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SANDY SOILS

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DRAINAGE OF SANDY SOILS

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SUMMARY

Sandy soils are found in deserts as well as in valleys, alluvial fans and deltas. In the lowlying areas they may have natural high watertables, and irrigation usually results in the need for drainage.

The type of drainage to be applied depends largely on the type of sand. Sands may be coarse and pervious or fine and containing some silt and clay particles which may make it less pervious. Such other physical characteristics as infiltration rate, water retention and effective porosity differ widely from one type of sand to another and have a great impact on the design drainage rate. In general designed sub-drainage systems will tend to be deep and relatively narrowly spaced on fine sands that have a high silt and clay content, whilst they may be shallower and more widely spaced as the coarseness of the sand increases and silt and clay decrease. Surface drainage may be important on soils that run together easily on wetting. Vertical drainage possibilities may be limited by low soil permeability.

Fine sands are often layered and may contain thin layers of silty or poorly pervious materials. The horizontal permeability of such a soil is usually much greater than the vertical permeability. Subsurface drainage systems should permit and promote the lateral flow of perched water through the more pervious layers to the drains. When pipe drains are used, care should be taken to use backfill material that remains permeable through which water may reach the drains.

Cover or envelope materials should be well selected in relation to the type of sand. Indications are that there is no difference between the performance of plastic and clay or concrete pipes when adequate cover materials are used and when pipes are laid under favourable working conditions. It appears, then, that it is the combination of pipe and cover materials in relation to the soil type, rather than the pipe only, that governs the drain performance. Thin sheets of fibre glass appear unsuitable as cover material. More voluminous materials would seem preferable but a series of practical tests is needed for a more accurate basis for advice.

Open ditch drains in unstable sands, especially in salty areas, are very difficult to maintain. The installation of pipe drains in these soils, however, is not always easy. The sand may run into the ditch before the drainpipe has been blinded or filters have been placed, causing displacement of the pipes. The problem is not easy to solve without high monetary expenditures. Using plastic pipes that have been prewrapped in the plant, or that are simultaneously provided with cover material by the trenching machine will in many instances facilitate the installation and reduce the risk of failure.

7.1 NEED FOR DRAINAGE

Sandy soils are not only found in desert areas but valleys and flood plains, alluvial fans and deltas also normally contain sandy deposits. They are found in old stream beds, in lenses, in stratified profiles and in deep extensive layers.

Not all of them are in need of drainage. Sandy soils along streams and river ridges may have adequate natural drainage under good irrigation practices. Parts of the sandy areas in alluvial fans may have deep watertables and sufficient groundwater drainage toward lower parts of the fan.

Pervious sands may overlie relatively impermeable fine textured soils. Upon irrigation a perched watertable may be formed which can be lowered by a drainage system. Such soils may be found in transitional zones between deserts and deltas, coastal and other plains, valleys or smaller topographical depressions.

7.2 TYPES OF DRAINAGE

From a theoretical point of view the drainage of sandy soils does not basically differ from that of more finely textured soils. The mathematical expressions describing groundwater flow to parallel drains apply equally well or equally poorly, depending on whether the soil profile lends itself to a realistic simplification to suit the expressions. The problems of hydrologic simplification are probably no more or less complicated than for other types of soil. Both clayey and sandy soils may have a high or low hydraulic conductivity or permeability. They may be deep and uniform or shallow and layered. Especially on the latter type will it be difficult to describe water flow in quantitative terms, and a drainage system design will need to be largely based on practical experience.

Coarse textured sandy soils generally have a high hydraulic conductivity. Surface runoff following rain or irrigation will be small or absent altogether. Drainage of these soils, therefore, is a matter of watertable control. Whether this is to be achieved by interceptor drains, by a grid system of drains or by pumping from wells depends on the prevailing topographic, hydro-pedologic, climatic and economic factors. A coarse sand does not automatically imply that vertical drainage will be applicable. Much depends on the depth of the profile, the presence of poorly pervious, cemented materials and deeper aquifer systems. Fine sandy soils may be in need of surface drainage, especially when the surface soil runs together during rains or when poorly pervious materials occur close to the ground surface. Vertical drainage possibilities may be limited by low permeability of the soil.

7.3 CHARACTERISTICS OF SANDY SOILS IN RELATION TO DRAINAGE

Though the planning of drainage systems in sandy soils does not basically differ from that in other soil types, sandy soils have a few rather special qualities that should be taken into account. The discussion of these and their effects will be limited to soil profiles that are sandy from the ground surface down to at least the depth of subsurface drains, about 2 metres.

7.3.1 Swelling, cracking, compressibility

The clay content of sandy soils is low and the expansion of clay minerals on wetting (if any) will have little impact on the profile. Sandy soils are hard to compress and very little cracking occurs during drying.

These features contribute largely to the stability of the larger pores through which saturated water movement takes place. Therefore, apart from those parts of the soil profile that are subject to mechanical impact, that is by flowing water and raindrops, the hydraulic properties of sands may be considered as fairly constant.

A practical consequence of the low compressibility of sands is that trenchless drainage machines, which operate on the basis of forming a mole by pressing soil outwards, may be less suitable for sands.

7.3.2 Permeability

The permeability of sandy soils may vary from as low as a few centimetres per day to as high as tens of metres per day. The lowest permeability is usually found in very fine loamy sands and sandy loams. It follows that the density of a subsurface drainage network in sands is not necessarily low. On the contrary, the drains will sometimes have to be narrowly spaced, which renders the system expensive. Coarse sands, on the other hand, are usually quite pervious and generally require widely spaced drains.

The measurement of permeability of sand *in situ* is not an easy task as the walls of boreholes easily cave in and may need to be protected by special filters. The evaluation of the result of measurement may be complicated by the layering of the profile. A high permeability measured in layered sand may result from the contribution made by a tiny layer of coarser materials and provides little information on over and underlying strata. Permeability measurements, therefore, should always be coupled with profile studies in pits. It is noted that the permeability of nearly pure sands may also be calculated from grain size analyses.

7.3.3 Infiltration rate

The infiltration rate is usually high on coarse sands. On fine sandy to loamy soils, especially those that are unstable, the infiltration rate may be considerably reduced when the surface soil runs together following wetting. This easily occurs in arid and semi-arid areas where the soils contain little organic matter. Rains, as a consequence, may start flowing overland and a surface drainage system may be required on sloping lands. The irrigation efficiency may also be affected by unstable surface soil and this, in turn, will influence the required subsurface discharge rates.

7.3.4 Soil water retention

Sandy soils in arid and semi-arid zones where the organic matter content is low usually retain little water. Whereas the available water in clayey soils is normally in the range of 10-20 percent on a dry weight basis, it is often less than 10 percent in fine sands and loamy sands. Coarse sands may retain less than 5 percent of water.

These differences in waterholding capacity strongly affect the timing of irrigation and the depth of water to be applied. Both factors are an influence on the volume and rate of water losses. As a general rule, the coarser the soil the lower the application efficiency and the more water must be drained through the subsoil. Under specified conditions, however, sprinkler and other special systems of irrigation may be applied and they result in considerably smaller losses. This is mentioned further in paper III.6 Irrigation of Sandy Soils.

In more humid areas where irrigation is supplemental in character, sandy soils are often drought sensitive. Rapid drainage increases the need for irrigation. To save on irrigation water the drains are sometimes wholly or partly blocked in early spring, causing the watertable to drop more slowly. Thus plants may obtain a larger portion of their needs from groundwater.

7.3.5 Porosity

The porosity or drainable pore volume refers to the volume of water released or taken up by a unit volume of soil in the zone which may be under the influence of a fluctuating watertable. This latter zone in a well drained irrigated soil is found roughly between 1 and 2 metres in depth. Pore size is greater in sandy than in clay soils; this results in larger channels for water conveyance through coarse soils than through fine textured ones. This characteristic is of considerable importance for the establishment of design criteria, as will be discussed later.

7.3.6 Structure stability

Sandy soils are often unstable, which consequently requires that side slopes of ditches and canals be relatively flat, 1 : 2 or 1 : 3, and flow velocities low.

Flat side slopes imply that much land is lost to agriculture, especially when drain spacings are close. An open field ditch 1.5 m deep in sandy soils may easily have a top width of 10 m. Land loss and high maintenance costs of open ditches make it attractive to install pipe drains in sandy soils.

7.4 DESIGN DISCHARGE RATE AND DRAIN DEPTH

Since the pore size of sandy soils is large, the watertable rise following irrigation or rainfall may be relatively small. It will be limited to 15-30 cm for a soil at field capacity before water application, having an effective porosity of 10-20 percent and deep percolation losses of 30 mm per application. Such losses easily result from surface irrigation methods if 100 m of water are needed per application to cover crop requirements and the field application efficiency is 60-65 percent.

Similarly, the drainage of 30 mm of water will also cause only a slight lowering of the watertable. The coarser the soil, therefore, the smaller the watertable fluctuations for a given set of recharges and discharges.

In humid areas the drain depths do not vary much with the type of mineral soil. The small watertable fluctuations imply that for a given set of recharges stemming from rainfall, the watertable will not attain a certain high level as frequently as on finer textured soils. As a result the design discharge rate may be smaller resulting in wider drain spacings.

In irrigated areas the drainage rate is also affected by the storage capacity but the conditions of recharge and discharge are now slightly different. Irrigation, deep percolation losses and the required leaching are normally drained off before the next water application. These losses cause relatively small fluctuations of the watertable in soils having large pore spaces. As a consequence the average hydraulic head will tend to be higher during the peak irrigation season and so will the discharge rate. A wider spacing would therefore be theoretically justified. In practice, however, the difference often appears to be small. The usually lower farm irrigation efficiency on coarse soils and the subsequent higher losses may even lead to closer spacings.

The small watertable fluctuations on coarse textured soils make it possible to place the drains at a higher level without running the risk that the watertable would exceed a predetermined highest level. Losses of 30 mm cause the watertable to rise by 15 cm on sands whereas it may be 60 cm on fine sandy loam soils. With a higher allowable level of 1 m, and adding a 20 cm "rest value" to the hydraulic head, the drain depths should be at least 1.35 m and 1.80 m respectively. Obviously when drain depths are raised the drain spacings will need to be closer.

It will not always be practical to install drains at higher levels in sands. First deep drains provide the advantage that the watertable will not rise to its highest permissible level after one irrigation. The watertable could be allowed to rise gradually and reach its highest level in the peak irrigation season. As a consequence not all water losses need to be drained off between two water applications. The design discharge rate, therefore, can be lower and the drain spacing may be made somewhat wider.

A second reason to keep the drains deeper is related to capillary phenomena in fine sandy loam soils. Whereas capillary water does not rise high in coarse sands there may be considerable upward flow to heights of over 50 cm above the phreatic level in fine sandy loam soils. The danger of capillary salinization is therefore greater in these latter soils and deep watertables are preferable. A drain depth of at least 2.0 m would seem practical whilst it may be as little as 1.4 m in coarse sands.

In conclusion, the type of sandy soil, its physical characteristics and the method and practices of irrigation appear to have a considerable impact on the design discharge rate and the drain depth.

In general, drainage systems will tend to be deep and relatively narrowly spaced on fine sands that have a high silt and clay content, whilst the drains may be shallower and more widely spaced as the coarseness of the sand increases.

7.5 DRAINAGE OF LAYERED SANDS

Sandy profiles, though they may look fairly homogeneous at first sight, often appear to consist of layers that differ widely in physical hydrological properties. There may be thin layers of finer sands that are more silty and whose permeability is low, or there may be small layers of cemented materials which are almost impermeable.

The horizontal permeability of such a layered soil is usually much greater than the vertical permeability. As a result, the "internal" drainage of the soil may be slow and perched watertables may develop after irrigation or rains.

The internal conditions may sometimes be improved by such soil amelioration measures as subsoiling, deep ploughing, etc. In some instances, adapted cultural practices may help improve water percolation.

Subsurface drainage systems should permit and promote the lateral flow of perched water through the more pervious layers towards the drains. This requirement is met by open ditch field drains in which water can flow out freely.

When pipe drains are used, the trenches should be filled with pervious material to ensure that perched water can move rapidly downwards in the trench to reach the drain. As in some stratified heavy clay soils, the satisfactory functioning of the drainage system may depend largely on the possibility of water flow in the backfill. Trenchless pipe-laying techniques, therefore, should not be used on such soils before their applicability has been demonstrated in field trials.

7.6 PIPE DRAIN AND COVER MATERIALS

The costly and difficult maintenance of open ditch drains in unstable sands makes it often attractive to use pipe drains.

Opinions differ as to the suitability of clay or concrete and plastic pipes for various types of sandy soils. Experiments in several countries indicate that clay or concrete pipes would be preferable to plastic pipes of the same inner diameter where no or inadequate envelope material is used or where the pipes are laid under unfavourable weather conditions1/. This applies notably to fine sandy loam soils and is largely due to differences in circumference between clay and concrete pipes on the one hand and plastic on the other. Increasing the diameter usually leads to improved flow conditions in and around the pipe. Considerations of pipe strength and cost, which increase with diameter, have in many countries resulted in the tendency to keep plastic pipes small.

Where adequate envelope materials are used and pipes are laid under favourable working conditions, i.e., no rain and watertable below the trench bottom. it is believed that clay, concrete and plastic pipes are equally suitable. It appears, then, that it is the combination of pipe and envelope materials in relation to soil type rather than the pipe only that governs the performance of the drains. Such combinations have been studied in several countries but it is often difficult to compare the results due to variations in climatic, topographic and soil conditions. Moreover, there is no uniform methodology for the investigations and experiments which renders evaluations of results difficult. Standardization of test procedures and processing techniques is very desirable.

Provisional experience with plastic pipes indicates that corrugated pipes have a good inflow capacity. It would seem however, that their transport capacity is slightly lower than that of smooth plastic pipes. Larger diameters are needed which can be used for main drains as well as laterals.

Envelope materials are permeable materials placed on and around the drainpipe to prevent the finer particles of surrounding soil from being washed into the drain and to improve the flow conditions around the pipe. It is particularly important to prevent deposits in the drains in sandy soils of flat areas. The slope of the drains in such areas is small and the deposited particles - especially the silty and larger ones - cannot be flushed out easily. Application of adequate cover material is therefore indispensable.

There is a great variety of materials being used in various countries: sand and gravel, fibrous peat, shells, flaxband, fibreglass, plastic fibres. The type that functions best for a certain type of soil depends largely on the qualities of that soil.

Experience shows that thin sheets of fibreglass become easily clogged by the finer soil particles and are not usually considered successful in fine sandy soils. Fibreglass sheets may do well, however, on coarser textured soils that contain few fine particles. Fibrous peat appears to be effective under a variety of conditions and so do other more voluminous materials.

To enable further mechanization and also prewrapping of pipes, some materials are combined with carrier-layers of various fabrics into bands. Experience gained so far with flaxband (about 2 cm thick) seems promising. In arid lands sands and

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1/ Drainage Materials, Irrigation and Drainage Paper No. 9, Water Resources and Development Service, FAO, Rome 1972 gravels are locally available and are much used cover materials. They are considered highly effective when well designed, that is when their gradation characteristics are designed for the soil to be drained. Handbooks on drainage engineering usually contain the specifications.

7.7 INSTALLATION OF PIPE DRAINS

Sandy soils often present special problems during the installation of pipe drains: the side walls of the trench tend to cave in easily; sand may run into the trench before the drainpipe has been blinded or filters have been placed. This may cause the drain to be displaced. Blinding is done to protect the drain line against the excavated soil when this is pushed back into the trench. In humid areas, when the topsoil is stable and pervious, the upper part of the trench is shaved off and placed on the drain for that purpose. Caving in may occur in dry sandy soils as well as in wet sands. It happens more easily and rapidly when the watertable at the time of installation is above the drain.

The problem is not easy to solve. Often the protective shield at the rear of the pipe laying machine is made longer, but on modern machines that have a higher working speed this does not always solve the problem. Using plastic pipes that have been prewrapped in the plant or that are simultaneously provided with a filter by the trenching machine will in many instances facilitate the installation and reduce the risk of failure.

In spite of some problems, pipe drainage appears to be the predominant future system of farm drainage throughout much of the Near East area. Bearing this in mind, programmes for solving problems and answering questions still to be asked concerning pipe drainage are necessary for a continuation of successful agriculture in the Region.