

AGRICULTURAL ENGINEERING

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COMMON PROBLEMS WHICH CAUSE SUBSURFACE DRAINAGE SYSTEMS TO FAIL

by

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Summary: Subsurface drainage systems can provide many long term benefits when properly designed, installed and maintained. This bulletin discusses the common problems that lead to premature failure and dissatisfaction of the performance of subsurface drainage systems. Becoming familiar with these most frequently encountered problems should help to obtain a high quality, effective subsurface drainage system for the investment.

Key Words: subsurface drainage, drainage outlets, soil permeability, grade control, maintenance

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INTRODUCTION

With investments of several hundred dollars per acre for a pattern subsurface drainage system, one wants to be assured that a subsurface drainage system will perform satisfactorily for many years. Subsurface drainage systems have been known to perform adequately for several hundred years when properly designed, installed and maintained. There are many factors which attribute to the premature failure of a subsurface drainage system. This bulletin will address these factors so one knows what to look for to obtain a quality subsurface drainage system.

The most common problems mentioned here have been determined from many personal communications, observations, experience and inspection reports. While many of the problems do not lead directly to drain system failure, many of them seriously reduce the effectiveness of the system's performance. Consequently, the investment in the drainage system provides less than optimum return through reduced benefits and drain life expectancy.

BASIC CONSIDERATION FOR A QUALITY SUBSURFACE DRAINAGE SYSTEM

There are several distinct elements involved in assessing and obtaining a quality subsurface drainage system. If these elements are properly considered, a drainage system will perform satisfactorily for a long period of time. The life expectancy of a drainage system will decrease or the system performance will be inadequate if one or more of these basic elements is not properly addressed. The basic elements are:

1. Resource Condition - soil, water, topography, and plants to be grown
2. Planning and Design
3. Construction and Installation
4. Equipment and Materials
5. Inspection and Maintenance

RESOURCE CONDITION - SOIL, WATER, TOPOGRAPHY AND PLANTS

Understanding the soil, the topography and where the excess water is coming from is essential to obtain a quality drainage system. On-site investigation is an important part of this process. Making these parameters to the needs of the plants to be grown assures an effective drainage system. The soil drainage classification is an integrated indicator of the soil, water, topographical and plant growth condition in which the soil formed. Figure 1 illustrates some soil drainage classifications and the characteristics of these soil profiles. Well drained soils can still have surface water management problems. However, if the soil is in the moderate, somewhat poor, poor and very poor drainage class, the soil experiences temporary or prolonged real or perched water tables close to the surface. Consequently, subsurface drainage is needed to facilitate the management of these soils.

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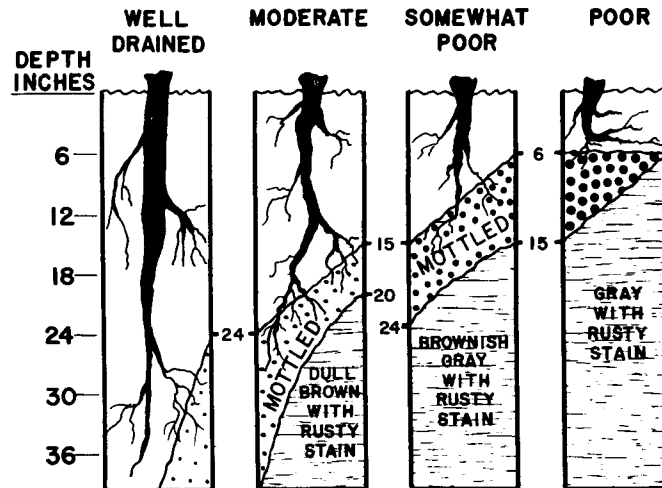


Figure 1. The plant root growth and soil profile conditions which are characteristic to some of the soil drainage classifications. The mottled zone is saturated for some part of the year.

Soils with low permeability present major drainage problems. *Soil permeability* (the rate at which water moves through the soil) is an important factor in determining the appropriate drainage system. Difficulty in measuring permeability occurs because soil permeability changes from place to place and with depth for most soils. In most cases, permeability is estimated from soil textural class and drainage designs are then based on local experience and drainage guide recommendations. Problems occur when the design from general recommendations results in a drainage system which does not perform as well as expected. Soil permeability should be measured in those soils where low permeability values are expected in order to determine the best and most economical drainage system. (See Figure 2).



Figure 2. Measuring the soil permeability (saturated hydraulic conductivity) is important in determining the proper drain spacing.

Although the *soil texture* and structure affects permeability, other drainage system problems occur when the soil texture contains large percentages of fine sands and silts. These soils tend to be unstable when saturated and can move into the drain. (See Figure 3). Tight gapping of clay tile or synthetic filter fabric materials placed over a drain tube may correct some of these problems by keeping out the fine sands. However, where the soil silt content is high (over 40%), the synthetic filter materials also can clog. Graded gravel envelope-type filters are then required to stabilize these soils. Hay, straw, corn cobs and sawdust have been used to simulate a filter but these materials tend to degrade quickly and may not always prevent soil movement. Furthermore, hay, straw and other compressible organic materials should not be used under plastic tubing since they do not provide the proper bedding conditions to prevent collapse. Unstable soils are encountered usually during drain installation and especially when soils are saturated. At this time it is often too late for appropriate corrective measures. Where unstable soils are suspected, drainage installations should be planned for the driest time of the year to minimize the problem of soil movement.



Figure 3. Soils which contain a high percentage of fine sands can quickly fill a tile line when it is not adequately protected by a filter.

Other problems associated with the soil are bedrock, stones, soils with low water holding capacity, acidity, dealing with layers (i.e., hardpans or fragipans) which restrict water movement, determining the exact location of seeps and springs; and ochre clogging of drains. Bedrock and stones usually present problems during construction. Soils with low water holding capacity can become droughty when drained so controlled drainage structures may need to be used. Acidity can adversely affect some materials, particularly metal and concrete, thereby reducing their life expectancy. Layered soils present problems with determining the best drain depth. Sometimes gravel backfill is necessary to ensure adequate permeability around the drain and up through the impermeable layer. Accurate location of seeps and springs and sizing the open ditch or drain correctly to handle the water flow often can present problems. Seep areas can be unstable, particularly when soil profiles are exposed on cut away slopes or in open ditches. Predicting locations and water flows is generally difficult because of the unique characteristics of each situation. However, on-site investigation usually creates an awareness of potential problems and they can be dealt with more effectively during the construction phase. Ochre clogging of drains occurs when the soil is aerated and certain forms of aerobic bacteria react with the soil organic

material and the iron and manganese in solution in the groundwater. Most of the clogging occurs in the filter material, the inlet holes, and/or in the soil immediately approaching entry to the tile. Soils most susceptible are those containing fine sands, silty sands, the organic soils and those soils where organic effluent have been spread. However, not every one of these soil types are affected. A laboratory procedure has been developed to test for ochre, but it is not readily available. An economical, long lasting solution for clearing ochre clogged drains is still not available.

PLANNING AND DESIGN

Planning and design includes assessing the soil, topography, source of the water problem, the outlet condition and incorporating these resource conditions with other information on trafficability requirements, crops to be grown, and the farmer's overall management schemes and objectives. A drainage system plan utilizing this information is developed to include outlets, drainage methods, specifications of elevation, grades, quantities and sizes of construction materials.

The designer usually performs on site investigations, surveys, and then prepares maps, plans and specifications necessary for construction. Other factors of design may involve cost-benefit calculations (especially where there are several alternatives), advising on legal and permit requirements, and assessing environmental considerations.

The most common problems associated with planning and design are: (1) improper considerations of the outlet, (2) inadequate pipe sizing, (3) spacing the laterals too far apart, (4) shallow drains, and (5) failure to consider total or future needs. Improper consideration of the outlet is the most often encountered problem and generally deals with placing the drain outlet pipe too low in the open outlet ditch. A minimum of one foot drop is the recommended practice for the system to function most efficiently. Improper placement occurs because the major open drainage channels have insufficient depth, the grade on the land is flat, and sometimes survey information and alternative solutions (i.e., pump outlets) are not adequately considered. In many cases, obtaining sufficient outlet depth for subsurface drains involves lowering a culvert or deepening the channel on adjacent property owners. When this is necessary additional cost and time is involved in coordinating people and obtaining the necessary easements and permits. Consequently, the process is often considered uneconomical. Various programs do exist, however, to assist landowners with these problems. Improper placement of the outlet can cause erosion at the outlet leading to early failure of the drainage system. (See Figure 4). Outlet pipes of sufficient length and the proper structures for handling surface and subsurface water should be an integral part of the drainage system. In addition, the proper rodent protection of the outlet is necessary to minimize problems.

Undersizing drainage mains and laterals may reduce initial capital costs, but it can severely restrict drain performance, cause higher maintenance costs, reduce the return on the drainage investment, and lead to early drain system failure. (See Figure 5). Too often six-inch diameter outlets are used where larger diameter outlets are required. Improper pipe sizing puts stress on other weak parts of the system-like connections and the unstable soils, causing blowouts and suck holes. Design recommendations using the proper drainage coefficient, inflow rates and drain capacity limitations should be adhered to and this information is available in local drainage guides.

The problem of spacing the laterals too far apart is often associated with other factors not directly related to soil permeability. Although soil permeability can be measured and an appropriate drain spacing determined, economics and a misunderstanding of drainage needs for proper soil management and plant growth often lead to design compromises which result in inadequate drain spacings. Orienting the drains improperly for the topography, or parallel with field travel directions, or not placing the subsurface drains deep enough also affect the problem of spacing and the overall satisfaction with drain system performance.



Figure 4. Proper placement and protection of the outlet is necessary to minimize soil erosion.



Figure 5. Undersizing drainage outlets restricts drain performance and can lead to early failures.

Shallow drains are a common problem which occur because of inadequate survey design information and because of careless installation practices. Oftentimes the land is very flat adjacent to outlet ditches which are too shallow, and so the whole system can be bad if not enough survey information is obtained. Also, many fields consist of rolling land with several low spots, and drainage of these low spots becomes a limiting factor. Shallow drains can be observed during installation so the problem should be dealt with immediately. Sometimes this means redoing a large part of the system. At least two feet of soil over the top of the tile should be maintained at all locations in mineral soils and more for organic soils. Where shallow drain placement is unavoidable, because of ditch crossings for example, suitable material such as metal culverts should be used to support the load.

Future needs are often ignored when planning and designing drainage systems. Fields are dealt with specifically because of the economics or the lack of future intentions are unclear. Too often expansion dictates the need to add additional drainage which is most easily tied into already existing systems and mains. If the existing system is not adequate, additional expense is usually required to prevent overloading. Early planning of future needs is generally less costly in the long term.

CONSTRUCTION AND INSTALLATION

Construction and installation consists of all the detailed functions of building the drainage system. The many factors associated with this include installation method and machinery for drain placement, grade control, making connections, material handling, proper placement of soil and construction materials, and finalizing the as-built plans. The construction and installation element is very important to obtain quality subsurface drainage systems because building the system right in the first place is essential; yet the many unpredictable factors encountered such as weather, stones, unstable soils and old tile lines make it difficult to achieve quality control. Many times decisions and adjustments to the design must be made in the field to circumvent the many problems encountered.

The most common problem associated with construction and installation is grade control. Reverse grades or grades which are too flat or steep can reduce the effectiveness of a drainage system and even cause total system failure. Reverse grades and clay tile misalignment reduces the effective flow area. Flat grades lead to inadequate flow velocity and sedimentation in the lines. (See Figure 6). Steep grades (particularly on main lines) lead to high velocities and soil instability. Follow the recommended design guides for appropriate grades, pipe sizes and velocities to minimize problems.

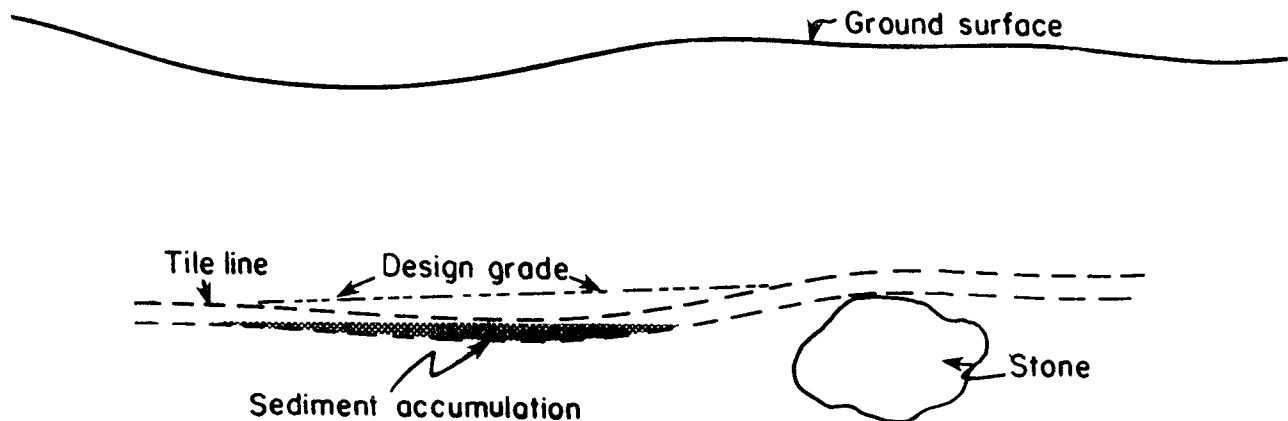


Figure 6. Maintain uniform grade. Avoid low spots in line which create sediment traps and sudden grade changes which can reduce effective area of opening.

It is important to know how grade control equipment works, the limitations of the equipment, and how to check and adjust the equipment. Stringlines, targets and laser equipment are all satisfactory methods when used properly. Stones and unstable soils create problems with maintaining uniform grades. Equipment rides up or sinks depending on the condition and affects proper drain placement. Grade control has to be maintained on site during construction, so the best preventative maintenance is careful installation procedures. (See Figure 7).

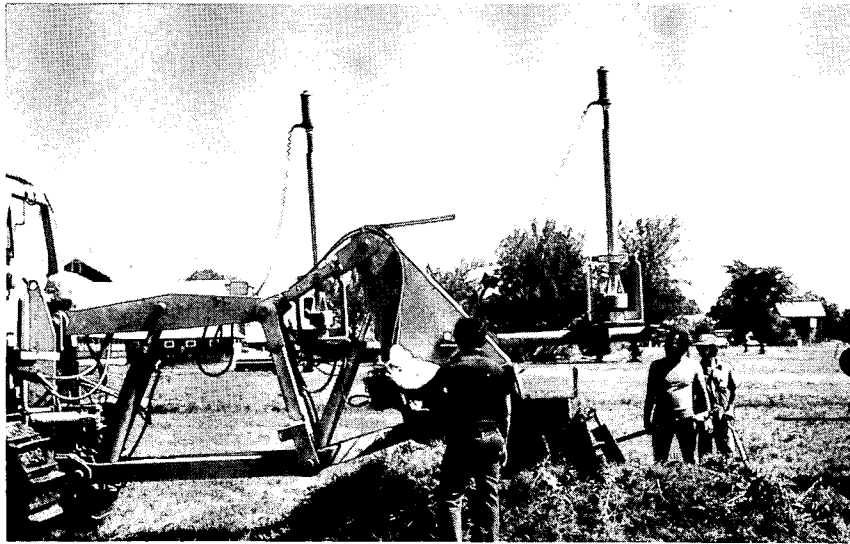


Figure 7. The dual masts of this laser-controlled plow were designed to minimize chute rise and sinkage.

Improper connection is perhaps the next most common weak link during drain installation and often cited as the cause of later maintenance needs. The problem occurs because manufactured fittings are not used or misused, connections are improperly fitted together, joint spacing is too large or small between clay tiles, or there is overdigging and inadequate blinding when making the connection. Manufactured fittings should be used to join materials together. Since many material and fittings are not standardized, obtain the materials and fittings from the same manufacturer to insure compatibility. Using the proper fittings maintains strength in the materials and minimizes flow restrictions. Installation often occurs when the soil profile is saturated, so it is difficult to make connections in the trench and provide the proper bedding and blinding in the disturbed area. Connections need to be performed as accurately and quickly as possible under these conditions. (See Figure 8).

A problem which is becoming more common is cutting off old tile lines. Replacement of old malfunctioning drainage systems and the increased use of the trenchless (drain plow) installation method have aggravated this problem. When old lines are encountered, even if they don't appear to be working, they should be connected to the new system. Direct connection or the use of permeable materials such as gravel are suitable methods to tie the old and new systems together. Many old lines still provide flow channels and they need to outlet somewhere.

Working when the ground is too wet can create major problems during drainage installation and long afterwards. (See Figure 9). Drainage installation during wet conditions intensifies problems with maintaining grade control, making good connections, smearing and sealing of soil adjacent to



Figure 8. Connections are difficult under wet conditions so they must be made as quickly and accurately as possible using the proper manufactured fittings.



Figure 9. Drainage installation during wet conditions intensifies problems with grade control, making connections, compaction, sealing of the soil, and dealing with unstable soils.

the drain, and dealing with unstable soils. Furthermore, deep soil compaction can occur on some soils when drainage installation equipment is working under wet conditions. Compaction is related to overall equipment weight even if track ground pressure is low. Wet conditions may be inevitable in some drainage projects and a gradual dewatering scheme will be necessary to get equipment onto the land. However, in most cases installation could be delayed to drier periods. Proper planning would minimize the impact of installing drains during the summer growing season.

The construction and installation of a drainage system usually involves large amounts of material handling. Clay and corrugated plastic materials need to be handled carefully to avoid breakage, stretch and physical damage. Plastic tubing is temperature sensitive. When it is cold, the material must be uncoiled slowly to avoid cracking. When plastic tubing is hot (i.e., surface temperature of tubing can reach 120°F when laying in the sun), it can easily be stretched or damaged which reduces its ability to support soil loading. Plastic tubing stretch can occur during stringing and while it is passing through the installation chute. Power feeders or manual methods are recommended to help push the tubing through the chute to minimize stretch. Both types of materials need to be bedded properly in the trench bottom groove. In open trench installations, blinding with loose permeable material is necessary to protect the material from falling stones and clods during backfilling. Synthetic filter fabric materials must be handled carefully to avoid tearing and unwanted holes.

EQUIPMENT AND MATERIALS

The types of equipment used in drain installation, equipment limitations, proper use and adjustment of the equipment and special equipment features all affect the quality of drainage system installations. The equipment used must be suited to the conditions of the site and for the material being used. Equipment specifically designed for subsurface drainage installation usually does a better quality job than general digging equipment or modified dozers and tractors. Most installation methods are satisfactory if proper care is exercised and site conditions are good. However, knowing the limitations of the equipment becomes more important under adverse conditions. For example, in unstable soils under wet conditions, the trenchless method will provide a better chance for maintaining grade control. On the other hand, the trenchless method does not do a good job of soil fracturing in excessively wet silty clay soils and this leads to reduced drain inflow. An important equipment limitation which is often overlooked is the ability of laser grade control to react quickly enough to excessive travel speed.

Proper use and adjustment of the equipment is necessary for satisfactory performance. Wearing surfaces must be maintained. Laser grade control must be set up correctly on the machine. Special equipment features such as power feeders, attitude indicators, cross tilt sensors, mounted stringers and others all help to provide better quality installations.

The type and quality of materials are important in obtaining a quality drainage system. Use materials which meet or exceed the minimum specifications of the American Society for Testing and Materials. All materials have advantages and disadvantages so become familiar with their characteristics. Select the type and quality which will work best for the site condition and the anticipated soil and loadings. Some soils have high corrosivity to concrete and metal, so these materials should be avoided for these site conditions. Materials which are thin or brittle or have poorly made openings should be avoided. Some materials have openings and special additives which are designed to handle special problem soils. Many times material failures are related to other problems such as drain tubes too shallow and not of adequate strength to support heavy equipment traffic, root plugging because open lines are placed too close to trees and shrubs, shifting tiles because of improper bedding, or sediment plugging because of flat grades, improper filters or inadequate outlets.

Precautions also need to be taken when storing materials. The impacts of moisture (freeze-thaw cycles), sunlight and rodents can quickly degrade material quality. Minimize the long-term storage of materials and try to use recently manufactured items.

INSPECTION AND MAINTENANCE

Once a drainage system is in place, it should not be out-of-sight and out-of-mind. The best design and installation can still fail in a short time if not inspected and maintained. A survey of 95 tile mains in Ohio showed that 25 percent of the drains 10 years old or less needed repairs. Thirty three percent of the drains needed repairs for those with 10 to 20 years of life. All drains over 40 years needed repairs and six percent needed to be replaced. However, many drains over 50 years were still working. A systematic (annual) maintenance program, which is started early, is the key to obtaining long-term performance of a drainage system.

A map or photograph which documents the drainage system as it is built is necessary to begin the inspection and maintenance program. (See Figure 10). Repairs and improvements to the drainage system will be much easier with good maps. The map also serves as a useful record for tax and resale purposes, and a copy should be kept with the deed.

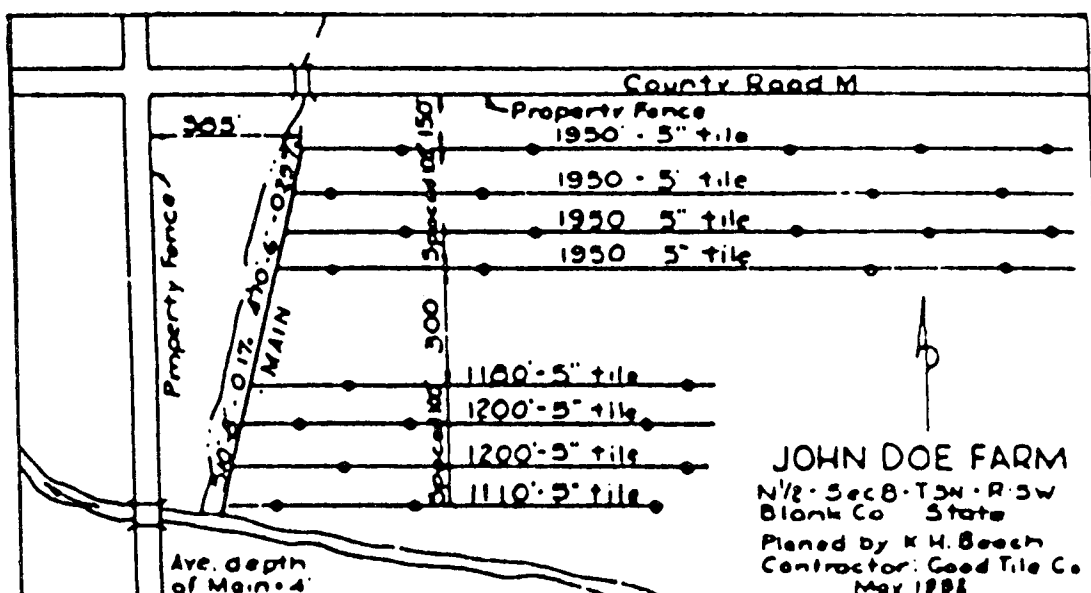


Figure 10. A map of drain locations and sizes should be made after installation and filed with important records.

A good inspection program involves many things. The outlet is generally the most vulnerable area where outlet pipes and animal guards need frequent maintenance and replacement. Many problems also develop at the connections of laterals to mains causing blowouts (water bubbling up or holes in the ground) and these sections should be repaired quickly. The uniformity of soil drying, drain outflow rates and sediment accumulations in the drains and outlet channels should be regularly observed, and if possible measured, to assure the drainage system is performing adequately. Junction boxes and sediment traps should be used on complex systems and where surface water is admitted to a subsurface system. These sediment traps will facilitate inspection and maintenance procedures.

SUMMARY

Subsurface drainage is a long-term water management system investment that offers many years of benefits and additional returns for the right soil and plant growing conditions. There are many factors to consider in minimizing the risk of early failure of a drainage system. The items mentioned above address the most frequently encountered problems contributing to poor quality drainage systems and may not necessarily mention every detail to be considered. However, following through with the basic considerations of planning, careful installation, good quality materials and regular maintenance should assure adequate drainage system performance for many years to come.

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