Prevention & Control of Floods in West Pakistan

By

*MIAN MUZAFFAR AHMED

INTRODUCTION

Battle against floods is a part of the struggle of mankind for producing sufficient food and for raising the standard of the people. With the advancement of knowledge improvement is being made in the methods of flood control and more attention is being paid to the combined development of water resources for various uses such as flood control, soil conservation, irrigation, navigation and hydel power.

Every metdod has its merits and demerits. Out of the technically feasible methods, a method or a combination of methods which is most economical or gives the highest benefit-cost ratio is generally adopted.

The physical, hydrological and economic conditions of different countries are different, therefore flood control methods vary from place to place.

A very brief account of some of the chief methods of flood control *e.g.* reservoirs, dikes, soil conservation, spill diversion channels, channel improvement etc. is given in this note.

Flood control problem requires detailed physical hydrologic, contour and other surveys of a country before any successful plan for flood control can be worked out. In West Pakistan these surveys should be made as early as possible to chalk out a long range integrated scheme for controlling the floods.

Stable and Unstable Rivers.

Rivers may be divided into three classes stable, nearly stable and unstable. Change is the unchangeable law of nature and therefore perfectly stable rivers are seldom found in nature. In the second class of rivers there is a condition of apparent equilibrium characterised by the stability of their alignments, slopes and regime which may be highly variable during a year but show little variation from year to year There is no important change over a long period of time. The stability has been reached after periods as long as geological ages between various factors that gave them birth such as bed slopes from the source to the sea, run off and erosion in the catchment area, cross-sections etc. It is very difficult generally to alter this stability.

* Director, Irrigation Research Institute, Lahore.

In comparison to these two types of rivers there are others which are in a perceptible condition of instability indicating that their evolution is yet far from complete.

According to Mead floods will occur on a given drainage area when the following conditions occur and will increase in intensity and duration as the conditions become more favourable to increased run off.

A. When the rainfall on the drainage area is of :

a) Great intensity.

b) Wide distribution

c) Long duration

B. When the surface of the drainage area is impervious form :

a) Saturation by previous rainfall

b) Frozen condition of the ground

c) Normal geological structures

C. When retention is at a minimum on the drainage area from ;

a) Cool weather
b) Absence of vegetation
c) High humidity.

In addition to the above, floods sometimes result from or are augmented by ice and log jams and the failure of reservoir dams.

In the comparison of floods on different drainage areas other factors are important : Topography, shape, geology, arrangement of tributaries, surface conditions, location relative to storm paths and sources of vapour, climatic conditions, temperatures, wind velocities, snow accumulation, etc.

The maximum floods on all streams are due to a storm or a series of storms that have covered the drainage areas so as to produce a synchromism in the discharge of the various tributaries whereby the maximum flood accumulates at the locality under consideration.

Rivers as they grow older generally widen their valley unless prevented by some geological formations. The size and the discharge of a river varies with its drainage area and the rain over that area. The rainfall varies considerably both in its annual amount and in its distribution during the year. Its amount fluctuates from year to year. The variations may be great according to variations in elevation and distance from the sea. The proportion of rainfall in respect to its flow depends on the nature of surface strata, slope of the land, extent to which it is covered with vegetation and on the season of the year. The available rainfall flow has been seen to vary from 75% of actual fall on impermeable bare, sloping, rocky strata to 15% on flat permeable soils.

The rate of flow of rivers depends upon their fall. In large basins rivers begin as torrents with variable flow and end as gently flowing rivers with comparatively a regular discharge. In hot countries subject to periodical rains rivers have floods during the raining season and a little flow during the remaining period.

Thus we have seen that rivers come into existence as a result of rainfall and snow-melt andtheir major function is to drain off all surplus water to the sea along a more or less defined channel. When the rainfall is excessive, we get floods, that is rivers swell beyond the banks. The object of flood control is to stop the river water to overflow the banks within which it is normally confined. In this field there is a general tendency on the part of the public never to lock the barn until the horse has been stolen. It is rare that any flood protection measures have been taken until after a devastating flood has occurred. There are many dangerous centres where the inhabitants are peacefully lulled by a sense of false security, blissfully ignorant of the terrible havoc that can and some day will be wrought by the innocent looking stream that flows by their doors and that throughout the memory of the oldest inhabitant has always been comparatively docile and well behaved.

Floods also arise due to deforestation, rise in beds of rivers and artificial barriers.

There are no two countries with the same hydrology and no two rivers in the same country with the same regime and no two floods in the same river have the same physical and meteorological characteristics. Therefore flood control measures differ from place to place and one cannot say that a method which has proved useful at one site will definitely prove so at another site. It is possible that a method which has proved successful at the lowest cost at one place may prove totally in-adequate and extremely costly at another. However from the experience gained in this field in various countries of the world some general ideas can be formed of the problem and its solution.

Falling of heavy rain is beyond human control. We can only try to minimise the ill effects of heavy rainfall. If the rainfall is light some of it might be absorbed by the soil but in case of protracted heavy rainfall the excessive run off has got to be dealt with in the rivers and streams.

Some hydrological details of the Indus basin rivers are given below :

TABLE 1

River	Length in miles	Hill catchment area in Sq. miles	Glacier area in Sq. miles	Mean annual rainfall in inches	Mean annual run off in m. a. f.
Indus	1830	118,400	14,415	17·74	87·36
Jhelum	430	12,445	142	42·33	23·86
Chenab	640	11,399	1,475	47·24	23·28
Ravi	410	3,562	100	52·00	6·54
Beas	220	5,384	227	56·50	12·55
Sutlej	900	23,400	2,468	19·71	13·94
Total :—		174,590	18,827		167.53

Map of West Pakistan showing rainfall is appended at the end.

There is a large variation of flow in our rivers, the maximum discharges being 50 to 100 times greater than their minimum. The floods, with varying intensity and frequency, occur mostly during the monsoon season when the intense rainfall in the catchment combined with water from the snowmelt causes serious floods. Also the hydrograph shapes of all the rivers are very similar thus accentuating the floods.

The scourage of floods has become a matter of almost yearly occurrence in West Pakistan, the Ravi and other rivers and hill torrents have ravaged entire districts not less than 4 times since the independence. The violence and intensity of the floods has sometimes been unprecedn-ted and has caused great loss and misery. The 1956 flood caused heavy damage to public works and private property in almost all divisions of West Pakistan. The area affected in 1956 has been estimated at 29,065 square miles, including 3,404 squrare miles of cultivated area, which was badly damaged. Over 11,000 villages were affected where 164,598 houses were destroyed.

Repairs to danaged irrigation works cost Rs. 10.7 million and damage to property of other departments amounted to another 10 millions. Crops worth Rs. 79.3 million were destroyed.

It has been estimated that the total loss to the nation due to floods during the last 10 years amounts to Rs. 1000 million, say on the average Rs. 100 million per year.

The following are some of the measures adopted in connection with flood control.

1. Reservoirs.
2. Levees.
3. Land management.
4. Spill Diversion channels.
5. River training, channel improvement, development of drainages and digging of new drains.
6. Pumping stations.
7. Villages situated in low areas abandoned and shifted to higher levels.

These methods have merits and demerits of their own.

The applicability of a method does not depend only on its technical qualification but it has a direct bearing on the financial and economic conditions of the people of that area. In an area which is highly advanced in its agricultuIe, industry and systems of communication it is advantageous to resort to permanent and durable methods of flood control which are usually more complicated in their construction and

A very brief account of the verious measures adopted in connection wtih flood control are given below :-

1. **Reservoirs.**

Floods are caused when the river flow is more than what can be carried within the stream. Any agency which helps in reducing or delaying the amount of river flcw will tend to lower the flood levels. Lakes, Swamps, natural and artificial reservoirs fulfil this function. Detention reservoirs in hilly catchments are very effective measures to control floods. Construction of reservoirs only for flood control is rather a somewhat costly affair, this may be justified only when protection of important cities or of well developed areas with vast populatons is under consideration. The success achieved of a great unified scheme of multipurpose reservoirs (*i.e.* reservoirs serving more than one function *e.g.* flood control, power generation, irrigation, navigation etc.) in the Tennessee valley in U.S.A. has arrested the attention of the whole world and made "basin-wide multi-purpose development" very popular. The work inthe Tennessee valley includes very little irrigation but in areas where irrigation has to be done on a large scale multi-purpose reservoirs prove all the more useful because a good amount of revenue is obtained from irrigation.

The various combinations of flood control with other purposes can be :—

1) Flood control and water power.
2) Flood control and irrigation.
3) Flood control and navigation.
4) A combination of two or more of the purposes mentioned above.

a) The demands of flood control and water power are conflicting but by making some sacrifice of both the measures a combined use of the same storage is possible.

b) For irrigation there should be a dependable water supply and for flood control there should be a dependable reservoir capacity. Since floods occur during certain seasons therefore it is practicable to keep a greater storage capacity during the flood season and to conserve greater volume of water when the flood season is over for a dependable water supply for irrigation.

c) Combination of flood control and navigation is similar to that of irrigation but it offers less possibilities because we need large flow for navigation and therefore little storage is left for flood control.

The direct benefits derived from irrigation and power are more than those from flood control but the elimination of suffering, loss of human and cattle life, and stability of social and political conditions cannot be measured in terms of money. Their importance is exceedingly great and hence flood control is the most important benefit which must be considered.

Direct benefits from power development are generally more than from irrigation, but from sociological point of view adequate production of food is more important than power. Power production is essential for industrialsation which helps in the balanced economy and national defence. Hence in the planning of a basin, flood control should have first importance, then should come irrigation, power production and navigation.

The planning of multi-purpose reservoirs is closely related to their operation. Both these should be critically examined at the beginning. The size of a multi-purpose reservoir can be economized by improved operating technique and more reliable rainfall prediction. The correct operation of a reservoir is of very great importance. Delicate timing is required which is usually complicated by weather changes and therefore prompt and accurate run off computations and stream flow routings are very essential. During floods, schedules of flows have sometimes to be revised twice or thrice daily taking into account changes in rainfall and run off. For this it is necessary to have a flood forecasting service functioning very satisfactorily. It may be added here that perfect or 100 percent accurate weather forecasting is not possible even in the most advanced countries. Close co-operation between engineers and meteorologists would however solve many difficulties in this respect.

Melting of snows has a great effect on the food discharge. Widespread snow surveys should be undertaken in consultation with the Meteorological Department.

Again some people have worked out relationships between rainfall in the catchment area and water level at a station lower down on the river. Such relationships might hold good in the case of gauge sites where the bed of the river is rocky these cannot possibly hold true for the gauge sites in the alluvial plains where bed is always undergoing a change.

Encroachment on flood space should not be allowed, because if the available storage capacity of a reservoir at the flood time is less than the prescribed, then the safety of the reservoir is at stake and if it fails then a multi-purpose reservoir instead of being useful becomes a surce of great trouble. The life of a reservoir depends to a great extent on the silt load of the river. Various methods are suggested for controlling the entry and deposition of silt in the reservoir *e.g.* soil conservation, deep sluices at suitable levels in the dam to allow density currents to pass below the reservoir etc. but opinions of evperts differ on the success of these measures. Watershed management can be successful in flood control and in preventing sediment from going into the reservoirs in the case of small floods but not in the case of larger floods. The cost of watershed management is also high.

A density current is a gravity flow of fluid under, over or through the fluid of nearly equal density. In the silting of reservoirs density currents of importance are those that carry sediment from the upper and higher parts of the reservoir to the lower reaches. When a muddy stream enters a reservoir it mixes with the clear water which may have different temperature and salt contents. If this mixture is heavier than the reservoir water it sinks until it meets water of equal density and moves there between more dense and less dense layers and if such a water is not available then it sinks to the bottom.

Studies on the filling of the Imperial Reservoir in U.S.A. showed that trap efficiency remained above 95% until the detention period was less than a day. In Elephant Butte reservoir on Rio Grande, where density currents attracted attention, it was seen that 98% of the incoming silt load was trapped in the reservoir. It is advocated that unless the reservoir is designed to pass the greater portion of the fllood with little or no storage such as Aswan on the Nile or where it is rapidly evacuated after the flood, the trap efficiency should be taken as 95% and rarely should it fall to 90%.

Since the operation of multi-purpose reservoirs is a specialised activity requiring quick decisions and execution therefore their charge should be entrusted to very efficient resourceful and responsible engineers.

Advantages and disadvantages of reservoirs are discussed below.

If a reservoir is properly designed and contructed than as compared with other methods, flood control through a reservoir is dependable. Its maintenance is simple and direct and its operation can be done by a small team of technicians. Besides flood control we can get other benefits such as irrigation municipal water supply, fish and wild life conservation, creation of recreation areas, and generation of hydroelectric power.

In the case of rivers with high silt load provision has to be made for dead storage for silting. A very high percentage of sediment, often more than 95, is trapped in the reservoir with the result that storage capacity goes on decreasing. Soil conservation and other measures may prolong the life of a reservoir but ultimately it must silt up. In the interval there is a tendency to neglect the maintenance of other flood control measures. The high water bed is likely to be obstructed by buildings and plantations for industrial and other uses. A very serious problem will be created if these lands are flooded again. It is advisable to keep these lands always free from any encroachment.

Construction of a dam requires the submersion of a big area and the displacement of large populations.

If the percentage trap efficiency of sediment is high then retrogression takes place immediately below the reservoir and it is followed by aggradation further downstream. Such changes may not be desirable.

The effect of reduction of peak flow goes on decreasing with the increase in distance below the reservoir.

If a reservoir gets silted up then it becomes difficult to find another site to replace the old one.

In West Pakistan the upper catchment areas of the rivers are in India or in India held Kashmir. Explorations are in progress in finding out suitable sites in Pakistan for reservoirs. Some sites have already been selected and work of the construction of reservoirs started and suitability of some other sites is under examination. The completr regulation of the mean annual flow of the Indus system will require more than 100 m.a.f. of reservoir capacity, whereas the present known sites offer a storage of 25 m.a.f. The topographical and geological characteristics of some of the sites limit the height to which the dams can be built and a further limit is imposed by the high silt content of the rivers.

The reservoirs approved or under contemplation are :—

Table No. 2

S. No.	Name of River	Reservoir Site	Storage capacity	
1.	Indus	Kalabagh	4.5	m.a.f.
2.	Indus	Kot Kai	3·5	m.a.f.
3.	Kabul	Warsak	62,000	ac. ft.
4.	Kurram	Baran	80,000	ac. ft.
5.	Kurram	Kurram Tangi	—	
6.	Gomal	Gul Kach	250,000	ac. ft.
7.	Swat	Kalangai	3·5	m.a.f.
8.	Swat	Kalam	300,000	ac. ft.
9.	Jhelum	Mangla	3·5	m.a.f.

With the construction of these reservoirs the floods will be controlled considerably and many other advantages described above such as industrial development, increased and secured irrigation, improvement of transport etc. will accrue.

2. Levees or Dikes.

Prevention by dikes is one of the oldest methods used for the control of floods and is one of the earliest engineering achievements of mankind. History gives an account of the embanking of alluvial lands of the river Nile by the Egyptians and the city of Babylon was protected by levees. It is said that a Chinese King Kwan attempted to dike the overflowing banks of the yellow river in the 23rd century B.C.

From the historical records of all great levee systems in the world quite a few aspects are common. The construction of the embankments is extended slowly or piecemeal. No great system was completed in one attempt. Private persons acting individually or by groups, tried to protect their land against the action of floods by building small dikes around them. These were gradually strengthened or raised and joined to similar works constructed by their neighbours. As these systems developed their control, maintence, reinforcement and expansion were taken over by the Government. In general the dikes are aligned on the high ridge or the natural bunds of the river banks, where the land is high and the soil more useful for foundation.

The first problem to be solved in the design of a levee system is the determination of the probable maximum discharge. This is an extremely difficult problem. According to Hayford a river flood depends on not less than 23 factors. There are cycles of floods of varying magnitude and if we have a record for a short period then it is possible that it may correspond to a low or high cycle and therefore may not represent average conditions. In estimating the maximum flood discharge from the existing record it must be remembered that what has occurred in the part must needs be exceeded in the future. Also it is possible that extreme floods of a small frequency may follow each other at shorter periods. It is not possible to estimate the magnitude of the maximum possible flood on a river to any great degree of exactness, a rough estimate can however be made by the usual methods such as emperical formulæ, drainage area and maximum discharge envelope curves, probability methods etc.

The spacing and height of levees are interdependent. Levees can be made low and far apart or they can be made high and closer together. The correct positon is that which gives sum of the cost of the levees and the value of the unreclaimed land in the flood way a minimum. The spacing and height are found out by a number of trial solutions.

The levees should not be located very close to a bed in the river channel so that it might be undermined by the caving of the river bank or be subjected to the erosive action of the higher velocity of the current during floods. The levees should be as straight as possible, changes in direction should be made by curves of large radius. A free board of 3 to 4 feet should also be provided.

A metalled road constructed on the top of the dike or preferrably on the berm on the land side is very useful for efficient supervision, transportation of material for emergency works during flood and for keeping rats and some other small animals away from the dikes through the noise of traffic. The advantage of making a road on the berm is that the dike can be raised afterwards if desired. However carefully they may be constructed, earthen dikes are fragile works and are subject to breaching during floods if they are not very carefully maintained and supervised. The causes may be overtopping, erosion of river side slopes, caving in of the banks, infiltration through the dike or the foundation, leaks due to holes dug by rats, crabs and white ants, rotton roots and cracks due to shrinkage of soil, loosening of the dike by action of wind on large trees. To protect the dikes it is essential to have a strict supervision of the dikes during floods and enough labour and materials and depots of materials and tools along the dikes. Radio telephone liaison should be ensured.

In under-developed countries with availability of surplus man-power and the lack of capital and of heavy equipment dikes have been and will remain the cheapest, direct and immediately effective method of flood control. They should have adequate cross-section, be well constructed and efficiently maintained. If the silt load in the river is very heavy, the use of dikes should be accampanied by other means of reducing a part of that load such as reclamation of low lands outside the dikes by controlled silt deposition and soil conservation measures in the silt producing areas.

Too early diking in delta areas adjacent to the Sea should be avoided until the land is much above sea level to allow efficient drainage.

Overall strengthening should be done of the existing dikes where sections are inadequate as improper protection is more harmful than no protection at all.

Advantages of Diking.

1. Dikes are the only means of preventing flooding in tidal flats where the land is below the tidal level.
2. Diking is a very cheap method.
3. It can be done and maintained by local resources in unskilled labour and materials.
4. It can be done on a piece-meal basis and can be instantly effective.

Disadvantages of Diking.

1. It causes the rise of high water levels.
2. Dikes are fragile works, even small animals like rats, crabs and small worms can cause the breaching.
3. The Upper limit of the height is limited depending upon the material used.
4. A single breach can render the remainder of the dike useless. Due to flooding large areas may be inundated and

rendered sterile through the deposition of large quantities of sand.

5. Dikes are open to direct attack from river flow.
6. Drainage is obstructed.
7. Dikes prevent the fertilisation of the adjoining lands through silting.
8. In case of rivers carrying large amount of silt, dikes prevent deposition of silt on the flood plain and thus results in extension of the delta towards the sea and aggradation of the river bed.

In West Pakistan, Indus is double—embanked almost continuously below Kashmore to near Nawabshah and is further diked along the left bank to the sea, the land along the right bank in this reach is high. Government took control of the dikes in 1874-75 and active construction was taken up in 1900-1910. The height of the dike varies from 5 to 21 feet with a free board of 6 feet above the high flood level. The cross-section is according to a saturation gradient of 1 : 6 and 4 feet soil cover is provided over the point where the saturation line intersects the original ground level. The top width is 12 feet and side slope 1:3.

Due to high temperature in summer and low rainfall cracks develop in soils containing high clay content. Dikes are made generally of soils containing less clay content and if such material is not available at site sand core or a masonry wall is provided. Sand core checks the leakage and formation of rat holes. To prevent cracks method of soaking the dike is widely used before the floods. Soaking is done as follows.

1. An additional bank is provided thus forming a trench and this is filled with water about 6 inches above high water level by breaching water from an irrigation channel or by artificial pumping.
2. Parallel ditches are dug on the land side slope and these are filled with water by manual labour.

Shrubs are usually grown on foreshores of the dikes. Revetment is done where necessary.

Figure 1 shows the Indus river basin and the dike system.

The Lahore Protection Bund has now been raised and strengthened at a cost of Rs. 3 million.

Some of the disadvantages of diking have already begun to show their appearances. In Sind where diking along Indus has been practised since long waterlogging and detereoration of soil on account of obstructed drainage are progressing. The river bed is aggrading and bunds have to be raised higher and higher. Unless drainage of the surrounding country is improved and water collection due to local rains is drained off conditions will get worse.

3. Land Management.

The use of soil conservation measures for reducidg flood flow has been a subject of great controversy. Some people think that if the land is well covered with vegetation (forests, grass etc.) floods cease to occur. Others hold the view that whatever amount of vegetation may be done floods will continue to occur. Both these ideas are the two extremes. From observations on experimental plots and similar drainage areas with different surface cover it has been seen that vegetal cover reduces flood flow. Engineers are interested not in the qualitative effect but in the quantitative effect of the vegetal cover. They want to assess the precentage reduction in the flood flow obtained through the use of different soil conservation measures with rainfalls of varying intensities and durations and on lands of different soil characteristics.

The greatest single step forward in the study of the effect of vegetal cover on the run off was the development of the Infiltration Theory in 1930 and H.L. cook presented an excellent paper in 1949 on the quantitative effect of the vegetal cover and soil conditions on the flood run off. A brief summary of his views is given below.

Floods are made up of surface and sub-surface run off. If the rainfall intensity is greater than the infiltration capacity of the soil water flows as surface runoff. Infiltration capacity of the soil depends largely on the vegetal cover. Fig. 1 gives curves showing wide range in surface run-off under different cover conditions on the same soil.

Subsurface runoff is the part of flow which infiltration in the gound returns soon to the stream and adds to the surface run-off. It is different from the ground water run-off which pertains to the permanent zone of saturation.

On thin soils a flood may be composed largely of subsurface run-off and in such a case vegetal cover will not materially affect the run-off. However if flood occurs at a time when soil moisture is low vegetal cover may prove useful in minimising the flood run-off. In deep soiled areas the infiltrated water has to pass through a considerable depth of soil and if its moisture content is below field capacity it can store a large amount of water. On such lands the vegetal cover is most effective in abating floods.

Cook has depicted the results of quantitative estimates of flood reductions achieved through treatment of land in Fig. 2. It is seen that vegetal cover has a greater influence on the reduction of smaller floods but it has a smaller effect on large floods.

The effect of vegetal cover on the prevention of soil erosion and thereby reducing the sediment flow has been proved by experiments conducted all over the world. Results of one such experiment are given below. This experiment was conducted on plots of 3125 sq. cm. receiving natural rainfall during a period of 18 months.

Tray number	1	2	3	4	5	6
Vegetal cover	Grass	Grass	Grass & Scrub	Grass & Scrub	Bare	Bare
Rainfall inches						
Run off percent			98·51			
Soil eroded	15·1	19·2	9·4	12·2	46·4	49·6
(100 lbs/acre)	41·3	53·6	45·1	53·7	461·2	435·8

In another experiment it was seen that with the same soil, slope and rainfall the rate of erosion on land used for continuous row crops (cotton cover or tobacco) was more than 100 times as great as on land for hay, pasture, woodland and forest.

Results of yet another study conducted over a large area of 62000 hectares showed that increased deforestation, reckless cultural methods and pasturing doubled the rate of soil erosion in a period of about 23 years.

It has also been seen that gullying on land under intensive cultivation is more rapid than that on grazing grounds and that conversion of such areas to pasture land is an effective method of erosion control. Other things being equal the steeper the slope and the greater the length of the slope the more erosion will result. Vegetation acts in two ways on precipitation. It absorbs the energy of drops instead of allowing that energy to be used in splashing. The splash process, acting on bare soil, dislodges soil particles and throws them into suspension to be carried off by surface flow. It clogs soil pores into which water might otherwise infiltrate. Secondly vegetation promotes infiltration.

Experimental stations should be set up to study the methods of erosion control, but due consideration should be given to the increasing population and the critical food problems. Cheap and simple methods of soil conservation should be evolved.

As a flood control measure, the damaged watersheds should be repaired through revegetation of slopes with trees, grass, soil building crops, fire protection, stopping overgrazing regulating shifting cultivation, gully control measures and check dams. Also the watersheds should be properly managed by proper falling of forests, correct grazing of pastures, improved cultivation practices on sloping land through use of terraces, contours, strip cropping, crop rotation, sodding of drainageways. These are essential for the maximum yield of useful run off of high quality water, to attain sustained production of timber, forage and crops. and to help owners both to conserve and preserve lands.

Land management has important beneficial effects other than flood control. It is the purpose of land management to maintain harmony and stability among soil, water, plants, birds, animals, fungi, insects and men.

Departments of Agriculture and Forest can render a great help in this direction by making a detailed programme of soil conservation in consultation with Irrigation Department.

Pakistan is extremely short of forests. The total area under forests is 4·4 million hectares which is about 6·8% of the total Pakistan area. The percentage of forests in West Pakistan is about 2·5. In economically well developed countries 25% of the Iand area is generally covered with forests. In addition to reducing flood flows forests produce very useful fuel and timber and other products for the economic needs of the Country. Soil erosion, especially in the upland districts of West Pakistan, is very serious. Three million acres of once fertile land are being eroded and turned into a desert. By constructing small detention dams, contour diking and gully plugging and by taking proper soil conservation precaution measures, the situation could be improved in these upland district.

In order to check wind erosion in desert regions in West Pakistan, a part of excess flood diverted for basin irrigation of the desert reaches will be helpful in reducing wind erosion, and the planting of tree belts will serve as wind breaks. It is considered that in the ex-Punjab area alone about 5 million acres of land are at present being eroded due to the wind erosion. In Middle East and Australia soil stabilisation is being done by the growth of tamarisk and it might help in Pakistan too.

Since independence about 1·84 million acres of land have been brought under the control of the Forest Department. Due to the war and some other reasons whole-sale and indiscriminate hacking down of precious forests was perpetrated before independence. This denudation of the catchment area has been one of the chief causes of seasonal floods of increasing intensity. This 'operation axe' resulted in soil erosion and it allowed the sub-soil water to trickle down the river beds with no tree roots and porous soil left to hold the moisture.

The first duty of the Forest Department under these conditions was to adopt measures to conserve the soil under crop land, range land and forest area. The I.C.A. gave some aid for the project started in 1954 to adapt the American method of soil conservation to local conditions. Soil and water conservation measures, like broad-based contour terraces, diversion terraces, bench terraces and agronomical measures like improved crop varieties, continuous cropping and use of manures and fertilizers have already been tried with success and rewarding effects in 4 projects started in Attock, Rawalpindi, Jhelum and Gujrat districts where the problem of soil erosion is acute. Government is considering to extend this work to the whole of West Pakistan.

A five-year Silviculture Research Programme has been formulated to find solutions to the various forestry problems.

Every year popular compaigns are conducted to stress upon the public the need of growing more trees. 'Tree Planting Weeks' are observed and saplings are distributed among the people to help the Forest Department in their efforts to increase the forest wealth of the country. About 32·4 million plants have so far been distributed in various suitable area of the Province.

4. Spill Diversion Channels.

Flooding takes place when due to the increased run-off water in the river spills over the banks. Sometimes it is possible to provide a spill diversion channel to drain away the excess water from a river in flood to :

(*a*) another river if the flood peaks in the two rivers do not synchronise.

(*b*) sea, if possible, in case of diversion done in the lower reaches of the river.

(*c*) some diked areas or suitable depressions or lakes so that only a particular area is inundated in times of floods instead of flooding any area the river chooses.

Such diversions are usually made in diked rivers when further raising of the dikes is either uneconomical or unsafe. The intake for the withdrawal of water may consist of :—

(i) A lowering of a certain section of the dike with or without concrete, masonry or stone surfacing. Surfacing helps in avoiding uncontrolled flow after the flood.

(*ii*) Sometimes the dike is blown off by dynamite.

(*iii*) Constructing masonry spillways with gates for regulation. This method is rather expensive unless irrigation is combined with flood control. In the absence of a regulator at the intake the diversion channel may draw either more or less than the desired quantity of water and thus impair the silt carrying capacity of the river.

Construction of spillways generally meets with severe opposition from the people who own the lands as they do not want to be penalised to save the lands of the other people and they demand that it should be left to nature to decide on the areas to be inundated. Very great care should be taken to select the suitable sites.

Floods have been causing more and more havoc in the country and to some extent the causes lie in the doings of man. During the last 50 years or so, considerable developments have been made, no less than 11 Headworks have been constructed across the rivers where the supply is headed up and during most of the year the whole of the supply upstream of the rivers is diverted into the canals and very little discharge is allowed to pass in the river downstream. River beds keep on aggrading and it has been estimated that the beds of our rivers are being raised by ·05′ to ·2′ a year. The floods that come suddenly find various obstructions such as bridges, roads, railways and canals constructed across the natural drainage without adequate crossing or leading drains. Slopes have been flattened and drainage through the natural channels is becoming more and more difficult.

One of the examples of tampering with the natural drainage is the example of Sidhnai which is given here to show how far man's own efforts are responsible for creating conditions which result in flooding of the areas. River Ravi used to flow independently near Multan. Some one thought of making a short cut 9 miles long and dropping the Ravi Water into the Chenab. Ample slope was available and the cut developed and served its purpose for a considerably long time. Later on it was decided to build a headworks across river Ravi near Sidhnai. The selection of the site for the headworks however from the point of view of floods was not very happy. Instead of building the headworks at the head of the cunette it was built at the tail end. The cuts only develope if they have ample slopes and are allowed to erode their tail freely, according to the discharge which is likely to pass. In this case a non-erodable barrier was constructed at the tail end and the slope was flattened out with the result that this cut no longer remained in a position to function and serve the purpose for which it was originally constructed. Since then the river started over-flowing near the head of the cut into the original bed. During a period of low rain-fall the damage done was not considerable especially when the land was lying undeveloped. Later on however with the introduction of Lower Bari Doab Canal system the area was brought under cultivation, new villages and towns sprang up and more difficulties were felt.

The position was futher complicated on account of the fact that Haveli Canal was constructed and instead of dropping near the headworks it falls into the river 5 miles upstream. The canal has formed its regime, berms have developed with the result that the capacity in this reach is reduced to the capacity of the canal and not of the headworks. Floods find it difficult to erode this reach with the result that surplus water over-flows into the old bed of the river. Floods will continue to play havoc so long as the headworks is situated at the tail end of this cut or another diversion is constructed which is large enough to take the whole of the flood water and the cut is allowed to cater for the canal water only.

Similarly man has interfered into the working of nature by the deforestation in the hilly catchments, overgrazing and tempering with of nature's protections against the ravages of floods and now he is paying the price for it through damages caused by floods to his belongings.

5. RIVER TRAINING

Meandering :—

A river channel is formed by its normal flow and when the fluctuations in this normal discharge are great there is an excess energy which cannot be absorbed by the bed and the sides of the river channel. This results in meanders and overflow of banks. Such changes take place during heavy floods, and they depend upon the nature of the sides and bed. Near the hills there are boulders and coarse material in the bed, slopes are steep and the excess energy is dissipated by the formation of rapids or the channel often bifurcates into streams thus increasing the wetted perimeter and therefore the resistance to flow. Below the boulder and shingle reach the river enters plains and the bed consists of sand but the slope is still fairly steep. Here the rivers tend to be shallow and wide and spill over the banks even in smaller discharges. In the lower portions near the sea the banks due to the deposition of alluvium are comparatively tough and meanders develop more fully than upstream. To protect the river from these changes it is useful to provide spur dikes or revetments.

Channel improvement :—

The object af channel improvement is to increase the discharging capacity of the stream in such a way as to pass the water at a lower level. This may be done through straightening the channel, improving its cross sections, lining or reducing its length by cut-offs.

The most common application of channel improvement Is in the case of a river reach which is flowing through some big city or an area which is highly industrialised or is of great value and where levees are not possible due to high cost of land and interference with transportation routes and reservoirs are uneconomical or impracticable. The solution is the improvement of the channel within that area so that the water passes at a lower level.

The effect of cut-offs is somewhat similar to that of channel improvement. The velocity of flowing water varies as the square root of the slope. To double the velocity it is necessary to increase the slope 4 times. Since the total fall between any two points on a stream is constant therefore to increase the slope we must shorten the channoel length of the stream. This is done by the construction of cut-offs acrss the narrow necks of land made by sharp loops in the channel. The purposse of cut-offs is to increase the velocity, shorten the distance which the water has to travel and to decrease the length of levees if these are to be used as a part of flood protection works.

Cut-offs are recommended only where a considerable rectification is possible at a small expense. Model tests help a great deal in these studies.

Drainages :—

The existing drainages should be developed to be able to drain off the run-off of heavy and unprecedented rains. New drains should be dug to give relief to those flooded areas which are not served by any drains at present. These shuld be linked to major drainage systems of the region. Training of drainages should be done along with provision of marginal bunds.

Drainages can help a great deal in minimising the havoc wrecked by the floods but they cannot prove a complete remedy for the exceptionally high floods.

The cost involved in a comprehensive drainage system will be very heavy, the work should be done on a scientific and well co-ordinated basis. To do this it is essential that accurate and detailed data should be collected giving the following information.

(i) Particulars of towns and villages heavily flooded, with highest flood marks and duration of sumergence.

(ii) The various natural and artificial drainages that have functioned during the floods, their high flood marks, the directions of flow and the discharges.

(iii) Detailed rainfall data at the rain gauge stations in the area, giving intensity, duration, and quantity of rainfall, etc.

As the drainage problem is very vital and colossal therefore it can be advantageous if the Government authorities take the fullest cooperation and help of the people themselves whose houses, lands and other properties are affected. Considerable savings can be affected if the lands and labour are forthcoming from the owners free of charge. The lands can be reverted to them after improvements. A lot of propaganda is needed to induce them to adopt this attitude in the interest of their betterment and protection. Some of this work may be given to the village councils under the guidence of the engineers.

In the plains in West Pakistan slopes are flat and there are inadequate opportunities of surface water disposal. Protection should be provided to railways, roads and canals by constructing additional cross drainage works and raising the roads above flood levels to safeguards all essential communications and leading drains must be constructed.

As a rule drainage schemes involve works in which Irrigation, Buildings & Roads Branches and N. W. R. are all concerned and this results in delay in correspondence. A committee consisting of the Chief Engineers of all these departments should be appointed to frame and implement the drainage schemes.

A special River Survey Division under the Directorate of Irrigation Research, Lahore, has been opened to make necessary survey in connection with flood control.

Due to varying discharges passing through the syphons silt is deposited in them and waterway is reduced and the capacity for which they were designed is not available during floods. In future projects the idea of syphoning canals under the nullahs as far as practicable should be tried.

In West Pakistan due to the configuration of the country and its arid nature a proper drainage system has not been carved by nature. The general slope of the country is about one foot per mile and even this has been crossed by various canal embankments, roads and railways. The underground drainage is similarly not efficient and is supposed to be obstructed by impervious barriers running across the Indus valley at more than one point. To meet with the situation, in addition to the tubewell pumping which should be done, the surface drainage system has also to be improved The surface drains tried so far have inadequate outfalls and insufficient bed slopes. To cause proper gravity flow in our drains it would be necessary to install pumping plants It is estimated that about 30 to 40 thousands K. W. will be required for this purpose in West Pakistan.

As explained above there are small chances of big reservoirs in West Pakistan. Also there is a limit to the construction of dikes in the upper portions of rivers. Again the soil conservation measures can reduce the flood flows but they cannot totally control the extreme floods. Under the circumstances drainage measures are considered to be very effective in controlling the floods. In addition to flood control they help a great deal in avoiding waterlogging and thur formation of large areas. Whenever there is poor drainage water collects on the land. Some of it seeps into the soil and raises the sub soil water table. Water-logging generally occurs over such areas. Due to evaporation salts deposit on the surface and lands get thur affected. Crops cannot be grown on these areas in a satisfactory manner and this aggravates the the food problem of the country which is already very grave.

Like most arid regions the vast alluvial deposits of the Indo-Gangetic plain hide the underlying rock floor. The few surface exposures at Shahkot, Sangla Hill and Chiniot and a large exposure of rock south of Sukkur show that in these parts at least there are very considerable irregularitities under the alluvium. The Shahpur — Delhi ridge lies directly across the otherwise normal direction of flow of sub-soil water. When roads, railways and canal projects were undertaken little attention was paid to the surface and sub-soil drainage. There should be no blockade to the surface or sub-surface drainage of the country and it is very essential to open out obstructed drainage and dispose of the storm water as expeditiously as possible so that no flooding takes place. When the surface drainage is blocked, either the blockade should be removed or diversion of the stream should be considered.

An area should be carefully studied before planning a drainage system. The study should include a survey of the general geology of the area, measurement of depth of water-table, finding the direction of flow of ground water, determination of the physical and chemical properties of the soil and a survey of the general topography of the area.

In ex-Punjab the Drainage Circle constructed several storm water drains to carry away the rainfall run-off from the land within a period not detrimental to crops. Their design and capacity were based upon the consideration to carry away the rain water within a specified period. The alignment of the drains followed the natural drainage of the country. The main drainage systems in the ex-Punjab area are.

1. Chaj Doab.

(1) Budhi Nallah System.
(2) Fadinian Sillanwali drainage system.
(3) Lower Raniwal drainage system.
(4) Mona drainage system.
(5) Alla drainage system.

2. Rechna Doab.

(1) Niki Deg System.
(2) Chicho-ki-Millian Drainage system.
(3) Rechna Outfall drainage system.
(4) Ahmadpur Kot Nikka Draiage system.
(5) Ahmadpur Wagh drainage system.
(6) Aik Nallah drainage system.
(7) Jaranwala main drainage system.
(8) Chiniot drainage system.
(9) Modduana drainage system.

3. Bari Doab.

(1) Sukhawal drainage system.

The total mileage of drains on various canal systems is given below : —

TABLE No. 3

S. No.	Name of Canal	Length of drain					
		Seepage drains		Storm cum-seepage drains		Storm water drains	
		Miles	Feet	Miles	Feet	Miles	Feet
1.	Lower Chenab. East.	22	—	490	—	3	—
2.	Lower Jhelum.	278	2650	—	—	391	4000
3.	Upper Jhelum.	107	—	141	—	114	—
4.	Uppe Chenab. (including LHR. Div.)	519	2196	38	600	202	3649
5.	Central Bari Doab.	331	750	—	—	—	—
6.	Nili Bar Canal.	—	—	—	—	—	—
7.	Haveli Canals.	1	993	1	840	—	—
8.	Lower Chenab. West.	115	305	184	3321	17	214
9.	Derajat.	3	2000	29	1000	—	—
10.	Lower Bari Doab.	—	—	12	1000	382	4100

		Miles	Feet.
1. Seepage Drains.		1377	3894
2. Storm cum-seepage drains		896	1761
3. Storm wate drains.		1111	1963
	Total	3385	2618

The drainage capacities of the drains in the two doabs are 13832 and 2901 causecs, respectively, and these flow to capacity for hardly ten days a year and carry either no watar or very little discharge at other times of the year. Outfalls are poor and most of the drains fail to function during a period when they are most needed due to flat slope. Efficient pumping plants are necessary to be installed at the outfalls on most of these drains. The mileage of drains as compared with the Irrigation System is very little and as explained above is quite ineffective.

6. **Pumping Stations.**

In localities where drainage is poor pumping stations should be established to deal with accumulated run off. If pumping stations cannot be established, the trucks for carrying pumps should be fitted with a device called Power Take-off. This removes the necessity of carrying heavy prime-movers.

7. **Shifting Villages in Low Areas to Higher Places.**

In case of villages situated in very low places where damage due to floods is very heavy and which involves the reconstruction of the whole village such habitations should be abandoned and new villages sited on higher places.

8, **Flood Control Measures now being adopted by West Pakistan Govornment.**

The Provincial Government have now set up a Flood Commission for West Pakistan to deal with the problem of recurring floods in the province on a long term basis. It consists of the heads of the various concerned departments as its members under the Chairmanship of the Flood Relief Commissioner who will be a member of the Board of Revenue.

The terms of reference of the Commission are very detailed and exhaustive. In short, the commission will assess the flood problem of the province as a whole taking into account the adequacy of the existing data and prepare a comprehensive programme for further surveys. investigations and collection of data. It will prepare an integrated and suitably phased flood control plan of short and long term measures and work out detailed individual schemes.

The Secretariat of the Commission shall consist of one Additional Chief Engineer (Floods), two Assistant Directors (Executive Engineers) and other ancillary clerical and drawing staff.

For the sake of collection and compilation of the necessary data to be put up to the Flood Commission it has been decided to create a Directorate of Hydrology under a whole time Superintending Engineer and two posts of Executive Engineers for the former Frontier and Quetta Regions. These two Executive Engineers will collect necessary data from their respective regions in the same way as the two Executive Engineers of Discharge Division, Lahore and Research Division, Karachi are collecting data for their respective areas. The Director, incharge of the Directorate of Hydrology will coordinate the activities of these organisations and will be responsible for compiling, processing and putting up all such data as is needed by the commission for the formulation of their policies, schemes and projects. The local officers will also supply relevant data to this Directorate.

The Indus River Commission will continue to function with the difference that the Additional Chief Engineer (Floods) will act as its Chairman. The functions of the Indus River Commission will be limited exclusively to Bund work and will not include any other types of flood works.

The execution of the schemes approved by the Commission will be done by the Regional Officers.

Conclusion.

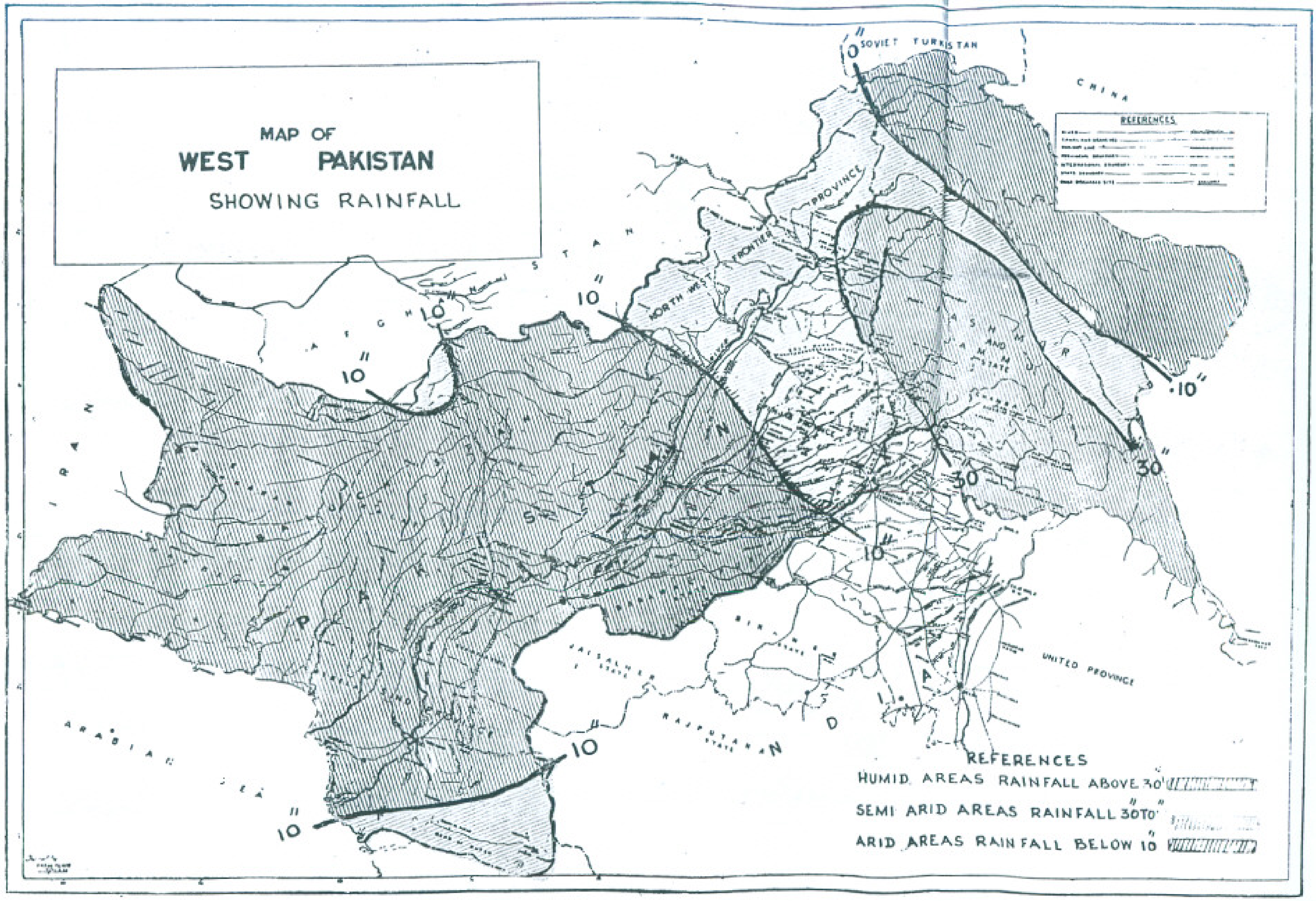
The experience of the last few years shows that great havoc is being caused to West Pakistan and considerable damage is being done to her. Unless effective measures are taken based on proper investigations and studies there will be colossal recurrent losses to the country by floods. The step now being taken by the West Pakistan Government is in the right direction. Flood control needs detailed planning on scientific lines for which accurate surveys, discharge data, flood heights, flood routing etc., are required. Opening out of the natural drainage of the country along with improvement in the existing drainage for expeditious disposal of a flood water and removal of unnecessary obstructions are very essential. This requires a lot of spade work and studies before a well planned scheme can be put up. The necessity of proper investigations and research cannot be over emphasised in the matter of flood control otherwise half-hearted measures or incorrect measures are likely to do more harm than good.

ecessary data to
:ided to create a
nding Engineer
r Frontier and
:ollect necessary
: two Executive
ivision, Karachi
:tor, incharge of
vities of these
processing and
or the formula-
fficers will also

nction with the
) will act as its
will be limited
types of flood

Commission will

it great havoc is
s being done to
r investigations
the country by
Government is
l planning on
flood heights,
al drainage of
age for expedi-
ary obstructions
l studies before
roper investiga-
natter of flood
measures are



For th
ut up t
torate o
wo post
Regi
from the
eers of
llecting
rectora
isations
g up all
their p
relevat

The In
nce th
nan. T
ively to

The ex
e by th

sion.

The ex
used t
nless
udies th
The
right
ific lines
outing
ntry al
isposal
y essen
planne
nd rese
other
to do m

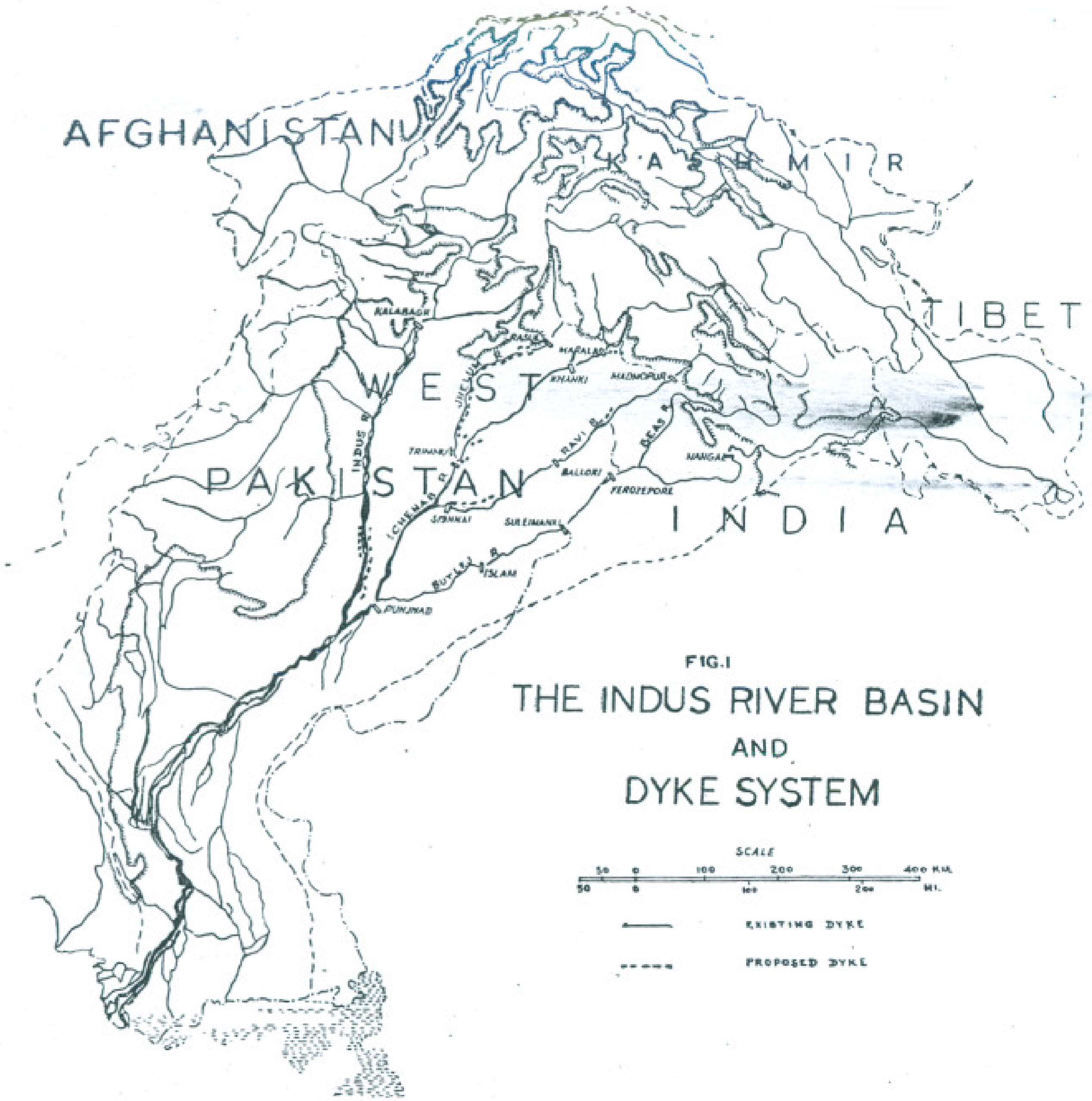


FIG.1

THE INDUS RIVER BASIN AND DYKE SYSTEM

FIG.2

ILLUSTRATING THE EFFECT OF VEGETAL COVER UPON THE SURFACE RUN-OFF CAUSED BY INDIVIDUAL STORMS-AVERAGE RELATIONSHIPS AT ONE SITE

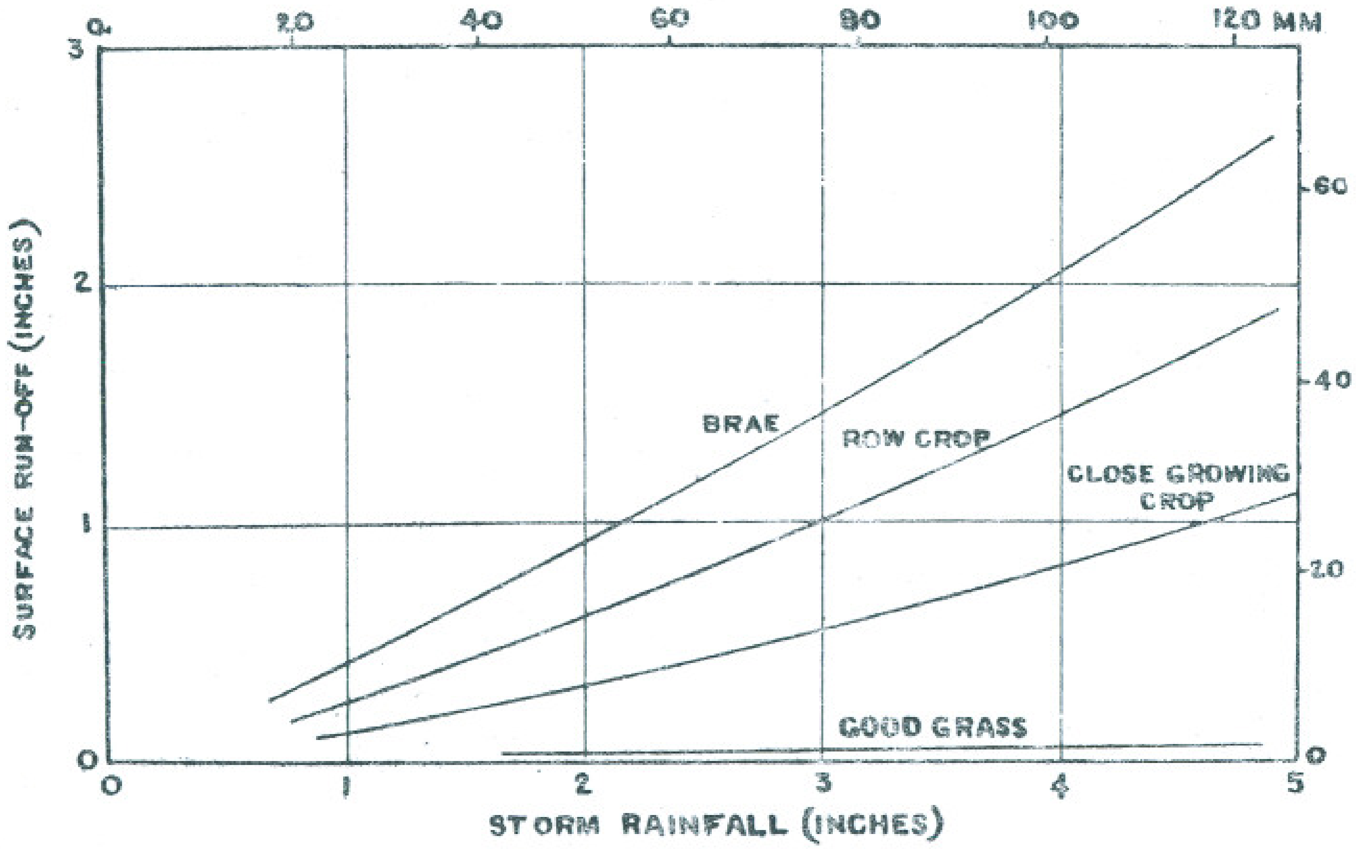


FIG. 3

TYPICAL CURVES SHOWING AVERAGE REDUTION IN FLOOD RUN-OFF ATTAINABLE THROUGH TREATMENT OF THE LAND