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HOW TO DESIGN LAND CONSOLIDATION IN INDONESIA

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ULTURAL DEVELOPMENT COOPERATION DEPARTMENT
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PREFACE

A Land Consolidation Scheme has the purpose of (1) increasing agricultural production such as production of paddy, upland crops, and fruit, and (2) the improvement of agronomic management from the point of view of the economics of labor productivity.

If there is a labor force surplus in farming regions. It is profitable to utilize manual labor than machines, and to arrange the farmland for such use of manual labor.

Thus, a Land Consolidation Scheme is required to meet social and economic demands.

In this report, the basical ideas of such a scheme are described in the case of modernized mechanized farming on paddy fields, and these ideas are adoptable for the large scale paddy field farming, of more than 3 hectares, such as may be managed by a farmer's association-

The following matters are very important when a land consolidation scheme is promoted.

First, at the same time that the Land Consolidation scheme is put into practice, it is necessary to collect scattered plots of farm land in one place with financial assistance of the Government.

Second, the Land Consolidation Scheme requires a huge amount of capital, so the government authority concerned should give subsidies to the farmers who strongly desire to cooperate with the Land Consolidation Scheme.

Finally, these basic ideas should be improved by the use of new ideas, and practical experience gained year by year in the field, these reports were edited by the Japanese Society of Irrigation and Drainage Reclamation Engineering, under my supervision, to provide information of value for the development of Indonesia's agriculture.

Any suggestions, advice and comments that readers wish to make would be greatly apreciated.

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LAND CONSOLIDATION

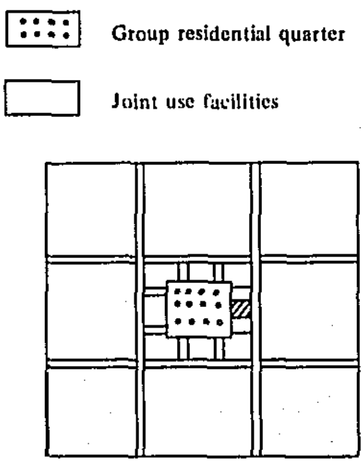
1. Connection between Fields and Outside Areas.

Facilities such as machinery sheds, repair shops, drying and adjusting facilities, storehouses and parking area should be grouped in one location at a peripherel part of the farmers' residential quarter; these facilities and the fields should be connected by farm village community roads if possible, or otherwise by trunk farm road.

(*Explanation*)

1-1 If joint production facilities are located in the farmers' residential quarter it will increase the volume of traffic of heavy goods there, creating noise and raising dust.

Therefore, it is desirable to locate these facilities, grouped together, near to the peripheral part of the quarter, and if possible near the center of the fields.



1-2 Farm roads are classified into the following four kinds based on road functions.

(a) Farm village community road: These are used in connection with marketing and selling of agricultural products and purchasing of fertilizer and other farm materials as well as for community life in farm village.

(b) Trunk farm roads: These connect the arable land with the mechanization center, the drying and adjusting facilities and the farm storehouses; they carry a large traffic volume.
(c) Branch farm roads: These are either cultivation roads or connecting roads. Cultivation roads are necessary for cultivation activities such as tillage, insecticide application and harvesting. Connecting roads are used to transfer the work from field block to field block, for drawing water from a branch canal to ditches and for distributing water.

The width of each class of these roads in described in C-1 below.

1-3 In many cases, the farm village community roads is existing as a part of concurrently a residential quarter, forming the outline of a field's shape. Since the existing community roads are likely to have many curves and be of insufficient width, they will make it difficult for fields to have regular shapes, and therefore they must be improved or widened. Class 2 farm roads will be good for connecting group residential quarters, but when the road passing through a residential quarter has a large volume of traffic, a by-pass route should be provided, if possible, and its width should be that of a class 1 farm road.

Apart from this, one should consider the necessity of building a ring road to connect various farm roads with each other at the outskirt of the entire district.

2. Layout of Irrigation and Drainage Channels and Farm Roads in Field

2-1 Layout of Irrigation and Drainage Channels, and Farm Roads

1. Main irrigation canals and main drains should be arranged as shown in Figs. 2 and 3. The selection between both systems should be made chiefly on the basis of topographical conditions.

2. Branch irrigation canals and branch drains as well as their tributaries should be arranged as shown in the figures, according to the principle of completely separating irrigation and drainage.

3. Farm roads should be arranged along the main and branch irrigation canals and drains and the irrigation ditches. Also, they should be built along small drains in any case where they are needed for insecticide application.

(Explanation)

(1) Basic Idea of Layout

The location of the main irrigation canals in the district determines the framework of a paddy field readjustment project.

Where there is a slight unevenness in the topography of the district, the main canals are arranged on the higher part, as a rule, and the main drains on the lower part (see Fig. 2). On the contrary, where the topography is flat and even, the main canals and the main drains are located along the both sides of the road (see Fig. 3).

As to branch canals and drains and their tributaries, there are two possible systems as shown in Fig. 2 and Fig. 3; that is, ditches and small drains depart from the branch canal and drain to one side of it (as shown in Fig. 2) or to the both sides of it (as shown in Fig. 3).

Farm roads are arranged, as a rule, along irrigation and drainage channels.

In general, location, regime and improvement of rivers have a close relation with drainage planning. Excess and deficiency of irrigation water resources, location and method of water intake, and water use practice have a close relation with irrigation water planning. Further, the present situation and projects concerning national roads, prefectural roads and city, town or village roads have a close relation with farm road planning. Therefore, in forming these plans it is necessary to examine thoroughly the relation between the present situation and future projects in these wider regions.

(2) Irrigation and Drainage Channel Networks

The drainage control of a paddy field on flat land is an important factor in paddy production and of improved use of the paddy field. Particularly, in the water-logging or semi-water-logging paddy field zone where the groundwater level is high at all times, it is necessary to lower the groundwater level to dry the paddy field.

Therefore, the branch drains should be completely separated from the small drains and the facilities are needed to enable reasonable drainage control.

The branch canals and the ditches supply water to paddy fields through an independent irrigation network. This irrigation network should not only supply the necessary quantity of water on the planned basis but also facilities which enable good water control.

Although water control requires that irrigation and drainage be separated from each other in their terminals, the general situation at present from the broader regional point of view is that the water in drainage channels from paddy field is used again for irrigation. Accordingly, it is necessary that the irrigation and drainage channels network in the broader region be so organized as to enable to repeated use of water for irrigation; this is desirable also from the standpoint of water use.

The method to form such a cyclic system of irrigation and drainage sometimes involves or requires the pumping of water and pump drainage, and, also, there is needs to consider the possibility of building a pipeline in order to rationalize water control and water use.

General typical types of irrigation and drainage channels are shown in Fig. 2 and Fig. 3, though they may not necessarily be adopted in specific cases because of the natural conditions of the district concerned as shown below.

(3) Road Network

The arrangement of farm roads in a field is planned, as a rule, in harmony with that of irrigation and drainage channels (see Fig. 2 and Fig. 3).

In this connection, as a branch farm road (cultivation road) is indispensable to farm work, it must be always built along any one side of a unit field block. It should be located along the shorter side of a block to make economical use of land area, with its

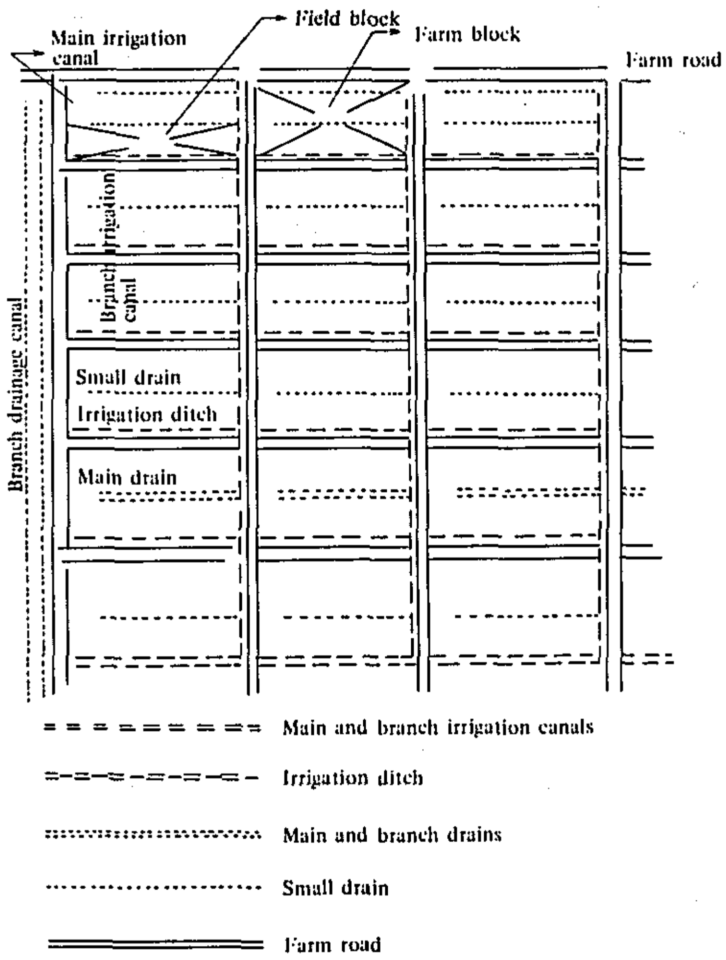


Fig. 2 Typical Layout with Main Irrigation Canal and Main Drain Separated from Each Other

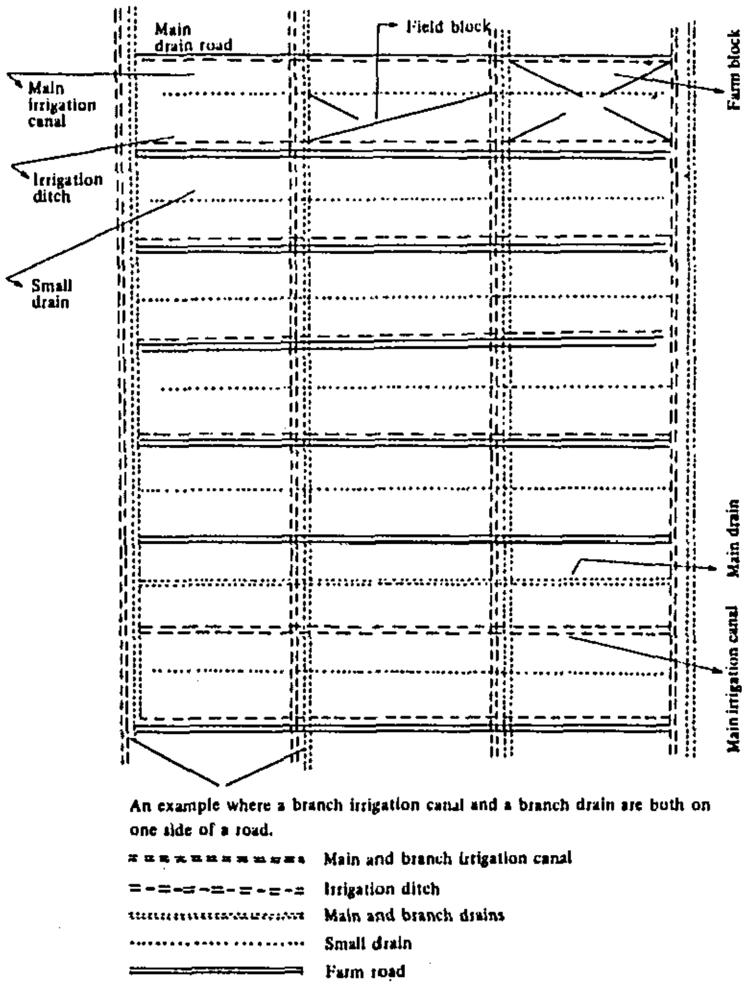


Fig. 3 Typical Layout with Main Irrigation Canal and Main Drain Provided on Both Sides of a Road

direction agreeing – with that of the irrigation ditches and small drains. On the other hand, the branch farm roads (connecting roads) are not necessarily frequently used as a communication road under the joint operating condition. However, since the long sides of field blocks are restricted to 300 – 600 m by reason of irrigation and drainage as is mentioned in B-3, the connecting roads will be naturally arranged at these intervals.

(4) Application to Linear and Dispersed Pattern Group Residential Quarters

Since arable land is separated from group residential quarter – which forms a line farm roads are the same as those in the case of arable land of concentrative group quarter. If the farm roads are arranged orderly like a checker board pattern where residences are dispersed or scattered, the roads will have many curves because of the need to pass around the houses, and the roads will have to be longer than otherwise required. Because the roads, if curved, will interfere with traffic, the intervals of the branch farm roads are determined – adapting to the positions of residences, instead of setting a uniform layout of roads. If possible, relocation of residences should be taken into consideration.

Ideally, cultivation roads connect cultivated land with the residences and the connecting roads link the blocks of cultivated land with each other, but a disorderly pattern of the location of residences renders it impossible to make a functional distinction between cultivation roads and connecting roads. Therefore, if the connection between residences and cultivated land is taken into account, closely arranged roads, are necessary and the field block surrounded with roads becomes smaller than that of the concentrated residential quarter.

Since the residential layout is not fixed, it cannot help but to form a road plan case by case.

2-2 Shape and Size of Compartments

Compartments are classified into farm blocks, field blocks and unit field blocks. First, the type of field block must be determined to plan the layout of blocks.

(*Explanation*)

(1) Names and Description of Compartments

A farm block is a unit of management and work control and normally comprises two field blocks. The shape and size of a field block should be such as to enable proper carrying out of irrigation and drainage control.

The shape and size of a unit field block should be such as to enable efficient control of use of large farm machinery, and generally field block is an aggregation of unit field blocks.

To explain this more concretely, the farm block may be pictured as a rectangular block surrounded by farm roads. It is a unit for planning of management, cultivation control and land use, to enable water control and farm management to be performed under uniform conditions.

The field block is a block of the maximum size and optimum shape to enable farmers to carry out the proper water control in paddy cultivation, being a unit to be determined by such conditions as the soil and groundwater conditions of the district, the irrigation and drainage system of the broader region, the topography and the climate. In general, a farm block consists of field blocks locating on both sides of a small drain. Accordingly, the field block is a block surrounded with such permanent facilities as farm roads and irrigation and drainage systems.

The unit field block has the shape and size determined as a suitable working unit for farm machinery. The unit field block is bounded by borders and generally their aggregation is a field block.

(2) Determining Block Shape and Size

The basic idea to keep in mind when determining the shape and size of a block is that shape and size be such that efficient work can be carried out by use of machinery, that farm management is capable under mechanization system which can be established as a farm management system in the district concerned in future, and that water use facilities are improved so as to enable proper control of irrigation and darinage of paddy field to advance the land productivity and the paddy field use.

However, the true state of affairs is that neither mechanization nor a farm management system is concretely established yet.

Thus, since a factor which in a way can be deemed as stabilized in the long term is irrigation and drainage control, the shape and size of a field block is determined at first by taking it into account the need to form a plan with unit field blocks constituting a variable determinant.

2-3 Shape and Size of Field Blocks

The shape and size of a field block will be determined within the following limits in reference to longer size a and shorter side of such a block, as shown in Fig. 8.

1. The length of a longer side is the permissible length of an irrigation ditch, that is, 300 to 500 m.

2. The length of a shorter side is fixed within the range that surface drainage can be smoothly effected, that is, 100 to 300 m, taking account of the distance from the small drain. Accordingly, the areas of field blocks range from 100 x 300 m (3 ha) to 150 x 600 m (9 ha).

(Explanation)

(1) Longer side (a) 300 – 600 m

As to the determination of the permissible length of an irrigation ditch, see D-2.

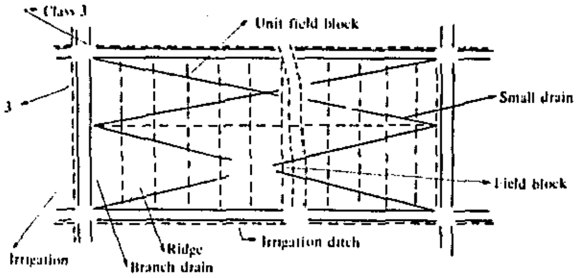
(2) Shorter side (b) 100 – 150 m

The condition for properly removing of surface water, based on a certain area, differs according to the distance from the small drain, the soil texture, the groundwater level, the existence of sub-drains and the evenness of surface. It is proper to set the maximum length at 150 m at first.

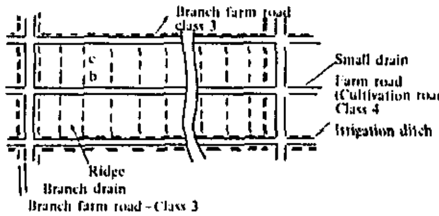
Exact determination of the length is to be made based on the soil texture, with 100 m used for clay.

See D-4.

(A) Case where border sprayer is used



(B) Case where a border sprayer and speed duster are concurrently used or a border sprayer is used with being more than 100 m



(C) Case where a speed duster is used

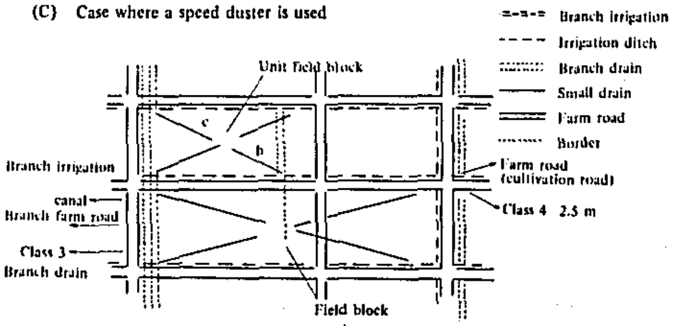


Fig. 7 Relations of sprayer to farm, field and unit field blocks, farm road and irrigation and drainage channels

2-4 Shape and Size of Unit Field Block

The shape and size of the unit field block will be determined within the following limits in reference to longer side b of such block (shorter side of field block) shown in Fig. 7 and shorter side c (Fig. 7-B) or 'C (Fig. 7-C).

1. The length of longer side b is determined as the maximum figure according to the type of insecticide applying machine within the limits of 100 to 150 m.

2. The length of shorter side c is adapted to spraying of a liquid agent by a border sprayer, with the standard figure of c at 30 m. In this case, the boundaries between unit field blocks are borders on which farmers can walk.

3. The length of shorter side c' is adapted to dusting of powder insecticide by a speed duster, with the standard figure of c' set at 300 m.

The standard or the maximum area of a unit field block is 300 x 100 m (0.3 ha) for a border sprayer and 300 x 100 m (3 ha) for a speed duster.

4. Where a speed duster is used, Class 4 farm roads are to be built along the small drains.

(Explanation

(1) Farm Machinery which Restrict the Shape and Size of Unit Field Blocks (See Fig. 7)

The shape and size of the unit field block are determined chiefly by the suitability of the operation efficiency and optimum use of farm machinery. Therefore, they may differ in accordance with the expectations regarding the types, sizes, performances and manner of use of the farm machinery to be introduced after the completion of the field readjustment.

At present, insecticide applying machines, among large farm machinery, restrict the shape and size of a block much more than machinery for flowing, puddling and harvesting, and they seem to be the factor which determines the shape and upper limits of size of unit field blocks.

Insecticide applying machines include sprayers (for liquid agent) and dusters (for powder agent). Because the liquid and powder agents have different characteristics which may make it difficult at times to select between them, and because the types of unit field blocks differ greatly in accordance with such selection, the border sprayer and the speed duster are mentioned here as examples.

a. Where only the border sprayers are used.

b. Where only the speed dusters are used.

c. Where both are used in combination.

The following considerations are made on each standard type of the insecticide applying machines.

(2) Where only the border sprayers are used

Since the presumed standard hose length is 100 m, the longer side b cannot exceed 100 m.

As the standard of the effective spraying width is 15 m x 2 presuming to spray the both sides from a border, it is necessary to build such borders at intervals of 30 m; thus the shorter side c is determined. Accordingly, the standard area of the unit field block will be 100 x 30 m (0.3 ha). Since this size presumes the performance of a border sprayer as its restrictive condition, it is needless to say that such a size should vary in accordance with any change in the assumption. The same applies to the following cases of (3) and (4).

(3) Where only the speed dusters are used (Fig. 7 (c))

As the effective range of the speed duster is taken to be 100 m in a state of calm and the dusting is possible only from windward, farm roads on which the speed duster can pass must be provided at intervals of 100 m. Accordingly, there is need to build the farm roads of Class 4 (see 3-1) along the small drains as determined in 2-3, which constitutes the upper limit of b. Further, c' does not need to be restricted if only the use of a speed duster is taken into account.

Therefore it may be of the same length as that of the longer side of the field block, and the area of the unit field block will be 100 x

300 or 600 m (3–6 ha). However, it is safer for the machineries in present use to limit the puddling work to 3 ha a day at the maximum, and if this is to be the upper limit of a unit field block, then c' = 300 m if b = 100 m.

(4) Where both are used in combination (Fig. 7 (2))

Class r farm roads are built along the small drains, putting the size of a unit field block at 100 x 30 m (0.3 ha) with borders on which a farmer can walk.

(5) Managerial Condition and Unit Field Block

Where there is joint ownership of the farm products, the shape and size of blocks can be determined on the basis of technical conditions alone. In the case where the products belong to individual farmers even though the principal works are performed jointly, the individually owned plots of arable land are bounded by a border which constitutes the condition which usually restricts the shape and size of a unit field block owned by smallholders, speaking here of the situation in Japan. In some cases, the unit field blocks may be enlarged only showing the boundaries by stones of pegs.

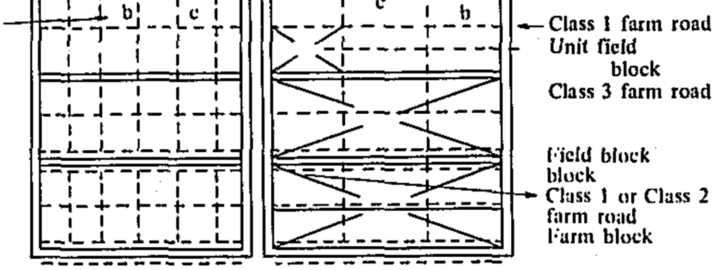


Fig. 8

3. Farm Roads

3-1 Width

The width of a farm road will be the sum of the effective roadbed width and the width of both shoulders, putting it at 7 m for Class 1, 6 m for Class 2, 4 m for Class 3 and 3.0 m for Class 4 farm roads.

(*Explanation*)

Farm roads are classified into the following four classes on the basis of width.

A Class 1 farm road has a width of 7 m. This class includes farm village community roads with heavy traffic.

A Class 2 farm road has a width of 6 m. This class includes farm village community roads and main farm roads

A Class 3 farm road has a width of 4 m. This class includes branch farm roads (cultivation and connecting roads) except the following Class 4 farm roads.

A Class 4 farm road has a width of 3.0 m. This class includes branch farm roads (cultivation roads) parallel to the small drains, which are necessitated when the speed duster is used for applying insecticide.

Usually, the width of a road is determined taking into account the kinds of vehicles used on it, the frequency of use, the converted land, the construction, maintenance and operation costs and the future prospect of widening, but here the standard is shown based on only the vehicles used on it.

For Class 1 and Class 2 roads, the medial clearance between vehicles is put at 0.5 m and each outer allowance at 0.3 m with about 0.5 m provided for the shoulder portion.

For Class 3 and Class 4 roads, widths are determined providing about 0.5 m as the shoulder portion. The width of a Class 1 road is 7 m to allow the anticipated passing of tractors (2.4 m wide).

A Class 3 road is located in the jointly – used arable land areas and the sufficient width of it 4 m even if a combine runs on it as there will be no passing by. Class 4 road is used only for the speed duster, and 3.0 m suffices for its width. The widths of vehicles expected to run on the farm roads are approximately as follows:

Motor car	1.9 m
Truck (5 ton)	2.4 m
Tractor (40 PS class)	2.0 m
Trailer	1.9 m
Combine (3.0 m in harvesting width)	3.5 m (overall width)
Speed duster (tractor-drawn type)	1.9 m

3-2 Height

The height of road should be 30–50 cm.

(*Explanation*)

Although the larger the height of a road the better from the maintenance standpoint, a proper height is about 30 cm considering the access of machinery to the arable land from the road and the ventilation of air. Extra banking is provided on the weak foundation against any anticipated subsidence. The height of Class 1 road is set at 50 cm.

3-3 Form of Cross-Section of Roads

Slopes should be provided from the road center toward both sides to improve the drainage of the road surface. The angle of slope should be 3–6 % for sand or gravel roads and 1.5–2 % for concrete or asphalt roads. The gradient of banking will be 1: 0.5–1.

(*Explanation*)

The form of the road in cross-section need not be parabolic and it is enough just to make the road center higher to some extent. As to the cross-slope the greater it is the better it is for drainage, but for use by vehicles the less of a slope the better. However, a relatively greater cross-slope is better for farm roads because the vehicles used on them are operated at low speeds. The gradient of banking should be 1 : 0.5–1 in order to reduce any converted land.

3-4 Pavement

The types of pavement include type pavement, asphalt and concrete pavement. The type to be used will be determined taking construction cost and traffic volume into consideration.

(*Explanation*)

The sand-type pavement includes gravel roads, crushed stone roads and sandy clay roads. The pavement cost accounts for a large part of the road construction cost. The price of gravel, of which purchase and transportation costs account for the principal part of the total cost, varies greatly by districts. Saving in the read cost may be effected by reducing the amount of gravel use or by carrying out appropriate maintenance and administration of sand road, or both measures. The usual depth of gravel layer is 10–15 cm: the precise depth is determined by judging the strength of soil and the muddiness. It is an effective way to spread the gravel in several times over some years, because too much gravel covering the road makes the vehicles difficult to run on it them?

3-5 Intersections

The intersections of roads will be provided with corner out-offs to facilitate turning of vehicles and maintenance of roads. However, this is not needed for intersections of Class 1 or Class 2 roads. Corner cut-offs, 1.5 m on a side, should be provided only at the intersections of Class 3 or Class 4 roads.

(*Explanation*)

The corner cut-offs are restricted to the minimum since they break the orderly shapes of the unit field blocks and the farmers dislike them. Taking account of the widths of tractors drawing trailers and of combines, the corner cut-offs 1.5 m on a side are provided only at the intersections where Class 3 roads and Class 4 roads cross each other.

3-6 Access Road

One or two access roads should be built at each unit field block, with hume pipes laid in the small drains alongside of the farm roads or V-type flume pipes covered with concrete plates so that any machine can have easy access to the farm land. The width of the access road should be 4 m, with a gradient less than 18°.

(*Explanation*)

An access road must be built so that any machine can have free access to the field even if the difference in grade (elevation) between it and the farm road is 30 cm, because an irrigation ditch is usually located alongside the latter.

A unit field block of 50 ha or less is to be provided with one access road at its left when facing it from the farm. This is because the combine very often is operated by making clockwise turns. A *unit field block of 50 ha or more should be provided with two* access roads at the left and right ends when facing it from the farm road. The width of the access road is put at 4 m, taking into account the turning radius of the tractor and the use of the combine. Where the difference in elevation is less than 30 cm the access road is formed with hume pipes covered with earth. As the limit of hill-climbing ability of a tractor is 18°, the gradient of the access road should be less than 18°.

3-7 Road Bridges

The width of a road bridge on Class 3 or Class 4 farm roads should be the same as that of the road. Its railings should be as low as possible.

(*Explanation*)

As stated above, since the widths of the farm roads are precisely defined, the width of a bridge on Class 3 or Class 4 road is the same as that of the road. If the width must be reduced, corner cut-offs are built at the approaches of the bridge. The shoulders of a bridge on Class 1 or Class 2 farm roads is about 0.25 m. If the length of a bridge is less than 10 m the width of the bridge should be the same as that of the road. The height of railings is to be kept as low possible providing that wheel will not run over them, taking account of the loads on vehicles and the width of machines.

4. Irrigation and Drainage Facilities

4-1 Water Requirements

(1) It is assumed as a condition that the supply of the total amount of water required during an irrigation period and that of the water requirements, by seasons, will be secured adequately.
(2) The standard average water requirement in depth on every parcel of paddy field will be 20–30 mm/day.

(Explanation)

The types of irrigation and drainage facilities described in the following can only be dealt with based on the assumed condition that the sufficient amount of required water is secured, in order to effect the proper water control by parcels of paddy field in harmony with the growth stages of paddy, the climatic conditions and each phase of cultivating work.

Paddy fields having the water requirement in depth of 20–30 mm/day are deemed not only proper for growing paddy but desirable because of both their surface drainage and underdrainage characteristics. Therefore, with the proper water requirement of 20–30 mm/day set as future standard, it is necessary to improve the irrigation, drainage, and soil layer conditions so as to enable to control the amount of percolation as well in harmony with growth stages and climatic conditions.

4-2 Irrigation Canals

(1) The type of water channel will be an open channel or pipeline. In the case of an open channel, the branch cannals as a rule will be lined, and the ditches will be earth or lined canals of flumes.
(2) The cross-section of the channel will be such which can bring water at peak water requirement and the head allowance be one-third of the maximum water flow.
(3) The length of irrigation ditches will be 300–600 m with the same cross section at both the upstream and downstream.

(*Explanation*)

(1) Comparison of the Advantages of Open Channels and Pipelines

So far, the general practice has been to build the branch irrigation canals and irrigation ditches of the paddy field as open channels. In the future, there will be some cases where a pipeline is more advantageous in view of the convenience of maintenance and use, the improved pipe materials, the convenient access of machines to the unit field blocks and the demand for reducing converted land.

The pipeline is more advantageous than the open channel where the following conditions exist.

(1) Where the water pressure can be increased by pumping up from the water source.

(2) Where the cross-section of the open channel becomes substantially large because of the small gradient of the channel due to flat terrain.

(3) Where the local demand is for changing a part of the converted land to road and water channel.

(4) Where the reduction loss of water during conveyance and distribution is particularly desired because of a deficient supply of water.

(5) Where there are particular demands for the savings in the labor for maintaining and operating water channels and for controlling water.

(6) Where the ground is well stabilized, and there is no fear of uneven subsidence.

(7) Where there is no remarkable difference in construction cost between an open lined channel and a pipeline. If the above conditions are satisfied, selection between a pipeline and open channel should be made on the basis of design-related criteria.

Although there are many cases, in general, where the pipeline system is more advantageous, from the functional point of view, on flat land but the greatest problem here is the whether its benefits justify the construction cost.

(2) Necessity for Lining of Open Channels

Where the irrigation ditch is built as an open water channel, whether it is necessity to line it (including flume) should be decided on the basis of the following points. If any one of these criteria are satisfied, the open channel should be lined.

1. Where the leakage loss exceeds 100% due to the great permeability of soil layer (above K - 10^{-4} cm/sec.)
2. Where the ground foundation or the earth of a water channel is liable to scouring and decaying, resulting in difficulty in maintenance and operation.
3. Where the greater cross-sectional area is needed because of the small gradient of the water channel due to the flat land.
4. Where the ground is well stabilizet, without any fear of uneven subsidence. If the above conditions are satisfied, the comparative design of the open channel against the earth canal is prepared to decide the necessity of lining.

Where the branch canal is built on flat land, it is a rule to reduce the cross-sectional area by decreasing the coefficient of roughness and to install a lining taking account of convenience in maintenance and operation.

(3) Cross-Section of Irrigation Canal

The cross-section of an irrigation ditch is determined based on the maximum water flow, which is in turn determined according to the water distribution plan prepared by referring to the three standards shown below, after the examination of the optimum paddy cultivation period and the operational efficiencies of various machines at the time of the peak water requirement mentioned above (at the time of puddling, initial water application to direct sowing dry field and germination of direct by sown flooded field, immediately after "nakaboshi" drainage, and at the time of weeding, applying insecticide and manuring).

1. That the water application to each unit field blocks is completed in the daytime.
2. That the water application to the respective field block (300—

500 ha) is completed within ten days.

3. That the water application in the district is completed within ten days. The water supply at the time of the above peak water requirements and the routine supply must be carried out on the 24-hours per day irrigation basis (excluding pump irrigation), otherwise the water cross-section will become excessively large. Therefore, where it is needed to provide concentrated irrigation during only a few hours in a day, some measures must be taken to regulate the water utilization. The desirable free-board of an irrigation canal is one third of the maximum water flow.

The water cross section of a pipeline is calculated from the correlation to the above peak water flow and the increased pressure, and the equivalent of the free-board is added in calculating the increased pressure.

(4) Difference in Elevation of Irrigation Canal and Field Surface

If the level of the irrigation canal-bed is excessively higher than that of the paddy field surface it will not only interfere with the access of machinery to the cultivated land, but also necessitate provision of a special device at the water inlet to prevent the land from scouring. If the canal-bed level is excesively lower, water intake to the unit field block will be difficult. The permissible difference in elevation of the canal-bed level against the field surface is within the range of -5 to +10 cm.

The height of a water channel bank should be limited to the same level as that of the road surface, at the most.

(5) Length of Irrigation Ditches

If the area irrigated by the ditch diverging from a branch irrigation canal is excessively broad and the number of unit field blocks to which water is distributed is increased, the length of such a ditch will be liable to cause a conflict of interests between its upstream and downstream areas in regard to the equal distribution of water, and a deficiency of water is apt to arise in its downstream area unless a special regulation of water utilization is made.

The ditch must bring a large amount of water to the unit field blocks at its most downstream during the puddling period and the like; or, if any water intake is suddenly suspended at its upper stream area during the routine water application time, there is a fear that an excess amount of water will reach its downstream area; and it is a rule that any one ditch has the same water cross sections upstream and downstream.

Therefore, it is not desirable that the length of one ditch be excessively long, from the standpoint of the water control as well as construction cost. On the other hand, an excessively short ditch causes the high density of Class 3 roads along the branch irrigation canals, with the converted land increasing.

4-3 Water Inlets

(1) Regarding layout of water inlets, one or more inlets should be built at the side along the irrigation ditch of each unit field block, at intervals of 50 m, or less, and if there is one inlet for a block it should be provided at the upstream part on such side.

(2) The cross-section of the inlet from an open channel should be determined according to the amount of intake water, with the upper limit of the width being less than 50 cm, or, two inlets should be built where a larger width is needed. The level of the inlet bed will be set at 10 cm above the field surface.

(3) It will be built as a permanent construction and so that control of its opening is convenient; or, a valve system may be used in the pipeline.

(*Explanation*)

(1) Number of Water Inlets and their Layout

The number of water inlets necessary to bring water from the irrigation ditch to the individual unit field blocks is determined by the area of the unit field block, the maximum intake water flow to be decided on the basis of maximum intake water flow, in turn to be decided on the basis of the time required for the water application and the length of the side along the ditch of such block.

For example, if 200 m of water required for puddling (usual requirement is 120–180 mm) is applied to 1.0 ha in 24 hours, the necessary water flow will be 23.1 l/sec which shows that one inlet will suffice generally for up to 1.0 ha, from the viewpoint of the possible intake water flow of one inlet (as mentioned below).

Where the ditch is arranged along the longer side of the unit field block, it is desired to provide two or more inlets at intervals of 50 m or less even if the required intake water flow is small, in order to expedite the water circulation in the block at the time of water application.

It is advantageous to locate the inlet at the upstream part of the side which gives the largest head between the water level of ditch and the field surface.

(2) Cross Section of Water Inlet

The allowable velocity of flow in the vicinity of the water inlet is deemed about 40 cm/sec (critical to lodging of paddy plants and scouring of the field surface) so if the head between the water level of the ditch and the field surface and this allowable velocity of flow are given, the width of inlet may be determined.

As a very wide inlet cannot be easily opened, the maximum width is limited to within 50 cm. If the required intake water flow needs a larger width than this, two or more inlets are to be built.

The level of the inlet bed is dependent on the level of the ditch bed, but it is desirable to be within the range a maximum of 10 cm above the field surface, to prevent scouring at the time of inflow.

(3) Structure of Inlets

Where the unit field block is larger, the intake water flow becomes larger as well, so that a mere notch cut in the ditch bank cannot be easily maintained and operated. Therefore, the inlet should be a permanent structure of concrete with corner cut-offs or of the sluice type.

Where a pipeline is used as the irrigation ditch a valve system is to be applied.

4-4 Field Surface Drainage

It is necessary that the field surface drainage of each field block can be completed within one day after the drainage is begun, and conditioned must be arranged so that this can be attained.

(Explanation)

(1) Necessity of Field Surface Drainage

Since the flatness of a paddy field surface deteriorates with the expansion of a compartment, to expedite drainage of the standing water on the field surface is more difficult than for the former smaller compartment. On the other hand, the expedited drainage is needed more keenly because of the physical change for operation of large machines and the introduction of new cultivating methods.

Thus, field surface drainage is the most important prerequisite for the mechanization by use of large machines, and the various characteristics (flatness of field surface, soil improvement, under-drainage, training drain and outlet) must be improved so that this prerequisite is satisfied.

(2) Allowable Number of Days for Field Surface Drainage

Summarizing the data of experiments and the experience in the past, it may be said the standard number of days allowable for draining the standing water on the paddy field at different times in the year is generally as follows.

1. Irrigation period:

Time of applying weed killer and liquid manure within 1–2 days of germinating time of directly-sown flooded

Field	within	1 day
Time of "Nakaboshi" drainage	"	2–3 days
Final time of irrigation..............	"	3–5 days
Drainage of water standing (excess of 10 cm in depth) due to heavy rain	"	1–2 days

2. Non-irrigation time (drainage of standing rainwater):

Period of tillage and stamping work	within	1–3 days
Seeding period of directly-sown dry field. .	"	1–2 days

Germinating period of directly-sown dry
field . . . . within 1–2 days
Cultivation period of second crop . . . . . . " 2–3 days
Autumn plowing period . . . . " 3–5 days

Therefore, it is desirable for the paddy field to satisfy the condition of the field surface drainage so that the standing water on the field surface can be drained within one day.

(3) Paddy Field with Poor Quality of Surface Drainage

In general, the paddy fields on which standing surface water cannot be drained completely within one day are those shown in the following.

1. Paddy field of which longer side of the compartment (or the distance to a small drain) is more than 100 m.

Judging from the investigations and experiences in various regions, where the permeability of the soil is poor, standing water is often present at places 100–150 m away from the outlet after more than one day even if the field is relatively flat and the standing water is apt to remain particularly in depressions.

2. Paddy field with an uneven surface

Where the field surface is uneven, even if the longer side is less than 100 m, standing water remains every - where, and it cannot be drained from the outlet as surface water.

3. Paddy field of which the sub soil layer has poor permeability

Where the paddy field subsoil has poor permeability, the standing water on the field surface must be entirely drained from the outlet as surface water, and the remaining water stands still for several days.

(4) Measures for Field Surface Drainage

In order to effect the quick drainage of the field surface it is necessary to improve the surface flatness, the soil layer, the underdrainage and the outlet and to build field surface drains. The drains are built in the lateral direction to the drainage channel (or generally in the direction on the longer side), at intervals of 10–20 m, with their terminals connecting to the outlets, and it is at times effective to connect them with branches to the depressions liable to retain standing water.

The preferred method of constructing field drains where the direct sowing dry field is concerned is to dig them by use of a plow at around the seeding period, and for puddling, to dig them between ridges by hand at the time of "nakaboshi" drainage.

4-5 Outlet

(1) The layout of outlets: one or more outlets should be built at the side along the small drain of each unit field block, at intervals of less than 50 m, and if one inlet is provided for the block it should be built at the downstream part of such a side.

(2) The cross-section of the outlet will be less than 50 cm in width, or two outlets should be built where the larger width is needed. The level of the outlet bed will be set at 5–10 cm below the field surface.

(3) It will be built as a permanent structure and in such a way that it is easy to control its opening, with its small drain side being of the drop type.

(Explanation)

(1) Number of outlets and their layout

The outlets necessary to remove the standing water on the field surface of an individual unit field block into the small drain should be built at the rate of one for every 50 m or less, taking account of the flow out from the field surface drains, though one outlet for every 1 ha may serve where the water is deep.

If one outlet is built for a block it is advantageous to provide it on the lower part of the side, in view of the head between it and the water level of small drain and of the connection to the training drain along the borders.

(2) Cross-Section of Outlets

The inner width of the outlet is limited to up to 50 cm for ease of controlling its opening, and if a width of more than 50 cm is needed by the required drainage discharge two outlets should be built.

It is advantageous to set the level of the outlet bed at 5–10 cm below the field surface, both for increasing the discharge at the initial period of drainage process and for connecting to the field surface drain.

4-6 Drains

(1) The drainage channel type will be open channel.
(2) The cross-section of the drain will be of two types depending on the groundwater level.
1. Where the groundwater level is low at all times, cross-section will be such that the maximum drainage discharge of surface water can flow through it, with the depth limited to 50–60 cm below the field surface.
2. Where the groundwater level is high, small drains will be made as deep as 1 m below the field surface, taking account of the underground drainage.
(3) The structure of the drain will be of the open channel type, as a rule, and the bank revetment work will be performed if necessary. The check dams will be built in the small drains by field blocks or by heads of 50 cm in accordance with the topographic gradient.
(4) The upper limit of the length of a small drain is 600 m.

(*Explanation*)
(1) Function and Cross-Section of Drains
Where the paddy fields are such that their subsoil water level of the non-irrigation period is several meters below the field surface and, even during the irrigation period, the standing water on their surfaces and the subsoil water do not saturate and connect with, making free seepage (fields on a tableland or the upstream part of an alluvial cone) the drains of small depth with the function only to discharge the surface water will suffice for such fields.

In this case, the cross-section, being the optimum one in view of the topographic gradient and the amount of earthwork, is determined on the basis of planned drainage discharge estimated from the run-off ratio which is computed taking account of the rainwater storage on the field surface.

It is a usual practice to limit their depth within 50–60 cm below the field surface.

Where the paddy fields are such that their subsoil water level during the non-irrigation period is as high as 1 m or less below the field surfaces, or such level raises in the irrigation period or the subsoil water and the ponded water on the field surface become saturated and connect with even though it is low in the non-irrigation period (usual flat paddy fields), the drain must function in two ways; the surface drainage and the subsurface drainage functions. Therefore, the cross-section of the drains for these fields should have the capacity to carry the water discharged from the surface and at the same time the depth of about 1 m below the field surface necessary for the subdrainage.

However, where the sub-drainage is separated from the surface drainage by means of the underdrainage (collecting galleries) and the subsoil water is taken well outside of the district, the drains which discharge only the surface water may suffice for the latter fields mentioned above.

In general, as it is difficult to provide the necessary gradient for collecting water in the gallery on flat land and the connecting portion of absorbing and collecting galleries is liable to damage, it is desirable to have each absorbing gallery opened toward the small drain. Therefore, the small drains are needed to have the depth of about 1 m below the field surface.

(2) Structure of Drainage Canals

As a rule, the drains are constructed as earth channels in order to reduce construction costs. But for the deep drains in respect of which the subsurface function is taken account of, the bank revetment is needed in the following cases.

1. Where the soil of the slope tends to lose its shape.
2. Where the ground foundation is weak and apt to subside.
3. Where the soil is liable to becoming eroded due to the high velocity of flow.

4. Where the water level varies very frequently due to the control of the channel water level.

Where the bank revetment is practiced, the revetted surface should be of transmissive structure, with emphasis laid on the *subsurface drainage function.*

(3) Water Level Control of Drains

In order to control the amount of percolation in accordance with the growth stages of paddy by controlling the water level of the drains and to regulate the subsurface drainage on one field block basis, it is necessary to build a check dam at the small drain terminal of each field block or at every half-way point of the field block where the head varies by 50 cm, so that the subsurface drainage can be controlled at will in harmony with the growth of paddy and the management of farm work and cultivation.

(4) Length of Small Drains

If the length of any small drain extending to join to the branch drain is excessively long, the cross-section of the downstream part is increased, which increases construction cost, and it is apt to cause a conflict of interests between the upstream and downstream areas. Since such disadvantages are prominent where the small drain exceeds 600 m (20 blocks of respectively 30 a), it is desirable to build branch drains at the intervals of 600 m or less laterally to the small drains to be connected to them.

4-7 Block System Drainage

(1) In some cases, it is necessary to consider the adoption of a block system drainage for the purpose of the vertical control of water and the repeated use of water.

(2) The size of a unit block deemed to be suitable in respect of the drainage control is generally 30–50 ha.

(3) The necessary facility is a small pump to be installed at every unit block.

(*Explanation*)

(1) Necessity of Block System Drainage

In order to enable the vertical control of water taking account of the behavior of water in the soil layer at about 1 m below the field surface, with the purpose of strengthening the bearing capacity and of proper percolat, the water level of drains in the field must be kept deep in keeping with requirements.

This in turn necessitates deepening the branch and main drain in the district, with the resultant need for pump drainage instead of the usual natural drainage or with the existing pump drainage necessitated to increase the lift head. The necessity to lower the water level of the terminal drains calls for excessive remodelling of the drainage system and facilities in the entire district.

A measure which may be used in this situation is block system drainage by the use of small pumps. The method of construction is determined taking into due consideration the construction cost, the maintenance and operating cost, the convenience of water control and the repeated use of water.

There is a tendency for water requirements to increase with the modernization of paddy cultivation and the read justment of fields. Furthermore, where it is difficult to find a new water source to meet those requirements, the necessity to make the repeated use of water systematically increases its importance. The flat land makes it difficult to practice the repeated use of water by such means as a special irrigation and drainage system or backwater device, and this too necessitates the drainage by the block system which allows for the repeated use of water.

It is the maintenance and operating cost of pumps which so far has limited the diffusion of the block system drainage by a small pump. However, in some advanced paddy cultivation zones such as Niigata, Nobi and Saga plains, the block system drainage has been partially practiced with some effedtiveness. It is believed that this drainage system will be widely used in the future for improving the field conditions in order to better adapt to the mechanization by large machines and the high-yielding of crops.

(2) Area of Unit Blocks

The area of a unit block for the block system drainage varies according to the topographical conditions, the irrigation and canal system and the bearing capacity for the maintenance and operating cost of pumps. The experiments and experience at various districts has shown that the suitable area is 30–50 ha, in view of the easiness to perform the regulation of water level throughout all fields and of the maintenance and operating cost. A pump with a small lift head and of 1 HP/ha in output will suffice for flat land, and a unit block of 30–50 ha does not necessitate such a large pump. Such a pump can be regarded as a part of work machines just like the large machines, and can be used jointly.

4-8 Underdrainage

4-8-1 Planning of underdrainage

The planning of underdrainage should be determined in the order of the depth, the intervals and the gradient, and the layout of the absorbing pipes it as per Fig. 9. The sub-drains are buried in the soil layer with good permeability as deep as possible, but within a range of 0.6–1.25 m, taking account of the surface drains, at intervals to be determined by depths and permeability of soil.

(Explanation)

Since the improvement of the permeability of the soil layer and the strengthening of the bearing capacity of the field are the principal objectives of underdrainage and they constitute the important conditions of planning of this underdrainage, the following descriptions are made referring to the paragraphs dealing with the soil layer. Also it has close relations to the subsoil water level and the flatness of field.

The depth of sub-drains is usually determined prior to setting their intervals, and is influenced by the depth and water of the small drains; it is found empirically from the difference in the soil properties and the density of planting. That is, they are buried in the soil layer with good permeability as deep as possible, but within a range of 0.6–1.25 m, so far as the depth of the small drains permit it. In particular, as the crack is the principal factor of seepage for the clayish soil, it is necessary to ascertain the carry-depth of crack.

There is a problem in selecting the site, as generally the permeability before the construction work is at the lowest point and increases annually after construction. Thus, the site should be determined in the light of the prospects for at least for one year after construction, referring to the data of adjacent and the similar land.

The average permeability of soil calculated backward from the variations in the water level of drains and the daily recessions of water depth,

Coefficient of permeability	Depth of sub-drain (m)		
(cm/s)	0.9	1.2	1.5
$0 - 3.5 \times 10^{-5}$	0–4.5 m	0–6 m	0–7.5 m
$3.5 \times 10^{-5} - 1.4 \times 10^{-4}$	4.5–9.5	6–12	7.5–15
$1.4 \times 10^{-4} - 5.6 \times 10^{-4}$	9.0–18.0	12–24	15–30
$5.6 \times 10^{-4} - 1.7 \times 10^{-3}$	18–33	24–43	30–54

The above table calculated by C.B. Slater determines the figures of intervals for each depth higher than those calculated by Schroader to take into consideration the time needed to lower the groundwater level to a certain depth. It is believed those figures are suitable for the planning of underdrainage to introduce machines into the fields.

(1) Slater, C.B.: ("The depth and spacing of tile drains")

In using the above table, the coefficient of permeability at the place must be measured, presupposing the soil behavior after the construction of the sub-drain. It is dangerous to plan the underdrainage on the basis of the coefficient of permeability obtained other than under the actual water use conditions at the site, as through the indoor experimentation.

If the required time for lowering the groundwater level at the center of the sub-drains to 50 cm below the ground surface, all over the district, is put at 5 days, the depth of sub-drains is to be 1 m and the spacing interval is to 14 m, being in the range of Slater's figures.

In the case of clayish soil, it is necessary to start the construction of sub-drains after the permeability of the soil has been increased by the development of cracks. For this, it is necessary to build temporary drains, or to lay mole drains at the depth of only 0.3–0.5 m, to expedite the drying of the arable land surface. In this method, the real sub-drains are built by the combined mole-pipe drain system, that is the clay pipes were buried in a deeper position than and in the lateral direction to the mole drains, and both are connected by means of a cinder layer. It is an effective method in a district where mole drains can be built.

The layout of absorbing pipes for the underdrainage is as shown in Fig. 9-(1), and the pipes are opened toward the small drain one by one to connect to it, with any locks omitted. In this case, the weirs provided in the small drain serve as locks.

Where the depth of sub-drain does not match favorably with that of small drain, the desirable arrangement is to separate the underdrainage from the surface drainage and connect them to the downstream or branch drain through the collecting galleries. In this the locks are built some times (Fig. 9-(2)). Also, there is a method to connect several absorbing pipes to the collecting gallery at the terminal which is provided with lock to connect it to the small drain (Fig. 9-(3) and (4), but in view of the requirements of their operation and the possibility of dreakdown of a lock, the layout shown in Fig. 9-(1) is more desirable.

4-8-2 Sub-drain Materials

The materials used are sub-drain pipes are earthenware unglazed clay and plastic (vinyl fiber). In back filling, care will be taken not to reduce the permeability of the excavated soil layer.

(Explanation)

(1) In order to secure the initial effect of the underdrainage in full, it is necessary to wrap the pipes. Clay pipes should be wrapped

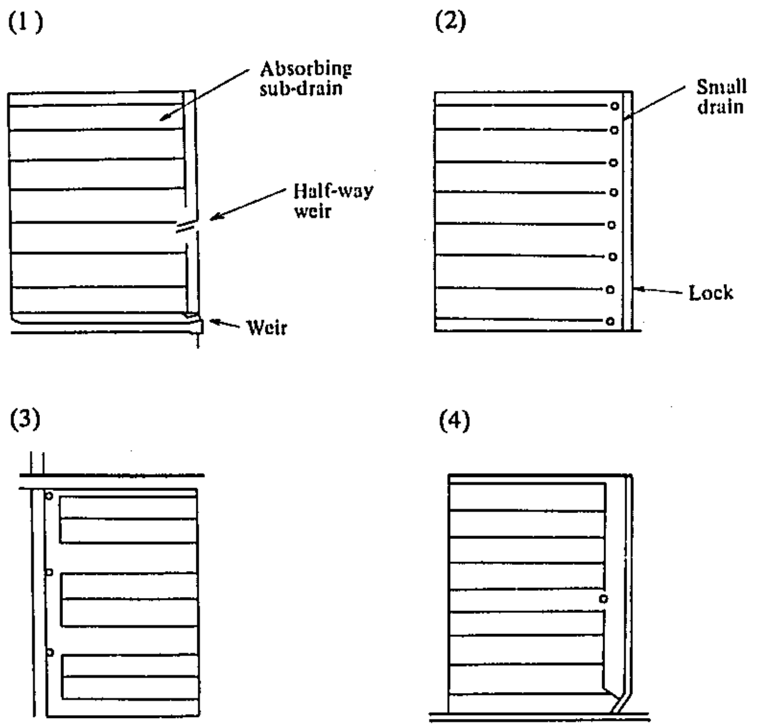


Fig. 9 Layout of Underdrainage

with coarse fiber such as straw or brushwood at the rate of one and half bundles (a bundle of 1 m in length and 0.4 m in circumference) or more per unit length of pipe, or for clay pipes, wrap the joints with 0.2 bundle (a bundle of 1 M in length and 0.9 m in circumference) or more of fresh pine leaves.

Where the plastic pipes such as vinyl chloride pipes are used it is suffice to wrap them in straw. But as they are made of light material it is important to place the protective material of coarse fiber on their top side and both sides, not beneath them. The necessary amount of chemical fiber to wind round the vinyl chloride pipes is 40 g more per 1 m^2 of pipe surface and that of glass fiber is 80 g or more of 16 mioron in size.

(2) Since the permeability of the excavated soil layer is liable to deteriorate by machine excavation, it should be avoided as far as possible to fill back immediately after the execution. Instead, the pipes are to be pressed with a small amount of dry surface soil so that they are stabilized, and several days there after the back filling is executed with the excavated earth sufficiently air dried. In particular where the soil is heavy clay it is important, in view of the drainage function, that the excavated part is permeable to water for which care must be taken.

As the materials of sub-drain are generally dropped into the channel bottom, they should be laid so as not any pipe will be broken or the uniformity of the protective materials be decreased. In back filling, care should be taken of not to break pipes with clod or stones.

5. Soil Layer

5-1 Depth of Soil Layer and Content of Gravel

It is desirable that the depth of surface soil is 15 cm or more and the effective depth of soil layer including the surface soil is 30 cm or more. Also, the surface soil of which gravel content is less than 20 % (in volume) must be more than 15 cm in depth.

(*Explanation*)

(1) Definition

The surface soil means the soil which is turned and stirred in performing the plowing and puddling. The effective soil layer means the soil within the range of which layer the paddy roots can extend and develop with sufficient vitality.

(2) Basis

The depth and property of the soil layer have a unseparably close relation with the soil fertility, and in the first crop after the field readjustment the decrease in the trop yields is caused usually due to considerable irregularity in the growth of plants. Therefore, where the target of the crop yields is set at those before the field readjustment or the higher yields, a special care must be taken of the depth and property of the soil layer. The field readjustment must enable large machineries to operate on the fields, and this also requires to pay a regard to the soil layer. Therefore, there are many cases where a positive improvement of the soil layer is needed. Gravel layer or hard ground impedes the extension of plant roots. The existence of clay layer constitutes an impediment for root system, where the depth of the effective soil layer is less than 30 cm, improvement of the soil layer must be planned in order to remove the factors impeding paddy growth, where the surface soil contains more than 20 % of gravels, mechanical impediment will be caused in the management of cultivation, usually resulting in more troublesome operation from the view-point of the cultivation technique.

The surface soil must have the bearing capacity which will not cause any obstruction to the operation of combine in harvesting period.

(3) Method of Investigation into Present Status

If it is found that the gravel content of the soil is not very great (or not more than 20 %) by the ordinary sampling test, it may be used as surface soil. The content of gravel is found by measuring the weight of content in excavated soil and shown as % in volume of gravels not weathered. In this the amount of gravels found as % in weight is converted into % in volume by the following formula:

$$P = \frac{g.b}{g.b. + a(100 - g)} \times 100$$

p = % of gravel in volume

g = % of gravel in weight

a = specific gravity of gravel

b = tentative specific gravity of soil in the place

(4) *Methods to improve soil layer*

There are several method for improving the soil layer as shown in the following

(a) Improvement of soil layer by manuring operation.

Where there is a fear that the soil fertility not homogeneous between the cut and filled portions influences the growth of crop because the treatment of top soil is not performed, the homogeneity of growing soil layer is seeked for through improvement of manuring and devising of plowing work. The cut earth portion needs a large amount of manuring, because the influence of deficiency in nitrogen is strong with the absorption coefficient of phosphoric acid increased.

The filled earth portion has a tendency to yield too much crop, as a result of excessive amount of nitrogen where the subsoil is converted into the surface soil due to the readjustment earth works, it often causes impediment to the growth of paddy, thus necessitating for manuring control; such impediment may not be removed in one or two years.

Although the measures in these cases vary with the kinds of soil, it is usual to practice the increased application of heap and farm manure (2t per 10a), application of siliceous calcium (300 kg per 10a) and the increase in the amount of ordinary fertilizers (by 5–10 %). For volcanic ash soil, it is effective to apply large quantity of phosphatic fertilizer. Where there is red withering which sometimes develops on the surface soil converted from the subsoil, it is necessary to prevent extraordinary reduction by "nakaboshi" drainage, avoiding excessive application of immatured barn manure. If the impediment against the growth of paddy is of more than mean magnitude, it needs to practice the improvement of the soil.

Where the subsoil is of inferior soil texture, the depth of flowing is to be increased year by year instead of deep plowing at a time.

(b) Top Soil Treatment.

It is disirable no to perform the top soil treatment as far as possible, in view of lightening the farmer's burdens. Therefore, detailed examinations must be made for the following three cases;

(i) Where it is needed
(ii) Where it is needed
(iii) Where it is difficult to perform the top soil treatment.
(i) The top soil treatment is not needed

Where the subsoil is of nearly the same property as that of the surface soil, with the effective depth of 30 cm or more, and can be converted into the mold by fertilization control; or, where the soil fertility is promoted by mixing the top soil with the subsoil due to the low fertility of the surface soil; or where the more than one third of the depth of the surface soil is not cut and filled.

(ii) The top soil treatment is needed.

Where the effective depth of soil is small and the subsoil being excessively deficient is gravel materials and organic matters, is extremely different from the surface soil so that it cannot be converted into the same soil as the surface soil even by fertilization control; where, in particular, the subsoil includes a hard gravel layer which impedes the spread of paddy roots; where the permeability of subsoil is extremely different from that of surface soil; where the fertility of surface soil is very high, resulting in an economical cost of the surface soil treatment; and where only some small parts (less than 30 % of the total) do not need the surface soil treatment.

(iii) The top soil treatment is difficult.

Where the effective depth of soil is less than 30 cm and it needs to bring earth to place all over the readjusted area; where the readjustment work is executed on the weak ground or the water-logging paddy field in poor drainage condition.

(c) Evenness of subsoil – Reference is made to the standard of evenness for the subsoil.

(d) Evenness of field surface – Reference is made to the standard of evenness for the field surface.

(e) Brought earth from another place – Earth is brought from another place to improve the mold bed or the surface soil or the both of them. The effect of the soil brought from another place for the purpose of improving the physical nature of soil (mainly the permeability) appears quickly. The effect to improve the soil fertilization appears gradually. Although it is desirable to mix the brought soil throughly with the ordinary surface soil, except where the ground is being raised, the brought earth, where it is placed on the peat, is mixed little by little with the decomposition of peat, instead of mixing them at once.

The silt of the river, lake or pond is used as the brought earth for the purpose of replenishing the organic matters. In this, it is necessary to dry the matters to expedite their decomposition in advance. Special care should be taken no to cause excessive content of nitrogen.

5-2 Permeability

The permeability of the soil layer will be such that the coefficiency of permeability of the soil layer with the least permeability is within the range of 10^{-4} - 10^{-5} cm/sec.

(*Explanation*)

1. Basis

Where large machineries are used, it is desirable for the operation of them that the permeability of the soil in non irrigation period is high with a good drainage resulting as well, where as the extremely high permeability of the paddy field in irrigation period is not desirable in view of both the use of water resource and the growth of paddy.

The spacing and depth of irrigation ditches vary with the permeability of soil layer for the direct sowing dry field and with the permeability of subsoil layer, the position of ground water level and the spacing of under-drainage for the puddling paddy field. In order to allow the seepage of 20 mm/day, a permeability of about 2 - 5 x 10 cm/sec is the lower-limi of that of the subsoil (including mold bed).

Where a paddy field has a layer of soil, of which coefficient of permeability is less than 10^{-6} cm/sec, any variation in the hydraulic conditions has almost no relation to the seepage amount of that field. Even if the hydraulic condition usch as the water level of the drain (hydraulic gradient) varies substantially, the seepage amount is no more than 10 mm/day with variation less than only 1 mm/day, thus the large machineries are often impeded in their operations in the harvesting period. Therefore, it is necessary that the permeability of the soil layer is within the range of 10^{-4} - 10^{-5} cm/day for a soil layer having the lowest coefficient of permeability.

a. Method of Investigation into Present Status

It is measured by the plot survey of water requirement in depth about the time of "Nakaboshi" drainage. In carrying out the measurement of the plot water requirement in depth, the fields adjacent to the plot is ponded to the same extent so that there will be no border seepage and its outlet and inlet are ascertained so that no water flow in nor out. K-type water requirement test equipment is used in the measurement for the survey to be made prior to the execution of field readjustment.

2. Improvement of Soil Permeability

(a) Improvement of permeability by means of "Nakaboshi" drainage and intermittent irrigation – It is possible to increase the permeability by drying the soil and causing cracks by means of "Nakaboshi" drainage or the intermittent drainage. Even where the permeability cannot be increased only by the "Nakaboshi" drainage is effective in many instances. Improvement of permeability by means of dry paddy field direct sowing, paddy cultivation by irrigation field, and ritable paddy field – The introduction of the dry paddy field direct sowing, the paddy cultivation by irrigating field and the rotable paddy field promotes drying and crack generation of the soil because no water is pended on the paddy field surface in the period of brisk evapotranspiration. In particular, it is effective for increasing the permeability to introduce those cultivation system after, the groundwater level has been lowered.

(b) Improvement of permeability by installing underdrainage system – Reference is made to the paragraph dealing with the under drainage.

(c) Other artificial improving – In many cases the permeability of the soil is improved due to the cracks generated by drying the soil positively, but there is no assurance that such cracks can be always generated at any time and in any place. Some artificial methods are necessary to improve the permeability of soil where no crack is generated by introducing any of the above methods to dry the soil as far as the conditions permit it, or where the cracks cannot be used effectively for practical purpose due to the extre-melag in their generation. Effective for this are crumbling of subsoil reversion, brought earth from another place, deep plowing and, in some cases, mole drain.

On the other hand, where the permeability of soil needs to be reduced in view of the water rescurce and the growth of place brought clay or to use bentonite.

5-3 Groundwater level

The groundwater level in the non-irrigation period will be about 50 cm or more below the field surface.

(*Explanation*)

It is necessary to lower the groundwater level about 50 cm or more below the field surface as a condition to enable the second cropping and to form the mold bed which constitutes the principal factor of the bearing capacity. The subsoil the under-drains, being the average subsoil water level referring to the length of absorbing under-drains.

The time needed to lower the groundwater level from the surface to 50 cm below it is set at 5 days or less, which seems to be the allowable limit for the purpose of introducing large farm machineries.

In measuring the subsoil water level, a hole is bored with auger from the field surface, as shown in Fig. 10, in which vinyl chloride pipe (with round holes or slits) is inserted with space between it and the hole wall filled with coarse sand; thus the pipe is buried in the free water of the soil. Several such measuring pipes are placed on the center line between the absorbing under-drains, to calculate the average level which is regarded as the groundwater level of that field.

Where the groundwater level is easily measurable and confirmable as such, the level after the completion of the field readjustment is presupposed in the course of planning to consider whether cause any impediment in respective stages of farm management. If any impediment is caused, the planning of open drainage or under-drainage is necessary for coping with it.

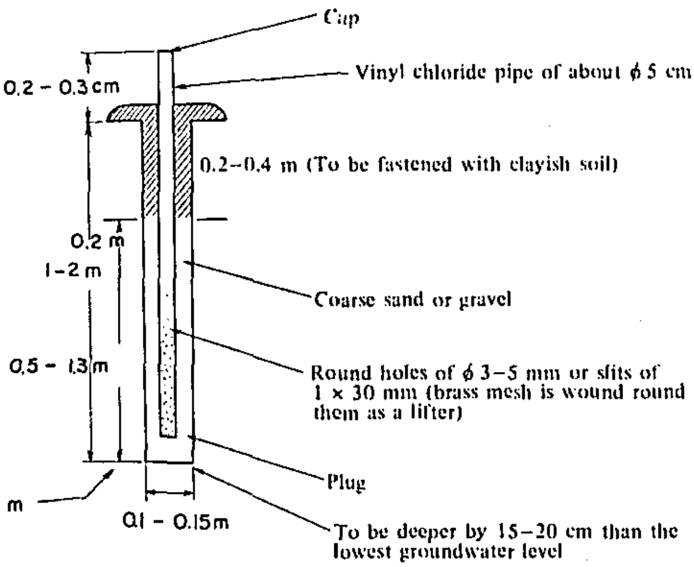


Fig. 10

Where it is difficult to measure and confirm the groundwater level as such, for example, as in the case of pushed water from the outside of the distric or impermeability of soil, the crib test is executed at the place to practice the measurement taking account of any variation of the soil after the execution of the readjustment.

For example, K-type water requirement test equipment is used for this purpose.