

ILL DRAINED AREAS and their RECLAMATION



ILL-Drained Areas and Their Reclamation

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P R E F A C E

Importance of Soil and Water Conservation cannot be over-emphasized. All life except perhaps fish depend on food grown on land. It is, however, a law of nature that good things are accompanied with-evil things. In proof of this law, soil and water conservation measures are accompanied by problems of water-logging and land drainage.

The Sub-committee of the Deccan Agricultural Association in its "WORKING-PAPER" prepared in July 1960, has estimated the acreage of about 15 lakh acres that has been affected by ill-drained conditions in rainfed areas of this State. The distribution of this acreage carrying ill-drained conditions and consequently thrown out of cultivation, as has been pointed in the said 'Paper' is as under:—

(i) Purna Valley:—A tributary of Tapti itself accounts for 12 lakh acres.

(ii) Remaining three lakh acres area is spread over in patches in the river valleys of Katepurna, Nalganga, Bhima, Godawari and Purna (Tributary of Godawari).

These ill-drained areas need immediate attention and installation of suitable drainage measures for restoration of their prospective productive capacity and in view of the recent promulgated State Government's policy of attaining self sufficiency in respect of food within next 2 years, they cannot be offered to be neglected over a single season hereafter.

Reclamation of the affected areas stated above need a community approach on sub-catchment basis. Reclamation measures are costly and cannot be undertaken by individual cultivators. The problems of ill-drained conditions and damaged lands have passed beyond the stage of small scale and laboratory research. Under these circumstances, and in view of the urgency of attaining self-sufficiency of the State, in respect of food, reclamation measures are necessarily to be taken up the State-sector.

In order to enable the departmental officers to successfully take up these new type of works, there has been a long felt need of a technical bulletin on the subject of reclamation of ill-drained areas. Dr. N. K. Ghumare, who had recently been deputed to States, has specialised himself in 'Reclamation of Saline-Alkaline Soils'. He has prepared this bulletin, based on the relevant literature, both from this country and U. S. A., supplemented by his personal observations and experience gained by him on our soils.

This bulletin is intended primarily for soil conservation Engineers and also for officers working in related fields. It includes principles of drainage, a review of the fundamentals needed and different methods of surface drainage that are backed up by latest research findings in U. S. A. and are successfully been practised and therefore have gained confidence of cultivators in American Agricultural Field. It is hoped that officers in Soil Conservation Section will find much of the technical matter in this bulletin useful for designing and installation of drainage schemes to meet the ever increasing demands for reclamation of ill-drained soils.

Poona-1

The 24th November, 1965.

L—S (Q) 1047—ii

S (Q) 1047—ii

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Chapter I

GENERAL

One of the recommendations in the Land Use Planning is the necessity of the provision of proper land drainage. It is possible that in some lands and in certain situations, though the lands are fit for crop production, bad drainage conditions will limit the productive capacity of the lands affected. Reasons for ill-drainage are many and the same have to be studied further carefully. For the successful working of drains and bunds on integrated plan beyond the boundaries of the individual land holdings, it is quite necessary to treat the whole natural unit of practical size. This may be a small practical watershed from ridge to ridge or catchment area so that the whole problem can be tackled successfully on a community basis; however because of the local, social and political influences combined with physiographic pattern, the size of catchment most favourable for co-ordinated action is likely to vary in different localities.

Causes leading development of ill-drained conditions may be many. They may be one or more as detailed below:

- (1) Chocking of natural water courses and feeder drains due to neglect of land and for want of proper soil and water management practices;
- (2) Construction of 'Big-Tals' without adequate surplusage arrangements;
- (3) Aridity of the climate with great soil depth and heavy texture;
- (4) Topographic situation, which affects the surface soil due to salt washings from the surrounding areas;
- (5) Nearness of saline sub-soil water;
- (6) Impervious sub-soil conditions;
- (7) Saltbearing sub-soil strata;
- (8) Seepage from canal or reservoir;
- (9) Presence of impervious strata;

Pre-requisite conditions for reclamation of ill-drained or water logged soils is provision of satisfactory drainage system and deepening of nalla courses—wherever necessary.

After establishing the drainage system Agromonic and Chemical amendments may be needed for complete reclamation of soils which might have developed excessive salinity or alkalinity.

How drainage promotes crop-growth

A wet soil is a cold soil. This is because, it takes much more heat to warm water than to warm soil. When soil is drained, air replaces the water that is drained away. It takes relatively little heat to warm this air. To grow well,

plants of course, need warmth and air in the root zone. The bacteria that change organic matter and fertilizer into something the plants can use, require air and warmth. A wet soil is likely to be tight or compact or dense. Plant roots cannot spread easily through such soil. Soil building crops cannot grow and we cannot allow a balanced crop-rotation. Liming is also often useless in a soggy-soil. A wet soil when drained of excess water can come to wapsa earlier and can be worked well. A properly drained field will not have wet spots.

How land is drained

Excess water can be drained from land either by open surface drains or by under-drains, usually tile. Each method has advantages and disadvantages. Open ditches occupy land. They are usually hard to cross with farm machinery. They chock up with weeds and silt and have to be cleaned very often. Unless they are deep they drain only the surface, not the soil. But their initial capital cost for outlay is less than the tile drains. For tight soils in humid areas surface drainage is usually necessary. Maintenance recurring cost for open ditches is essential for its efficiency. Tile drains, on the other hand, waste no land and do not interfere with farm operations. They need little care once they are installed. Since they drain the pores of the soil, roots of crops can spread. But usually tile drains require more cash outlay in the beginning and they are not effective in some soils.

Planning drainage system

Only conditions in a particular area can determine the kind of drainage needed, and the method of its outlay. What is good in one place may not be good in other. The type of soil, the nature of sub-soil and hard incrustations if any, the ground slope, the crops grown and to be grown and repayment capacity of land for the capital expenditure for the installation of drainage system are the main considerations for devising the type of drainage system. Neighbouring fields must also be considered. An adequate drainage system often involves tackling of entire catchment from ridge to ridge and is not only economic and effective but a permanent improvement for better crops production.

The next thing is to decide the outlet position wherefrom the water will be discharged. Plans for successful farm drainage includes plans for controlling erosion on the land, on ditches and spoil banks, and at outlets. They include plans for farming the drained land in crop rotations

that will bring about good soil tilth, or structure. We have also to plan for maintenance of drains and for their continued efficacy.

Surface drainage principles

The surface drainage system can be conveniently divided into three functional parts.

(1) *Collection system*.—Bedding, surface field ditches, row-ditches, or diversion ditches, are parts of the system that picks up water from the land.

(2) *Disposal System*.—This part of the system receives the discharge from the collection system and conveys it usually in an open channel to the out-let.

(3) *Outlet*.—This is the end point of the drainage system to be installed.

Fundamentally, surface drainage uses the potential energy that exists due to elevation to provide a hydraulic gradient. The surface drainage system creates a freewater surface-slope to move water from the land to an outlet at lower elevation. The design of collection system such as bedding or field ditches in flat land is based mostly on empirical criteria. The rate at which the surface water must be removed from the land is a function of the crop requirement and the source of excess water.

Bernoulli's theorem is used to compute the hydraulic grade line for steady flow conditions. Losses of head due to friction are computed by an open channel formula, usually Manning's.

Sub-surface drainage principles

Forms of soil water.—(1) Gravity water; (2) Capillary water; (3) Hygroscopic water; (4) The water table and capillary fringe.

Principles of Flow in the saturated Zone.—Flow of water in the saturated zone involves mechanical, chemical, and thermal energy and molecular attraction.

Permeability and hydraulic conductivity

Permeability of a porous medium such as soil is its capacity to transmit fluids. It is a property of soil describing the ease with which the fluid is transmitted, such as rapidly permeable or slowly permeable. Hydraulic conductivity of a soil is a numerical value for permeability.

It is measured by Darcy's law. Accordingly, hydraulic conductivity is the effective velocity of flow when hydraulic gradient is unity. Hydraulic conductivity depends on properties both of soil and water. A high value is associated with high porosity, coarse open texture and highly developed structure. Fine texture soils may depend almost entirely on the structural pores for their conductivity. The quality of the water transmitted, particularly the salinity and alkalinity, may have a marked effect on hydraulic conductivity.

Sink Formation in sub-surface Drainage.—Sub-surface drainage is accomplished by placing below the water-table an artificial channel in

which the hydraulic head is less than it is in the soil to be drained. Hydraulic gradient and Hydraulic conductivity are the two factors that govern the rate at which water moves towards the sink.

The 'Hydraulic-Head' in closed and in open ditches depend upon the water surface elevation because the water is at atmospheric pressure.

Drainage co-efficients.—A Drainage co-efficient is that rate of water removal per unit of area used in drain design to protect crops from excess surface and sub-surface water. The co-efficient varies by geographical location, land use, and size of area to be drained. It may be expressed in terms of the equivalent inches of water removed in 24 hrs. or in terms of flow rate per unit of area, as cubic feet per second per unit of area. Rainfall frequency, intensity and duration, climate, soil permeability, crops to be grown and the size of the area to be drained are all considered in selecting-Drainage co-efficients.

The initial capacity of an open drainage channel is usually greater than its average capacity during the period between its construction and cleanout. A drainage ditch usually loses from $\frac{1}{3}$ rd to $\frac{1}{4}$ th of its original capacity before a cleanout is made. A good maintenance programme employing vegetative control and spot cleanouts may extend the period of cleanout from 15 to 20 years.

Ill-drained soils and the principle features of the water logged area from (affected catchments).—(1) The area in which vapsa condition is not restored within a couple of days after a rainfall of $\frac{1}{2}$ " to 1".

(2) Due to water logging, crop growth in parts of catchment suffers in patches considerably.

(3) Past history for more than 3 years reveals that yields are decreasing progressively.

(4) Natural water courses are usually choked up.

(5) The affected part of the catchment may carry slick spots.

(6) Soil structure is partly or completely deteriorated. In the latter case normal vegetative growth is absent.

✓ (7) In some cases under ground water table rises and soil gets soggy.

✓ (8) Salt incrustation is visible prominently along the water courses.

Ill-drained soil—finalisation of affected areas.

1. Either Agricultural Officer or Sub-Divisional Soil Conservation Officer concerned, should move over the entire catchment (Ridge to ridge) reported to have been possessing ill-drained pockets, water logged soils, or soils rendered unfit for cultivation.

2. With the help of village map ascertain the outside catchment for the affected part of tail and portion of a reported catchment and work it out correctly on the part plan of the village map tracing.

3. Mark out the major ridge line and examine whether runoff from upper reaches can be diverted outside the affected part of the catchment even if it means to cutoff some minor local ridge to avoid its concentration in the tail end part of the catchment.

4. Mark the position of the old 'Big-Tals' if any and their seepage zones on the part plan of the catchment.

5. Then mark out the major ridge and slope directions, slick spots and finally the exact portion of the affected catchment and indication of ill-drained area.

6. Enquire into the crop history; study the type of soil and other causes leading to the impeded drainage, such as silting up of the main natural water courses, and how far they are required to be deepened and widened. Mark out on the plan all these details.

7. Data regarding annual rainfall, highest intensities, extent of the span of spread and depth, accumulation of runoff, crops to be grown, should be carefully studied.

Survey work

8. In general, the topographical survey should be carried out at 55' grid. An accurate contour map when prepared, it is necessary to decide the type of drainage layout that will be suitable and economical. Then decide the position of mains submains and lateral drains, and the position of outfall-end or outlets. Mark out on the plan the dishy portions by thorough field inspection. Then take up detailed survey at 27½' grid along the mains and submains to be laid out and prepare their "L" sections, and plot them correctly either on contour map or on separate sheets. The rise and depth of underground water table if any should be carefully studied and noted.

9. Take up soil profiles @ 4 to 5 acres along the mains and also one or two along the proposed laterals, especially where there is a change

in soil type. Study carefully the horizonwise soil texture, structure, colour. Examine very carefully the different layers and their compactness, and presence of impervious layers if any. Yellow mottled spots will show impeded drainage and note its depth from the ground surface. Rise of underground table when visible, its depth from the ground surface should be carefully noted down in the description of the soil profile. Collect representative soil samples in cloth bags for the 1st foot depth of surface layer of about 1½ kilo weight and collect separately soil samples of depth of profile of about 12" to 48". Number the soil profiles, and mark their respective positions on the contour map by some legend. Then carefully name the soil samples with its description such as village, block No., soil depth, date and time of collection and despatch the samples collected to soils laboratory for analysis.

Design of drainage system

1. Compute accurately the total likely runoff as per procedure detailed pages 38-47, and the discharge at the Outfall-End and further calculate the size and specifications for a diversion ditch. The provision of diversion ditch will ward-off runoff concentration in the ill-drained and water logged parts of catchment.

Designs of mains and laterals

2. On the basis of the data collected and contour map prepared, it should be possible to decide the kind of drainage system needed. The soil type ground slope, clearance gradient (vertical fall) at the outfall end, the crops that the cultivator has grown and he desires to grow, and the value of land are all the points to be considered when deciding the type of drainage system needed for the reclamation of the ill-drained soils.

In major number of cases, surface—open drain system should suffice. In very heavy compact soils, the field ditches to a depth of 2½ feet to 3 feet are needed. But remember shallow ditches merely remove surface runoff. If the land also needs soil drainage, we must dig numerous and comparatively deep ditches, or construct under drains (Tile drains).

TABLE 1

Area of level to gently rolling land that can be drained by V-shaped field ditches running full

(Computed by Manning formula, $n=0.045$).

Depth of ditch (feet)	Top width of ditch	Side slopes	Excavation per 100 feet	Area drained by ditches with fall per 100 feet of									
				0.02 foot	0.04 foot	0.06 foot	0.08 foot	0.1 foot	0.15 foot	0.2 foot	0.3 foot	0.4 ft.	0.5 ft.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	feet		Cubic yards	Acrea	Acs.	Acs.	Acs.	Acs.	Acs.	Acs.	Acs.	Acs.	Acs.
1.0	6	3 to 1	11.1	10	14	17	20	22	28	32	39	45	50
	8	4 to 1	14.8	13	19	23	27	30	37	43	53	61	68
1.5	8	3 to 1	25.0	30	42	52	60	67	82	94	116	134	149
	12	4 to 1	33.3	40	57	70	81	90	110	137	156	180	202
2.0	12	3 to 1	44.5	64	91	111	128	143	176	203	249	287	321
	16	4 to 1	58.3	87	123	151	174	194	238	275	338	390	436

TABLE 2

Areas of level to gently rolling land that can be drained by small flat-bottom ditches with 2 to 1 side slopes, running full

(Computed by Manning formula, $n=0.045$).

Depth of ditch (feet)	Bottom width of ditch	Top width of ditch	Excavation per 100 feet	Area drained by ditches with fall per 100 feet of									
				0.02 foot	0.04 foot	0.06 foot	0.08 foot	0.1 foot	0.15 foot	0.2 foot	0.3 foot	0.4 foot	0.5 foot
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Feet	Feet	Cubic yards	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
1.5	4	10	38.9	57	81	100	115	129	157	182	223	258	288
	6	12	50.0	78	110	135	156	174	214	247	302	350	390
2.0	4	12	59.3	102	145	177	205	229	280	324	397	459	510
	6	14	74.1	135	191	234	270	301	369	426	525	604	700
2.5	4	14	83.3	162	230	282	325	363	445	515	630	800	970
	6	16	101.8	209	296	362	419	467	570	675	965	1240	...

(SOURCE:—"Farm Drainage" Farmers' Bulletin No. 2046, U. S. D. A.)

Velocity is within range 2.6 to 3.0 feet per second.

Topographical situation and the lie of the land, are the major consideration to decide the type of the drainage system that befits.

TILE DRAINS

Different types of tile drains:—

(1) Gridiron or parallel system; (2) Herring-Bone; (3) Random system; (4) Double—Main system.

Grades to be provided will be 0.2 per cent for the first 1000 ft. and subsequently 0.3 per cent throughout. The maximum grade to be provided will be 0.5 per cent depending upon the soil type.

Sizes of drains and permissible grades are given in Table 3 and 4 below:

TABLE 3

Areas from which 3/8 inch depth of water can be drained by tile in 24 hours.

(From Yarnal formula, $V=1.38 R^{2/3} S^{1/2}$)

Size of tile (inches)	Fall per 100 feet							
	5/8 inch (0.05 foot)	1 1/8 inches (0.1 foot)	2, 3/8 inches (0.2 foot)	3, 5/8 inches (0.3 foot)	4, 7/8 inches (0.4 foot)	6 inches (0.5 foot)	9 inches (0.75 foot)	12 inches (1 foot)
1	2	3	4	5	6	7	8	9
	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
4	...	4	6	8	9	10	12	14
5	6	8	11	14	16	18	22	26
6	9	13	19	23	27	30	36	42
8	20	29	41	49	57	64	79	91
10	37	52	74	90	104	117	143	165
12	60	85	120	147	170	189	233	268

(SOURCE:—"Farm Drainage" Farmers' Bulletin No. 2046, U. S. D. A.)

TABLE 4

Maximum length of tile lines at minimum grade

Size of Tile (inches)	Minimum grade per 100 feet	Maximum length
1	2	3
	foot	feet
4	... 0.10	1,300
5	... .07	2,000
6	... .05	3,000

Distances between laterals and their respective lengths of tile per acre are given in table below:

Laterals (feet)	Feet of tile required per acre
40	... 1,089
45	... 968
50	... 872
55	... 792
60	... 726
65	... 670
70	... 623
75	... 581
80	... 545
85	... 513
90	... 484
95	... 459
100	... 436
150	... 291
200	... 218

(SOURCE:—"Farm Drainage" Farmers' Bulletin No. 4046, U. S. D. A.).

Estimated cost of 100 running feet construction of different types of drains is calculated tentatively as under:

	Rs.
(1) Tile Drain — 4" dia. ...	350
(2) Country Tile — 6" dia. ...	225
(3) Boulder Drain ...	200
(4) Open Drain of 11 sq. ft. section.	66

Following are the actual expenditure amounts incurred on different types of drains in the Sub-Divisions under Sholapur Division.

CEMENT TILE DRAIN

Sub-Division	Item	Amount
1	2	3
		Rs. P.
Sholapur I ...	(i) Cost of tiles 4" dia. cement pipe at Rs. 1.87 per foot.	187.00
	(ii) Transportation charges of pipe for 16 miles at Rs. 0.10 per pipe.	10.00
	(iii) Excavation cost at Rs. 1.85 per brass for 18.00 sq. ft. section Rs. 17.55.	18.00
	(iv) Cost of filling the bottom length to the depth of 9" over a breadth of 6".	121.00
	(v) Boulders required for packing the tiles.	
	(vi) Cost of bamboo pieces for covering tile joints at 20 bamboos for 100 ft.	7.00
	(vii) Cost of grass to be laid on tiles ...	2.00
	(viii) Labour charge for fixing the tiles, filling with bamboo boulders, grass and top soil 20 labourers for two days.	45.00
	Total ...	840.00
Sholapur II ...	(i) 1500 cft. at Rs. 8 per 100 cft. section 15.00 sq. ft.	45.00
	(ii) Cost of the pipe for 4", dia. for 100 pipe.	150.00
	(iii) Cost of transportation of pipe from factory to site per mile.	2.00
	(iv) Cost of spongy material around the pipe. The quantity of material required will be 100 cft. i.e. about one cart.	40.00
	(v) Labour charges for installation of pipe drain i. e. two men and two women for two days and filling of the material around the pipe at Rs. 2.00 per man at Rs. 1.50 per woman.	14.00
	Total ...	251.00
Barsi-I	(i) Excavation 1100 cft. at Rs. 8 section 1100 sq. ft.	88.00
	(ii) Tile of 4" dia. at Rs. 1.50 per foot for 100 ft.	150.00
	(iii) Other material to be used for filling over the tiles.	75.00
	(iv) Filling of earth at Rs. 1.00 per 100 cft. for 900 cft.	14.00
	Total ...	272.00
Akalkot	Tile drains with 4" and 6" cement pipes with a depth of 5' to 6'.	
	(i) Cost of 4" pipe at Rs. 1.87 per foot for 100'.	187.00
	(ii) (a) Excavation of drain (b) Fitting pipe (c) Covering the drain etc.	54.50
	Labour charges.—	
	(iii) Cost of material required for the drain.	21.00
	(a) Boulders	8.50
	(b) Bamboos	8.00
	(c) Green material like grass etc.	8.00
	(d) Metal 8' to 4' size	8.00
	(e) Tur stocks or cotton.	8.50
	Total ...	21.00
	(iv) Transportation charges of pipe.	18.00
	Total ...	280.50

Sub-Division 1	Item 2	Amount 3
		Rs. P.
	(i) Cost of 6" pipe at Rs. 1.75 per foot for 100' length.	175.00
	(ii) As above	54.50
	(iii) As above	21.00
	(iv) As above	18.00
	Total	268.50
	1100 cft. at Rs. 2.50	27.00
		295.50
ABSTRACT		
		Rs. P.
Sholapur I	...	840.00
Sholapur II	...	251.00
Barsi-I	...	272.00
Akalkot	...	280.50
	Total	1098.50
	Average	278.97

COUNTRY TILE DRAIN

Sub-Division 1	Item 2	Amount 3
		Rs. P.
Sholapur-I	...	...
Sholapur II	...	...
Akalkot	...	...
Barsi-I	(i) 1100 cft. (dry soil) section 11.00 sq. ft.	88.00
	(ii) Country tile 6" dia. @ Rs. 0.50 per foot for 100' length.	50.00
	(iii) Other material to be used for filling over the country tiles.	75.00
	(iv) Filling of earth @ Rs. 1.50 per 100 cft. for 900 cft.	14.00
	Total	172.00
	Average	172.00
	In wet soil items as above (i) to (iv)	172.00
		+ 88.00
	Total	205.00
	Average	205.00

BOULDER DRAIN

Sub-Division 1	Item 2	Amount 3
		Rs. P.
Sholapur I	(i) Cost of excavation section 10.00 sq. ft. at Rs. 1.85 per 100 cft.	18.50
	(ii) Filling of boulders for 1st 15" therefore Qty. of boulders=5 brasses. Cost of boulders @ Rs. 12 per brass without lead.	60.00
	(iii) Cost of sand and gravel for second 9" layer @ Rs. 15.00 per Brass Qty. required 2½ brasses.	37.50
	(iv) Cost of filling the top soil to the remaining portion of 9" @ Rs. 0.60 per brass.	1.50
	(v) Labour charges for filling the boulders at Rs. 80 per 100 cft.	80.00
	Total	142.50

Note.—Instead of using bamboo pieces or hay or dried stalks, for blinding the tile lines, it is recommended that pebbles or metal be used for bedding or foundation of the tiles. Boulders be also used on sides and joints for packing tiles upto 6 inches height from bottom of tiles. On the top, gravel of the size of 2 to 3 mm to a depth of 9 inches be used. Above the layer of gravel loose earth layer to a height of 1 foot be spread all over.

Sub-Division 1	Item 2	Amount 3
		Rs. P.
Sholapur II	(i) Excavation 1500 cft. @ Rs. 3 per 100 cft. section 15.00 sq. ft.	45.00
	(ii) Section of boulder drain to be constructed will be half of the section of the drain 7.50 sq. ft. 10.00 = 75.00. Cost of boulders per 100 cft. @ Rs. 10 per 100 cft.	75.00
	(iii) Transportation of the boulder from quarry to the site @ Rs. 5 per 100 cft.	37.50
	(iv) Labour charges for two men and two women for two days. @ Rs. 2.00 per man @ Rs. 1.50 per woman	14.00
	Total	171.50
Barsi-I	(i) 1100 cft. (in dry soil) @ Rs. 3 per 100 cft. section 11.00 sq. ft.	88.00
	(ii) Boulders @ Rs. 12 per 100 cft. for 800 cft.	96.00
	(iii) Other material to be used for filling over boulders.	75.00
	(iv) Filling of earth @ Rs. 1.60 per 100 cft. for 900 cft.	14.00
	Total	188.00
	In wet soil items as above i to iv	188.00
		+ 88.00
	Total	191.00
	Average	191.00
Akalkot	...	...
ABSTRACT		
		Rs. P.
Sholapur I	...	149.25
Sholapur II	...	171.50
Barsi I	...	158.00
Akalkot	...	...
	Total	478.75
	Average	159.58

EARTH WORK (Open drain)

Sub-Division 1	Item 2	Quantity 3	Amount 4
			Rs. P.
Sholapur I	Excavation in dry soil upto 8' depth. @ Rs. 1.85 per 100 cft. section 15.00 sq. ft.	1500 cft.	20.25
Sholapur II	Excavation in dry soil upto 8' depth @ Rs. 3 per 100 cft. section 15.00 sq. ft.	1500 cft.	45.00
Barsi-I	Excavation in dry soil upto 8' depth @ Rs. 3 per 100 cft. section 11.00 sq. ft.	1100 cft.	83.00
Akalkot	Excavation in dry soil upto 4' depth @ Rs. 2.50 per 100 cft. section 24.00 sq. ft. Average per 100 cft. @ 16.25 sq. ft. section =	2400 cft.	60.00
Farsi-I	Excavation in wet soil upto 8' depth @ Rs. 6 per 100 cft. section 11.00 sq. ft.	1100 cft.	66.00

Chapter II

DRAINAGE DESIGNS AND LAYOUTS—SURFACE DRAINAGE

Surface drainage of the individual field has probably been the most neglected of all the different phases of the Agricultural lands. A small amount of labour with shovel or plow could have drained the accumulated runoffs at different sites. The farmer in some cases has tried to solve his surface drainage problem but his approach is generally piece-meal and not according to an overall analysis and plan. Bedding has been practiced in some localities for many years. Quite often the beds are located in wrong directions or the number and locations of collection ditches is not adequate for most effective drainage.

The control of surface runoff is one of the keys to proper moisture relationship for plant growth. The problem of control varies between permeable soils on hilly lands and tight soils on flat lands. On hilly land with permeable soils conservation of moisture is the goal which can be accomplished by contouring, strip-cropping, terracing and growing grass.

Water control on gently sloping to flat lands with permeable soils is by surface channels and tile drains. The highest degree of drainage for these soils is nearly always obtained by a combination of open and closed drains. To make more effective use of a tile system, the surface water should be removed rapidly from the field. As soon as the surface water has been removed, the tile can then start its job of removing the excess soil water. Too often the surface drainage is not given the investigation and planning that goes into the development of a tile plan. The two systems should be worked out together, and any final drainage plan should provide in detail for the surface and sub-surface drainage.

Adequate drainage of gently sloping to flat, tight soils can best be accomplished by using a complete drainage system. In general, these soils have a few inches of moderately permeable soils over a sub-soil that has slow to very slow permeability. Tile can and is being used on some of our tight soils where the moderately permeable soil is deep enough to provide a sufficient drainable area for the tile. However, for adequate drainage the tile spacing must be so close because of the shallow depth of permeable soil that tiling is seldom economical for general field crops.

'Clay-Plan' areas at some places in this State have from 9" to 20" of permeable top soil over a very slowly permeable or impervious 'Claypan.' The slopes vary from 0 to 5 per cent with most of the area predominantly levelled. In general tiling will not be economical or successful in these areas. There are also scattered small areas where the claypan is far enough below the ground surface to permit fairly successful tiling. Again some areas are reported to be poorly drained tight soil-areas. These soils generally have their top-soil over a siltpan. Internal drainage is poor from the plow-sole

downwards. Tile is not going to be effective in these lands, though the slope varies with them from 0 to 4 per cent. There are a number of depressions and pockets which add to the surface drainage problem of these areas.

The heavy clays in the big river valleys of this State are flat and drain slowly. These areas are covered with many ponding depressions varying from large to quite small pockets. Some of these areas in the river belts are spotted with knolls of sandy material over clay-base.

The purpose of a surface drainage system is to rid the land quickly of its excess water, thereby preventing the land from becoming too wet and soggy, and allowing the wind and sun to start their job of drying the soil, as soon as possible, after a rain. To accomplish this the surface drainage system must be so planned and installed, that surface water will not be allowed to collect and stand in any area of the field. The key to surface drainage is to keep the runoff water moving off the field as rapidly as possible without causing erosion of the land surface or in the ditches.

There are essentially five types of field surface drainage systems used. Occasionally it is necessary to combine two or more of these systems in order to secure the desired results. These five systems may be spoken of as the (1) bedding system, (2) random ditch system, (3) cross slope ditch system or drainage type terraces, (4) parallel ditch system and (5) field ditch system for water table control and surface water removal. The selection of the system to use on a given field depends upon the topography of the land, the soil type, possibly crops to be grown, and the farmer's desires.

① Bedding system

The "bedding system" (Fig. 1) of surface drainage is generally used on fields that are practically flat, slopes from 0 to 1.5 per cent, where the soils are slowly permeable and where tile drainage is not economically feasible. The system is designed, constructed, and maintained, so that excess surface water drains laterally from beds, similar to plow lands, into dead-furrows, thence into the collection ditches and finally into an outlet ditch. The beds should be laid out with the dead-furrow running in the direction of greatest slope. The collection ditches, which intercept the water from the dead-furrows, are laid out in the direction of lesser slope because they can be graded towards the outlet by construction methods.

Width of beds is governed by the following conditions:

(1) Kind of crops to be grown. Some permanent pasture or hay crops do not require as narrow beds as do general rotation crops.

(2) Slope of the field. Flatter fields require narrower beds.

(3) Drainage characteristics of the soil. Soils with low infiltration and poor permeability require narrow bedding.

(4) Adaptability to farming operations. It is usually unprofitable to grow row crops in deadfurrows. Thus, bed width should be adjusted so that the rows will fit the beds without unnecessary waste of ground along deadfurrows or crowding of rows too close to the deadfurrows. The width should be a multiple of one through or one round with the plow, planter and cultivator.

For the bedding system to function properly all deadfurrows must have a continuous grade with no obstructions or low points that would interfere with the complete drainage of the furrow. Where depressions obstruct the flow, this condition should be remedied by filling, cutting the deadfurrow deeper, or tapping the depression with a collection ditch.

The collection ditches are a very important part of any bedding system as they carry the surplus water away from the bedding furrows. These should be spaced at regular intervals across the slope of the field depending upon the amount of slope and the permeability of the soil. Where the land is nearly flat and the permeability of the soil very slow, a spacing of about 300 ft. is generally required. This can be varied upto 1,000 ft. for more slopping soil of fair permeability. Where collection ditches are placed at the end of the field, the ditch should be placed about 16 to 20 ft. in from the end to provide a turn strip so that drainage from the rows into the ditch will not be obstructed.

Some general recommendations on bed width and layout and construction details are given in Fig. 1.

Random ditch system

The "random ditch system" (Fig. 2) is adapted to depression type topography having wet pockets or depressions too deep or large to fill by land smoothing. The random surface ditch should meander from one low spot or depression to another so that the water flows towards the lateral outlet ditch.

The random ditch must be of sufficient size and depth to drain off the impounded water rapidly and completely. Soil from these ditches should be placed in the minor depressions that will not be drained by ditches.

To secure the highest degree of drainage the entire field should be smoothed or graded to fill all of the minor depressions and thus allow the surface water to flow to the ditched out depressions or directly to the ditch. On flat, very slowly permeable soils it may be necessary to combine this system with the bedding system to do an adequate job of surface drainage. On tileable land having large and deep depressions this system should be used in conjunction with the tile drainage.

The random ditch will usually be located in cultivated fields. Where not too deep, these ditches should be constructed so that they can be crossed with farm machinery. General recommendations are shown in Fig. 2.

Cross slope ditch system

The "cross slope ditch system" (drainage-type terrace) (Fig. 3) resembles terracing in that the drainage ditches are constructed around the slope on a uniform grade according to the lay of the land.

This method of surface drainage is adapted to sloping, wet fields of 4 per cent slope or less, where internal drainage is poor from the plow sole downward and where many shallow depressions hold water after rains. The nature of the soil is such that the surface water which collect in these low spots cannot infiltrate into the soil. The depressions are too numerous and the slope too great for successful bedding, and generally tiling is not practicable or feasible.

The cross-slope ditches or terraces should be constructed across the slope as straight and parallel as topography permits with limited cutting through ridges and humps. The spacing between ditches should be about 100 ft. on a 4 per cent increasing to 150 ft. as the slope decreases to 0.5 per cent. The cross-slope ditch differs from the regular terrace in that little or no ridge is permitted on the downslope side of the ditch. This provides for ease in crossing the ditches and reduces the damage caused from overflow. The excavated material from the ditches should be placed in the depressional areas between the ditches. After the excavated material from the ditches has been placed in the depressions, the area between the ditches should be smoothed or graded to eliminate all minor depressions and humps which might obstruct the free flow of surface water to the ditches.

It has been found that for ease of farming operation these ditches should be constructed with very gentle side slopes. Fig. 3 gives some recommendations.

The key to the success of this system of surface drainage is the elimination of the depressions between ditches so that no runoff will be permitted to collect and stand on the surface of the ground. With ditches spaced at regular intervals down the slope, the runoff can be collected and carried away from the field. Farming operations should be parallel to the ditches. Thus, by laying out the ditches as straight and parallel as possible, ease of farming operations is provided.

Parallel ditch system

The "parallel ditch system" (Fig. 4) is adapted to flat, poorly drained soils in which there are numerous small shallow depressions. Quite often in the past bedding has been used on this type of soil and slope. On many soils bedding can be eliminated provided the land is smoothed or graded to eliminate all minor depressions and provide uninterrupted crop-row drainage to the parallel field ditches.

The field ditches should be parallel but not necessarily equidistant. The success of the system depends largely upon the spacing of the parallel ditches and the smoothing or grading between ditches. The land should be prepared so that every row throughout its entire length will drain to a ditch. The ditches must be spaced so that the length of row drainage from a high point to a ditch is such that the row can safely carry the runoff without much overflow or erosion damage in the row. Another factor which influences ditch spacing is the amount of earth and the distance it will have to be moved to provide complete row drainage.

Field experience indicates that the maximum length of grade drainage to a given ditch should be about 600 ft. This maximum length of grade should be reduced on slowly permeable, highly erosive soils to about 300 ft. Therefore, the maximum spacing where the land drains in one direction should be around 600 ft. If the topography is such that the land will drain from a ridge located between the ditches, the maximum spacing could then be 1200 ft.

When the ground surface has some general slope in one direction, the area between the ditches can be smoothed, thus filling the depressions and removing barriers. It is not necessary that the slope be uniform between ditches—it can be broken according to the lay of the land.

On areas where the ground surface has little or no general slope, a grade should be established between ditches by moving from 0.1 to 0.2 ft. of the surface soil from the lower end of the area of the upper end, thereby establishing a slight uniform grade between ditches.

The original installation of this system may be a little more costly than the bedding system; however, it provides for ease in farming operations and fits in well with the use of large farm machinery. It is particularly adaptable to large fields as crops can be planted from one end of the field to the other over the ditches, thus providing the maximum length of crop rows. Suggestions for layout and design are shown in Fig. 4.

Field ditch system for water table control and surface water removal

This system (Fig. 5) is somewhat different from the other systems in that it serves a dual purpose by providing drainage for surface and sub-surface water, and is generally used on the more permeable soils. Here the field ditches are laid out in regular parallel pattern across the field, but are deeper than the ditches used in the other systems. This deeper ditch provides for lowering high water tables sufficiently for crop production, as well as providing a channel for removal of surface water. This system is used in soils where the lowering of the water table is necessary, but where the use of tile is not economically or physically feasible. Some typical soil conditions where this system may be used are on peat and muck soils where tiling is not applicable, on sands with high water table, and on moderately or highly permeable mineral soils which have a high water table.

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The ditches are laid out parallel across the field at depth and spacings which are governed by the various soil conditions. Minimum specifications for this system of surface drainage and water table control, based primarily on field observations and experience, are shown in Fig. 5.

Due to the depth and use of the field ditches in this system of drainage, it is seldom advisable to provide a ditch section that can be crossed with farm machinery. The excavated material from the ditch should be used to fill depressional areas between the ditches or spread sufficiently to allow the area next to the ditch to be used for turn rows or to permit cultivation. Farming operations in most cases should be parallel with the ditches. Crop rows, deadfurrows, and plow furrows, should be intercepted in shallow ditches and directed into the field ditches through protected overfalls. On the less permeable soils that are covered with minor depressions and pockets, land smoothing between the ditches will improve surface drainage.

Field ditches for surface drainage

An important part of any surface drainage system is the field ditch that must carry away the excess surface water. It is important to select and install the type and size of ditch best suited to the problem area. There are two types of field ditches which are commonly used in connection with surface drainage. They are the "single ditch", and the "double ditch", some times called W ditch or twin ditches.

The single ditch should be used when the excavated material is needed and can be placed in depressions adjacent to the ditch or where placement of the spoil on one side of the ditch will not interfere or obstruct surface-water flow into the ditch. When the excavated material from the ditch is used to fill field depressions, some type of earth-moving equipment such as scraper, carry-all or bulldozer is generally required. In this case, the excavated material provides two things; first, ditch capacity and, second, fill material for depression areas. The plow can be used in constructing the single ditch if the soil on either side of the ditch will not obstruct surface flow, or if it can be levelled out in such a manner as to provide free drainage to the ditch.

The double or W ditch is actually two parallel ditches spaced a short distance apart with the excavated material placed between the ditches. In this way surface water can enter the double ditch from each side without being obstructed. It is particularly adaptable to plow construction. This ditch has application (1) where the land drains toward the ditch from both sides, (2) where the land is very flat and row drainage enters from both sides, and (3) where excavated material will not be needed for filling depressions. The ditch can be farmed across or the area between the ditches planted to some other field crops or maintained as a hay strip. The crown between the two ditches can also be used as a field road. The channels of the two ditches

should be about 30 ft. apart as a minimum for a channel about 9 in. deep. As the depth of channel increases the width between ditches should be increased so that a side slope of about 8:1 or flatter can be maintained.

Land smoothing.—Land smoothing or grading has been suggested or recommended for each of the different types of surface-drainage systems. All indications are that with proper use it will become one of the important factors in completely successful surface drainage in the tight-soil areas.

Most of the tight soils are covered with depressions varying in size from small to large and in depth from almost nothing to a foot or more. In order to keep surface water moving, it becomes necessary to ditch out these areas or fill them. It is evident that it is impossible and impracticable to ditch out all of the depressions. The larger depressions, both as to size and depth, should be ditched out. This generally leaves many one and two-inch pockets which will collect and hold water for long periods after rains, thereby slowing up farming operations on the entire field and reducing or eliminating crop stands and yields, in those depression areas. Therefore, the logical solution appears to be the ditching out of larger depressions and filling the minor depression by land smoothing.

It is recommended that this land preparation work be spread over a two-year period or done in two operations the same year. First, roughly grade the area by eye, filling the larger depressions with a bulldozer or a scraper; then operate a land leveller or plane over the entire area, which will fill many of the minor depressions. The leveller

should be run over the areas from two to four times depending upon the roughness of the land. It should be operated across the area and then diagonally both ways.

After this is done a topographical survey may be needed to select and plan in the type of surface-drainage system best fitted for the field; then the field ditches should be located and constructed. Grade stakes should be set where additional levelling work is needed, and required cut or fill should be marked on the stakes. The cuts over 1/10 ft. should then be made with a bulldozer or scraper carrying this cut material to the fill area. After this has been accomplished, the area should then be finished with a land leveller or plane. It is not necessary that grading work be carried to a point of obtaining a uniform slope over long distances. The primary purpose is to grade the field so it will drain, filling in the depressions and removing the humps. Therefore, the slope should be broken whenever it will lessen the amount of earth to be moved.

Land smoothing will add an additional cost to any surface-drainage system, but all indications are that increased crop yields resulting from the elimination of the small depressions will pay the cost of smoothing in a relatively short time.

For any drainage system, outside catchment is required to be ascertained accurately and provision of a diversion ditch to cut off the upper runoff, is the essential step in the design. The method for maximum flood flow determination for designing diversion ditches and the monographs for cross sections of the diversion ditches and also for laterals are given in the following pages.

Chapter III

MAXIMUM FLOOD FLOW DETERMINATION FOR DESIGNING OF DIVERSION DITCHES

There are a number of formulae and methods for calculating the maximum rate of runoff from a given watershed, most of which are applicable to specific localities and to conditions peculiar to such localities; however, we may consider only one method which is most commonly adopted.

Rational Method:

The formula is, $Q=CIA$, where Q =Rate of runoff in cubicfeet per second
 A =Drainage area in acres;
 C =Runoff coefficient representing the ratio of runoff to rainfall;
 I =Maximum average rate of rainfall in inches per hour over the entire drainage area which may occur during the time of concentration.

The reason why acres multiplied by inches per hour in the formula gives answer in cubic feet per second is:

$$Q = C \times \frac{I}{5600 \text{ (sec. in hr.)} \times 12 \text{ (in)}} \times A \times 43560 \text{ (sq. ft. one acre)}$$

For practical purposes the factor 3600×12 is supposed to cancel the number 43560 leaving the formula as stated above. The runoff coefficient (C) must necessarily vary as the intensity varies; but because of the number of other factors also affecting it, intensity changes can usually be ignored. The coefficient will vary considerably depending on the characteristic of the watershed. The soil type, condition of soil vegetative cover, degree of slope and surface detention are major factors affecting the selection of a co-efficient. To estimate (C), a careful evaluation of the physical features of the drainage area must be made.

Recommended values of (C) are given in the table below:

Runoff characteristics	Co-efficients of runoff	
1	2	
Low (Timber rolling 5 to 10 percent slope).	.20	.30
Moderate, average between Low and Normal Pasture rolling 5 to 10 percent slope)	.30	.40
Normal (Pasture hilly 10 to 30 percent slope)	.40	.50
High (Cultivated rolling 5 to 10 percent slope)	.50	.65
Extreme (Cultivated hilly 10 to 30 percent slope)	.65	.80

Proper allowance should be made for changes in vegetative cover brought about by droughts, forest fires, alterations in land use, or in other ways.

Time of Concentration.—In order to determine the maximum average rate of rainfall (I), for a given drainage area, the time of concentration for the area must be computed. Time of concentration of given catchment area is the length of time as storm must continue to permit runoff to flow over the ground surface, without unreasonable delay, from each increment of area to the outlet. A storm of maximum intensity for a specific frequency continuing long enough to accomplish this will produce the maximum flood, for, in that period the maximum runoff from each increment of area will reach the outlet simultaneously. It is apparent that the time of concentration would be much less for range land heavily over grazed than for the same area before it had been over grazed and denuded of its cover of heavy grass and deep sod; likewise it would be less in years of severe drought than years of normal rainfall. Each area demands separate study because each has its individual set of variables and hence its individual problems. Experience coupled with judgment will enable the designer to make a close estimate of the average velocity of flow that will pertain to the main channel.

A reasonable estimate of the time of concentration can be obtained by dividing the distance from the most remote limit to the outlet of the area by the average velocity selected.

The velocities tabulated in table given below are recommended for use in determining the time of concentration, under conditions, where the main water ways are broad and flat and not gullied to any great extent.

Recommended Average Velocities for use in determining time of concentration.

Average slope of the channel extending from the farthest point of the watershed to outlet, in per cent	Velocity in feet per second
1	2
1 — 2	... 2.0
2 — 4	... 3.0
4 — 6	... 4.0
6 — 10	... 5.0

(SOURCE: Rainrao, M. S. V- 'Soil Conservation in India' I. L. A. R.)

The U. S. D. A. has published a bulletin, Miscellaneous Publication 204 entitled 'Rainfall Intensity—Frequency Data.' It contains a number of charts showing the maximum precipitation that may be expected to occur in period of five minutes to 24 hours with average frequencies of 2 to 100 years.

In case the bulletin is not available, the following table and chart Fig. 6 is useful for calculating the time of concentration of runoff from small watersheds.

TABLE 5

Time of concentration for small watersheds

Maximum length of flow, ft	Time of concentration in minutes					
	Watershed Gradient in per cent					
	0.05	0.1	0.5	1.0	2.0	5.0
1	2	3	4	5	6	7
500	18	13	7	6	4	3
1000	30	23	11	9	7	5
2000	51	39	20	16	12	9
4000	85	66	33	27	21	15
6000	119	91	46	37	29	20
8000	149	114	57	47	36	25
10000	175	134	67	55	42	30
20000	306	234	117	97	74	52

(SOURCE: Ramrao "Soil Conservation in India" I. C. A. R.)

Table given below provides estimates of the value C, (Ratio of the peak runoff rate to the rainfall intensity and is dimensionless), for different topographic, soil, and cover conditions.

TABLE 6

Runoff coefficients

Topography and vegetation	Values of C in $Q=CIA$			
	Soil texture			
	Open sandy loam	Clay and silt loam	Tight clay	
1	2	3	4	
Woodland—				
Flat 0.5 per cent sl pe...	0.10	0.30	0.40	
Rolling 5-10 per cent slope.	0.25	0.35	0.50	
Hilly 10-30 per cent slope.	0.30	0.50	0.60	
Pasture—				
Flat	... 0.10	0.30	0.40	
Rolling	... 0.15	0.35	0.55	
Hilly	... 0.22	0.42	0.60	
Cultivated—				
Flat	... 0.50	0.50	0.60	
Rolling	... 0.40	0.60	0.70	
Hilly	... 0.52	0.72	0.82	
Urban areas	.. 80 per cent of area impervious	50 per cent of area impervious	70 per cent of area impervious	
Flat	... 0.40	0.55	0.65	
Rolling	... 0.50	0.65	0.80	

SOURCE: U. S. Soil Conservation Service, *Engineering Hand-book for Farm Planners*. Upper Mississippi Valley Region III Agv. Hand-book 57 U. S. Government Printing Office, 1953).

From the charts in bulletin 204, U. S. D. A. also either direct or by interpolation, can be obtained the depth of rainfall for a period equal to the time of concentration for the largest storm of any specific rainfall frequency period. The depth of rainfall is converted into inches per hour by dividing by the time of concentration and multiplying the quotient by 60. The resultant figure is the letter (I) in the formula

$$I \text{ per hr.} = \frac{\text{Depth of rainfall in inches from the Chart} \times 60}{\text{Time of concentration in minutes.}}$$

To illustrate the use of the aforesaid principles, the solution of hypothetical problem is given below:—

The drainage area has the characteristics—

1. Topography ... Rolling (slope 5 per cent)
2. Soil type ... Loam.
3. Vegetal cover ... Fair to good grassland, but slightly overgrazed.
4. Length of drainage area. 2, 1/4 miles
5. Average width drainage area... 1/3 mile
6. Average slope of Main channel. 1.5%
7. Size of drainage area. 0.75 sq. mile
= 480 acres

The data as stated above after comparing the relevant description from the table of coefficient of runoff page 39, the latter is determined as 0.4. The first step is to figure out the time of concentration. The distance from the remotest point required to be travelled by the runoff is 2 1/4 miles—say 12000 feet. A study of the area indicates that the average velocity of flow in the main channel is about 2 feet per second. The time of concentration for the area is then

$$\frac{12000}{2 \text{ feet per sec.} + 60 \text{ sec.}} = 100 \text{ minutes.}$$

Referring to the rainfall intensity chart 5, "one hour rainfall in 25 year frequency" it is noticed that the 1.8 inch isohyral represents the 1 hour frequency and 2.3 inch isohyral represents the 2 hours frequency. The rainfall for a 100 minutes period would thus be about 2.1 inches. The intensity is:

$$\frac{2.1 \times 60}{100} = 1.26 \text{ inches per hour.}$$

This rate is the letter (I) in the formula,

$$Q=CIA.$$

Substituting,

$$Q=4 \times 1.26 \times 480=242 \text{ cubic feet per sec.}$$

The capacity of the spillway must therefore, be at least 242 cubic feet per second if the earthen dam is to be protected against the largest

storm that would occur in this drainage area on an average of once in 25 years. It is needless to stress the importance of correctly evaluating the factors that are functions of maximum runoff, if the results of calculations are to be of any value.

To illustrate, another example is given below. This pertains to another area identical in every respect to that considered in the first case dealt about, except in the shape of the area, which is assumed to be fanshaped.

Its size is the same—3 sq. mile; but the greatest distance travelled by a drop of water is 6000 ft. instead of 12000 feet. Thus the time of concentration would be 50 minutes instead of 100 minutes, and the greatest rainfall in 50 minutes for a 25 years frequency is shown by the chart to be about 1.7 inches. This rainfall would have on an average rate per hour of 2.04 inches, for the fanshaped area in comparison to 1.26 inches for the long, narrow area. Applying this value to the rate of 392 cubic feet per second is contrasted to 242 cubic feet per second is obtained.

The following example illustrates how the factor slope of the main channel may be treated where there is a considerable variation in shape throughout its length.

The characteristics of the drainage area are—

Topography	...	Hilly, 20 per cent
Soil	...	Sandy to loamy.
Cover	...	80 per cent cultivated
Length of main channel	...	2600 ft.
Average slope	...	Upper area 1050 ft. carrying 4.0 per cent slope, Ave. velocity table, =3.0
Average slope	...	Lower area 1550 ft. carrying 2.0 percent slope. Ave. velocity table=2.0
Drainage area	...	117 acres

Base design on 25 years frequency.

The area is hilly and largely under cultivation thus the runoff producing characteristics would fall in the category High. The coefficient selected from the table is 0.55.

$$1050 \text{ ft.} \div 3.0 \times 60 = 5.84 \text{ min.}$$

$$1550 \text{ ft.} \div 2.0 \times 60 = 12.90 \text{ min}$$

$$\text{Total} \quad \dots \quad 18.74 \text{ min}$$

Referring to the 'Rainfall Intensity charts' the 15 minute isohyetal gives a total rainfall of 1.50 inches and 30 minutes isohyetal gives a total rainfall of 2.25 inches. Interpolating, the total rainfall for the 18.74 minutes interval is noticed

$$\text{to be } 1.70 \text{ inches. The intensity is } \frac{1.70}{18.74} \times 60 =$$

5.45 inches per hour.

The peak for the area based on a 25 year frequency is: $Q=0.55 \times 5.45 \times 117=351 \text{ c. f. s.}$

The spillway structure must provide for a discharge capacity of 351 c. f. s.

The above said method of estimating the total runoff for any watershed will be of practical utility for designing drainage system, dams and diversion channels. For all earthen constructions rainfall frequency for a period of 15 to 25 years is considered adequate according to the estimated effective period of the proposed construction.

Thus by the use of the rational method, the runoff of a given watersheds from the highest point from ridge to the outfall-end can be very accurately computed.

TABLE 7

Statement showing sections of Laterals for 1 to 20 acres catchment (Please see Fig. 7)

Sr. No.	Water-shed area	Carrying capacity	Area of the section	Top	Bottom	Depth	Velocity
1	2	3	4	5	6	7	8
	acres	cusecs	Sq. ft.				
1	0 to 8	16	5.5	6'	1.5'	1.5'	3' /sec
2	9 to 15	27	9	7.5'	1.5'	2'	3' /sec.
3	15 to 20	40	18.1	8.5'	1.5'	2.5'	3' /sec

Note.—Sections are designed by Manning's Formula.

$$V \text{ (Velocity)} = \frac{1.486}{n} \times R^{2/3} S^{1/2}$$

$$\text{Where } R = \text{Hydraulic mean depth} = \frac{\text{Area}}{\text{Wetted Perimeter}}$$

S ... Bed slope which should be from 0.2 to 0.5 according to soil type.

N ... Coefficient of rugosity ;

TABLE 8

Statement showing sections of diversion or main drains for watershed area from 20 acres to 100 acres (Please see Fig. 8)

Sr. No.	Water-shed area acres	Carrying capacity cusecs	Gross sectional area sq.	Top	Bottom	Depth	Velocity
1	2	3	4	5	6	7	8
1	20	40	20.10	11.20	2.20	3	3'
2	30	60	20.10	11.20	2.20	3	"
3	40	80	25.70	13.40	4.40	3	"
4	50	100	33.00	15.50	6.50	3	"
5	60	120	39.90	17.80	8.90	3	"
6	70	140	46.80	20.10	11.10	3	"
7	80	160	53.40	22.30	13.30	3	"
8	90	180	60.00	24.50	15.50	3	"
9	100	200	67.50	27.00	18.00	3	"

Note.—Side slopes have been treated as 1, 1½; Velocity is kept constant at 3'/sec. and intensity as 2"/hr. (after allowing for absorption capacity of soil).

Plan and location of Tyle system.

An accurate contour map, the analytical data of Soil-samples together with the description of Soil-profiles is very necessary to decide the kind of layout, depth of tile lines, mains, submains, and laterals, of a underdain (Tile) of a drainage system.

Location of Tile-system.—Economy is obtained by using the longest practical laterals and reducing the average length of mains per acre. Practice varies with respect to placement of mains and laterals across the slope. Some designers prefer to place laterals in the direction of the greatest slope which provide maximum grade for the smallest tile. Others prefer to place laterals across the slope which will intercept a maximum of ground water moving down the slope. Where the trenches are back filled with more permeable material and will admit water more readily it is an advantage to layout laterals and rows where the water flowing in rows will cross laterals at frequent intervals. This benefit is ordinarily obtained by running laterals across the slope and rows in the direction of the greatest slopes. In the less permeable soils where it is necessary for surface water to enter tile; an independent surface drainage system should be considered. The local practice and consideration of these various factors will determine the placement of laterals with respect to slope.

In general the system designed with short tile mains is the most economical, and in the furtherance of this aspect in view, earthen tiles or boulder drains in accordance with the availability of material, may be profitably considered for being used for the construction of the laterals. Possibility of surface drains with adequate depth and spacings for laterals and field ditches according to soil types may also be considered; a good combination of surface ditches, country tiles or boulder laterals, and tile—mains or submains are the major consideration for efficient layout of a drainage unit. In general a system with short tile mains is the most economical.

Types of tile drainage systems

The most common types of tile-drainage systems are as follows. Please see Fig. 9.

Gridiron or parallel system

This system consists of parallel laterals located perpendicular to the main tile. It is used on flat, regularly shaped fields and uniform type of soil. Variation of the system are often used with other patterns.

Harringbons system

It consists of parallel laterals that enter the main at an angle usually from both sides of the main. This system is used where the main or sub-main lies in a narrow depression. It may also be used where the main is located on the major slope and the lateral grade is obtained by angling the lateral upstream. This pattern is used with other patterns in laying out a composite pattern on small or irregular areas.

Double-main-system

This system is a modification of the gridiron or harringbone systems and is applicable where a depression which is frequently a natural water-course, divides the field where the tile line is to be installed. Some-times the depressional area may be wet because of seepage coming from higher ground. Placing a main on each side of the depression serves a dual purpose. It intercepts seepage water and provides an outlet for the laterals. If the depression has depth and is unusually wide and only one main is used in the centre, a brake in grade line in each lateral may be necessary before they reach the main. A main on each side of the depression permits a more uniform lateral gradeline.

Random system

A random system of Tile is used where the topography is undulating or rolling and contains isolated wet areas. The main tile for efficiency is usually placed in the swales rather than in deep cuts through ridges. If the individual wet areas are large, the arrangement of submains and laterals for each area may utilise the gridiron or Herringbone-tile-pattern to provide the required drainage.

Interception system

This system usually intercepts seepage water that follows the upper surface of an impervious subsoil strata and removes the excess moisture in the wet areas that result from seepage. Proper location of the interception tile is very important. The seepage is located by soil boring or by trenching. The tile line usually should be placed at about the upper boundary of the wet area and across the boundary of seepage travel (Fig. 10). Interception drains are also used in areas of high water table, where the slope of the hydraulic gradient is 0.5 per cent or more, and where pervious layers are at a considerable depth below the normal-tile. Vertical relief wells may be installed at intervals from the intercepting tile into the pervious soil below the tile to permit the water in the pervious soil to rise to the tile-line (Fig. 10). Relief wells in interception lines serve the same purpose as relief wells installed for artesian flow.

Tile Depth and Spacing.—When a system of parallel laterals is used, the spacing between the laterals should vary according to soil texture, permeability, permissible depth, and depth to barrier. Tile spacing generally used in the various soil types is the result of the experience gained from actual installations. The general range for tile spacing, as has been determined from experience, follows:

Soil permeability	Spacing
Slow	... 30-70 feet apart
Moderately slow to moderate	... 60-100 feet apart
Moderately rapid to rapid.	... 100-300 feet apart

In many areas the depth and spacing of drain-tile is determined by observing crop conditions. If the tile is spaced too far apart; retarded growth and reduced crop yields in areas farthest from tile lines indicate damage to crops. Uniformly good crop stands are obtained by spacing tile closer together. Wet soil and vegetation that thrives in wet areas, usually indicate poorly drained areas of fields. Observations and a study of crop yields for a long period is the best available basic data on the proper depth and spacing in the humid areas. Often it becomes desirable to determine the depth and spacing by measuring the permeability or other characteristics of the soil. Usually the permeability varies greatly with depth and stratification.

The depth that holds the ground water at the best level for crop production i. e. beyond the root zone of the crops to be grown is the correct depth of the tile drains.

The depth of the drain is related to the spacing of the lateral drains. In general, lateral spacings may be increased as the depth of the drains increases. The depth and spacing of drains required to give the desired depth of water table are influenced by the tightness of the soil, amount and frequency of rainfall, seepage, capillary movement, and topography. In open soils, the rate of water movement increases with the depth of the drain, but in tight soils the reverse is true. In very sandy soils, capillary action upward is limited and depths should not be greater than 4 feet.

In general, the water-table depth is about 2 to 3 feet. This requires that the drain be placed not less than 3 and 4 feet.

The minimum depth of cover over the tile is influenced by the severity of frost action and impact loads from tractor and farm equipment.

The following recommendations are a general guide for depth of drains.

Mineral soils.—Minimum depth of drains should be at least 30 inches. Where soils are slowly permeable, contain impervious layers of soil, sand or large stones, the depth may be reduced. Sometimes depressional areas, shallow outlets, and the desire for rapid drainage of the upper horizon of the soil profile may require a reduction in depth. When the depth is reduced, there is usually a need for closer spacing of the laterals. The minimum cover should be 2 feet of soil over the drain.

Organic soils.—Organic soils should not be tiled until after initial subsidence occurs. Subsidence continues after the initial stage and averages about 0.10 foot a year due to oxidation under cultivation, compaction, shrinkage, and wind erosion. Since tile drains should be effective at least 10 to 15 years, the depth of drains in deep peat and muck should be 4 feet or more. Minimum cover in organic soils should be 3.0 feet.

Depth required for protection.—When it is impossible or uneconomical to secure the minimum cover previously specified, the drain-tile should be replaced with metal pipe or other high strength continuous pipe. Open ditches may also be used.

Design drainage coefficients

The drainage coefficient is the depth of water in inches to be removed in 24 hours from the watershed contributing to the tile. This coefficient may be expressed in inches in 24 hours, cubic feet per second per acre, cubic feet per square mile.

Drainage Coefficients for Humid Areas.—For use in the humid areas, drainage coefficients vary with local conditions. General guides in the selection of drainage coefficients follow:

1. When the land to be drained has a separate surface drainage system, either natural or artificial, the following table may be used:—

TABLE 9

Drainage coefficients without surface water inlets

Soil	Inches to be removed in 24 hours	
	Field crops	Truck crops
1	2 Inches	3 Inches
Mineral	3/8-1/2	1/2-3/4
Organic	1/2-3/4	3/4-1-1/2

(SOURCE: *Drainage National Engineering Handbook* Section 16 U. S. D. A., Soil Conservation Service).

2. Where it is necessary to admit surface water through surface inlets to the tile system, the values in the following table have been used successfully in the humid area:

TABLE 10

Drainage Coefficients with surface water to reach tile system

Soil	Inches to be removed in 24 hours			
	Field crops		Truck crops	
1	Blind inlets	Open inlets	Blind inlets	Open inlets
2	3	4	5	
	Inches	Inches	Inches	Inches
Mineral	3/8-3/4	3/4-1	1/2-1	1-1 1/2
Organic	1/2-1	3/4-1 1/2	3/4-1	2-4

(SOURCE: *Drainage National Engineering Handbook* Section 16, U. S. D. A. Soil Conservation Service).

3. When high-value crops might be damaged, a higher coefficient than those given in the above tables may be necessary.

4. Where no surface water is admitted directly to random, single, and seep interceptor tile lines, the required size of the tile may be based on the estimated inflow rate per 1,000 feet of tile.

Where permeable soils, sand, gravel, and springs are reached, the maximum flow from tile often exceeds the values given in the table below. It is given as a guide for estimating flows.

TABLE 11

Inflow rates for soil textures

Texture	Estimated inflow rates per 1000 feet of line	
	1	2
		c. f. s.
Coarse sands and gravel ...	1/	0.15-1.0
Sandy loams ...		.07- .25
Silt loams ...		.04- .10
Clay and clay loams ...		.02- .2

Land slope 2/	Estimated inflow rate 2/ increases	
	1	2
Percent		Percent
2-5 ...		10
5-12 ...		20
more than 12 ...		30

1/ Some gravels may discharge as much as 10 c. f. s. per 1,000 feet.

2/ For interceptor-tile lines on sloping land.

(SOURCE: *Drainage*, National Engineering Handbook Section 16, U. S. D. A. Soil Conservation Section).

Tile Sizes.—After the coefficient has been selected, the drainage area determined, and the grade known, the size of the required tile may be determined from the tile drainage chart (Fig. 11).

Minimum Tile size.—Four inch tile is the smallest tile in general use. The problem of maintaining an accurate grade and alignment and the possibility of unavoidable settlement encourage the use of larger tile to procure longer useful life of tile systems. The following are the guide lines for selecting the minimum size of tile.

1. Four or five inch tile may be used in mineral soils containing small amounts of sand or fine silt and where good alignment and uniform grade can be obtained.

2. The minimum size for tile lines with surface inlets and in unstable soils, such as peat, muck and sands or noncohesive soils should be determined on the basis of experience and site conditions.

Other methods.—Open drains are made applicable in soils unsuited for tile lines—such as sandy, silty, organic or alluvial or those with low fertility. They may be used on very flat gradient where the permissible depth of the outlet is not adequate to permit the installation of tile at the minimum required grade.

Open surface drains are best adapted to large, flat fields where lack of grade or outlet, soil characteristics, or economics do not favour tile drainage.

The spacing of these drains is usually close and the lengths of the interterrace lands between them must be sufficient say 1000 feet. The drains in most cases should be placed in the direction of the prevailing slope. The depths may range upto 6' but more generally between 3 to 4 feet in humid area. For general crops, spacings in soil moderately slow to moderately rapid permeability range usually from 200 to 600 feet; special crops require closer spacings.

TABLE 12

Range of dimensions of field ditches for water table control 1/

Soil	Depth	Bottom width	Side slopes	Spacing
1	2	3	4	5
	Feet	Feet		Feet
Sand	2-4	3-4	1:1	200-500
Silt loams except sand.	2.5-4.0	1-3	½:1 to 2:1	100-300
Stable clay & loams.	2.5-5.0	1-3	½:1 to 1½:1	100-300
Organic soils ...	2-5.2	1-3	Vertical to 2:1	60-300

1/ For general field crops only.

2/ Minimum 6-inch cushion of organic soil should remain in the bottom of the trench when organic soils overlay impervious material such as clay.

(SOURCE: *Drainage*, National Engineering Handbook Section 16, U. S. D. A., Soil Conservation Service).

Mechanical or vegetative protection should be provided where surface water enters the open ditch.

Special quality concrete drain tile are for land drainage of soils that are more acidic or contain higher quantities of sulphates. These are to be manufactured on special orders to meet the requirements, and specifications of the user based on site conditions.

TABLE 13

Guide for use of concrete tile in acid sulphates soils

ACID SOILS

Class of tile ASTM C412-58 T 1/	Lower permissible limits of pH values 2/	
	Organic and sandy soils 2	Medium and heavy textured soils 3
Standard quality ...	6.5	6.0
Extra quality ...	6.0	5.5
Special quality ...	3/ 5.5	5.0

SULPHATE SOILS

Permissible maximum limit of sulphates (Na or Ng) singly or in combination 4/	ASTM of tile and cement 5/	
	1	2
(Parts per million)		
7,000 ...	Special quality, type V or type II cement 6/	
3,000 ...	Extra quality, type V or type II cement 6/	
1,000 ...	Standard quality, any type cement.	

(1) Where manufacturer or seller desires to furnish tile of a class which fails to quality under limits shown in this table, he will be required to furnish proof that tile recommended will give satisfactory service life.

(2) Figures given represent lowest readings of pH values for soil water or soil at tile depth. Values to be confirmed by additional tests where desirable.

(3) Obtain high strength, low absorption tile where available. See Minn. Agr. Expt. Sta., Bul. 426, Making Durable Concrete Drintile, P. W. Manson and D. G. Miller.

(4) Highest reading of sulphates for soil or soil water at tile depth. Values to be confirmed by additional tests where desirable.

(5) ASTM specifications C412-58T and C150-55. Where manufacturer or seller desires to furnish tile or cement of a class which fails to qualify under limits shown in this table he will be required to furnish proof that tile recommended will give satisfactory service life.

(6) Type II cement to be of high sulphate resistance. The calculate tricalcium aluminate C_3A compound of the cement should be less than 5.5 per cent.

(Source:—*Drainage National Engineering Handbook* Section 16 U. S. D. A. Soil Conservation Service.)

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Design alignments

The basic principles in obtaining good alignment are to lay long, straight laterals and reduce curves to the minimum. Changes in horizontal direction should be made so that the specified grade is maintained, the flow of water is not impeded by excessive roughness, and the joint spacing on the outside of the curve is in accordance with the recommendations for tile placement.

A change in horizontal direction may be made by one of the following methods:—

(1) By using manufactured fittings, such as T—, Y-bends, etc.

(2) By using junction Boxes or Manholes.

(3) By using a gradual curve of the tile trench that the trenching machine can dig and maintain grade.

(4) By shaping the inner side of the curve and chipping the tile. Broken pieces of tile should be used to cover openings that occur.

If connections are not available at the junction, chip and carefully fit the pipes and seal with stiff mortar cement.

Filter materials and installation.—The filter material is placed around the tile to prevent sediment entry into the tile-line, and at the same time allow water entry more freely. In most of the humid areas top-soil or permeable material from the sides of the trench is placed around the tile, which serves the only filter material. Joints are covered with tarimpregnated roofing paper, glass-fiber-filter, plastic guards, burlap etc.

Joint covering is usually laid around the upper two-thirds of the tile to prevent sediment entry in tile lines. The most effective filter material is well graded gravel material. The design of gravel filter mixes are described below. Materials such as hay, straw, sawdust, wood chips, and corn-cobs are used on many installations. These are generally effective but for an indeterminate period. Observations of systems installed in organic soil, indicated that straw remained effective 6 to 11 years, wood chips were only slightly decayed after 9 years in the ground. Availability of filter material, its cost, and local experience usually determine the type of filter material that can be used successfully.

Gravel filters of pit run or graded material are extensively used in tile installations in the arid regions. They have been used in the humid areas also, where site conditions warranted the added cost.

The filter material should be more pervious than the base soil, so that hydraulic pressure will not build up. The voids between the filter particles must be small enough to prevent soil particles from entering the tile through the fil-

ter material. Clogging of the filter or excessive settlement due to soil movement may occur if the voids in the filter material are too large. The minimum thickness of filter material placed ground the tile should be 3 inches.

Construction

Setting Grade Stakes and Targets.—If the target method is used, grade stakes should be set at 100-foot intervals or less. Always have at least three targets set to avoid errors. Grade-stake lines usually are offset from 2 to 4 feet from the centerline of the tile out of the way of construction.

Grade stakes should be set every 50 feet if tilling is to be done from a string line. If string is used, a weight should be tied to each end and hung over the support so that the string is tight at all times.

Excavating Trench.—Digging of the trench should start at the outlet end proceed upgrade. The alignment of the trench should be such that the tile can be laid in straight lines or smooth curves. The trench width measured at the top of the tile should be about equal to the outside diameter of the tile, plus about 0.5 foot. This clearance between the tile and the sides of the trench is necessary for proper bedding and blinding of the tile. It is very important that the bottom of the trench be cut accurately to grade and shape. If the trench is cut below grade at any place, it should be backfilled with either graded gravel or well pulverised soil and tamped sufficiently to provide a firm foundation. The bottom of the trench is then recut to grade and shape.

Bed of tile

The bottom of the trench should be rounded so that the tile will be embedded in undisturbed soil for at least 60° of its circumference. Tile trenching machines shape the bottom of the trench as a part of trenching operations.

Laying tile

(1) *Joint spacing.*—Laying the tile should begin at the lower end of the line and progress upgrade. If a tile does not aline properly against the one previously laid, turn it until it fits correctly. The spacing between tile should be varied according to soil conditions. Silt and sandy soils require a tight fit. The gap should be about 1/8-inch for loam soils. The minimum for clay is 1/8-inch; however, local experience may indicate a wider spacing on some heavy soils. Peat and muck soils require 1/4 to 3/8-inch spacing. Where large gaps occur between tile, as on the outer side of a curve, cover the joints by broken tile or by another similar device.

When gravel filters are to be used, allow additional depth in the trench. Place filter material in the bottom of the trench, place the tile, and place the filter around the tile.

(2) *Sand.*—Special construction methods should be used when tile are laid through unstable pockets of soil such as saturated fine sand. Depending on the seriousness of the Condition place stable soil, coarse hay or straw, tough sod, crushed limestone or gravel in the bottom of the trench before laying the tile, or use a board cradle. Where cradling is done, use the rail and cleat method. In this method short boards (cleats) are nailed across a longer board (rail) to provide a greater bearing area when the board is used as a cradle.

Chapter IV

SALINE ALKALI SOILS

The diagnosis and treatment of saline and alkali soils is a problem in soil chemistry, but because it is so frequently associated with areas needing drainage, especially in the arid and semi-arid regions, it is necessary for the drainage engineer to become familiar with Diagnosis. A brief description on the subject follows:

These soils are grouped into 3 groups:—

✓ (1) *Saline soils*.—Soils for which the conductivity of the saturation extract is more than 4 mmhos/cm. at 25°C and the exchangeable-sodium percentage is less than 15; ordinarily the pH is less than 8.5. When adequate drainage is established, the excess soluble salts may be removed by leaching and they again become normal-soils.

|| (2) Saline soils are often recognised by the presence of white crusts of salts on the surface. Soil salinity may occur in soils having distinctly developed profile characteristics or in indifferiated soil material such as alluvium. The chemical characteristics of soils classed as saline are mainly determined by the kinds and amounts of salts present. The amount of soluble salts present controls the osmotic pressure of the soil solution. Sodium seldom comprises more than half of the soluble cations and hence is not absorbed to any significant extent. The chief anions are chlorides, sulphates and some times nitrates. Small amounts of bicarbonates may occur, but soluble carbonates are almost invariably absent. In addition to the readily soluble salts, saline soils may contain salts of low solubility, such as calcium sulphates (Gypsum) and calcium and magnesium carbonates (lime).

Owing to the presence of excess salts and the absence of significant amounts of exchangeable sodium, saline soils are generally flocculated; and as a consequence, the permeability is equal to or higher than that of similar non-saline soils.

② *Saline alkali soils*.—The conductivity of the saturation extract of the saline alkali soils is greater than 4 mmhos/cm. at 25°C. and the exchangeable sodium percentage is greater than 15. These soils form as a result of the combined processes of salinization and alkalisation. As long as excess salts are present, the appearance and properties of these soils are generally similar to those of saline soils. Under conditions of excess salts, the pH readings are seldom higher than 8.5 and the particles remain flocculated. If the excess soluble salts are leached downward, the properties of these soils may change markedly and become similar to those of non-saline alkali soils. As the concentration of the salts in the soil solution is lower some of the exchangeable sodium hydrolyzes and forms sodium hydroxide. This may change to sodium carbonate upon reaction with carbon-dioxide absorbed from

the atmosphere. In any event, upon leaching, the soil may become strongly alkaline (pH reading above 8.5), the particles disperse, and the soil becomes unfavourable for the entry and movement of water and for tillage. The management of Saline-Alkali-Soils present a great problem until the excess salts and exchangeable sodium are removed from the root zone and a favourable physical condition of the soil is re-established.

③ *Non-Saline-Alkali-Soils*.—With these soils the exchangeable sodium percentage is more than 15 and the conductivity of the saturation extract is less than 4 mmhos/cm at 25°C. The pH readings usually range between 8.5 to 10. These soils, are called Black-Alkali due to appearance on surface, as against White-Alkali—associated with white incrustation of sulphates in saline soils. They (Black-Alkali) frequently, occur in semiarid and arid regions, in small irregular areas which are often referred to as "Slick-spots". Except when gypsum is present in the soil or the irrigation water, the drainage and leaching of non-saline alkali soils leads to the formation of excess salts in such soils tends to increase a rise in pH of the soil. Dispersed and dissolved organic matter present in the soil solution of highly alkaline soils may be deposited on the soil surface, by evaporation, thus causing darkening and giving rise to the term "Black Alkali". If allowed sufficient time—non-saline-alkali soils develop characteristics morphological features. Because partially sodium saturated clay is highly dispersed, it may be transported downwards through the soil and accumulate in lower levels. As a result, a few inches of the surface soil may be relatively coarse in texture and friable; but below, where the clay accumulates, the soil may develop a dense layer of low permeability that may have a columnar or prismatic structure. Commonly, however, alkali conditions develop in such soils as a result of irrigation. In such cases sufficient time usually has not elapsed for the development of the typical columnar structure, but the soil has low permeability and is very difficult to till. The exchangeable sodium present in non-saline alkali soils may have a marked influence on the physical and chemical properties. As the proportion of exchangeable sodium increases, the soil tends to become more dispersed. The pH reading may increase, sometimes to 10. At the high pH and in the presence of carbonate ions, calcium and magnesium are precipitated; hence the soil solution of non-saline alkali soils usually contain only a small amounts of these cations, sodium being the predominant one.

Drainage of saline soils

Saline soils can usually be improved through leaching as the soluble salts Present will go into solution and be removed with the drain water.

In arid and semi-arid regions, it is usually necessary to supply irrigation to accomplish this leaching. The reclamation of saline soils can usually be achieved through some type of leaching without the addition of chemical amendments. Adequate sub-surface drainage is, of course, a prerequisite.

Drainage of non-saline soils

The treatment of these soils is different from that for saline soils, as it may be impossible to leach the soil until after certain chemical amendments are added. Through alkalisation soil undergoes certain textural changes. These soils tend to destroy original soil texture and leave the soil as deflocculated mass. Alkali soils have the consistency of tar or heavy machine grease, which is smooth and without texture. Spots of alkali soils in fields are called 'Slick-spots', meaning that they are denude of vegetation and are textureless. As the alkalisation progresses, the soil becomes less and less permeable. Strongly alkaline soils become virtually impermeable, and impracticable to drain under most conditions.

It is highly important that non-saline alkali soils be recognised as such before attempting to establish surface drainage, because these soils have lost some of their internal drainage characteristics and may not drain properly, regardless of the type of the drainage system installed. Where it is economically feasible to reclaim

these soils, chemical and agronomical treatments may be necessary to flocculate the soil particles and restore the soil permeability before leaching and drainage. Some of the chemical amendments commonly used are calcium chloride, gypsum (calcium sulfate), sulphur, and sulphuric acid.

Drainage of saline-alkali soils

The treatment of saline-alkali soils is much the same as for non-saline-alkali soils. Certain chemical amendments may be required, based on laboratory analysis of soil samples. In so far as the field technician is concerned, the difficult problem with saline-alkali soils is their identification as they may exhibit characteristics of both saline and non-saline-alkali soils. As pointed out in the definition of saline-alkali soils, they may be flocculated due to the presence of excess salts and may have a permeability equal to or higher than non-saline soils. This is often misleading and may give the impression that soils can be reclaimed through simple leaching. Actually this may not be the case because leaching will remove the soluble salts, thereby causing the soils to become strongly alkaline and the permeability will be materially reduced.

For this purpose it is absolutely essential to get soil samples chemically analysed before drafting a drainage plan for any area.

APPENDIX

Statistics for ill-drained soils acreage in Sholapur District

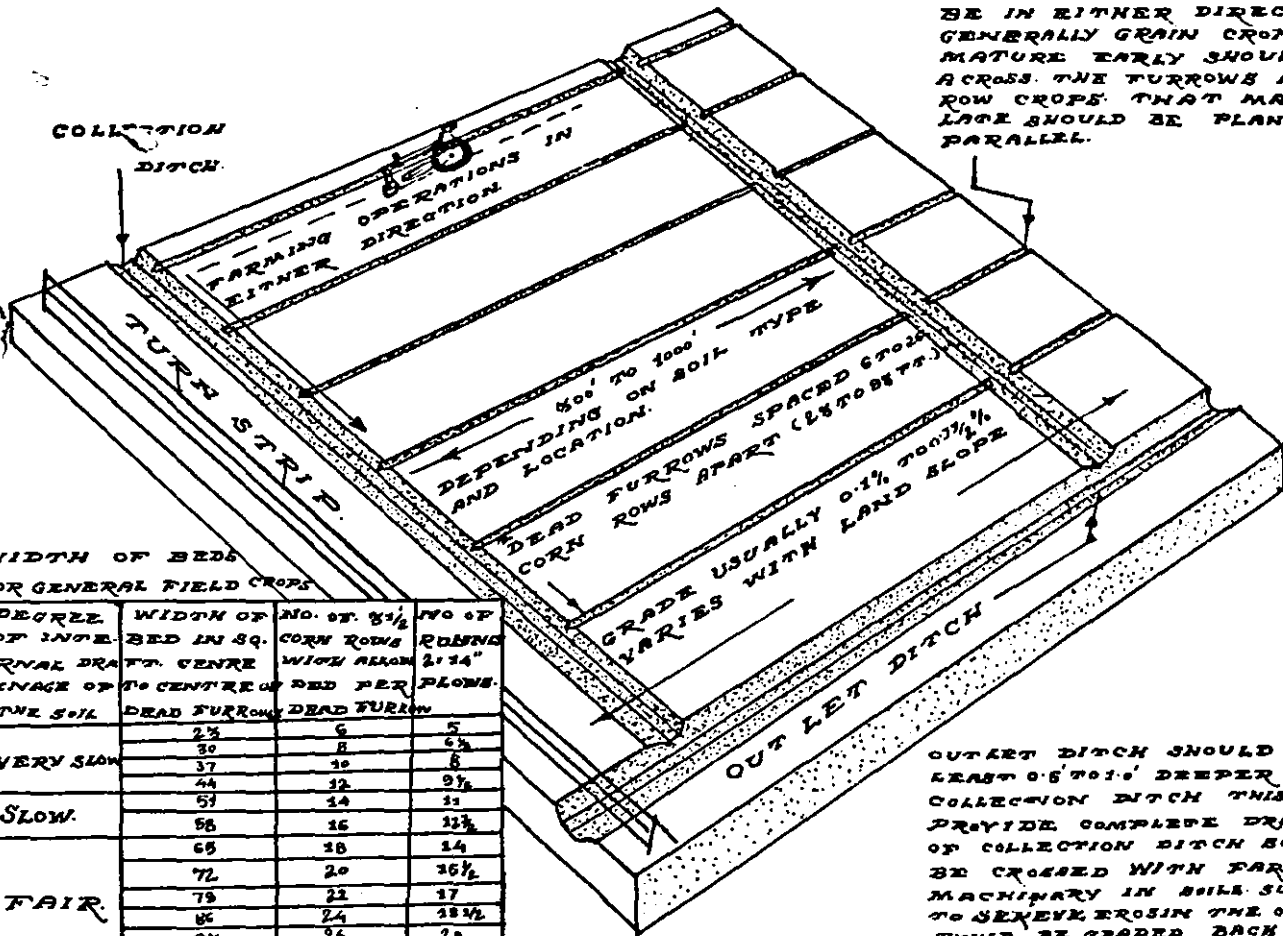
Sr. No	Name of taluka	Area in acres	Remarks
1	Sholapur South	2,081—19	
2	Sholapur North	1,471—01	
3	Barsi	4,397—00	
4	Akalkot	1,878—23	
5	Mohol	7,565—13	
Total		17,393—16	
6	Pandharpur		Information concerning to these talukas is not received from Pandharpur Division.
7	Malsiras		
8	Mangalwedha		
9	Sangola		
10	Karmala		
11	Madha		

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SURFACE DRAINAGE BEDDING SYSTEM.....

THE FURROWS DRAIN TO COLLECTION DITCHES PLANTING SEEDING AND CULTIVATING CAN BE IN EITHER DIRECTION GENERALLY GRAIN CROPS THAT MATURE EARLY SHOULD BE WORKED ACROSS THE FURROWS AND WORKED ROW CROPS THAT MATURE LATE SHOULD BE PLANTED PARALLEL.

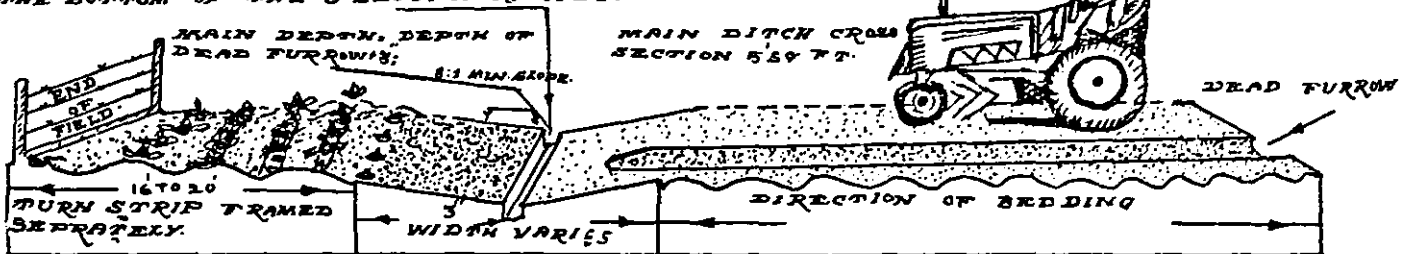


WIDTH OF BEDS FOR GENERAL FIELD CROPS

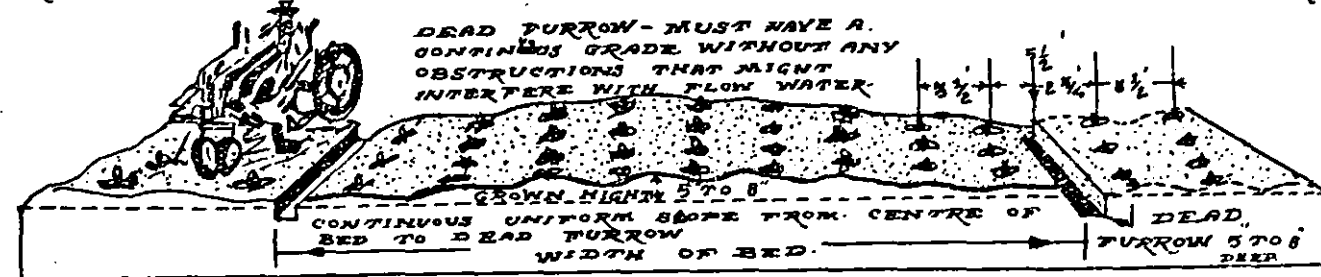
DEGREE OF INFLUENCE OF RAIN DRAINFAGE OF THE SOIL	WIDTH OF BED IN SQ. FT. CENTRE OF DEAD FURROW	NO. OF 3 1/2" CORN ROWS WHICH ALLOW 2 1/4" WICH PER FURROW	NO. OF ROWS PER FURROW
VERY SLOW	25	5	5
	30	6	6 1/2
	37	8	8
SLOW	44	10	9 1/2
	51	12	11
	58	14	12 1/2
FAIR	65	16	14
	72	18	16 1/2
	79	20	17
	85	22	18 1/2
	98	24	20

OUTLET DITCH SHOULD BE AT LEAST 0.5 TO 1.0' DEEPER THAN COLLECTION DITCH THIS WILL PROVIDE COMPLETE DRAINAGE OF COLLECTION DITCH SO IT CAN BE CROSSED WITH FARM MACHINERY IN SOIL SUBJECT TO SEVERE EROSION THE OVERALL SHOULD BE GRADED BACK ON A NON EROSION GRADE.

THE U SHAPED SECTION IN THE BOTTOM OF THE DITCH IS OPTIONAL IT PERMITS MAIN PART OF DITCH TO DRY QUICKLY SO THAT TRACTORS CAN PASS OVER EVEN THOUGH THE BOTTOM OF THE U SECTION IS WET.



CROSS SECTION AT END OF FIELD SHOWING COLLECTION DITCH AND TURN STRIP

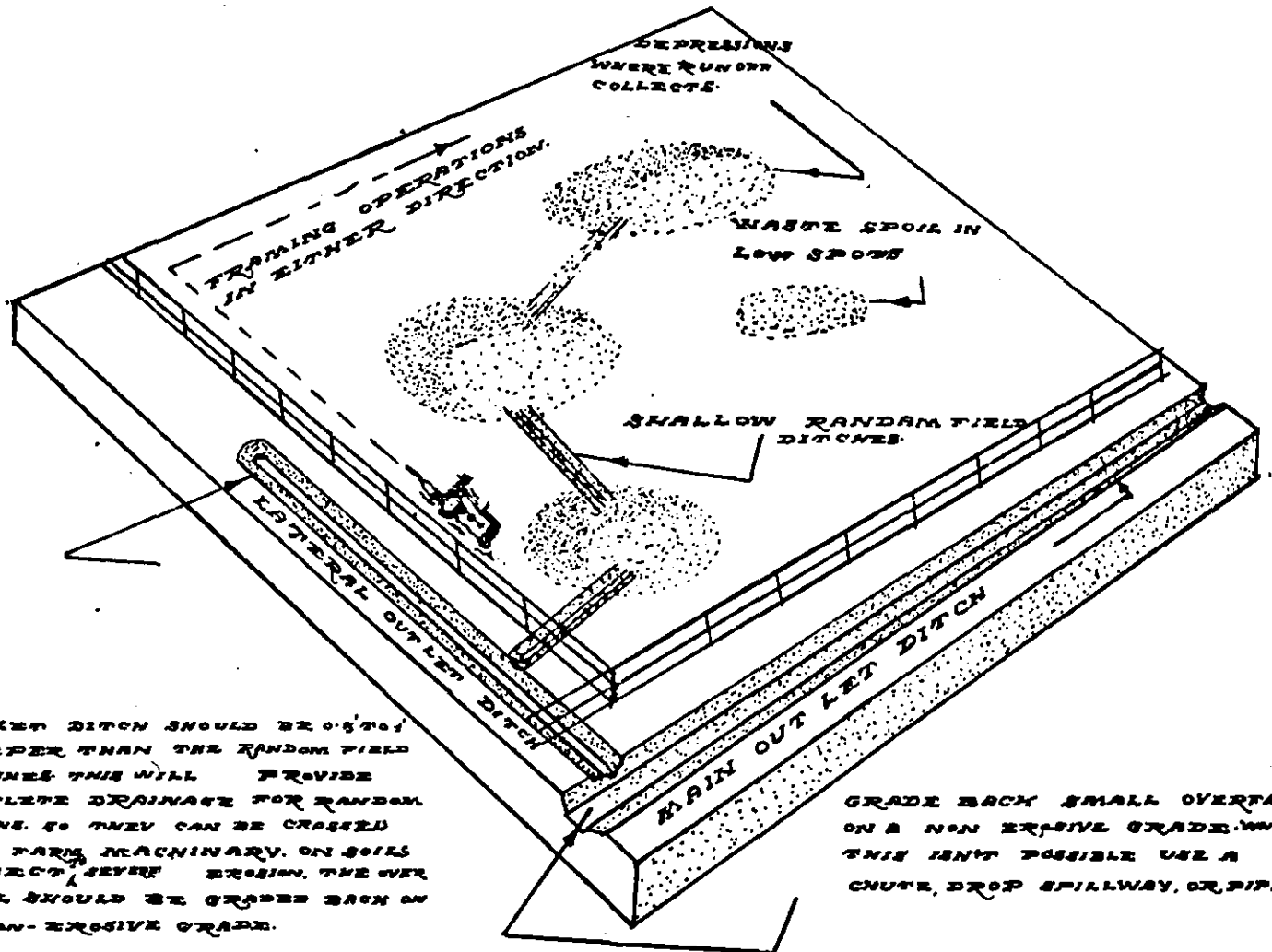


CROSS SECTION OF BED SHOWING CROWN EFFECT AND PROPER SPACING OF CORN ROWS.

COURTESY: AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

RANDOM DITCH SYSTEM OF SURFACE DRAINAGE

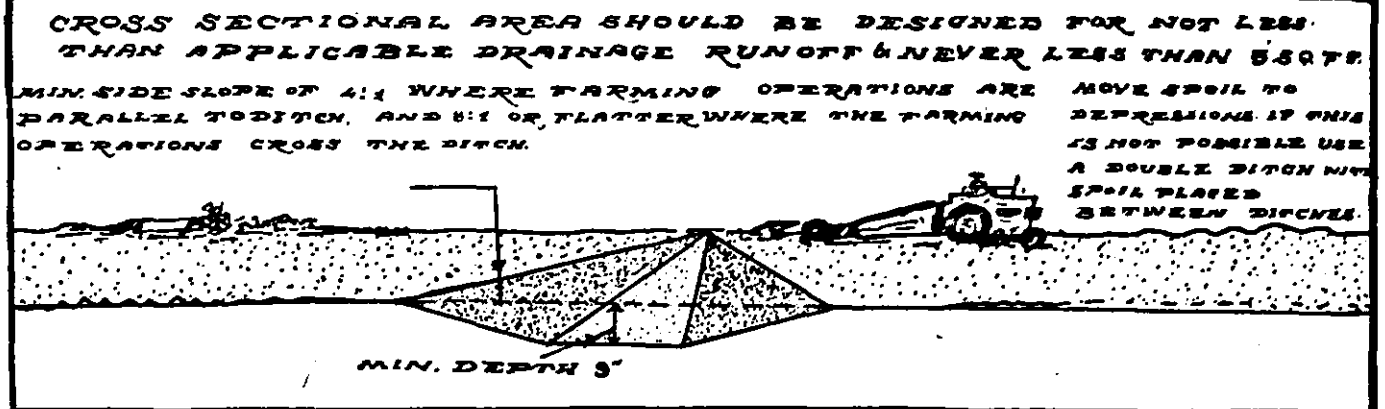
REMOVE MINOR DEPRESSIONS BY LAND SMOOTHING WITH LAND PLANE OR LEVELER SMOOTH AREA SO LAND WILL DRAIN TO THE LARGE DEPRESSIONS OR RANDOM DITCHES.



OUTLET DITCH SHOULD BE 0.5 TO 1 DEEPER THAN THE RANDOM FIELD DITCHES THIS WILL PROVIDE COMPLETE DRAINAGE FOR RANDOM DITCHES SO THEY CAN BE CROSSED WITH FARM MACHINERY. ON SOILS SUBJECT TO SEVERE EROSION THE OVERFALL SHOULD BE GRADED BACK ON A NON-EROSIVE GRADE.

GRADE BACK SMALL OVERTALLS ON A NON-EROSIVE GRADE. WHERE THIS IS NOT POSSIBLE USE A CHUTE, DROP SPILLWAY, OR PIPE.

CROSS SECTION OF RANDOM DITCH



COURTESY: AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

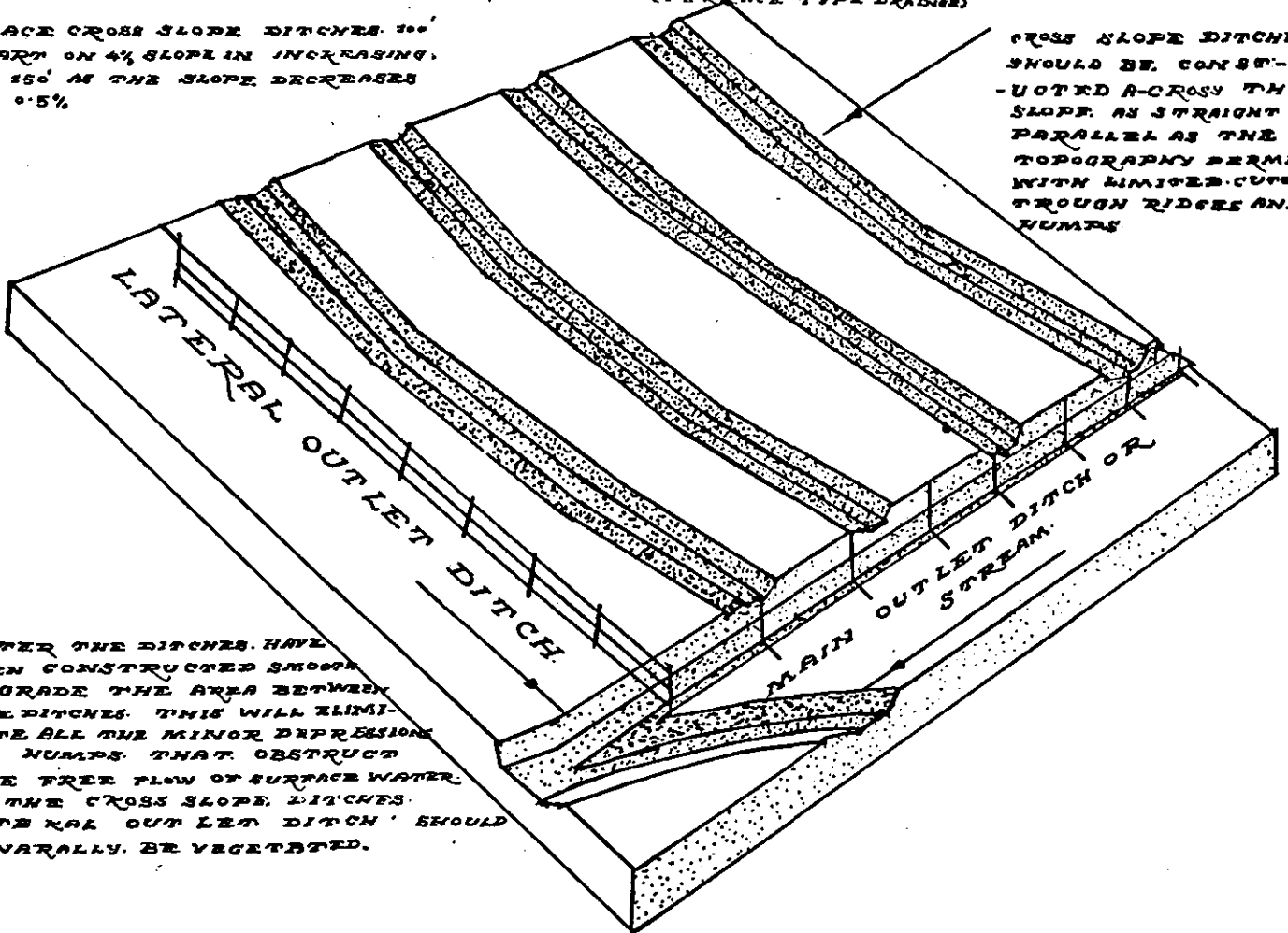
FIG. 2

CROSS SLOPE DITCH SYSTEM OF SURFACE DRAINAGE

(REFER TYPE DRAWING)

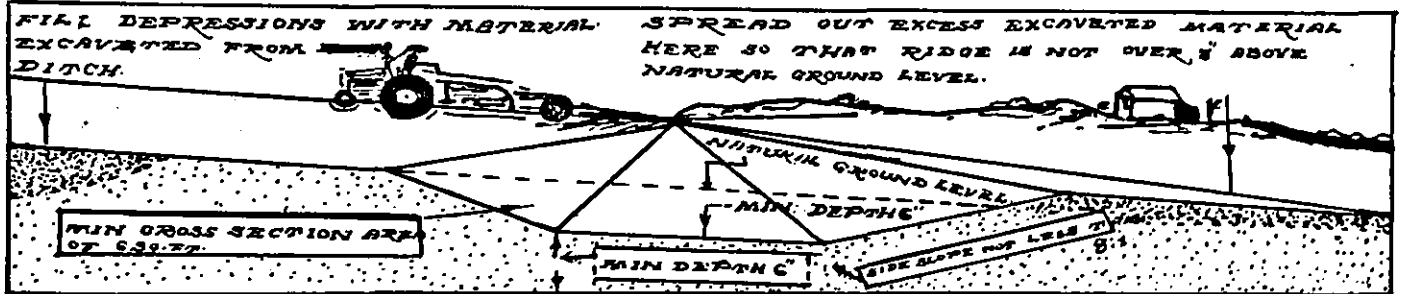
SPACE CROSS SLOPE DITCHES 100' APART ON 4% SLOPE IN INCREASING TO 150' AS THE SLOPE DECREASES TO 0.5%.

CROSS SLOPE DITCHES SHOULD BE CONSTRUCTED ACROSS THE SLOPE AS STRAIGHT & PARALLEL AS THE TOPOGRAPHY PERMITS WITH LIMITED CURVING THROUGH RIDGES AND HUMPS.

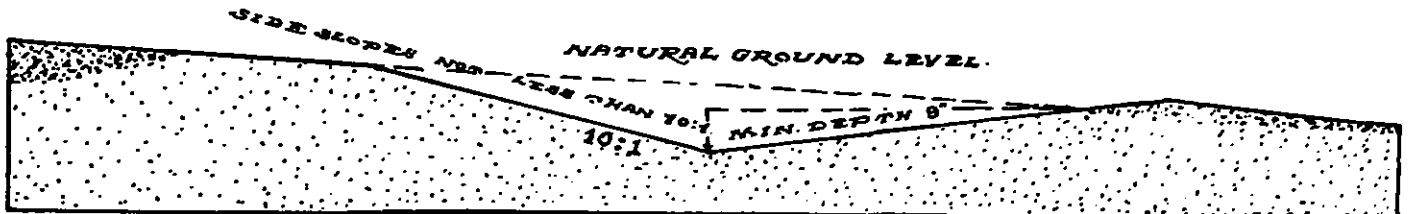


AFTER THE DITCHES HAVE BEEN CONSTRUCTED SMOOTH OR GRADE THE AREA BETWEEN THE DITCHES. THIS WILL ELIMINATE ALL THE MINOR DEPRESSIONS AND HUMPS THAT OBSTRUCT THE FREE FLOW OF SURFACE WATER TO THE CROSS SLOPE DITCHES. LATERAL OUTLET DITCH SHOULD GENERALLY BE VEGETATED.

TYPICAL FLAT BOTTOM SECTION



TYPICAL V-CANNEL SECTION

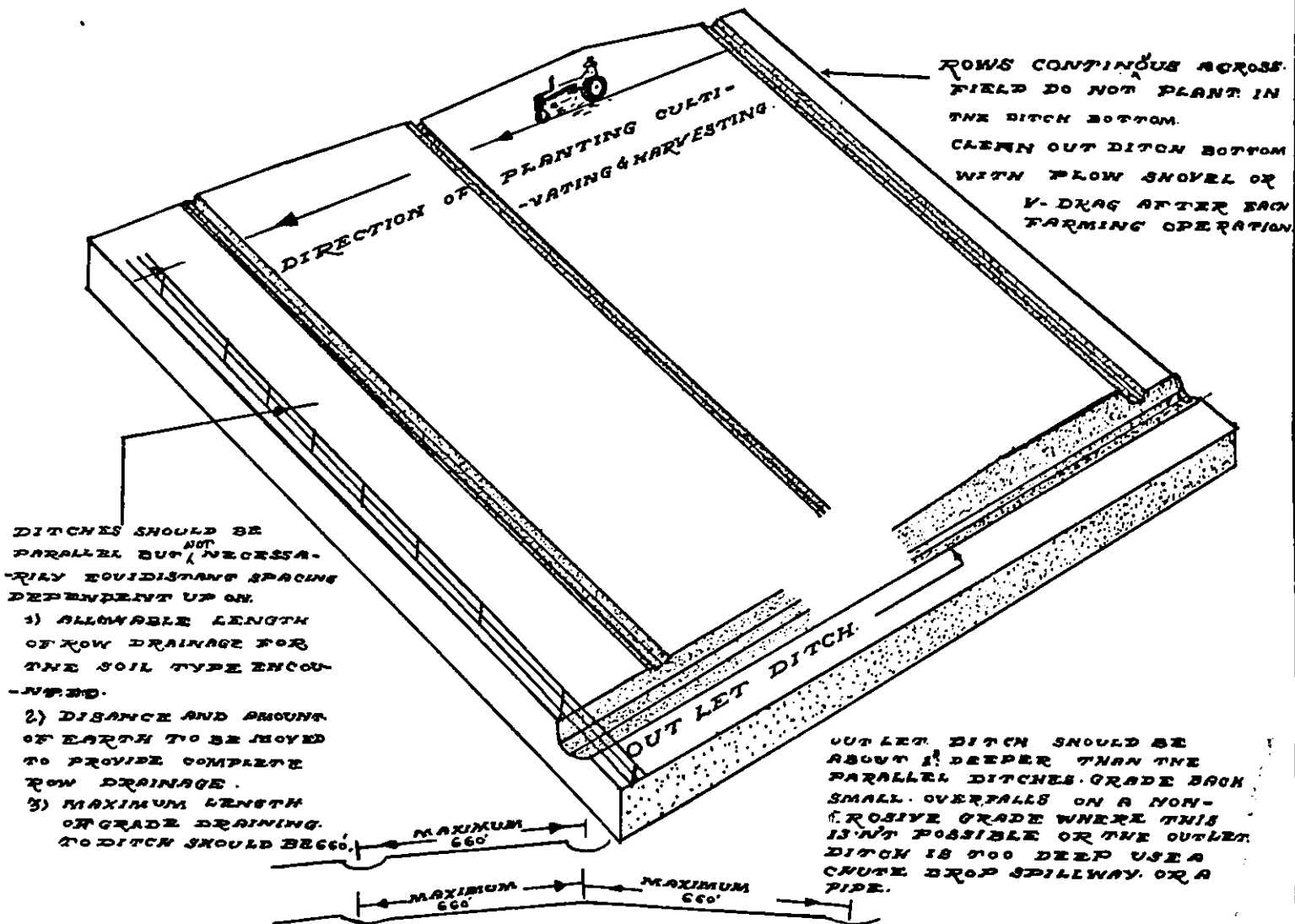


COURTESY: AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

FIG. 3

PARALLEL DITCH SYSTEM OF SURFACE DRAINAGE

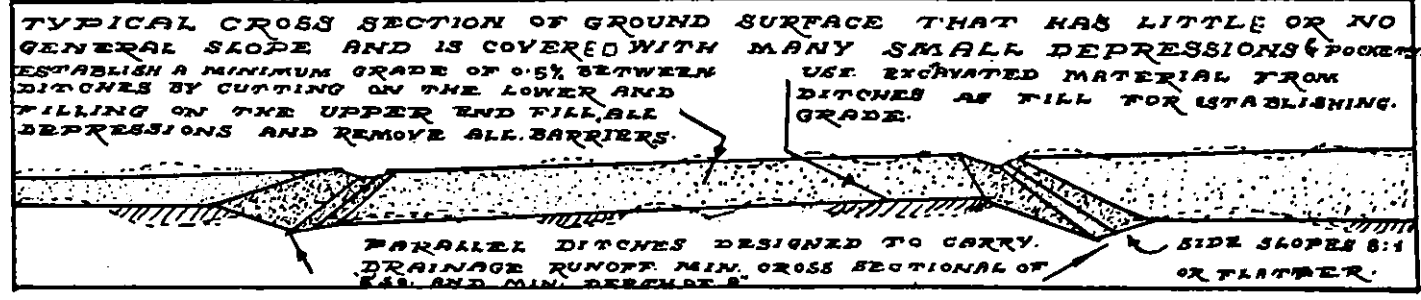
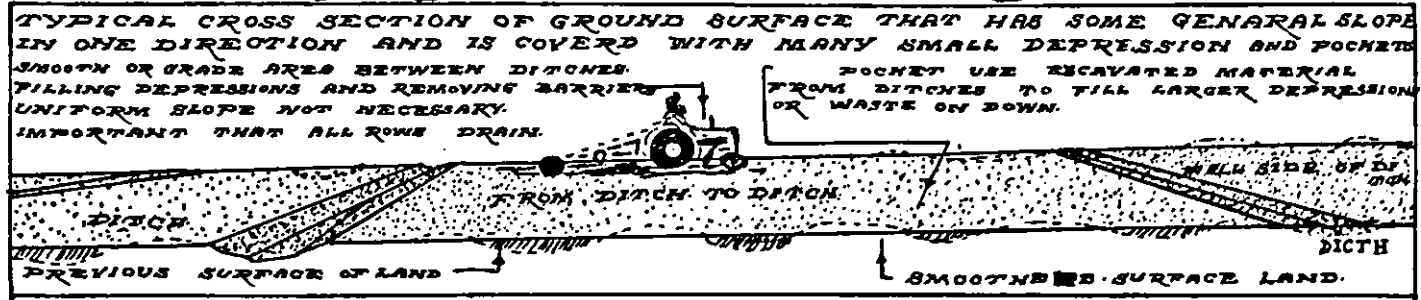
PARALLEL DITCHES TO INTERCEPT AND RAPIDLY REMOVE SURFACE WATER FROM THE FIELD AND REDUCE THE LENGTH OF ROW DRAINAGE.



DITCHES SHOULD BE PARALLEL BUT NOT NECESSARILY EQUIDISTANT SPACING DEPENDENT UP ON:

- 1) ALLOWABLE LENGTH OF ROW DRAINAGE FOR THE SOIL TYPE ENCOUNTERED.
- 2) DISTANCE AND AMOUNT OF EARTH TO BE MOVED TO PROVIDE COMPLETE ROW DRAINAGE.
- 3) MAXIMUM LENGTH OF GRADE DRAINING TO DITCH SHOULD BE 660'.

OUTLET DITCH SHOULD BE ABOUT 1' DEEPER THAN THE PARALLEL DITCHES. GRADE BACK SMALL OVERTALLS ON A NON-EROSIVE GRADE WHERE THIS IS NOT POSSIBLE OR THE OUTLET DITCH IS TOO DEEP USE A CHUTE DROP SPILLWAY OR A PIPE.



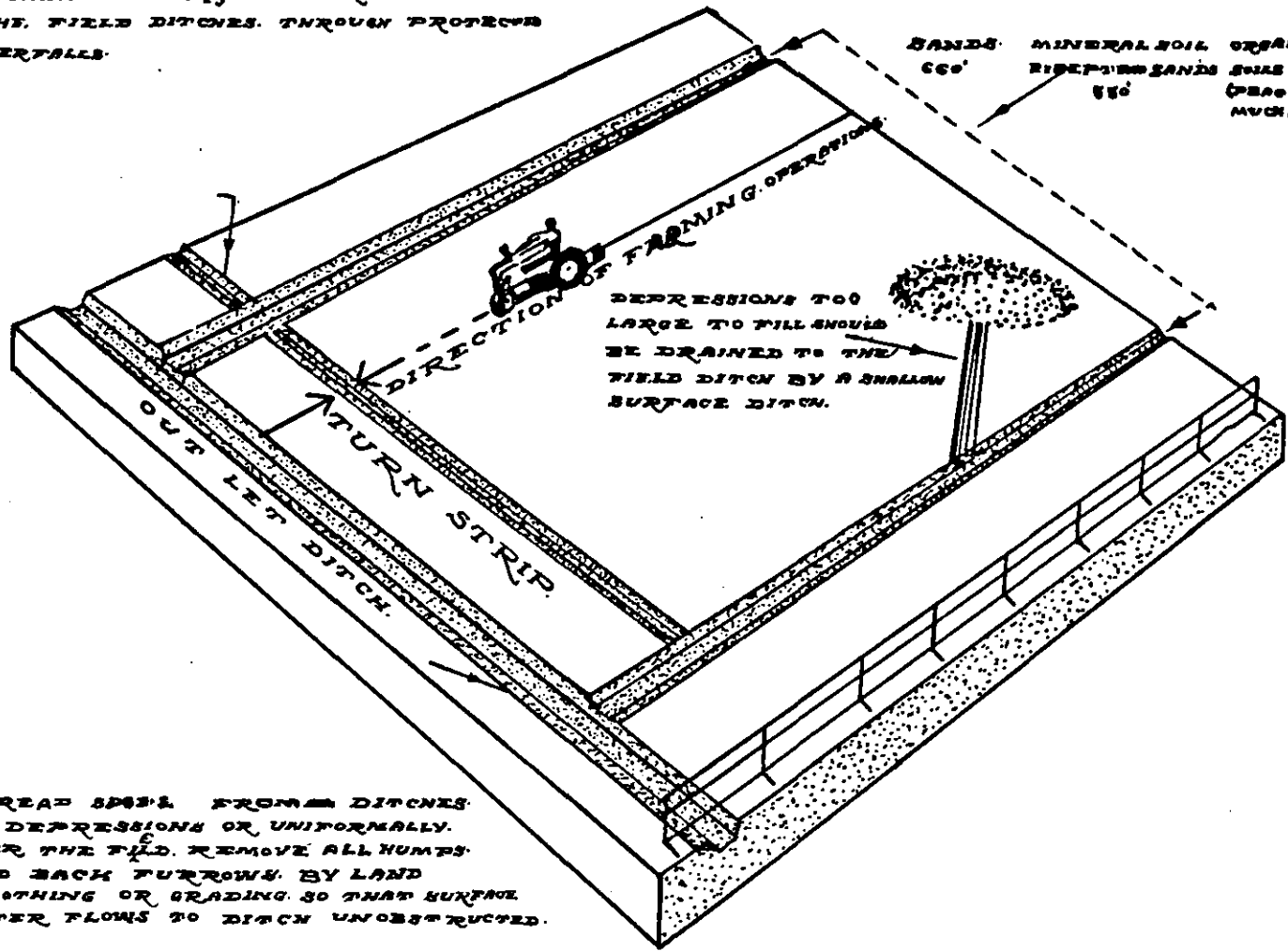
COURTESY: AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

FIG. 4

FIELD DITCH SYSTEM FOR WATER TABLE CONTROL AND SURFACE WATER REMOVAL

CROP ROWS DEAD FURROWS AND FLOW FURROWS SHOULD BE INTERCEPTED BY SHALLOW DITCHES AND DIRECTED IN TO THE FIELD DITCHES THROUGH PROTECTED OVERTALLS.

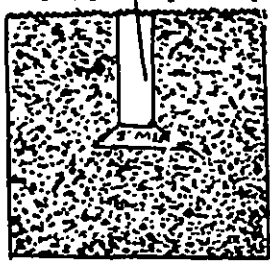
MAXIMUM SPACING OF PARALLEL FIELD DITCHES



SPREAD SPILL FROM DITCHES IN DEPRESSIONS OR UNIFORMLY OVER THE FIELD. REMOVE ALL HUMPS AND BACK FURROWS BY LAND SMOOTHING OR GRADING SO THAT SURFACE WATER FLOWS TO DITCH UNOBSTRUCTED.

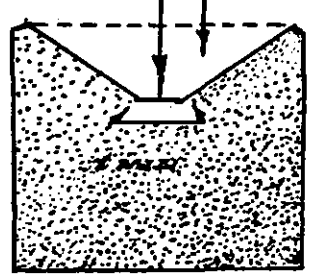
TYPICAL MINIMUM DITCH CROSS SECTION

MIN. SLOPE VERTICAL FOR RAW PEAT AND 3:1 FOR DECOMPOSED PEAT AND MUCK. MIN. D. 2'-6"



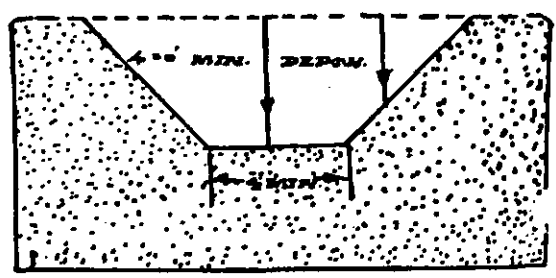
ORGANIC SOILS (PEAT & MUCK)

MIN. SLOPE OF 1 1/2:1 2'-6" MIN. DEPTH.



MINERAL SOILS EXCEPT SANDS

MIN. SLOPE OF 1:1 4'-0" MIN. DEPTH.



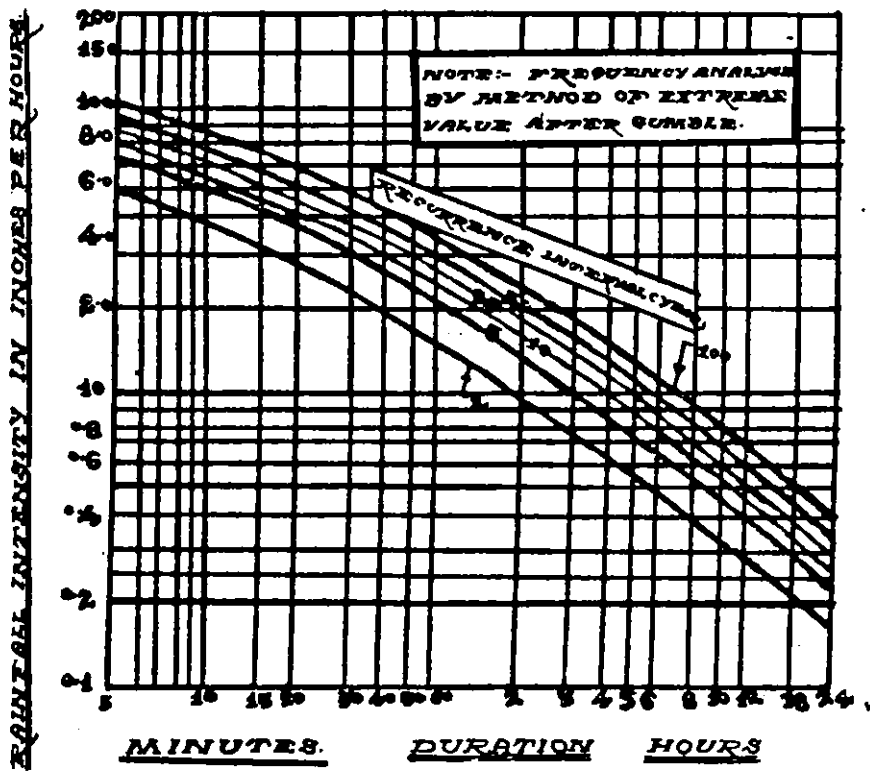
SANDS

COURTESY: AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

TYPICAL RAINFALL INTENSITY

DURATION RECURRENCE INTERVAL

RELATIONSHIP



FARM- U.S. DEPARTMENT OF COMMERCE

FIG. 6

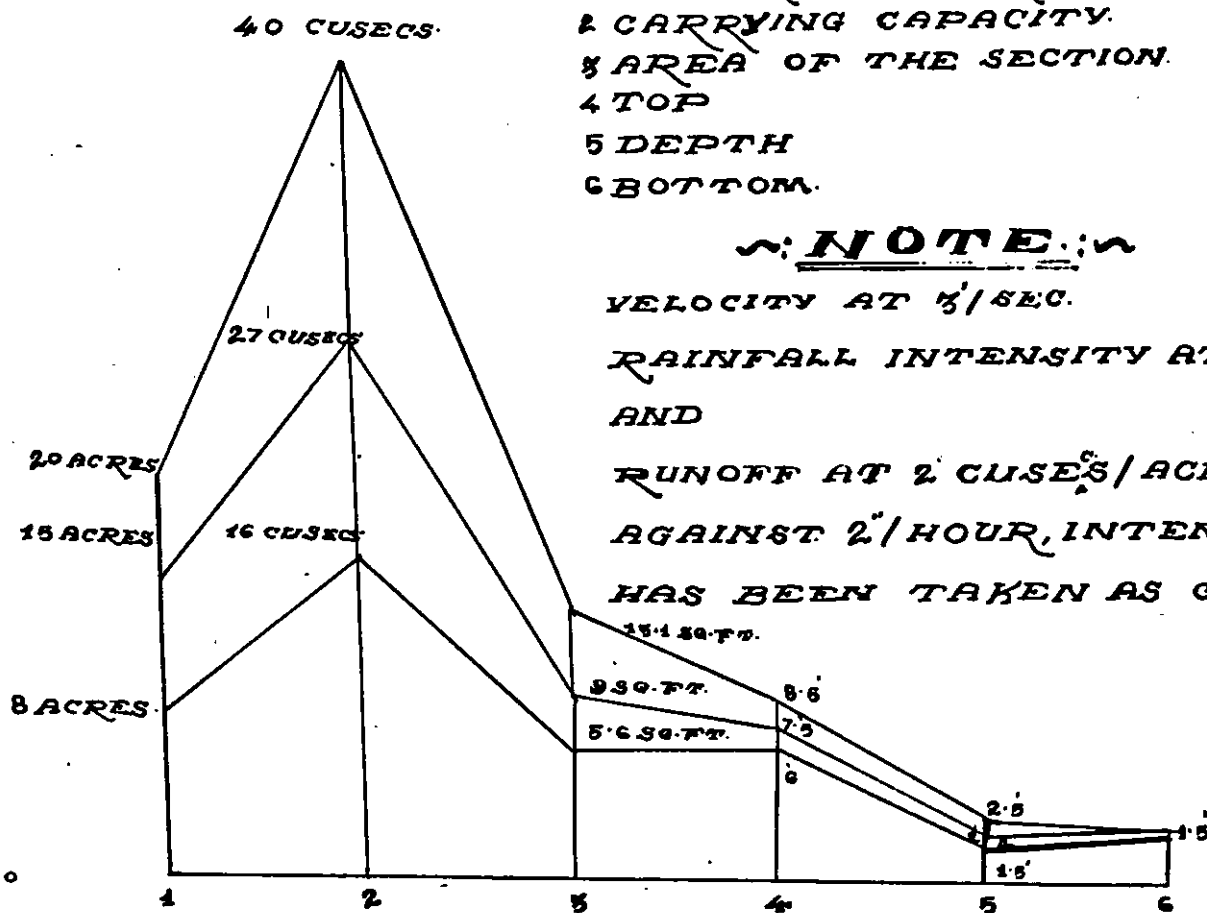
A GRAPH SHOWING SPECIFICATIONS LATERAL DRAINS

NOT TO SCALE

- 1 WATER SHED AREA.
- 2 CARRYING CAPACITY.
- 3 AREA OF THE SECTION.
- 4 TOP
- 5 DEPTH
- 6 BOTTOM.

NOTE

VELOCITY AT 1/3 SEC.
 RAINFALL INTENSITY AT 2" / HOUR
 AND
 RUNOFF AT 2 CUSECS / ACRE
 AGAINST 2" / HOUR INTENSITY.
 HAS BEEN TAKEN AS CONSTANT



WATER SHED	CARRYING AREA OF	TOP	DEPTH	BOTTOM
AREA IN ACRES	CAPACITY	THE SECTION.	IN FT.	IN FT.
	IN CUSECS	IN SQ. FT.		

FIG. 7

GRAPH SHOWING
SPECIFICATION OF
DRAINS FOR TROPICAL
SECTION FOR
DIVERSION DITCHES

NOT TO SCALE

- 1 WATERSHED AREA
- 2 CARRYING CAPACITY
- 3 AREA OF THE SECTION
- 4 TOP
- 5 DEPTH
- 6 BOTTOM

NOTE :-

VELOCITY AT 3'/SEC.
RAINFALL INTENSITY AT 2"/HOUR,
AND
THE RUNOFF AT 2 CUSECS/ACRE
AGAINST 2"/HOUR, INTENSITY HAS
BEEN TAKEN AS CONSTANT.

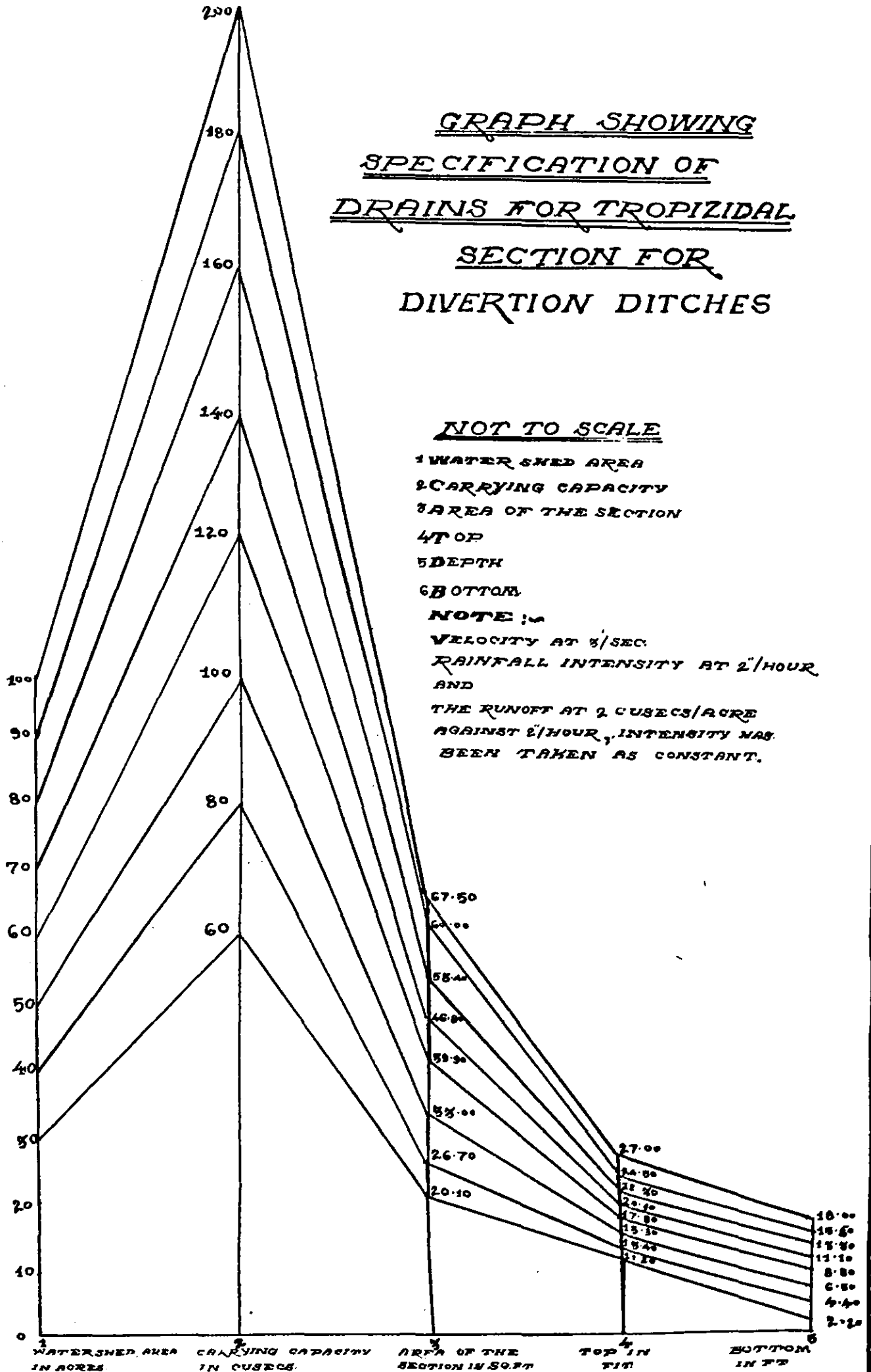
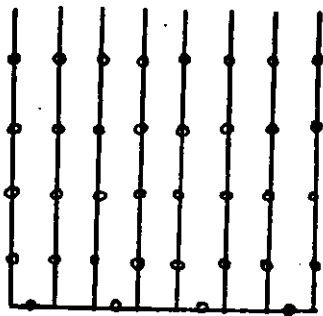
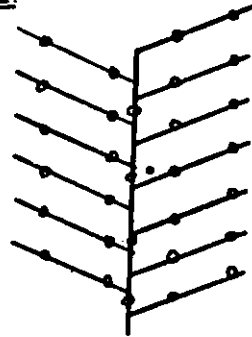


FIG. 6

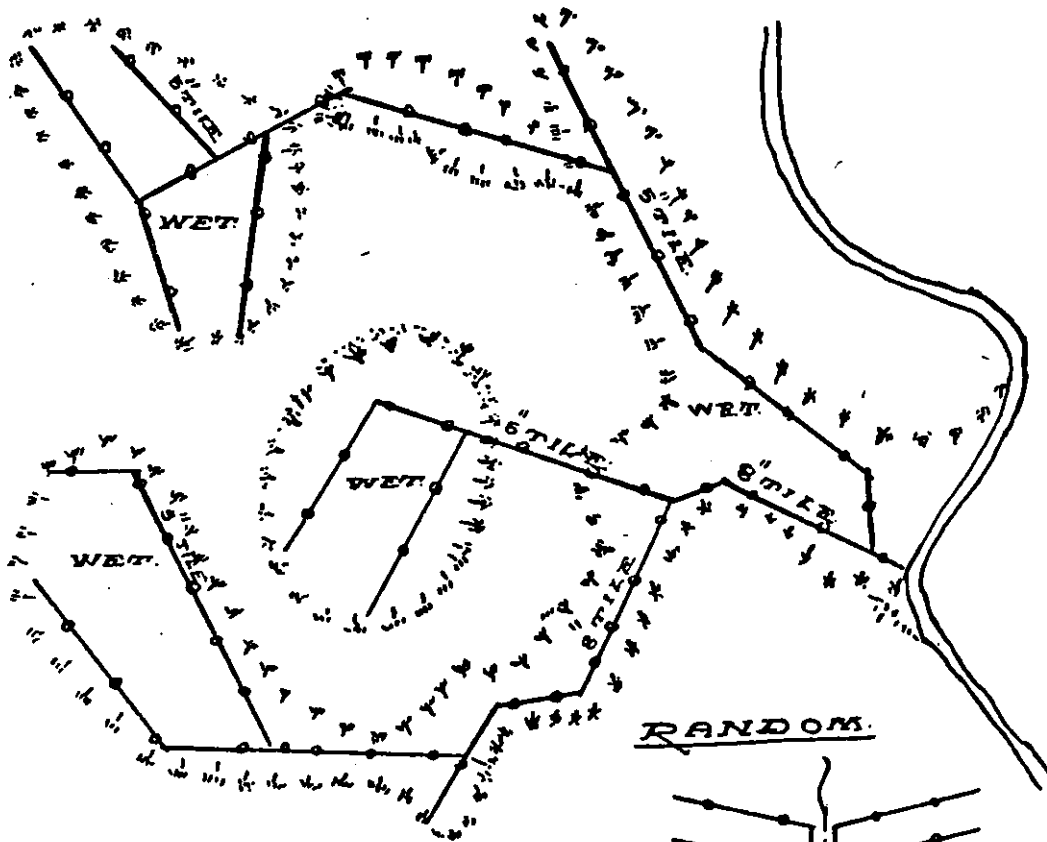
TYPES OF TILE-DRAINAGE SYSTEMS



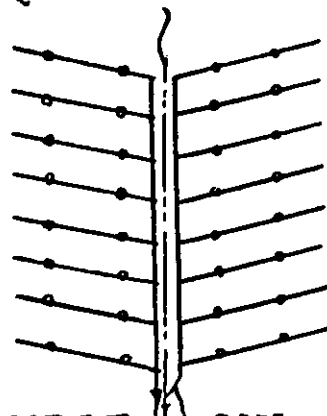
GRIDIRON OR PARALLEL



HERRING BONE

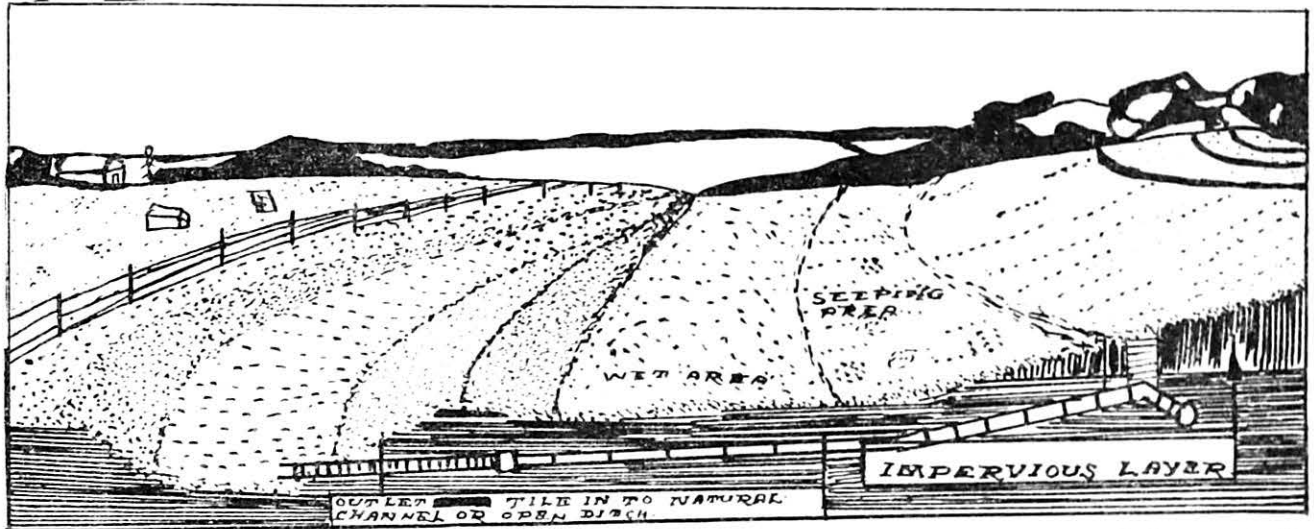


RANDOM

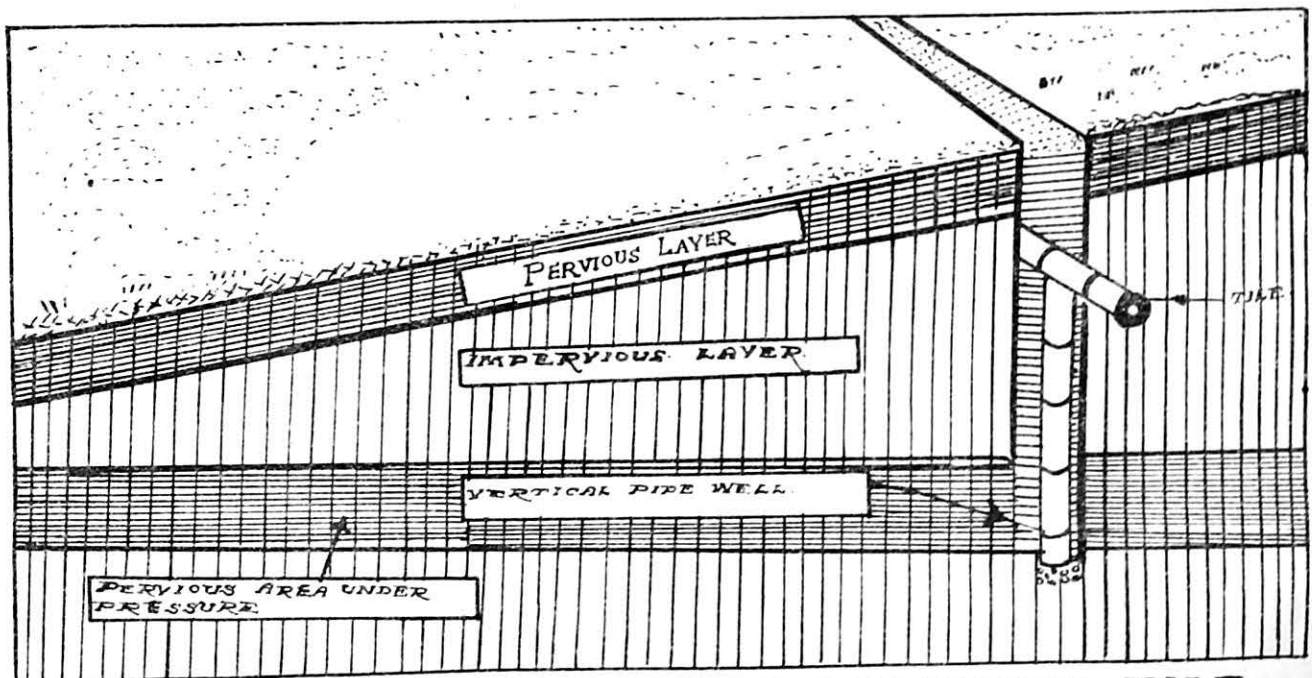


DOUBLE MAIN

SOURCE: "FARM DRAINAGE" FARMERS BULL. No. 2046 U.S.D.A.



INTERCEPTION OF SEEPAGE UNDER BARRIER CONDITIONS.



RELIEF WELL AND INTERCEPTOR TILE.

SOURCE: DRAINAGE NATURAL ENGINEERING HANDBOOK SECTION '16, U.S.D.A.
SOIL CONSERVATION SERVICE.

FIG. 10

G.P.Z.P. POONA, 66-Q-799.

