	0.82	0.525
27741	633149.926	1.25	0.800
23354	358199.974	1.00	0.640
18855	228185.629	1.08	0.691
8740	48255.828	1.17	0.749
5011	13789.201	0.90	0.576
1018	645.631	1.20	0.768
217	57.354	1.10	0.704
85	1.708	1.30	0.832
853	982.433	1.55	0.992
290	62.705	2.00	1.280
64333	2139586.914	0.97	0.620
26915	390624.059	0.60	0.384
16020	98147.836	0.91	0.582
13281	38417.614	1.10	0.704
9117	16838.439	1.10	4.704
7121	6288.940	1.00	0.640
23251	270426.157	1.20	0.768
20105	217667.090	0.85	0.544
1585	929.904	1.25	0.800
9560	38721.504	1.20	0.768
35670	522751.341	1.10	0.704
32088	368683.785	1.00	0.640
31305	240119.715	0.90	0.576
33099	443934.539	0.80	0.512
19925	166798.978	0.79	0.506
15774	39188.670	0.99	0.636
1835	960.726	1.20	0.768

S. No.	Name of river	Site	Date	Discharge
198.	,,	,,	19.6.61	355.64
199.	,,	,,	26.6.61	311.84
200.	,,	,,	20.7.61	3501.06
201.	,,	,,	21.7.61	3563.71
202.	,,	,,	23.7.61	6912.61
203.	,,	,,	24.7.61	10625.82
204.	Sukleji.	Sukleji Tangi.	4.3.61	27.467
205.	,,	,,	29.3.61	28.109
206.	,,	,,	14.4.61	23.871

P.P.M.	Load in tons/day.	E.C. x 10^3	Salt content grms./ltr,
8765	20186.605	1.00	0.640
8639	6402.506	1.05	0.672
26518	224147.073	0.65	0.416
29350	222073.681	0.60	0.384
34780	579413.588	0.50	0.320
48780	1225069,274	1.00	0.640
720	41.072	8.00	0.640
708	40.388	0.96	0.612
322	27.5507	1.00	0.640



Plate 1

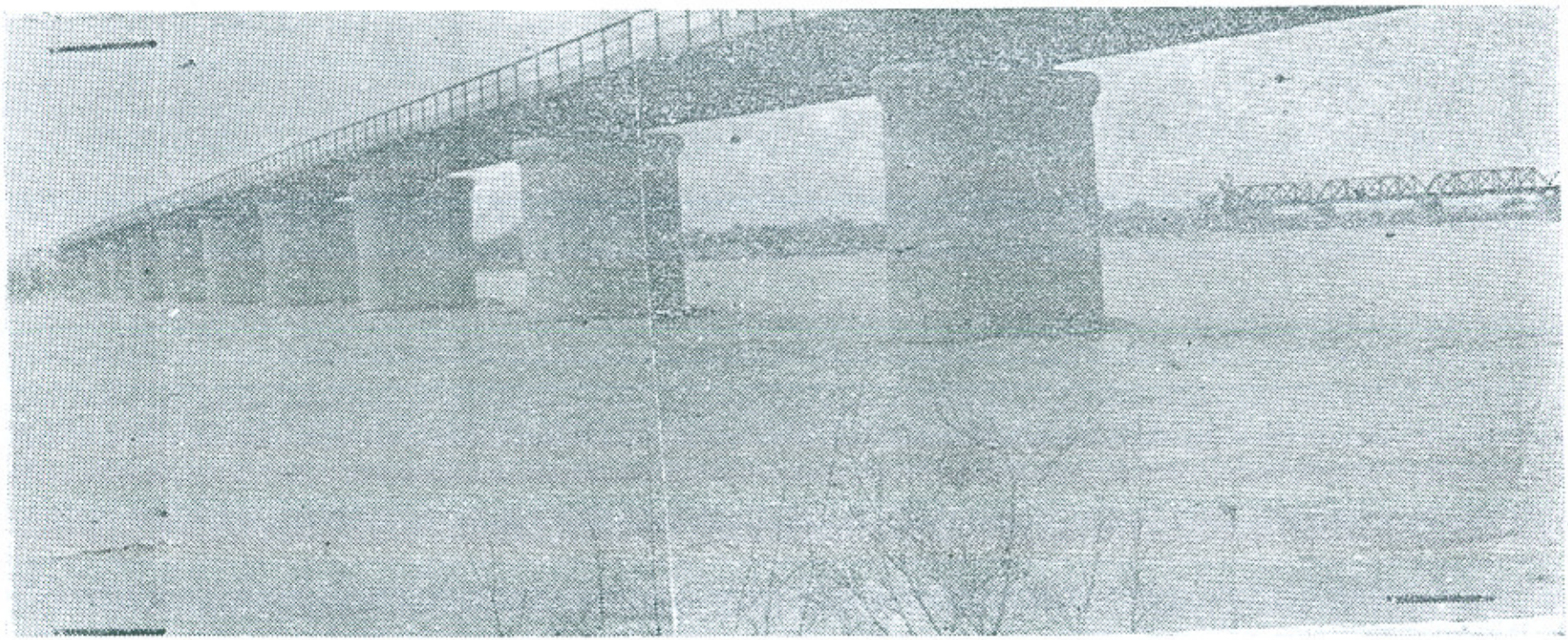


Plate 2

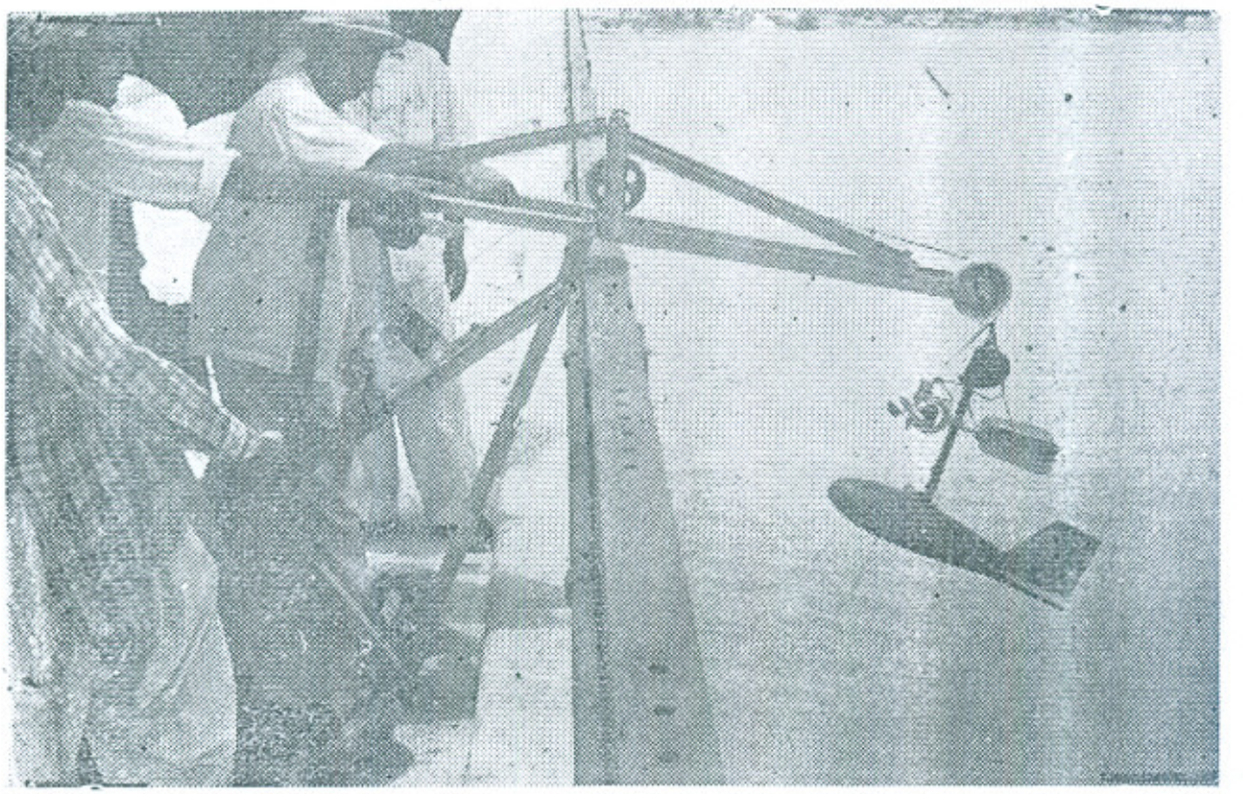


Plate 3



Plate 4

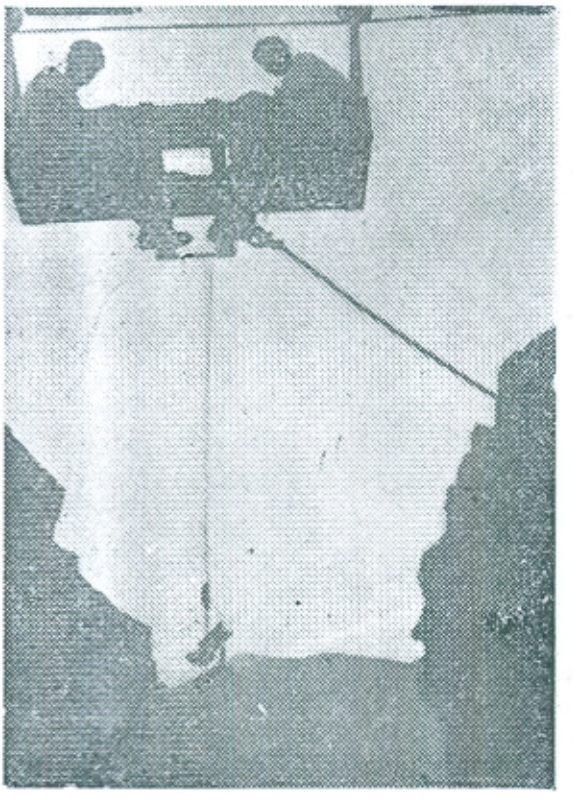
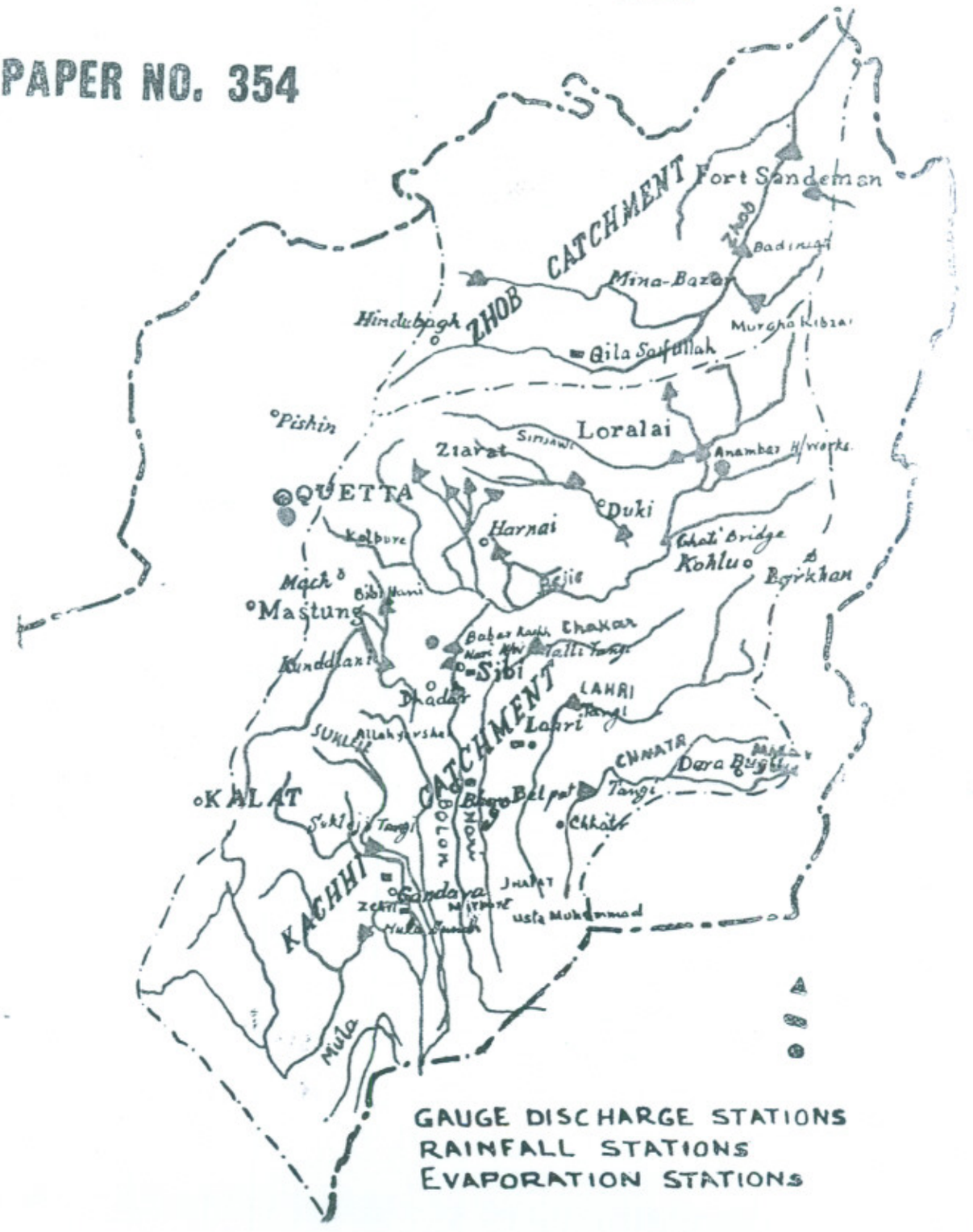


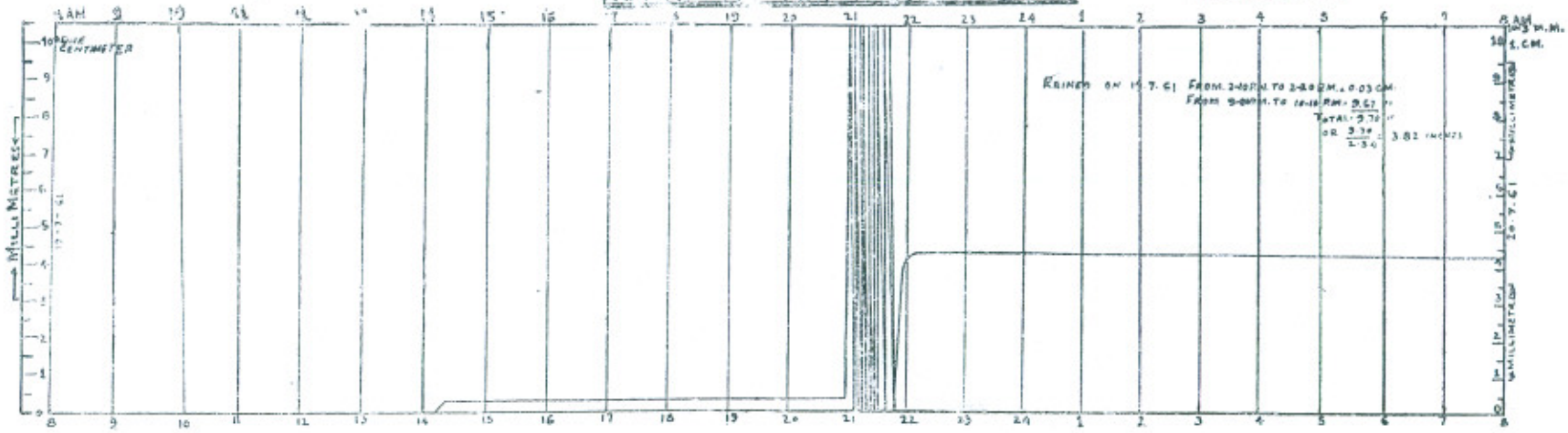
Plate 5

MAP OF BALUCHISTAN
SHOWING KACHHI AND ZHOB *CATCHMENTS*
SCALE :- 50 MILES TO 1 INCH

PAPER NO. 354

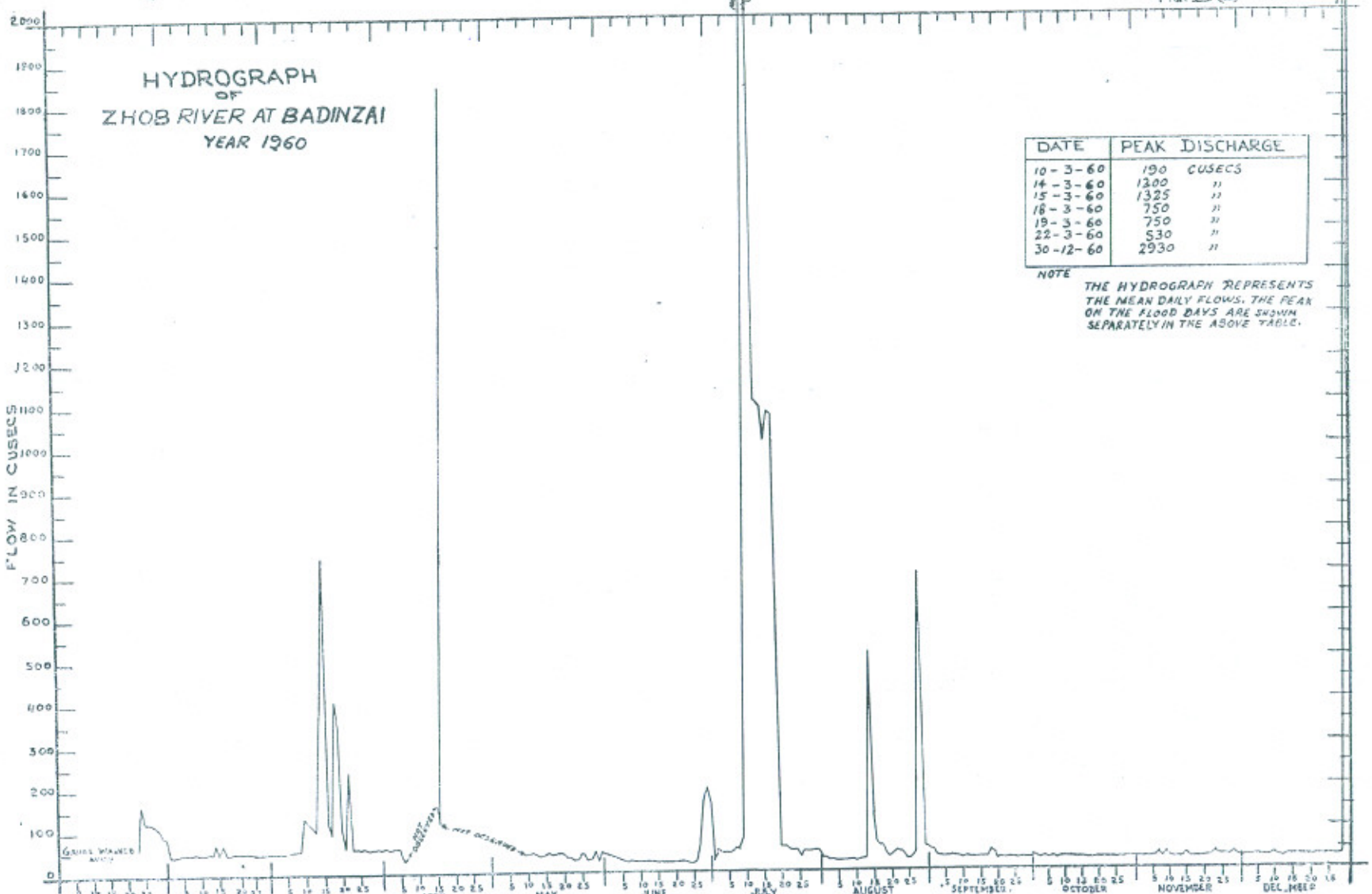


AUTOMATIC RAINRECORDER CHART PAPER NO. 354 Fig: II



PAPER NO. 354

Fig. III (a)



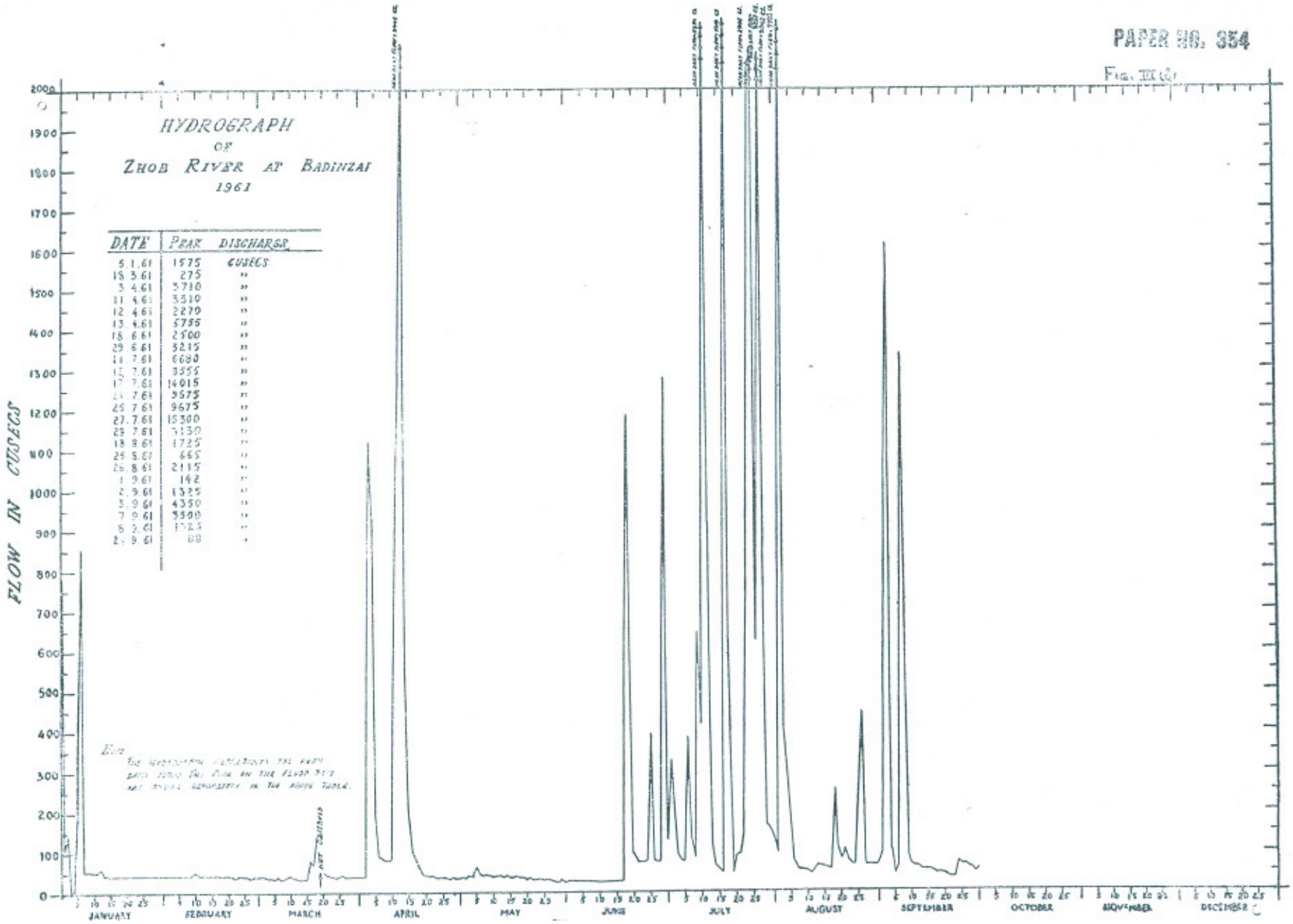
DATE	PEAK DISCHARGE
10-3-60	190 CUSECS
14-3-60	1300 "
15-3-60	1325 "
18-3-60	750 "
19-3-60	750 "
22-3-60	530 "
30-12-60	2930 "

NOTE

THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOWS. THE PEAK ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.

PAPER NO. 354

FIG. III (2)

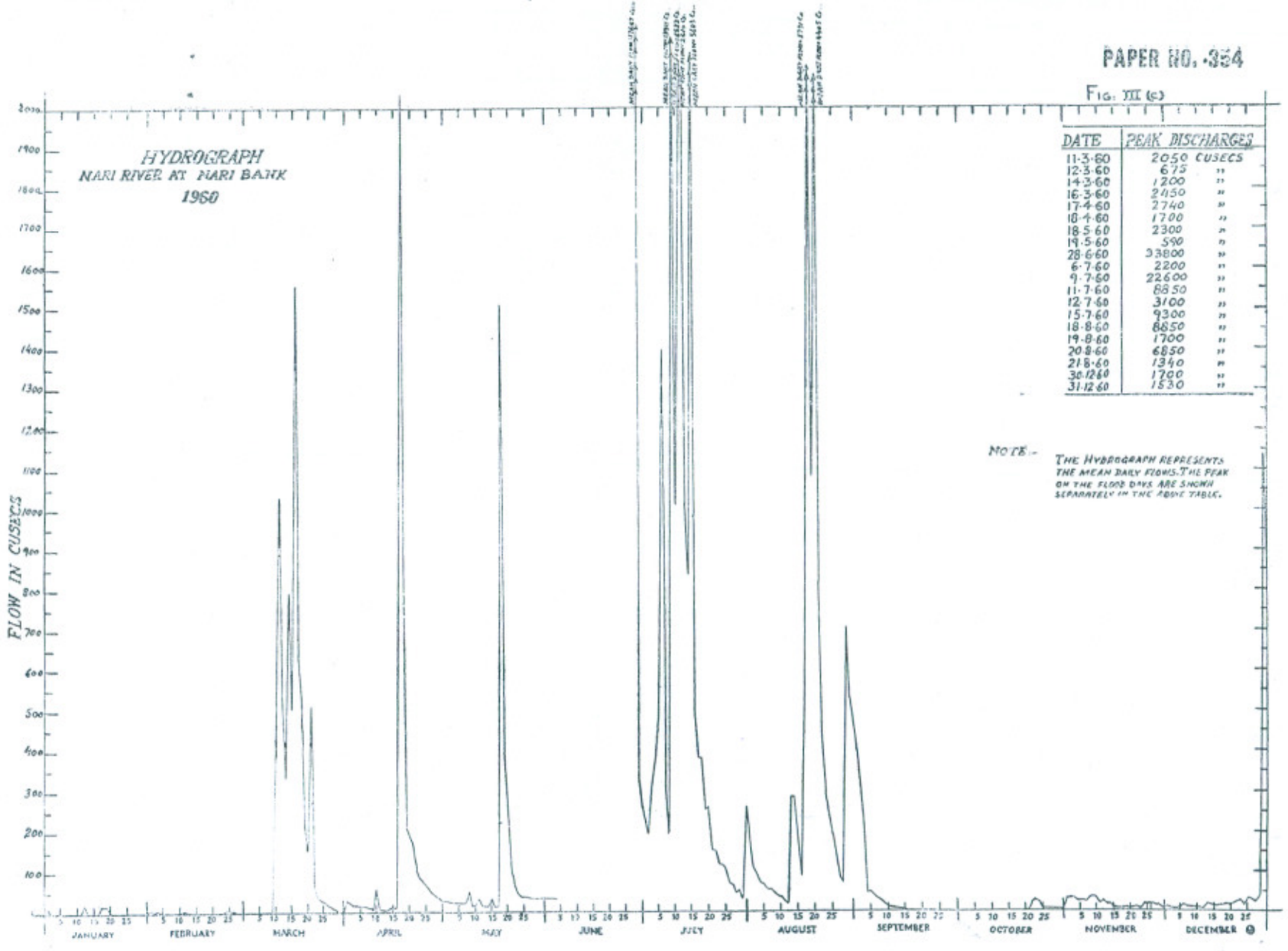


DATE	PEAK DISCHARGE
5.1.61	1575 CUSECS
18.3.61	275 "
3.4.61	5710 "
11.4.61	3510 "
12.4.61	2270 "
13.4.61	5755 "
18.6.61	2500 "
29.6.61	5215 "
11.7.61	6680 "
15.7.61	3555 "
17.7.61	14015 "
24.7.61	9575 "
25.7.61	9675 "
27.7.61	15300 "
29.7.61	5130 "
18.8.61	1725 "
25.8.61	665 "
26.8.61	2115 "
1.9.61	142 "
2.9.61	1325 "
3.9.61	4350 "
7.9.61	3300 "
8.9.61	1725 "
29.9.61	88 "

Note
THE HYDROGRAPH REPRESENTS THE FLOW BASED ON THE PEAK ON THE FLOOD DAYS NOT ON DAILY OBSERVATIONS IN THE ABOVE TABLE.

PAPER NO. 354

FIG. VII (c)



DATE	PEAK DISCHARGES
11-3-60	2050 CUSECS
12-3-60	675 "
14-3-60	1200 "
16-3-60	2450 "
17-4-60	2740 "
18-4-60	1700 "
18-5-60	2300 "
19-5-60	590 "
28-6-60	33800 "
6-7-60	2200 "
9-7-60	22600 "
11-7-60	8850 "
12-7-60	3100 "
15-7-60	9300 "
18-8-60	8850 "
19-8-60	1700 "
20-8-60	6850 "
21-8-60	1340 "
30-12-60	1700 "
31-12-60	1530 "

NOTE:- THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOWS. THE PEAK ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.

HYDROGRAPH OF NARI RIVER AT NARI BANK 1961

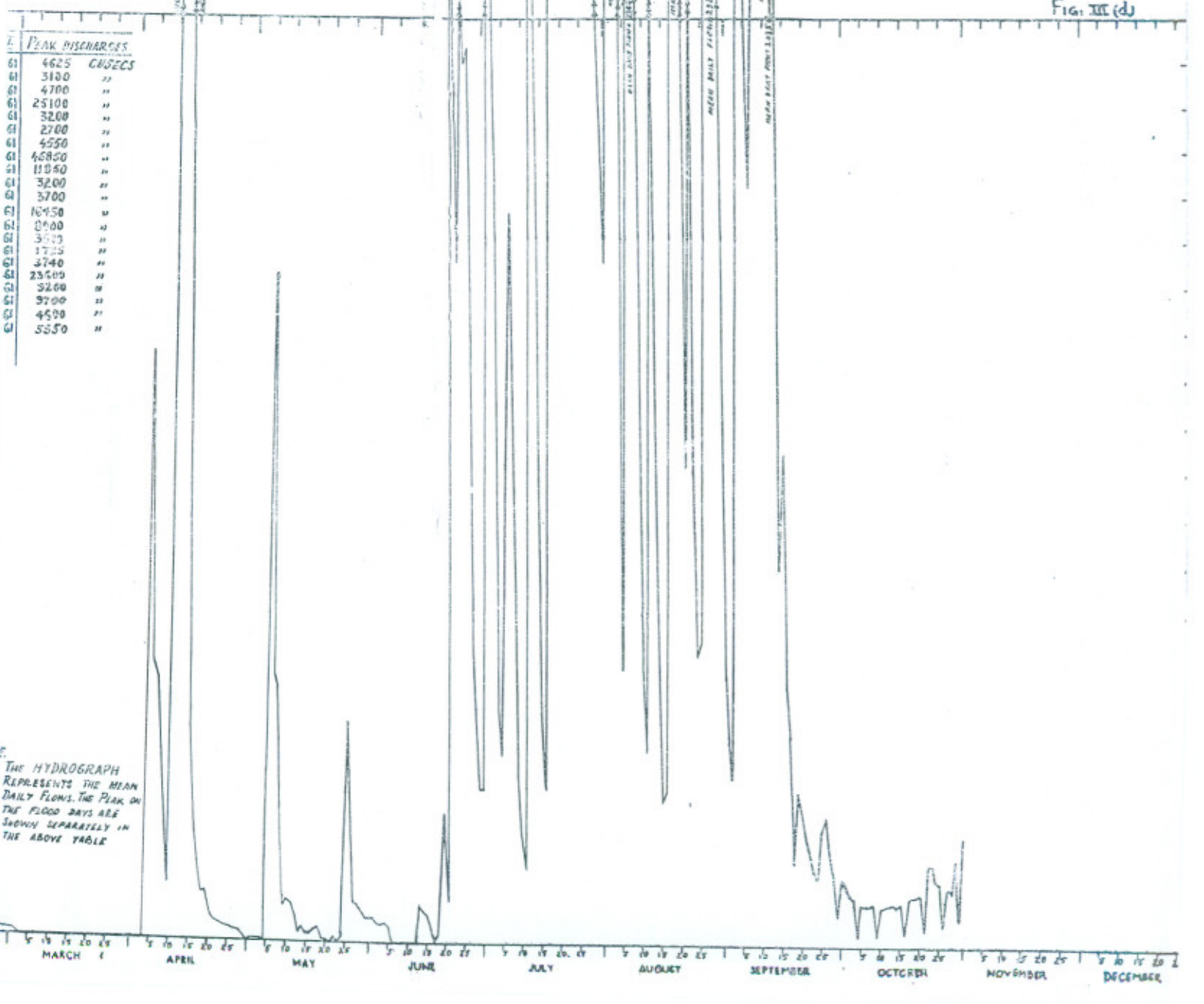
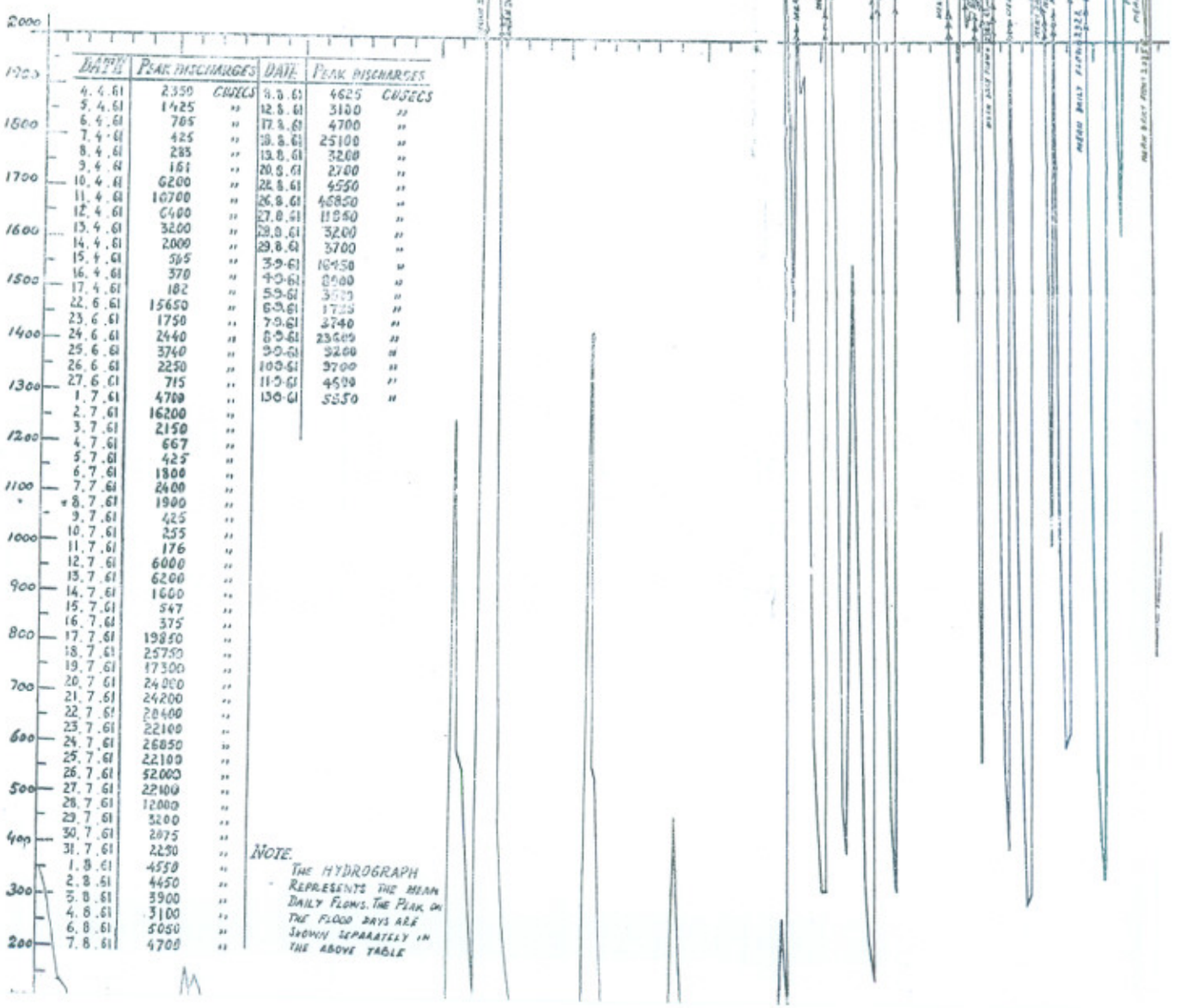


Fig. III (d)

	Peak Discharges	
61	4625	Cusecs
61	3100	"
61	4700	"
61	25100	"
61	3200	"
61	2700	"
61	4550	"
61	46850	"
61	11850	"
61	3200	"
61	3700	"
61	16450	"
61	8600	"
61	3525	"
61	1725	"
61	3740	"
61	23500	"
61	3200	"
61	9700	"
61	4500	"
61	5550	"

TE.
THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOWS. THE PEAK ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE

HYDROGRAPH OF NARI RIVER AT NARI BANK 1961

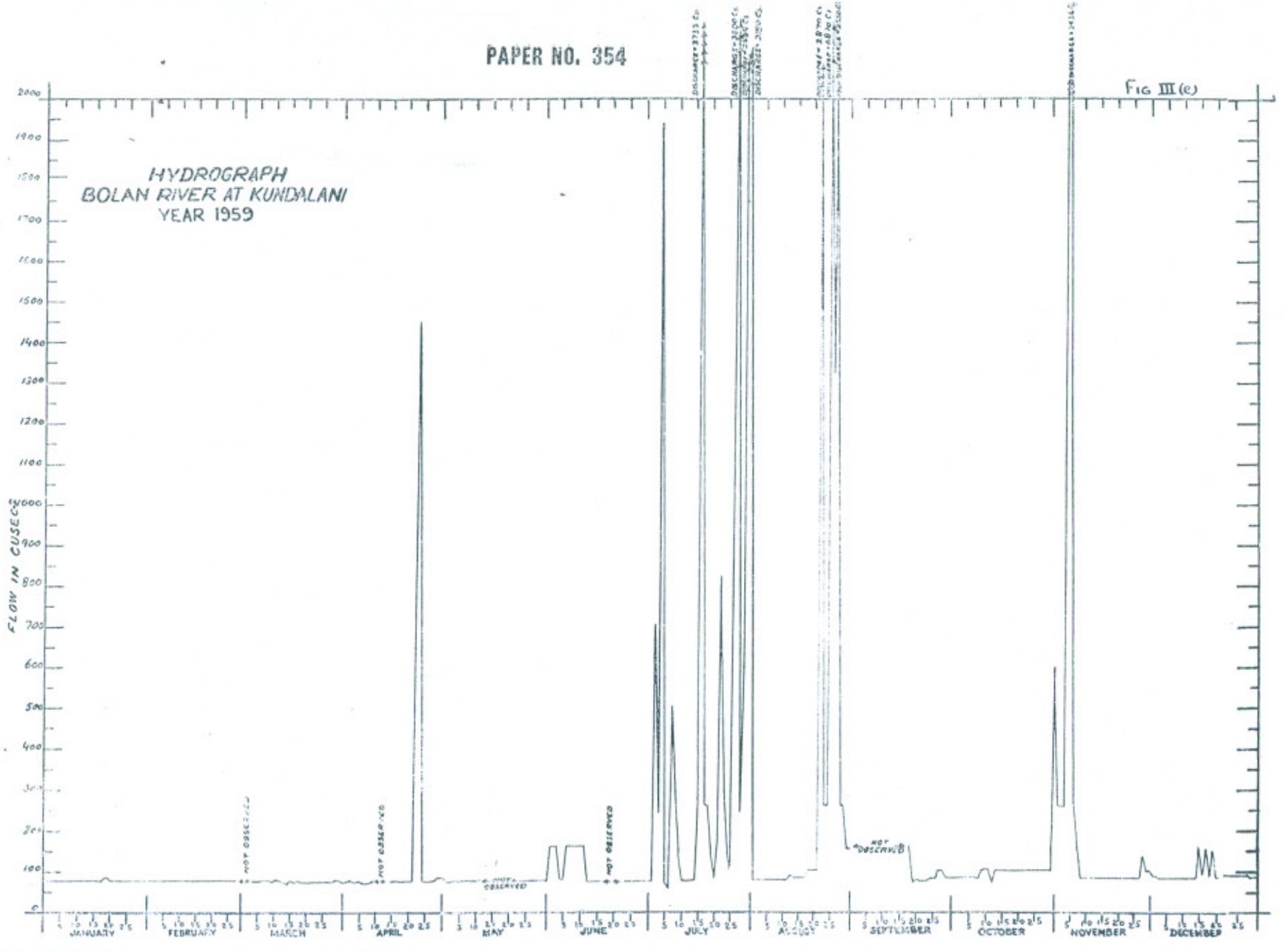


DATE	PEAK DISCHARGES		DATE	PEAK DISCHARGES	
4.4.61	2350	CUSECS	9.8.61	4625	CUSECS
5.4.61	1425	"	12.8.61	3100	"
6.4.61	705	"	17.8.61	4700	"
7.4.61	425	"	19.8.61	25100	"
8.4.61	285	"	13.8.61	3200	"
9.4.61	161	"	20.8.61	2700	"
10.4.61	6200	"	22.8.61	4550	"
11.4.61	10700	"	26.8.61	45850	"
12.4.61	6400	"	27.8.61	11850	"
13.4.61	3200	"	28.8.61	3200	"
14.4.61	2000	"	29.8.61	3700	"
15.4.61	595	"	3.9.61	10450	"
16.4.61	370	"	4.9.61	8500	"
17.4.61	182	"	5.9.61	3625	"
22.6.61	15650	"	6.9.61	1725	"
23.6.61	1750	"	7.9.61	3740	"
24.6.61	2440	"	8.9.61	23600	"
25.6.61	3740	"	30.8.61	3200	"
26.6.61	2250	"	100.61	3700	"
27.6.61	715	"	11.9.61	4600	"
1.7.61	4700	"	130.61	5550	"
2.7.61	16200	"			
3.7.61	2150	"			
4.7.61	667	"			
5.7.61	425	"			
6.7.61	1800	"			
7.7.61	2400	"			
8.7.61	1900	"			
9.7.61	425	"			
10.7.61	255	"			
11.7.61	176	"			
12.7.61	6000	"			
13.7.61	6200	"			
14.7.61	1600	"			
15.7.61	547	"			
16.7.61	375	"			
17.7.61	19850	"			
18.7.61	25750	"			
19.7.61	17300	"			
20.7.61	24000	"			
21.7.61	24200	"			
22.7.61	20400	"			
23.7.61	22100	"			
24.7.61	26850	"			
25.7.61	22100	"			
26.7.61	52003	"			
27.7.61	22100	"			
28.7.61	12000	"			
29.7.61	3200	"			
30.7.61	2875	"			
31.7.61	2230	"			
1.8.61	4550	"			
2.8.61	4450	"			
3.8.61	3900	"			
4.8.61	3100	"			
6.8.61	5050	"			
7.8.61	4700	"			

NOTE:
THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOWS. THE PEAK ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE

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Fig III (e)



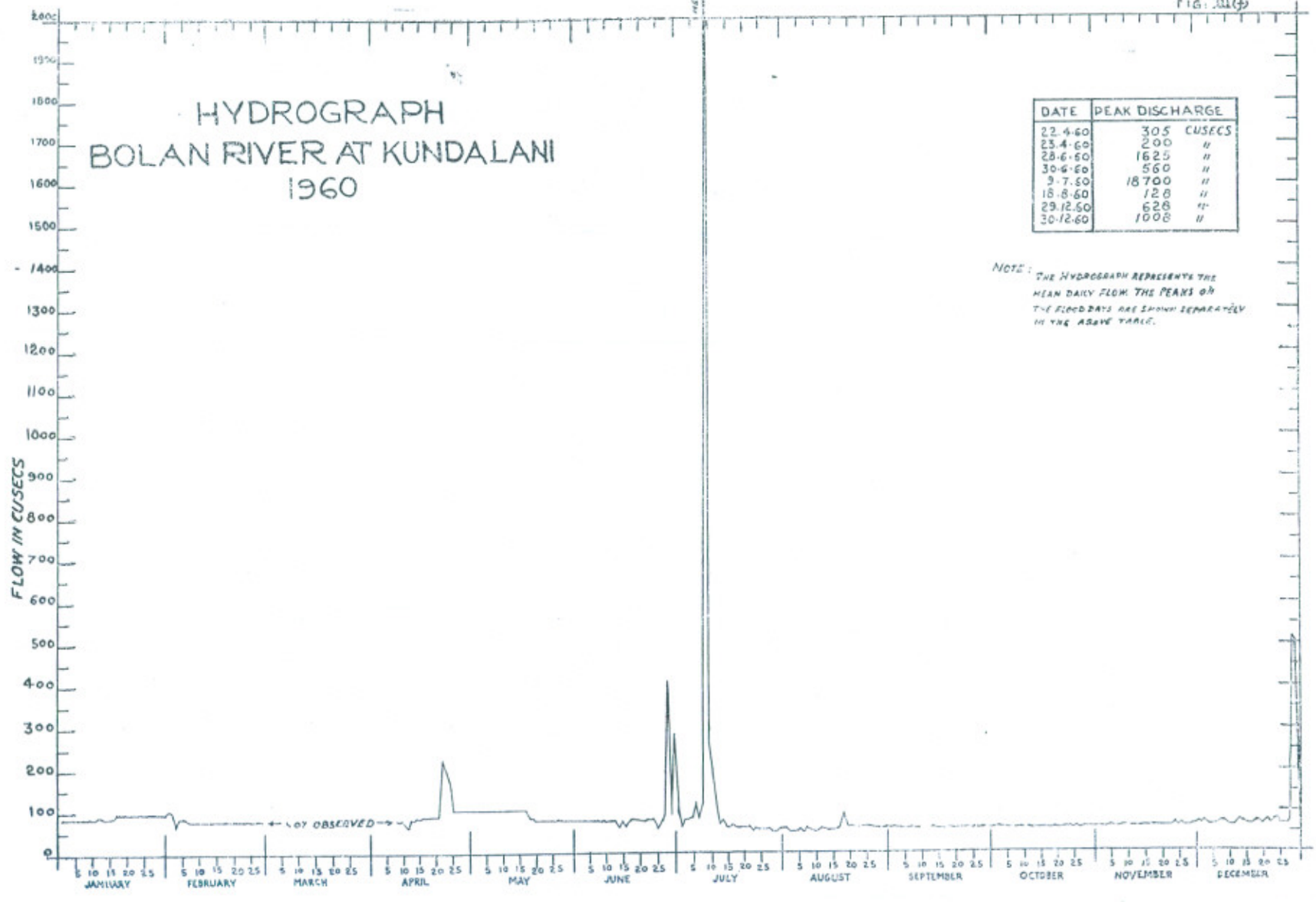
PAPER NO. 354

Fig. III(f)

HYDROGRAPH
BOLAN RIVER AT KUNDALANI
1960

DATE	PEAK DISCHARGE	
22.4.60	305	CUSECS
23.4.60	200	"
28.6.60	1625	"
30.6.60	560	"
3.7.60	18700	"
18.8.60	128	"
29.12.60	628	"
30.12.60	1008	"

NOTE: THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOW. THE PEAKS OF THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.



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Fig III (6)

HYDROGRAPH
OF
BOLAN RIVER AT KUNDALANI BRIDGE
1961

DATE	PEAK DISCHARGE	
4.4.61	116	CUSECS
1.5.61	680	"
2.7.61	4360	"
16.7.61	1900	"
17.7.61	2100	"
20.7.61	85800	"
21.7.61	22050	"
22.7.61	275	"
24.7.61	2775	"
25.7.61	20600	"
26.7.61	13700	"
27.7.61	10100	"
18.8.61	16780	"
19.8.61	251	"
4.9.61	15800	"
5.9.61	3170	"

MEAN DAILY FLOW = 1367 CS

MEAN DAILY FLOW = 6402 CS

FLOW IN CUSECS

2000 1900 1800 1700 1600 1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 0

JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER

NOTE: THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOWS, THE PEAKS ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.

PAPER NO. 354

FIG : III (h)

HYDROGRAPH
CHAKKAR RIVER AT TALLI TANGI
YEAR 1960

DATE	PEAK DISCHARGES	CUSECS
17.5.60	2775	"
28.6.60	11100	"
29.6.60	225	"
30.6.60	25	"
1.7.60	2775	"
4.7.60	50700	"
5.7.60	5800	"
7.7.60	14300	"
8.7.60	2320	"
12.7.60	6900	"
15.7.60	225	"
11.8.60	11100	"
12.8.60	225	"
17.8.60	920	"

FLOW IN CUSECS

0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

NOT OBSERVED

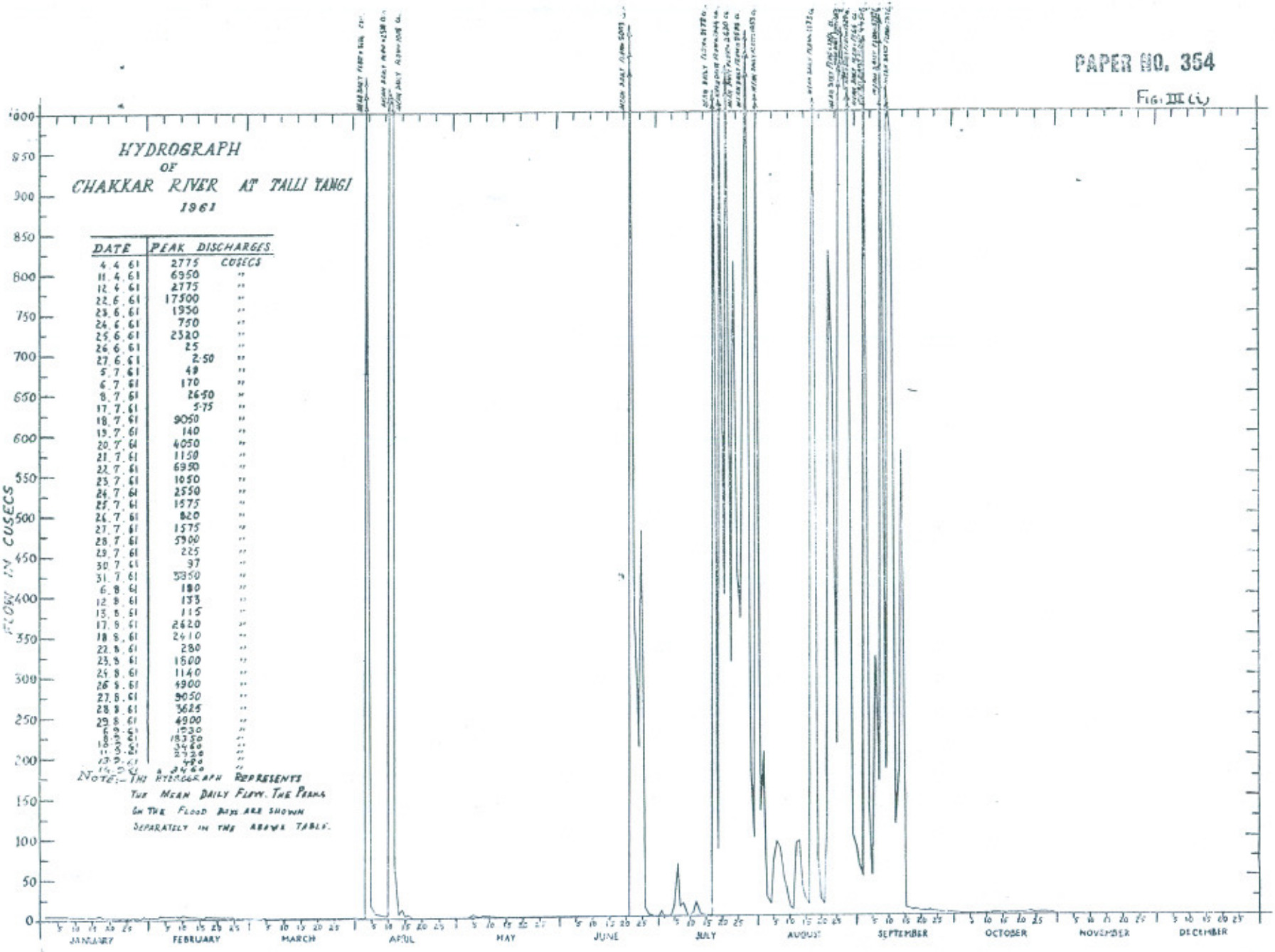
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER

NOTE

THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOWS. THE PEAK ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.

PAPER NO. 354

Fig. III (i)

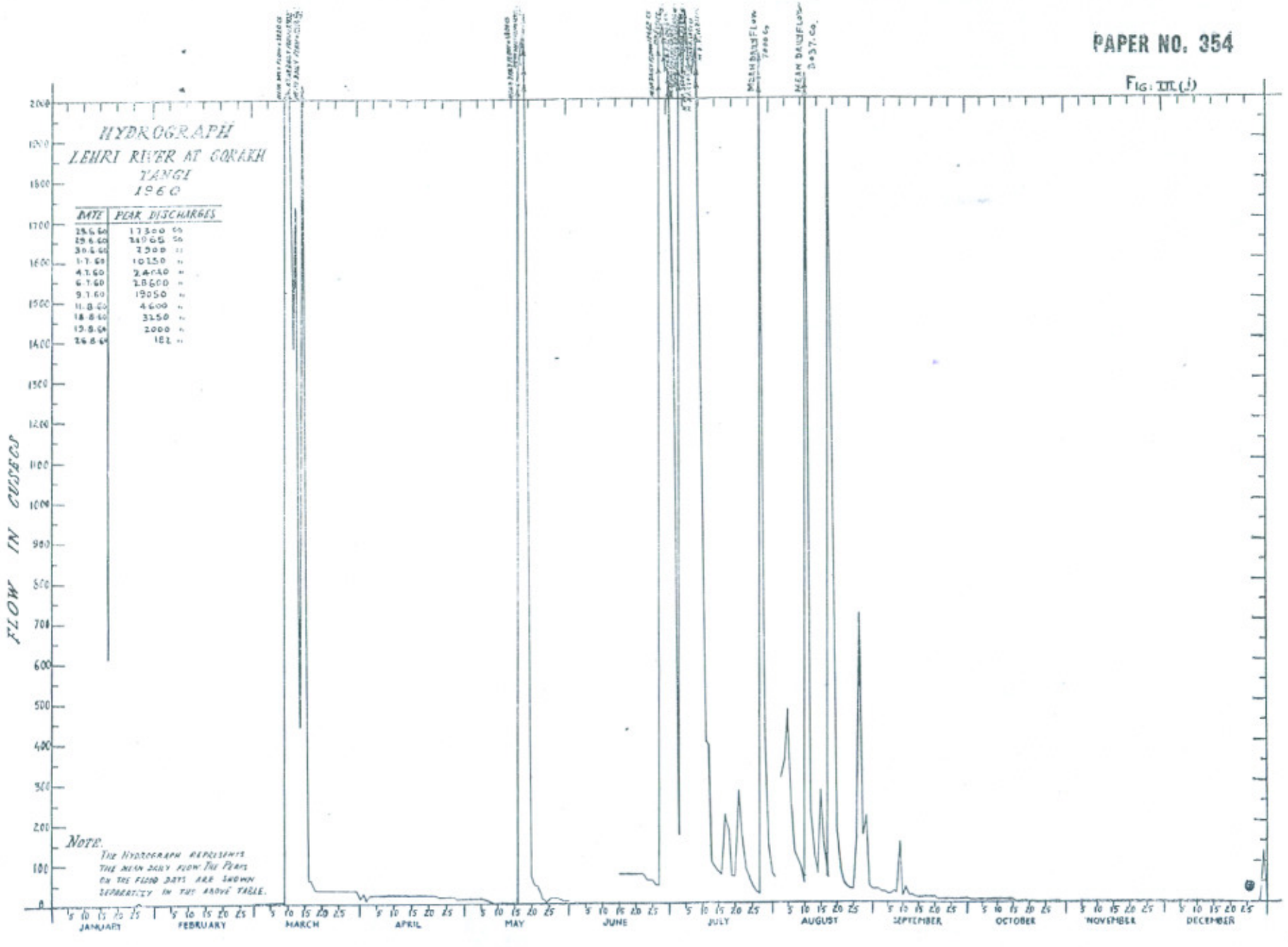


DATE	PEAK DISCHARGES	
4.4.61	2775	CUSECS
11.4.61	6950	"
12.4.61	2775	"
22.6.61	17500	"
23.6.61	1950	"
24.6.61	750	"
25.6.61	2320	"
26.6.61	25	"
27.6.61	2:50	"
5.7.61	49	"
6.7.61	170	"
8.7.61	2650	"
17.7.61	5·75	"
18.7.61	9050	"
19.7.61	140	"
20.7.61	4050	"
21.7.61	1150	"
22.7.61	6950	"
23.7.61	1050	"
24.7.61	2550	"
25.7.61	1575	"
26.7.61	820	"
27.7.61	1575	"
28.7.61	5900	"
29.7.61	225	"
30.7.61	37	"
31.7.61	5350	"
6.8.61	180	"
12.8.61	133	"
15.8.61	115	"
17.8.61	2620	"
18.8.61	2410	"
22.8.61	280	"
23.8.61	1500	"
24.8.61	1140	"
26.8.61	4900	"
27.8.61	9050	"
28.8.61	3625	"
29.8.61	4900	"
6.9.61	1530	"
8.9.61	183·50	"
10.9.61	3460	"
11.9.61	2728	"
13.9.61	470	"
15.9.61	2460	"

NOTE:- THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOW. THE PEAKS ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.

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FIG: III (J)



PAPER NO. 354

FIG. III (K)

HYDROGRAPH
LEHRI RIVER AT GORAKH TANGI
1961

DATE	PEAK DISCHARGE
22.6.61	4400
23.6.61	12270
24.6.61	4400
25.6.61	17800
26.6.61	3200
3.7.61	3200
12.7.61	5050
17.7.61	9620
18.7.61	3200
20.7.61	5170
21.7.61	12550
22.7.61	illegible
illegible	1100
12.8.61	7000
17.8.61	9100
18.8.61	4400
22.8.61	6450
23.8.61	illegible
26.8.61	1250
28.8.61	illegible
29.8.61	illegible
6.9.61	illegible
7.9.61	illegible
8.9.61	illegible

NOTE.
THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOW. THE PEAKS OF THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE

FLOW IN CUSECS

JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER

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Fig. III (L)

HYDROGRAPH

CHHATR RIVER AT PHULJI

1961

DATE	PEAK DISCHARGES
28 6 61	2983 Cs
26 6 61	2550 "
2 7 61	4510 "
6 7 61	1512 "
7 7 61	1940 "
12 7 61	1020 "
20 7 61	3900 "
21 7 61	3900 "
24 7 61	7140 "
25 7 61	5130 "
27 7 61	4320 "
28 7 61	6485 "
7 8 61	4600 "
17 8 61	2930 "
8 8 61	6250 "
22 8 61	6410 "
23 8 61	7200 "
24 8 61	2930 "
28 8 61	5760 "
3 9 61	1800 "
6 9 61	2930 "
8 9 61	9780 "

FLOW IN CUSECS

NOTE :-
THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOW. THE PEAKS ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.

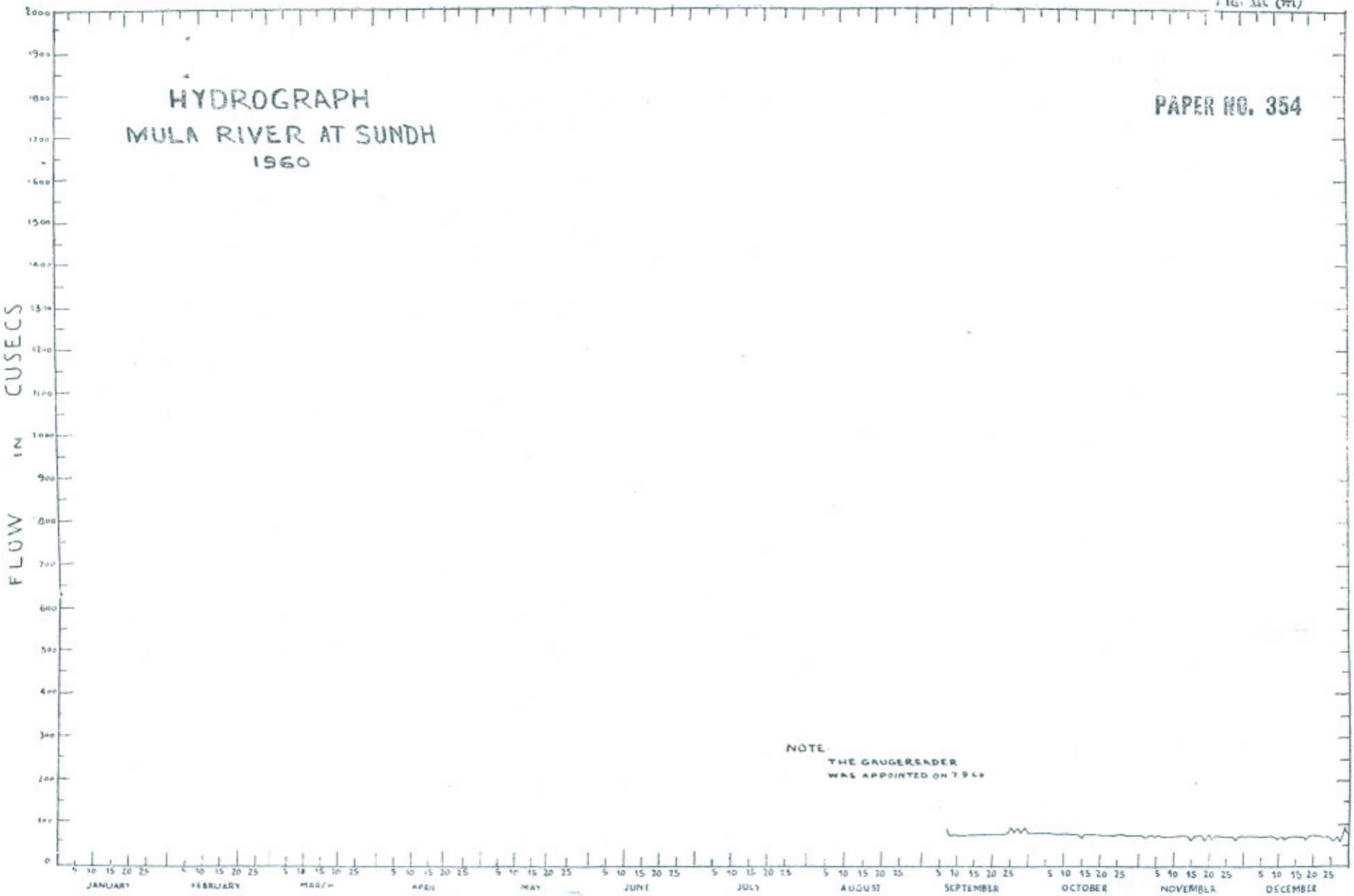
PLOTTED UP TO OCTOBER 1961 ONLY

JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER

Fig. III (m)

HYDROGRAPH
MULA RIVER AT SUNDH
1960

PAPER NO. 354



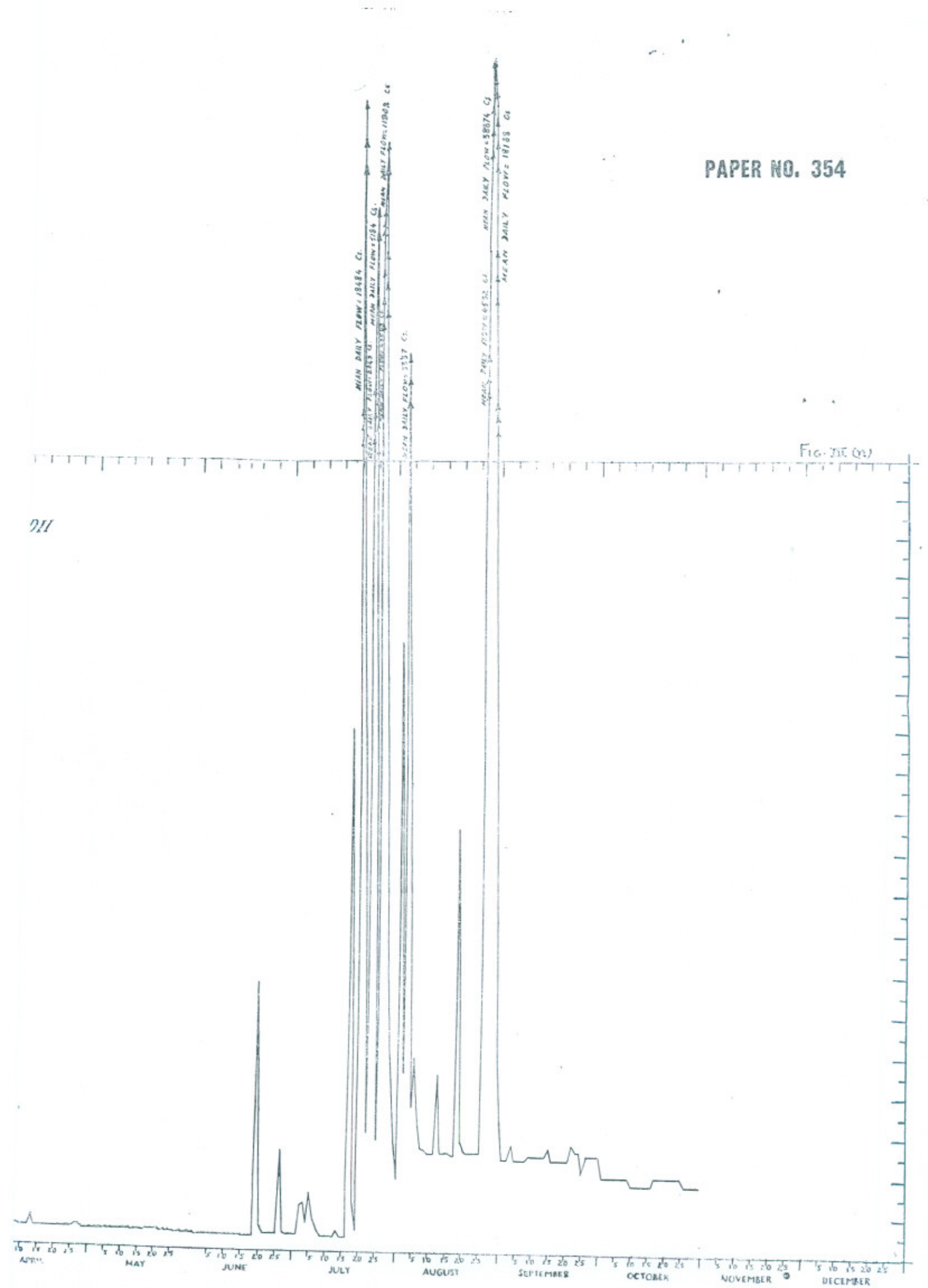
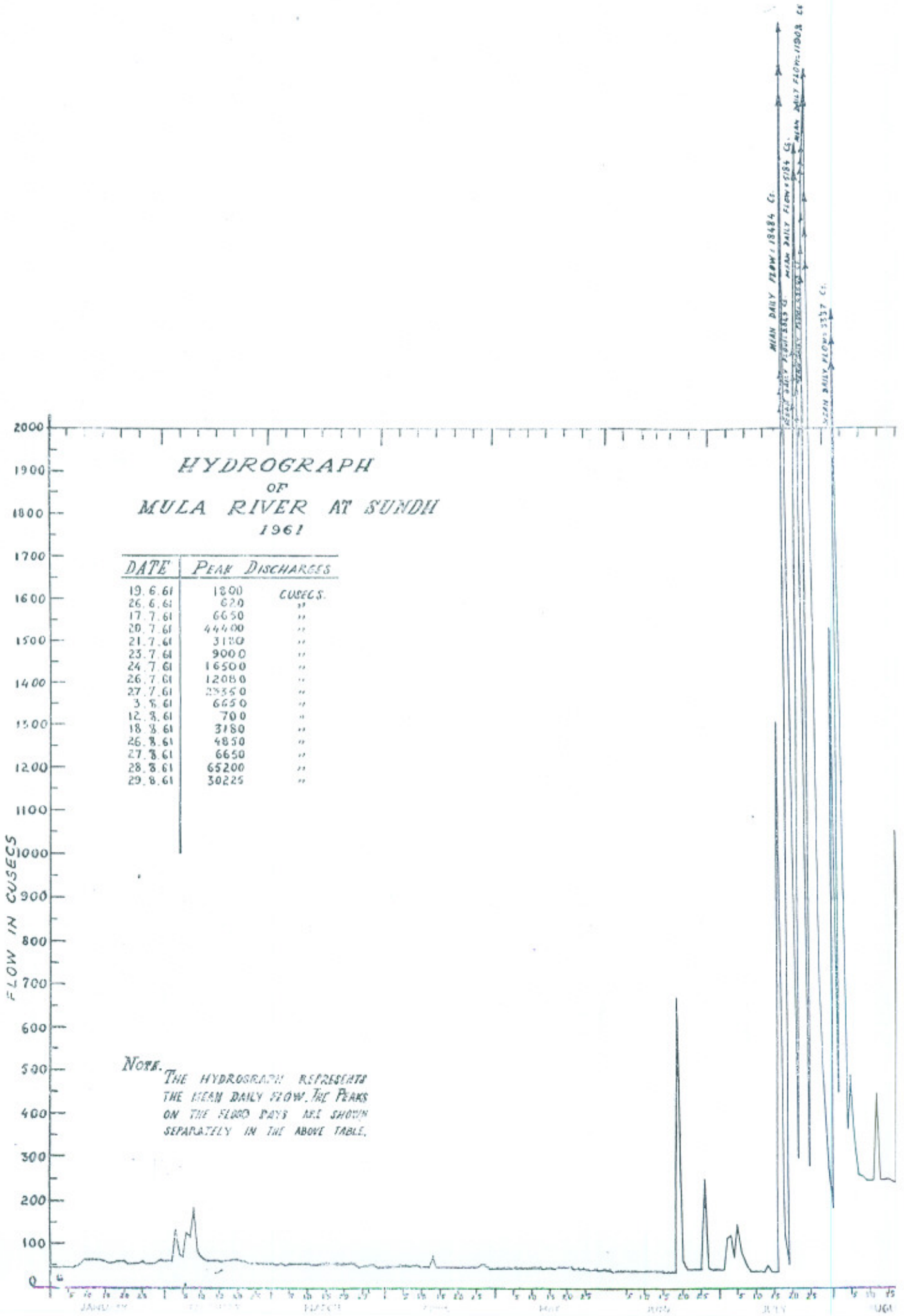

MEAN DAILY FLOW = 18484 CS.
MEAN DAILY FLOW = 5184 CS.
MEAN DAILY FLOW = 1808 CS
MEAN DAILY FLOW = 3537 CS.
MEAN DAILY FLOW = 5832 CS
MEAN DAILY FLOW = 5874 CS
MEAN DAILY FLOW = 1818 CS
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

FIG. XII (a)

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HYDROGRAPH
OF
MULA RIVER AT SUNDH
1961

DATE	PEAK DISCHARGES	
19.6.61	1800	CUSECS.
26.6.61	620	"
17.7.61	6650	"
20.7.61	44400	"
21.7.61	31100	"
23.7.61	9000	"
24.7.61	16500	"
26.7.61	12080	"
27.7.61	23350	"
3.8.61	6650	"
12.8.61	700	"
18.8.61	3180	"
26.8.61	4850	"
27.8.61	6650	"
28.8.61	65200	"
29.8.61	30225	"



NOTE. THE HYDROGRAPH REPRESENTS THE MEAN DAILY FLOW. THE PEAKS ON THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.

FIG. III (C)

PAPER NO. 354

HYDROGRAPH

SUKLEJI RIVER AT TANGI

YEAR 1961

DATE	PEAK DISCHARGES
17.7.61	286 Cs.
20.7.61	10200 "
22.7.61	1940 "
26.7.61	1970 "
27.7.61	4000 "
18.8.61	4000 "
22.8.61	1100 "
26.8.61	1400 "
28.8.61	20540 "
29.8.61	1760 "

NOTE:-
THE HYDROGRAPH IS REPRESENTS THE MEAN DAILY FLOW. THE PEAKS OF THE FLOOD DAYS ARE SHOWN SEPARATELY IN THE ABOVE TABLE.

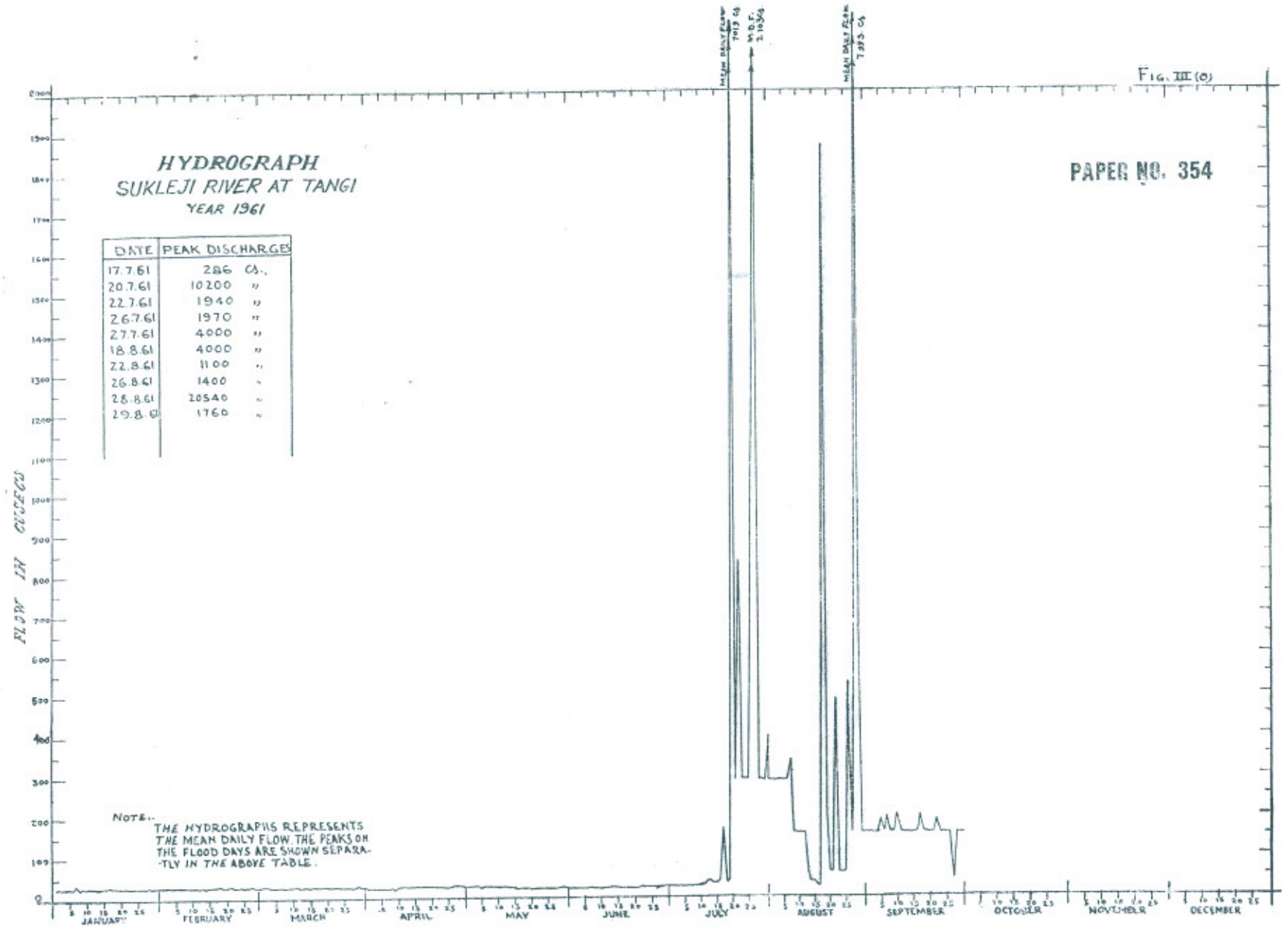
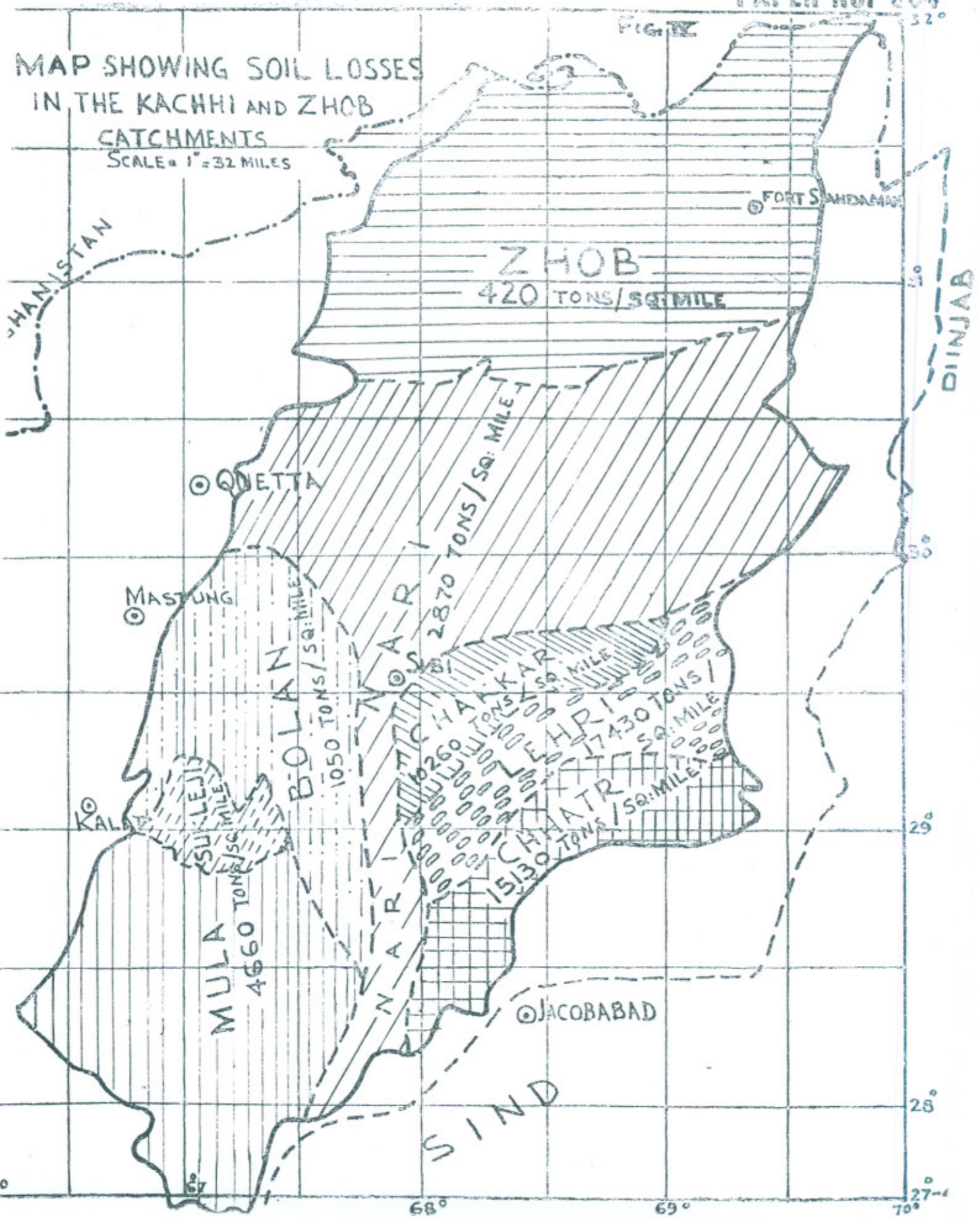


Fig. IX


MAP SHOWING SOIL LOSSES
IN THE KACHHI AND ZHOB
CATCHMENTS
SCALE = 1" = 32 MILES
ZHOB
420 TONS/SQ. MILE
NARI
2870 TONS/SQ. MILE
BOLAN
1050 TONS/SQ. MILE
MULA
4960 TONS/SQ. MILE
SULLEJI
KACHHI
10260 TONS/SQ. MILE
LEHRI
17430 TONS/SQ. MILE
CHHATR
15130 TONS/SQ. MILE
QUETTA
MASTUNG
KALAT
JACOBABAD
FORT SANDEMAN
SIND
PUNJAB
AFGHANISTAN
32°
30°
29°
28°
27°
68°
69°
70°