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WATER

SPREADING MANUAL

WEST PAKISTAN RANGE IMPROVEMENT SCHEME
LAHORE, MAY 1964

Foreword

Concept of Water Spreading is not altogether new in this part of the world. People living in the foot-hills, have been adopting various practices to hold flood water, on their lands by constructing dams or [illegible] for growing agriculture crops. Methods used, although not very [illegible] ive. The so-called "Rod-i-Kohi" cultivation [illegible] and Ghandi irrigation in Mianwali district [illegible] spreading. During the rains, lot of [illegible] flow of the water is diverted an[illegible]

Use of the w[illegible] ching which has not be[illegible] are not being used for [illegible] les. Such areas are o[illegible] is a basic industry [illegible] elands have been badly [illegible] that they are capable of produ[illegible] ing the number of livestock o[illegible] areas. Social conditions in the rural are[illegible] stockmen, makes it difficult to reduce the nu[illegible] alternative left is to increase the forage production. A l[illegible] waste into the sea which could be utilized for grass production by constructing water catching devices.

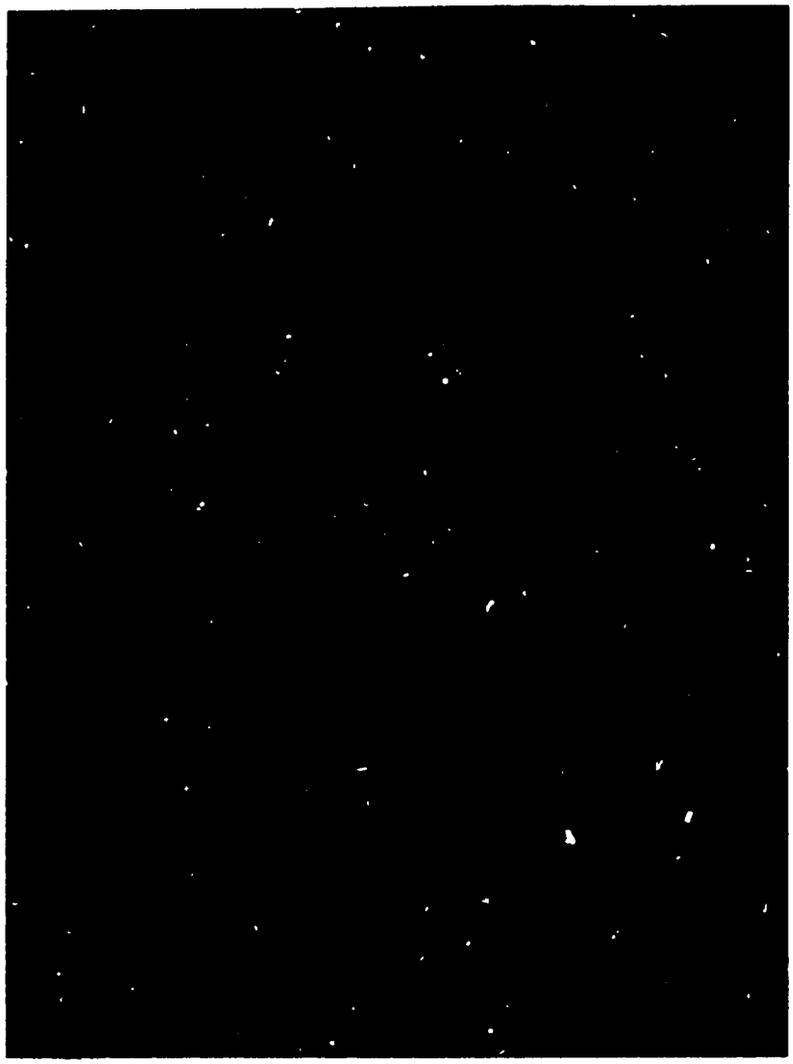
This wastage of great natural resource brings into lime-light the importance of water spreading in our Range Development Programme.

Effectiveness of the water spreading methods in improving the forage production has been clearly demonstrated in Rakh Mian Project Area under the West Pakistan Range Improvement Scheme. This booklet, on water spreading, provides the technical know-how for embarking upon similar projects in other areas. Conditions in Bannu, Kohat, D. I. Khan, D. G. Khan, Mianwali, Larkana, Dadu and Thatta districts and Quetta-Kalat Region, provide ample opportunities for adopting water spreading techniques with a view to increase forage production. This booklet is the first of its kind and provides adequate knowledge to the technicians in the field. It is a solid contribution to the subject of Range Management in West Pakistan and the authors deserve congratulation.

AMIR AHMAD KHAN S.K.
Joint Secretary (Forests)
Government of West Pakistan,
Agriculture Department.

Lahore :
5th March, 1964.

Survey for water spreading Dam



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Water in a desert and semi-desert area like West Pakistan is the very life blood of the country. Waste of water is a serious loss to the individual and the nation. Water spreading is a means of saving and using waste water or run-off water for crop or grass production.

Grass is life in arid climates, palatable forage produced by native grasses, legums and shrubs provides the feed for grazing animals on which the people of the world's deserts and semi-deserts largely depend. The hardy sheep, goats, camels, cattle, horses, donkeys and other grazing animals provide meat, milk, hides, wool, and work the essentials of food, clothing, and shelter, the very life of the desert people. Thus more forage means better living.

Water is a key to forage production in arid climates. Of all the essential elements for plant growth, water is most often limiting. Each drop of water that flows off the range is lost for forage production, but any water that can be held on the land means more and better forage.

Nothing equals a fully developed vegetal cover holding water on the land where environmental conditions are sufficiently favourable to sustain such a cover. In the more arid regions or because of marked deficiencies in precipitation and soils, the natural vegetation may be too sparse to retard run-off effectively. If established, downstream claims for irrigation or other purposes do not require all of the natural run-off whatever remains can be put to beneficial use on the range by water spreading, providing suitable areas are present.

There are many kinds and types of water spreading but the basic principles are very much the same. To catch, hold, divert and use run-off water for the production of a crop of grass or food crops.

Water spreading is a practical method of controlling soil erosion and the movement of sediment. At the same time water spreading conserves water for increasing forage production. It is a simple form of flood irrigation accomplished by diverting run-off from normal channels or water courses and spreading the flow over adjacent flood plains or valley floors. The diversion and spreading may or may not be controlled by a system of dams, dikes and ditches designed to accommodate a calculated rate and volume of flow.

Water spreading is most frequently practised on range and pasture lands and the systems are constructed so that operation is usually automatic whenever sudden, torrential, storms occur.

Water spreading is not new, in fact, it may predate actual irrigation. There is evidence of many water spreading systems built by the Romans throughout the Middle East. Some of these systems still have a beneficial effect and are producing more crops or more grass on a restricted area.

Water spereading is a common practice throughout much of West Pakistan, but here water spreading is practised for the production of food crops.

Rakh Miran D. I. Khan

The results of water spreading are sometimes very spectacular. The Rakh Miran water spreading project south of Dera Ismail Khan district has produced outstanding results in the first year. More than twenty five maunds (2000 lbs.) of goods palatable hay can be cut from each acre of this water spreading area. Yield of grass on similar adjoining areas, not affected by water spreading, will yield less than two maunds of poor feed per acre.

On one of the 5 water-spreading systems constructed in Jordan in 1952—53, 2½ tons of good hay was produced per acre. It must be remembered, however, that there was no production from the other 4 water spreading systems because no run-off water was available to these other systems during that year. The following year a good crop of grass was produced on other systems but the first productive project did not receive any run-off water the second or third year after construction. Most consistant result are obtained where run-off can be expected at least once each year

On one 23,000 acre range in Montana where water run-off is very reliable water spreading is used on 800 acres suited to the practice. This small portion now supports more livestock than the remaining 22,200 acres. Even more important, the extra forage on the spreader area permits resting the surrounding range so that it in turn is improving and producing more forage.

After Water Spreading more then 25,000 maunds of good hay were produced on Water Spreading area Rakh Miran West Pakistan.

Another 960-acre water spreading area supported 50 cows in the second year following treatment while before water spreading the area carried only 9 cows. On other ranges, water spreading has made it possible to increase the number of livestock by from 5 to 10 times on the area benefitted by spreading water

Another advantage of water spreading is in generally extending the season during which the forage is succulent and nourishing. Often, as a result of run-off from higher ground, growth begins earlier than on the surrounding area. This provides green forage at a time when it is especially needed. At the end of the growing season, when the grass outside the spreading area is dry and has started to lose some of its nourishment, the grass inside the spreading area is often still green because of the extra moisture in the soil. The grazing animals grow better and produce more milk on a ration of green forage which they relish and which is rich in essential food elements.

Another advantage of water spreading lies in its usefulness for hay production on ranges where improvement in hay fields cannot otherwise be developed.

The forage can be harvested for hay at a time when the nutrient qualities are at a peak or, if the forage species present cure well on the stem, then the spreader area can be reserved for later use when other forage supplies are not available.

The shortage of food for people as well as the shortage of feed for livestock often demands that water spreaders be used for food crop production. In fact, water spreading for food production is now practical throughout West Pakistan on a large scale. Most of the non-irrigated wheat, in the southern part of the country, is produced on land under a system of water-spreading. These systems could be greatly improved by adaptation of some of the basic principles found in the United States, to the present systems. A combination of water spreading systems to produce both food crops and forage for livestock may be most desirable and practical.

Opportunities for water spreading are found on many arid and semi-arid ranges, but water spreading is not a cure-all for every sick range. Water spreading sites must be selected with great care and with full consideration of topography, and the present and potential vegetation on the area. Structures must be located in accordance with the local conditions and needs on the ground. They must have correct design and engineering layout. They must also be built with careful attention to construction details

Hay cut early makes better feed and sells for better price - Rakh Miran

Laws and customs relating to the use of land and waters must be studied before water spreading is undertaken. In some places, efforts to hold water on the upper watershed cannot be applied because of conflict with downstream water rights. Grazing rights on spreading areas should clearly be understood by all concerned, not only to avoid disputes as to who shall reap the benefits of water spreading, but also to insure that grazing can be properly controlled and regulated, so that the forage can be correctly used and maintained

Planning for range reseeding where needed, for the development of livestock-water, and other range improvements, and for a long time improvement programme for the entire range unit, should be part of the overall plan which includes water spreading. Forage plants cannot grow and take advantage of the increased water supply unless grazing is managed so as not to disrupt the basic life processes of the plants. Enough growth must be left at the end of the grazing year to maintain plant vigour and protect the soil. Time of grazing must be planned to provide the kind of forage needed by the livestock at each season of the year, as well as to permit the plants to develop abundant leaves, flowers and fruit, and to provide favourable conditions for seeds to germinate and establish themselves. Unless these requirements are met for the entire range unit as well as the spreading area, the cost and effort of water spreading will be wasted.

Ranges suited to water spreading must have two essentials. The first is that surface run-off water, available for spreading, must be produced by the upstream drainage area. This means that the topography, geology, soil, climate and vegetation must combine to give at least a few sudden flows of water, large enough to be useful but not too large to be handled each year. The second essential is that suitable flood plains or gently sloping areas on which to spread water, must be conveniently located on the lower watershed. Here again the conditions, especially of soils and vegetation, must be such that additional water will increase the forage supply. Some aspects of these requirements are considered in the following two chapters of this handbook.

Run-off Water

The Water Supply

The water supply for water spreading will generally come from a stream channel which is dry most of the time but which flows for short periods following heavy rains or snow melt. The first job of the planner is to determine whether the watershed area above the spreading site will furnish an adequate water supply. A rate of flow large enough for satisfactory spreading, but not so large as to be unmanageable is necessary. A long period of water flow is also desirable.

The planner needs information on two points to decide on the sufficiency of the water supply: (a) The rate of peak flow per second, (b) The total volume available in a period of stream flow which will occur often enough to justify building the system. Total volume is expressed in acre-feet, acre-inches or any other unit depth and area. Peak flow is measured in cubic feet per second,(cfs).

Water Characteristics that Influence Run-off.

Watershed conditions are seldom uniform. They include a great variety of slopes, soils, vegetation, stream patterns and other variables which affect run-off. Examine the watershed with the following points in mind :

1. Topography—Observe the slopes and exposed rock formations. These may be very important. If the rock layers or strata are tipped or inclined into the drainage area, conditions should be favourable for good run-off. If the reverse is true run-off may be very low. On the other hand, a level bedded formation may provide an excellent site.

   Note which slopes have the most vegetation. In dry regions vegetation and water supply are closely interrelated. Where there is more vegetation there is more soil moisture. Rainfall usually increases with elevation above the surrounding country. The higher the drainage area, the better are the chances for abundant run-off. Great differences in rainfall may occur within a few miles. Other things being equal, northern slopes usually yield the most water. If the streams gradients are steep, the streams may carry a large amount of bed load or heavy material ranging from quite fine particles to coarse gravel and boulder which roll or slide along the stream bottom during periods of peak flow.

   Close observation of the small Nallah or depressions will indicate whether they carry water frequently. If flows are frequent, the channels will be swept clean excepting for drift material which is plainly water deposited. As a rule, the steeper the slope, the greater the run-off.

If the drainage area consists of many small, narrow valleys with steep slopes at right angles to the streams, the run-off will probably be rapid and total time of run-off short. With broad, flat valleys the period of run-off will be much longer. The stream grades themselves will also affect period of run-off and peak flows. A long narrow drainage will have a longer run-off period and a lower peak than one which is wide and relatively short.

2. Rainfall—Study all available rainfall records that may be representative of the drainage area. The distribution of the rainfall not only by months but by days is very important. Run-off for water spreading is usually produced by heavy rains falling in a short period of time. For example, if the average annual precipitation is 8 inches, and half of it usually occurs in June and July, it is desirable to know whether there are 15 days with rain during this period or only 5 in the average year. Local people can often give useful information on local rainfall as to intensity, time of storms, direction from which they come and some idea of the amount of rain required to produce a usable amount of run-off.

3. Soils—The soils of the run-off area should be carefully examined. Most clay soils absorb water slowly. Shallow soils, over clay or impervious rock yield high run-off after the permeable layers become filled with water. Deep sandy soils and soils with good structure will absorb water rapidly and release it slowly. Run-off from a drainage area of deep permeable soils may continue for several days or even weeks following heavy storm. Such flow provides a good supply of water for spreading. Sandy or silty soils are likely to be erodible, especially on steepslopes. Sometimes soils can be examined in the sides of gullies or cut banks to determine ther structure. Dune sand or very sandy soils do not yield good Run-off.

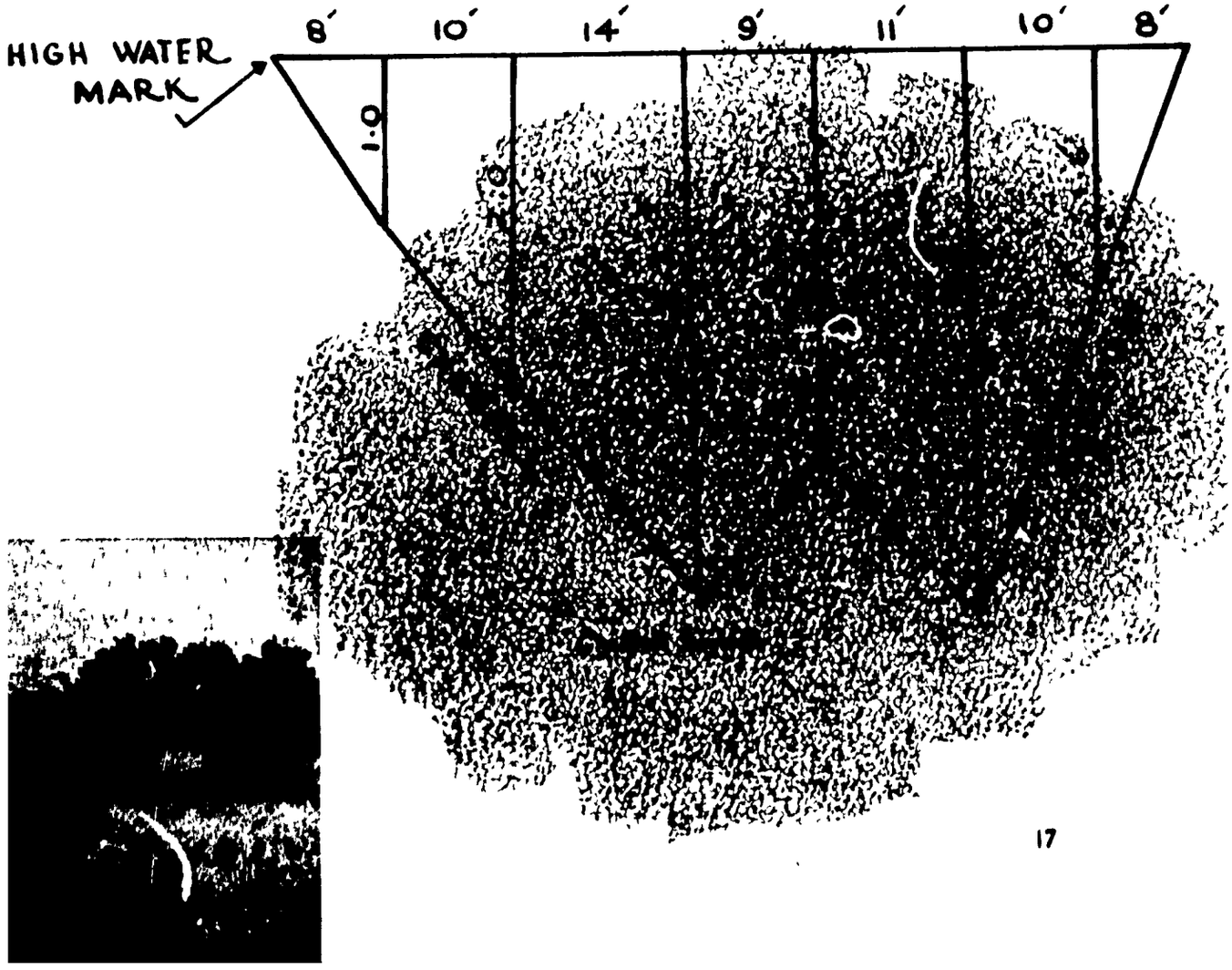
4. Vegetation—Vegetation is an important factor affecting water yield and type of stream flow. Watersheds with a heavy cover of grass, shrubs or trees seldom produce sudden heavy run-off. Vegetation aids most soils to behave as a sponge in taking up moisture as it falls and releasing it slowly. This condition is favourable for sustained stream flow. An appreciable portion of a rain may be intercepted by the leaves of trees or shrubs and if temperatures are high and humidity low, this moisture never reaches the ground. Vegetation is the most desirable medium of erosion contol. Run-off from a drainage area with good vegetal cover will not carry too much sediment to burden the spreading system. If within the drainage area the vegetation is mostly grass, the situa tion is ideal, and improving the grass cover will not greatly reduce the water yield. In fact, spreading conditions are likely to be improved since the run-off period will be longer. Grass cover on the watershed slows the run-off rate, permitting the spreading area to become moist to a sufficient depth to give good forage

growth. Run-off from vegetated drainage areas may carry considerable drift of grass blades, leaves, twigs and sticks which may be a nuisance in the spreading system but are to be preferred ot large volumes of sediment.

5. Available Run-off Records—Run-off records when available, are the best source of information on water supply, particularly records which are continuous for a 20-year period or longer. The records from gaging stations on reservoirs and streams are valuable, the former more so than the latter. Here again the records are not likely to be reliable unless they cover a period of at least 20 years. Often gaging stations are so far removed from the drainage area that considerable care must be exercised in using the records. Such data may be susceptible of only limited application because the areas are usually dissimilar in climate. However, if conditions are reasonably similar, records from drainage areas 50 to 100 miles away may be useful.

COMPUTING PEAK RUN-OFF BY SLOPE AREA METHOD

When run-off measurements are lacking the slope area formula is commonly used to compute peak discharge. The computation is based on water marks and drift lines left by high flows observed at several points. These water marks should be discussed with local people as to frequency and duration of flows at various heights. If any bridges exist they often have good water marks and definite stream cross section through them. Local information should, if possible, be obtained from several individuals. No two people will give exactly the same report of what they have seen.



By this method a reasonably straight, smooth [illegible] the stream channel is selected and a cross section obtained of past water flow [illegible] vation shown by water marks. This is done with a level [illegible] high water on each side of the channel and at numer[illegible] anges

If elevations of highwater [illegible] erage of the two as the water surface [illegible] e sum of each horizontal distance [illegible]

In this case th[illegible]

A=Area [illegible]

To Area=141.8 squa[illegible]

The horizontal distanc[illegible] 8+10+14+9+11+10+8=70 feet.

A point is next selected from 10[illegible] and this high water surface level, relative to the water surface level at the cross section, determined. Assume in the example that the second point is 200 feet upstream from the cross section location and the fall of the water surface is 1.6 feet, or the slope of the moving water is 1.6/200 or 0.008. The water surface should be checked at a third point 50 to 100 feet downstream from the cross section to make sure that the water surface grade did not change much near the cross section. If care is taken in selecting the portion of the stream channel for measurement, there will rarely be much change in surface grade.

Next, determine the hydraulic radius at the cross section which is the Area/wetted perimeter. The wetted perimeter is the length measured along the bottom of the cross section up to the high water line. If the banks are vertical this measurement is the distance across the stream bed plus the height of each bank. In the example, the banks are sloping but the bottom uneven. The wetted perimeter is 75 feet. Then the hydraulic radius is 141.8/75=1.89 feet or cross section area in feet, dividend by wetted petimeter in feet.

When water flows in a stream there is friction or resistance imposed by the bed and banks. The rougher the stream bed the greater the resistance. It is expressed by a decimal fraction called (N) the co-efficient of roughness. It ranges from 0.009 for a flume of planned lumber to 0.200 for rough, rocky mountain streams. The proper selection of the value of this co-efficient requires experience and judgement.

A nallah or stream with a rough, irregular channel with much angular rock and very little vegetation the co-efficient of roughness would probably be about 0.075. The same channel with a good growth of vegetation will result in a much higher co-efficient, around 0.120. In the example we will assume the value of the co-efficient of roughness to be 0.040.

Next, the velocity of the water in feet per second is determined and multiplied by the area of the cross section. This calculation gives the peak flow in cubic feet per second of time *

*The velocity formulas are cumbersome and laborious to solve. Excellent tables for their solution are published. One is entitled "Hydraulic and Excavation Tables" by the U.S. Bureau of Reclamation and sells for $ 1.50 per copy. One issued by the United States Army Engineers is even more useful when dealing with flow of streams rather than canals and sells for $ 2 per copy. Both may be obtained from the United States Government Printing Office, Washington D.C.

The kutter velocity formula is expressed as follows:

$$V = \frac{\left\{\frac{1.811}{n} + 41.6 + \frac{.00281}{s}\right\}}{\left\{1 + \left\{41.6 + \frac{.00281}{s}\right\}\frac{n}{\sqrt{r}}\right\}} \times \sqrt{rs}$$

r = hydraulic radius,

n = coefficient of roughness,

s = slope,

v = velocity

Substituting in the example,

$$V = \frac{\left\{\frac{1.811}{0.040} + 41.6 + \frac{.00281}{.008}\right\}}{\left\{1 + \left\{41.6 + \frac{.00281}{.008}\right\}\frac{.040}{\sqrt{1.89}}\right\}} \times \sqrt{1.89 \times .008} = 4.8 \text{ feet per second.}$$

The cross section area 141.8 Sq. Ft. x 4.8 = 680 cubic feet per second. The volume of flow (quantity of water) is usually expressed by "Q" and Q equals VA (Velocity times area).

The slope-area method gives maximum volume of discharge but no information on total volume to be expected from a given storm

Time of flow and total volume--These are factors which although they cannot be computed accurately are of great importance to the planner. Many uncertain factors such as the movement of a given storm whether down, up or across the drainage, affect peak and total yield from the storm.

A small flow will often continue for a long time, possibly a day or two after the storm. A common rule is to assume that the time of flow will be double the time of concentration and that the average flow will be one-half the peak. In some cases, the greatest peaks occur in a time obtained by neglecting the upper portion of the watershed, if run-off from it is slow due to low grades, good cover and a long narrow valley

Volume of water is expressed by the term "acre-foot". This is the volume of water which will cover 1 acre 1 foot deep.

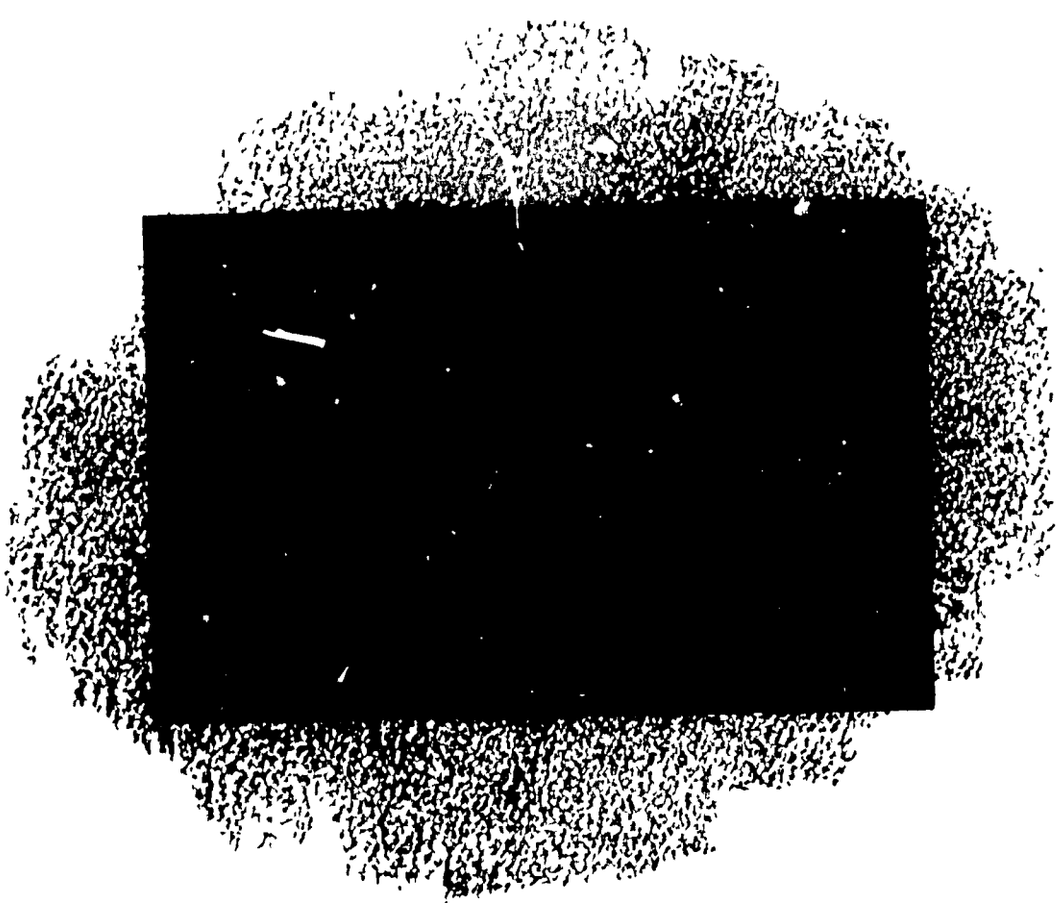
In converting rate of discharge to volume, a convenient figure to remember is that 1 second-foot flowing for 24 hours will cover 1 acre to a depth of 2 feet or 2 acre feet. Again using the example on page 20 peak discharge was computed as 680 second feet and assuming

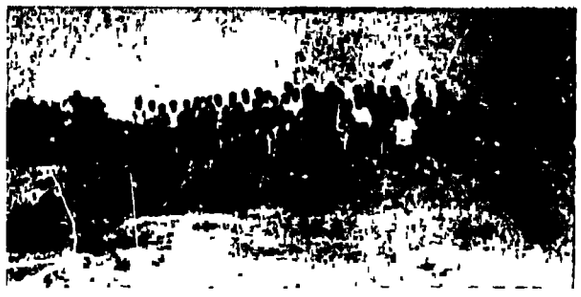
the time of concentration and time of rundown each to be 2 hours with an average flow for the 4 hours to be one-half the peak flow we have run-off in acre-feet, "Q" equals $\frac{680}{2} \times 4 \times {}_{24}$ or 113 acre-feet. If this were all diverted, it would (not computing losses) give a 4-inch depth irrigation for 339 acres. If this is the peak storm to be expected in 50 years, the average storm might give one-third or one-half as much water. All of the flow of the smaller storms could be diverted with a good spreader. If flows are frequent enough to justify the job the water supply should serve about 150 acres of spreading area.

The frequency of the flow necessary to justify construction depends on many factors, among them the scarcity of forage in the area. Can forage be harvested from the spreading area in wet years and stored for dry ones ? Will even a small amount of added feed relieve the pressure somewhat on adjacent grazing areas and make the whole local livestock operation more dependable ? These questions must be answered by the operator and planner on every job. In many locations unless one good water run can be expected at least once a year on the average, it may be questionable whether the spreading system should be built.

The final point to consider is whether the water from the drainage being investigated is now being used. This is important as use many miles downstream may be affected by the proposed spreading job.

Any local laws or customs regarding water rights or water use must be followed. The relative importance of the various uses of water may be an important factor. Use of water for man or livestock will usually have first claim, then water for irrigation. In many areas the type of run-off used for forage production through water spreading in the headwaters of major streams is not utilized. This water is lost before it reaches parts of the drainage where water is now fully used.





Rules of Thumb

It is veay difficult and not always necessary to come up with very accurate measurement of water run-off. Where long term records are not available any estimate of peak flows of water may vary several hundred per cent from basic calculations. Thus certain simplified methods are often used to determine expected peak run-off. These methods are called "*Rules of Thumb*".

If slope of stream channel is approximately 1% or one foot drop per hundred, approximate velocity of water should be 5 feet per second with normal stream flow resistance.

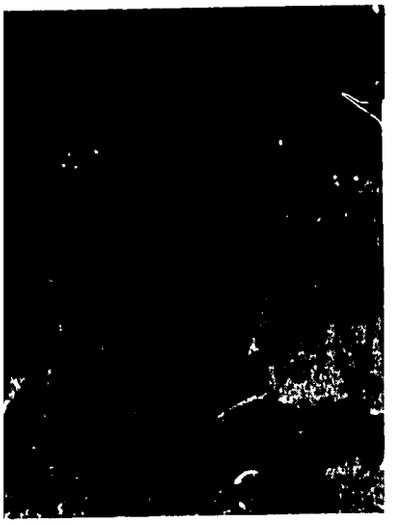
Thus if you find a small drainage channel or (Nallah) where you can measure the cross section area of the flood through this channel and you have a general 1% slope with average conditions of vegetation. The approximate peak flow would be the cross section area times velocity or 25 square feet of cross section of flood area times 5-foot velocity flow gives 125 C.F.S. Care must be taken that the flood channel is not measured where the water backs up or where there is sharp drop or a marked constriction of the channel section. It is always desirable to make several measurements to get average cross section.

It must be remembered that the smaller the cross section of the channel the greater the chance of error of calculations. In fact, water run-off flow from small drainages is always erratic even with the best measurements and records even calculated flood flows of water will be only approximate.

Of a more general nature a catchment area with silt loam or clay loam, slightly stony or rocky soil in an area which gets rain intensities of 2 to 4 inches per hour, a 1000 acre drainage should have peak run-off of around 100 C. F. S and a total volume run-off of around 100 acre feet.

In other words (where a 2" rainfall can be expected in a 4 to 6 hours period) and if the spreading area is 10% of the catchment area or 100 acres adequate water may be expected which will cover these 100 acres approximately three inches deep. If soils are sandy in character, the catchment area must be larger to provide adequate run-off water for the same area.

In countries where very high rainfall intensities can be expected, even with the best records and most accurate calculations, peaks of run-off can often vary 100% from the calculations. This makes it essential to build into the spreading system certain safety factors. These can be so designed that peak flows of over certain amounts will be by-passed from the system and it will not be seriously damaged. Dikes can also be constructed higher to accommodate large volumes of water.



The Spreading Area

Selecting the Water Spreading Site.

As stated in the Introduction, the basic requirements for water spreading are : (1) a supply of suitable water, and (2) a smooth area of good soil on which to spread water. Numerous favourable and adverse factors must be weighed against each other to determine whether a site is feasible, or to compare one site with another. An evaluation of these factors is also needed to determine the design of the spreading system. Some of the principal factors are discussed below

Water Supply Factors to Consider.

Both volume and frequency of flow are important. While one flow per year may put sufficient moisture into the soil to produce a satisfactory grass crop, frequent floodings will naturally produce more. A small volume (especially if combined with infrequent flow) may not be worth the cost of diversion. A large volume may be too difficult to handle or too much for the size of the available spreading area. In this case provision must be made to bypass the excess water.

The proper depth of water on the spreading area or rate of water application is also an important factor in planning the system The decision will depend on the water supply, the infiltration and penetration characteristics of the soil, the tolerance of the forage plants to inundation and the normal season of available water. Where surface and internal drainage on the spreading area are good and the water supply abundant, applications up to 12 inches in depth over the area are not too much. If water is scarce and the area suitable for spreading is greater than the water supply (as is frequently the case), the application of 3 to 6 inches when available may produce more feed than heavier applications on a smaller area. On steeper slopes where wild flooding is a system of water spreading, water is diverted from a main channel or Nullah, at one point, without any further control of this diverted flow of water it is used. Here the flow period is usually short (possibly not over 15 minutes) and penetration, will be very light.

There are instances where rainfall comes in concentrated periods, such as a monsoon season. In these cases over flooding of the spreading area may take place and much usable vegetation may be destroyed.

In connection with water supply, water quality is also a factor that must be considered. If the water contains excessive amounts of dissolved solids it may be unfit for spreading, and in a few years may ruin the soil on the spreading area. If the water supply is suspected of containing very high quantity of harmful salts, analysis should be made to determine if the quantity exceeds allowable tolerances.

Sedimentation Factors to Consider.

Frequent and heavy deposits of sediment may interfere with the effective operation of the spreader system. Such deposits will retard plant growth and may kill the younger plants.

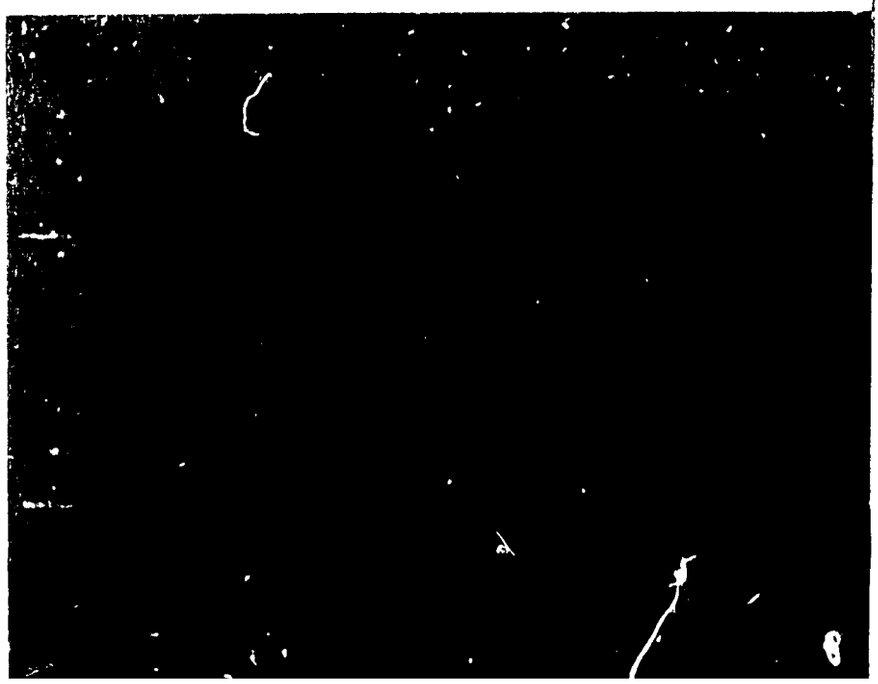
Even if the sediment is not excessive in amount, it may be made up of very fine material that will clog the soil pores on the spreading area and in time reduce the water intake. If the sediment contains sharp sand it may cause serious abrasive action on any concrete or masonry structures. In one case, a 6-inch concrete slab was cut through in a few days by a very heavy flow of concentrated abrasive material

If the water coming to the proposed spreading site is on a steep gradient and flowing at high velocity it may be carrying a large quantity of sediment Most of this load will be dropped when the velocity is checked or reduced. Such a quick and heavy deposit of sediment in one place is a distinct disadvantage and must be avoided.

If sediment of high silt content is deposited slowly it may be beneficial rather than harmful The spreading water tends to deposit the sediments in a gently sloping plane which fills the low spots and small gullies and other irregularities Silt deposited in such a manner actually improves the site for spreading purposes The silt also adds to the soil depth and thus generally improves growing conditions For example, a water spreading system built near Miles City, Mont , in Western United States in about 1888, on somewhat rough ground has now added 10 feet to the depth of the soil and is so smooth and level that it can be used for an airplane landing field From time to time, the dikes had to be raised or changed as the sediment accumulated but this expense was easily absorbed into the maintenance cost If the sediment is good top soil, as it frequently is, it may be valuable as a soil fertility builder.

Unlike most types of sediment basins, a water spreading system can function indefinitely without the loss of expensive storage capacity. As sediment accumulates the height of the dikes can be increased and the storage capacity restored and enlarged Rapid and heavy sediment accumulation, however, is usually indicative of serious soil erosion conditions in the drainage area upstream, and no time should be lost in applying corrective measures

The greater the velocity of water entering the spreading system the coarser the sediment particles are apt to become Direct stream diversions have placed heavy gravel and "fans" on good grassland. In many cases "fans" cannot be avoided and the system, therefore, must be constructed to function with this heavy accumulation of silt, sand or gravel.



Site Factors To Consider

Topography—The ideal waterspreading site is a broad, smooth gently sloping plain without gullies or channels.

The inflowing water is not carrying a large sediment load, the lower the gradient the better, since each dike will impound more water and fewer dikes will be required. Thus, on an area of 1 per cent grade, a dike will back water up twice as for as where the grade is 2 per cent. Grade under 1 per cent are desirable under conditions of slight to moderate sediment disposition. Where the sediment load in the water is great a somewhat steeper gradient is desirable so that the water will flow with sufficient velocity to carry much of the sadiment along. In such cases the wild flooding method of spreading is used and grades up to 5 per cent may not be too steep if the other factors are favourable, and there is a good soil cover of grass.

Soil—The ideal soil for water spreading is the same as for any other type of irrigation, that is, a deep fertile loam. Most soil types are suitable for water spreading excepting gravels and soils with an excessive soluble salt content. The method of spreading water, however will vary as the soils vary. If the soil permeability, slopes and length of run are such that there is sufficient water infiltration, a wild flooding system can be installed. If infiltration is too slow for the wild-flooding method, resulting in poor utilization of the water supply, long level dikes may be required. Tight clays in particular may require prolonged time of water application to obtain sufficient penetration, although after several years of water spreading the infiltration and retention properties improve with the improvement of the vegetal cover and root structure in the soil. Compacted clays and fine-taxtured soils with shallow impervious pans may require ripping to make full use of the available water supply

Deep soils will hold more water and produce more grass than shallow soils and are, therefore, preferred for water spreading. Deep soils may require a series of frequent heavy flows or several years of spreading to build up the subsoil to the maximum capacity.

Most native forage plants in arid climates are at least moderately salt tolerant. Consequently, a moderate salt content in the soil is not ordinarily a serious disadvantage. Nevertheless, soils high in soluble salts should be avoided. Such soils not only produce poorly when water is applied but they also are poor material for dike construction and require heavy maintenance.

The Spreading System

There are many types of water spreading systems and each type has definite functions and are adapted to specific conditions.

The Pond System.

This, as it is practised in Pakistan, is the simplest form of spreader system. Here on relatively uniform slopes a "U" shaped dike is placed below a piece of cultivated land to concentrate water for crop production.

This type of system has been in common use in Pakistan for thousands of years. It is simple and a necessity for rainfall is in very short supply, and if people are to live they must have food. This system puts more water into the soil for crop production. Advantages of the system are its very simple design. It is effective or it would not have survived this long period of years.

There are several apparent drawbacks to this type of spreading system :

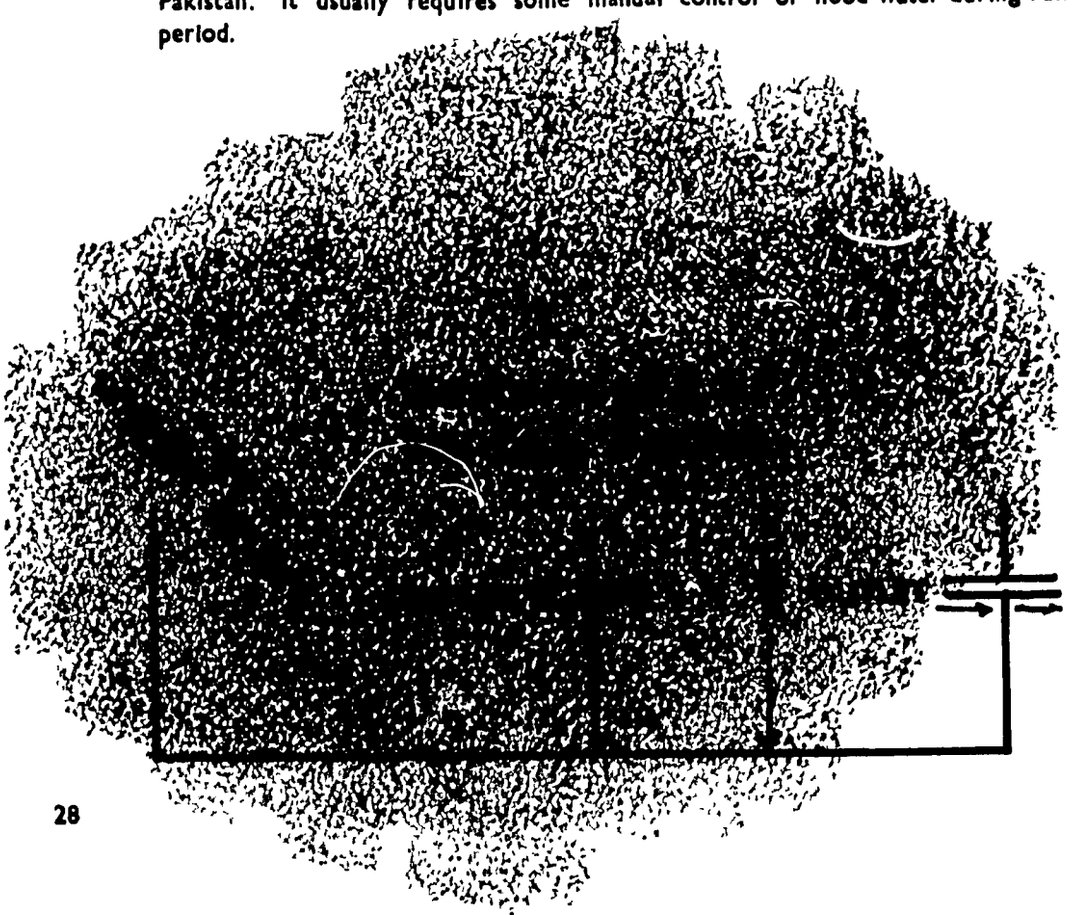
1. Many systems are washed out. As water moves into the system it moves directly to the lower side. As the water piles up on the ground there is a tendency for extra head to be developed against the lower part of the dike.

2. Water stands on the ground for long periods of time. This is especially true where earth for the construction of the dike is taken from the upper side of the dike. Thus there is little effective use of small volumes of water yet large volumes drown out significant areas of crops.

3. By turning the ends of the dike up hill any water which is excess to the needs of the system must flow out at the upper end of these dikes. Water is thus concentrated and may cause serious damage to the dike system itself.

4. This type of system traps small flows of water but does not make effective use of such water as they concentrate in the borrow pits.

5. The Ponding System as used on many areas in Western United States visualizes a series of ponds which are filled by flood water. The flood water then by-passes through this system and moves on to more ponds. This system is very successful but strict control of the maximum flow of water must be maintained. This system closely approaches the general method of irrigation now used over most of West Pakistan. It usually requires some manual control of flood water during run-off period.



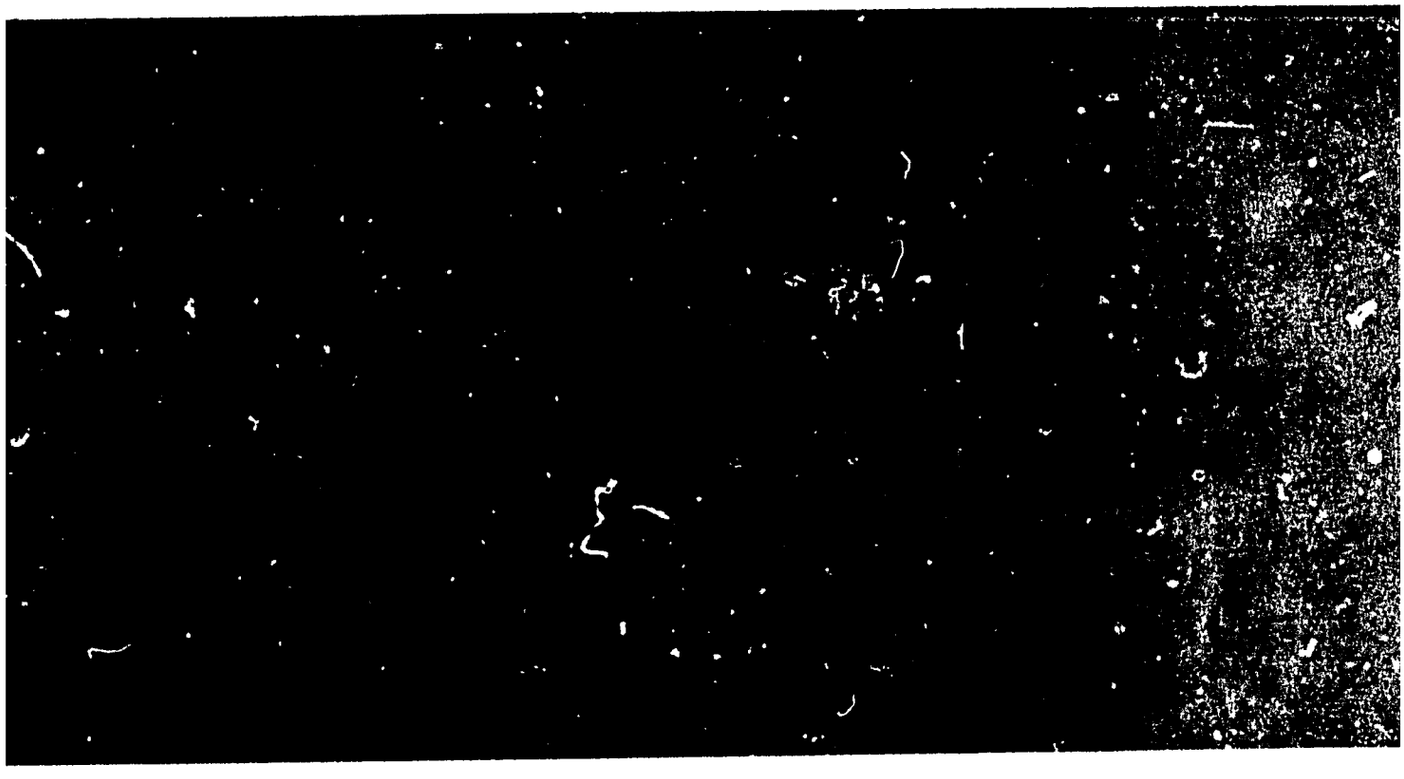
Wild Flooding System

This is a specialized type of system and must have carefully controlled flow of water.

The term wild flooding is generally applied to water spreading systems where water is diverted out of draws and Nallahs then spreads naturally over large areas. This is a specialized type of water spreading and requires a specialized type of topography.

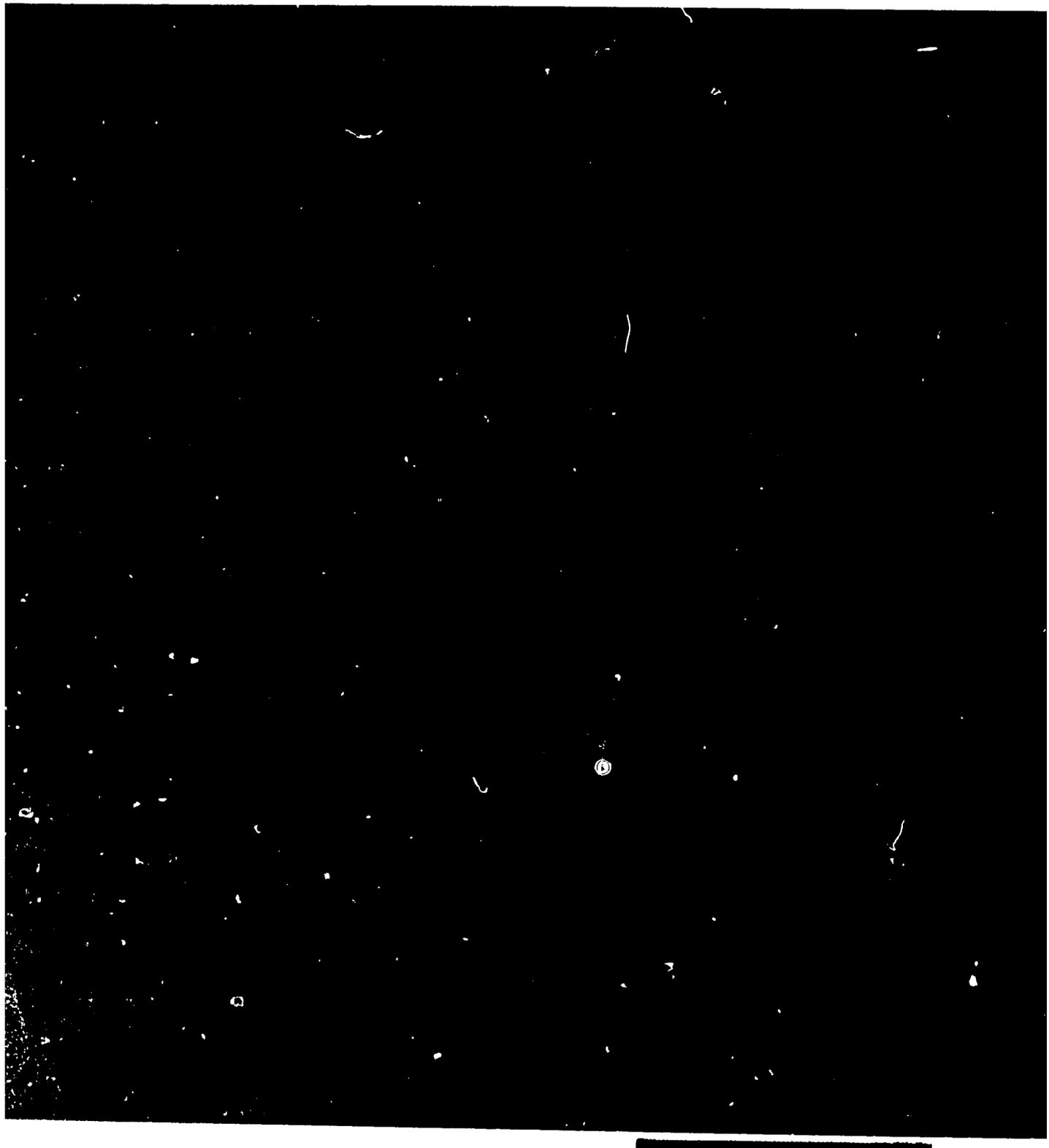
The land slope must be away from the stream channel.

In cross section the land would appear :



These conditions exist in the south wastern part of the United States. Where streams carrying heavy silt loads have cut through relatively flat areas. As these streams overflow their banks there is a gradual increase of ground level along the edge of the wash due to the deposits of silt from these peak flows The same situation may exist on alluvial bottom where streams meander and regularly change their stream bed. In such cases, a series of small dams or gully plugs are built across the wash. These are generally on the contour so that water will spread out above the dike or dam and cover a large portion of the flood bottom.

Where the stream channel is shallow a series of plugs may effectively divert the water from the channel and spread over a broad area of the flood plain bottom as in Rakh Miran in West Pakistan.



In many instances the small gully plugs have caused the channel to become filled with silt, grass has covered these silt fans and the entire flood plain bottom has regained its potential productivity.

Well Designed under Spreader handles big floods as well as small ones.

The principle in this type of water spreading is to eliminate the loss of water down the channel section.

Where serious erosion occurs on relatively large drainages large detention type dams or large over-pour structures may be required.

Water spreading, resulting directly from detention dams or over pour structures, usually occurs above the structure itself.

Most over pour structures are designed to by-pass all of the natural stream through or over the structure itself Thus as floods come into the structure they spread out over the major flood plane above the structure and remain there until such time as they are dissipated through the structure. The length of time that water remains on the land depends on the size of the flood and the size of the opening.

Where detention structures with pipe outlets are used, the flood water may remain on the land for several days about the structure.

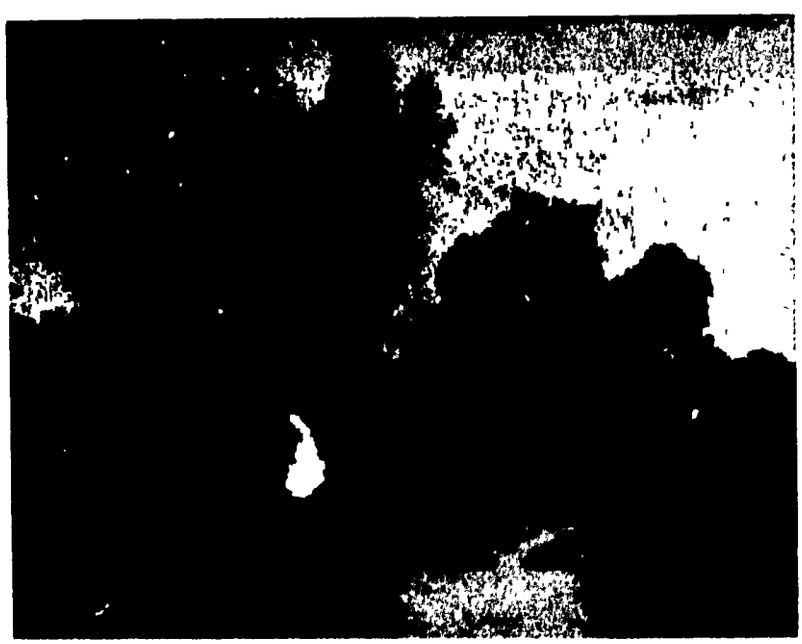
Both the over pour structure and the detention type dam need emergency spillways for unusual high peak flows of water.

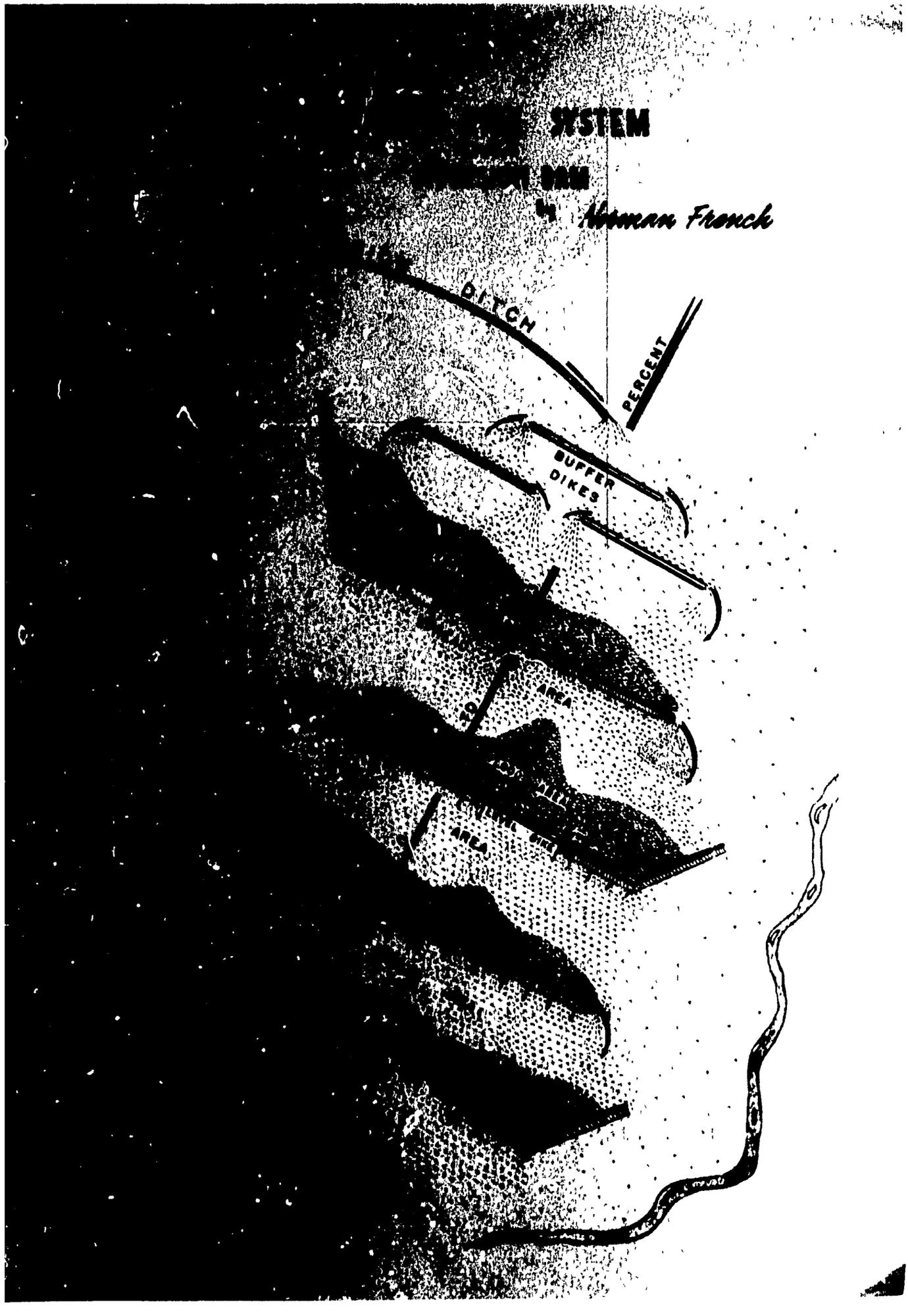
A typical water spreading system designed for the Dera Ismail Khan area for West Pakistan would come under this wild flooding system.

Due to the torrential type of storms which occur in that area and general topographic conditions large flood plains have developed. Most of the desirable sites have been taken up for cultivation and produce good crops under water spreading or flood irrigation.

The demonstration selected for Range Management was formerly an area which was cut for hay by the Army. It is a natural flood plain and in years of flood run-off it produces a good stand of grass. Recent years of over use have permitted gullies to develop through the entire area. At the present time only large floods have any significant benefit on the forage. All small or moderate flows of water follow the water channels and the water is lost for beneficial use.

The water spreading plan for this area is *Wild Flooding*. A number of small dams were placed across the major washes to divert the water from the channels. These dams have short wing dikes to assist in spreading the water out. A large number of small dikes were placed across the smaller water ways and channels. These were placed at right angles to the flow of water. The smaller flows of water were spread out and utilized. The large floods will cause some damage to the entire spreading system but by keeping in dikes relatively short with adequate height this damage was kept to minimum.




SYSTEM
by Norman French
DITCH
PERCENT
BUFFER
DIKES
AREA
AREA

This type of water spreading system consists of a series of long but level dikes. The alternate end of each dike is turned up or closed so that the flow of water can be only towards the open end

The flood water is in movement and it moves in a zig-zag pattern across the slope entirely through the system This type of system is very effective but it requires a reasonable accurate calculation of the peak flow of flood water which can be expected to flow through the system.

The dikes in this system should be long to be effective that is 1000 feet or more in length.

These dikes must also be high enough to force the water to flow along the face of the dike.

Several factors affect this type of dike system and they must be accurately calculated :

1. The slope of the ground must be low 1% or less.
2. The spreading area must be very uniform. That is: without gullies, ridges or other ground irregularities.
3. The peak flow of water must be calculated within reasonable limits and be relatively low.
4. The length of the dike is dependent on the calculated peak flow of water and the height of the dike.
5. The resistance factor of the vegetational cover to the flow of water within the spreading system.

The key factors in the design of this type of system is to get the dikes as long as possible consistant with the peak flow of water and the dike height required.

To make water flow over a surface it must have either slope or head. Since this type of dike is built on the absolute level there is no slope, it is therefore, necessary to build up a water head within the water itself so the water will, move along the face of the dike. If water does not move, it would quickly pile up against the dike and over top the dike causing a wash out and serious damage.

The greater the head which is developed within the water the faster the water will flow. The speed which water flows or velocity, time, the cross section of water in movement will give you the total volume flow at any particular time. This flow is usually measured in cubic feet per second or generally called C.F.S.

In order to visualize how water must flow along the upper face of a dike, a few basic calculations must be made :

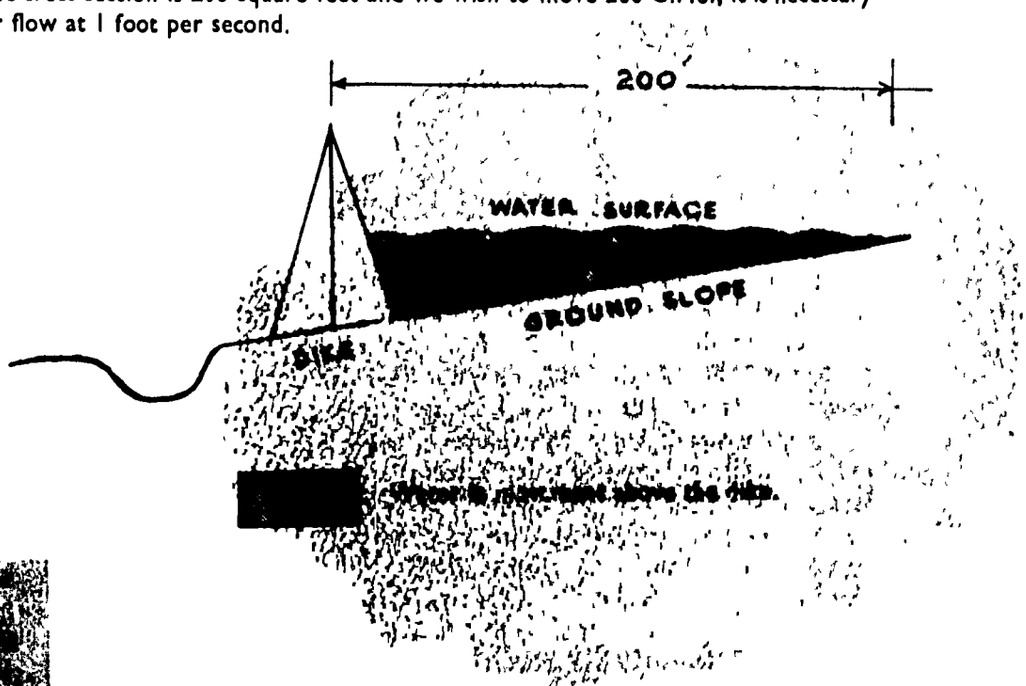
1. We must know the slope within the spreading area.
2. We must calculate the peak volume flow of flood water which the dike system must handle.

To illustrate this type spreading system and make a realistic design we will assume a basic situation. One per cent slope on the spreading system and a peak volume flow of water of 200 C.F.S.

As water moves along the face of the dike, it is in the form of a wide but flat triangle of water. Water is deepest at the dike and as it moves up the slope it approaches zero. If water were two feet at the dike, it would extend up the slope for 200 feet. Example

The cross sectional area of the water is $200 \times \frac{2+0}{2} = 200'$.

Thus if the cross section is 200 square feet and we wish to move 200 C.F.S., it is necessary that the water flow at 1 foot per second.



Calculation of Water Movement

Since water is moving over a level surface it does not follow all the criteria of water flowing in a channel. The channel slope is Zero but the surface slope of the water must be increased so that the volume of water to be passed through a given (so called) channel area above the dike increases. Further since the channel section varies with the head or depth of water at any given point above the dike. Thus both the "Area" changes and the slope within the moving water changes.

The critical area section on any dike is that section of water, measured at right angles to the dike immediately above the open end of the dike. Once water passes the end of the dike it picks up additional velocity since the water is now moving over sloping ground. Thus there is free flow at this point.

The following tables show the *water slope* required to move various volumes of water along the face of the dike. These tables are based a back water curve formulae. Only very approximate values can be arrived at by actual calculation due to the wide fluctuation in the value of "N" throughout the area of water movement. For basis of calculation, the height of water at the dike was used. For safety factor, the value of "N" has been taken as 0.15.

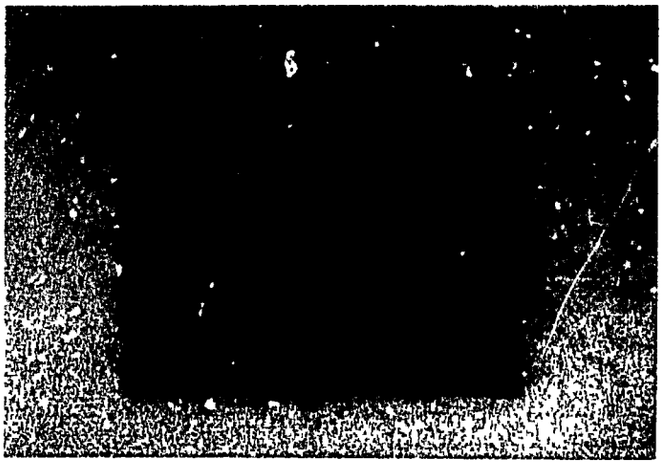
D Depth of water at Dike	A Area of Effective Water movement	V Average velocity flow	Q C.S.F. of water flow	S water head 0.05%
.5	19	.25	5	"
1.0	43	.55	20	"
1.2	62	.69	30	"
1.4	86	.79	42	"
1.6	114	90	58	"
1.8	145	1 00	81	"
2.0	181	1.12	115	"
2.2	220	1.23	156	"
2.4	263	1.32	206	"
2.6	310	1.40	268	"
2.8	358	1·50	336	"
3.0	412	1.60	424	"

To maintain this gow of water, the slope from the critical section of the water surface must be 1 force per 1000 feet or .001 slope. In other words, if 200 C.F.S. of water is to be handled, the dike must be 3.4 feet high at the open end 4.4 feet at 1000 feet and 5.4 feet at 2000. As the grade, or water head increases, the velocity increases and larger volumes of water will pass through the same cross sectional area.

In other words, where this volume of water is expected the height of the dike at the open end is one foot greater (for safety factor) than the water height of 2.4 feet. And for each 1000 foot of dike length from the open end the dike must be one foot higher.

These calculations are taken from S.C.S. hand book on Engineering for Division Terraces on land having 1% slope. These calculations also agree v ith basic Back Water curve formulae which give flow velocities from 0.22 feet per second on water with .5 foot depth to a velocity of 1.5 feet per second where the water depth is 3 feet. These calculations were made where the surface water slope was 1 in 1000.

Very accurate calculations in this type of water spreading are not necessary nor practical since a number of the basic factors will vary. The factor of N varies both with the depth of water and the amount of vegetation on the ground. This factor would vary from .05 which is for bare ground to 0.5 which would be used for low flows of water through a heavy stand of grass.



Construction

Construction of the water spreading system is as important as the basic design. It is not necessary to have or use heavy machinery to build good dams or dikes. The important point is that the basic principles of design must be followed.

Each type of system may have a different requirements but the key factors which must be followed are :-

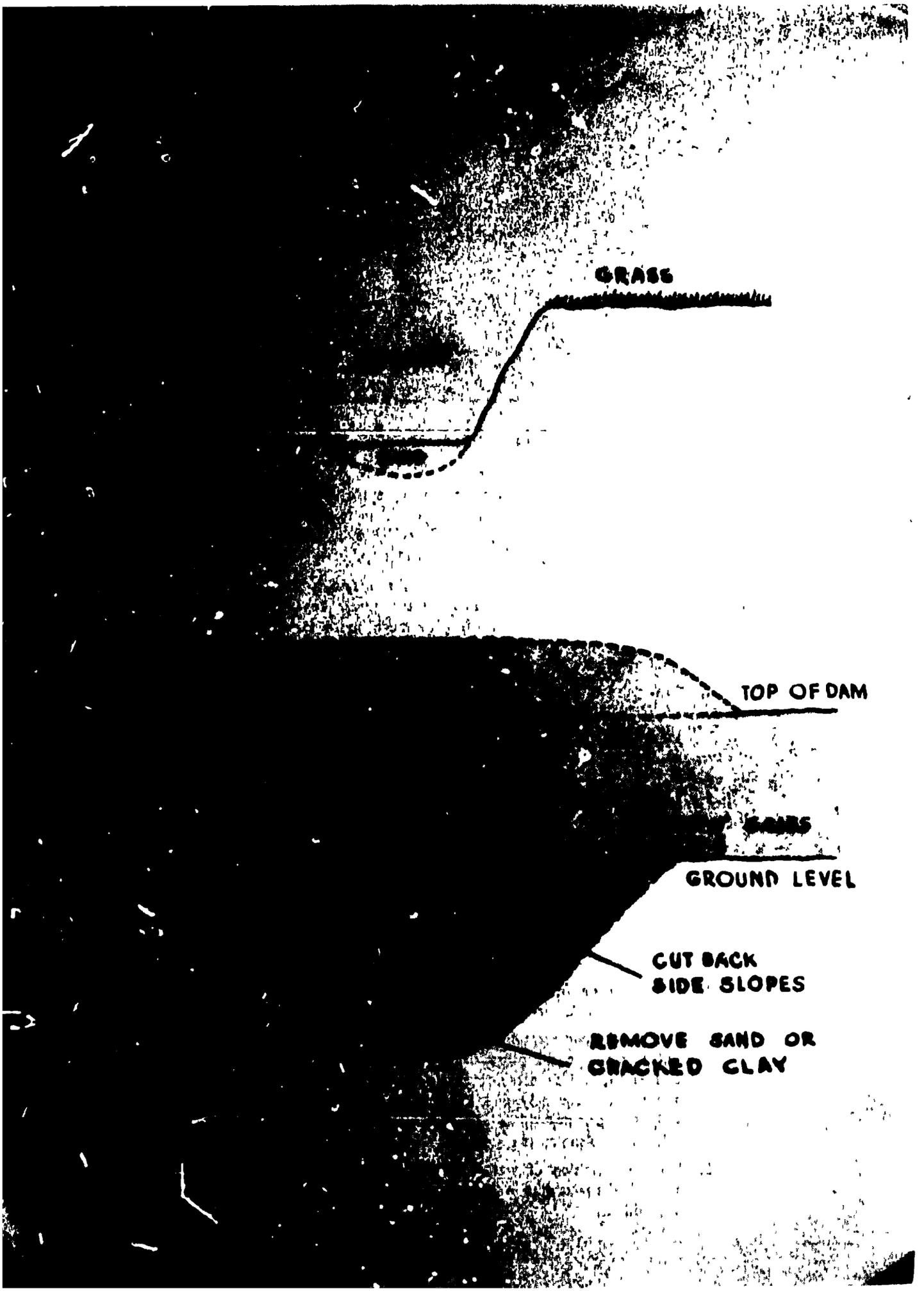
1. Earth in dams or dikes must be properly compacted :
   (a) Dry earth does compact well but by breaking up lumps of earth and walking animals or workers over the fill material a reasonable compaction will take place.
2. Banks of Nullas must be sloped to at least a 3 : 1 sloped so that earth fill material will make a firm bond with the earth in the base of the dam. In all cases, the banks of nullas must be cut back to a gradual uniform slope before any earth fill material is placed on the foundation site.
3. All loose material or vegetation must be removed from the base of the dam or dike before fill is added.

   Sand, gravel, rocks or cracked clay must be removed from the base of the dam or dike. If this material is not removed, it will cause failure of the structure.
4. Earth dams or dikes where they cross a nallah or depression must be built higher and stronger :

   (a) In general, flow of water in a channel will cause water to pile up on the dam or dike at this point. Thus it is very necessary that the dam or dike be made higher where it crosses the nallah.

   (b) Earth in a dam or dike will settle when it becomes saturated with water. Thus the higher the earth fill the greater the amount of earth fill which must be added to compensate for this settlement. Since the fill is greater at the channel points, much more settlement will take place at these points and the dike must be constructed higher at these points.
5. Earth fill material should be placed in thin layers starting at the bottom of the fill portion of the dam.

Coustruction by bullocks and small scrapers. Note that bullocks continually walk across the dam to give added compaction.


GRASS
TOP OF DAM
GROUND LEVEL
CUT BACK
SIDE SLOPES
REMOVE SAND OR
CRACKED CLAY

Operation, Improvement, and Maintenance of the Spreader System

Common Design Defects.

It is difficult to design a water spreading system which is free of flaws when first constructed The flow of water is seldom the same in any two storms. Nevertheless, the system must handle these variable flows by one automatic plan Incomplete and inaccurate basic data are frequently a further handicap.

Usually the first flow of water through the system will reveal the flaws in design If the designer can be on hand to watch the water flow through the system he will be able to recognize the defects of his plan much more quickly than if he has to study the effects of the flow after it has passed by Following are some of the effects that may appear after the system receives a flow of water :—

1. Too great a concentration of water hitting certain sections of a dike with too high velocity. This may cause the water to overtop the dike or to break through The solution of this problem may require a reduction of the inflow at the head of the system It might require the relocation or widening of a spillway from the dike above. The difficulty might be solved by a diversion dike or ditch above to increase the spread of the water. Possibly the dike may have to be raised in height or reinforced

2. Dry areas not receiving water. Often a short ditch leading water to the dry spot will solve the problem, or a dike may be required to divert water to the dry area A pipe may have to be put through a dike to let water come through to the dry spot. Sometimes partial dike or spillway relocation is necessary The designer should not expect to irrigate all of the spreader area in each run. If 65 to 85 per cent of the area can be given a good wetting in the average water run a successful design has been attained.

3. Too much or too little water coming through the openings in flood spreaders. This fault can be corrected by reducing or increasing the size of the opening.

4. Too rapid concentration of flowing water in the system. This flaw may require more small plugs or dikes in natural drainage ways, in old road ruts and trails, in low spots, in basin lips, in the borrow pits, etc., to turn out the water frequently and keep it in a sheet. Often in wild flooding systems only the primary dikes are constructed at the beginning and the secondary dikes will do the most good.

5. Improper division of water flowing into the borrow pit and that moving directly towards the next dike in flood spreaders. Corrections can be made with ditches or wing dikes.

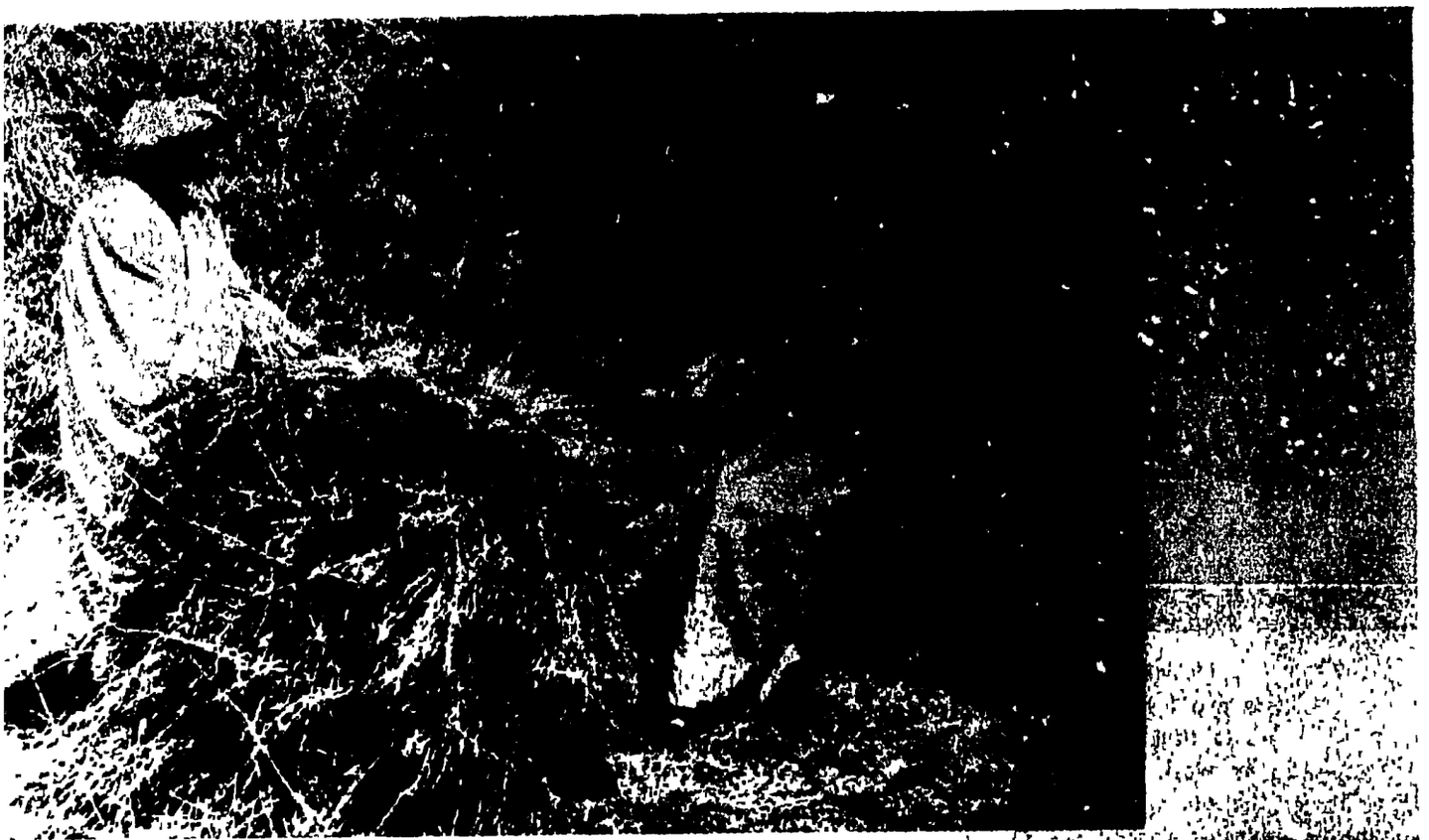
Maintenance of water spreading systems should be given prompt and careful attention to avoid much heavier costs later. If sediment accumulation is slow, the maintenance costs usually decline to a fairly low figure after about the third year. By this time the weak spots have been corrected in connection with maintenance work. In addition, the dikes have settled and have in some cases become partially covered with soil-binding vegetation. On the other hand, if sediment accumulation continues to be great, there may be heavy annual maintenance work to raise the dikes and adjust dike design as needed.

In some cases channels behind diversion dikes may have to be cleared of sediment. The elevation of the floor of the diversion may have to be raised to provide sufficient flow in channels made inadequate by sedimentation.

Very often heavy maintenance costs on a water spreading system can be reduced by improving vegetation on the upper watershed to help prevent the run-off from coming down in one big flash flood of terrific force but short duration. Delayed runoff may save dikes from being over-topped and breached. It will also reduce the amount of sediment carried from the watershed and stream channel into the spreading system.

Some of the more common maintenance problems are as follows ·

1. Gullying at the spillways Slight gullying at the spillways is frequent and nothing to cause grave concern. If the gullies spread or entrench quickly it may be necessary to make them wider by tearing down some of the dike at the spillway end in order to give the water more spread space. More openings or pipes may have to be put through the dike in order to cut down the amount of water going to the spillway.
2. Excessive widening or plugging of the spreader dike spillway. Excessive widening may occur as a result of erosion at the end of the dike. It can usually be stopped by building a riprap face on the end of the dike. Plugging is usually caused by deposits of sediment or debris which may have to be removed or smoothed out from time to time.
3. In straight channels paralleing dikes, obstructions such as rocks, drift, shrubs or earth projections, may deflect the current against the loose dike fill causing the dike to wash or cave in. Remove such obstructions to permit free flow.
4. Gullying in the return or excess water channel. It is well to note the tail water or excess water area particularly after a big flow. If head cuts are developing, direct the water to a more favourable location if possible. At least keep it in a thin sheet where it moves over areas likely to erode. It is sometimes impossible to avoid some



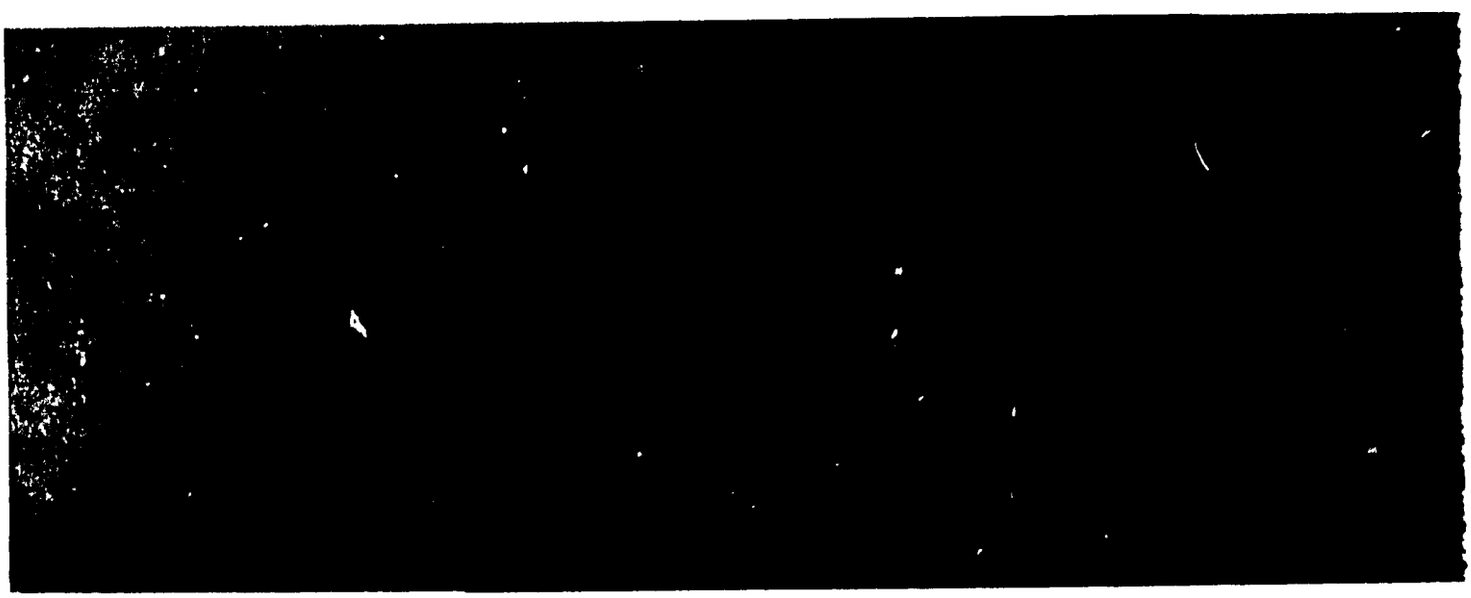
Hay produced on water spreading area Rakh Miran now being sold to local livestock owners.

erosion for a few years while an artificially sloped and vegetated area develops and adequate cover which will take the flow without eroding. The maintenance of the excess channel may require protection from grazing by fencing.

Summary

Water spreading both for crop production and the production of additional forage for livestock has a real and practical application in West Pakistan.

It must be recognized that water spreading is not the whole answer to the large problem of range management but rather are means of growing more feed for livestock.

Special care must be used in design and construction of any water spreading system. The water spreading project of Rakh Miran south of D. I. Khan clearly demonstrates the value of this type of range improvement. Many more areas can and should be developed throughout West Pakistan by water spreading.

Hay cut from water spreader provides good feed when no other grass is available