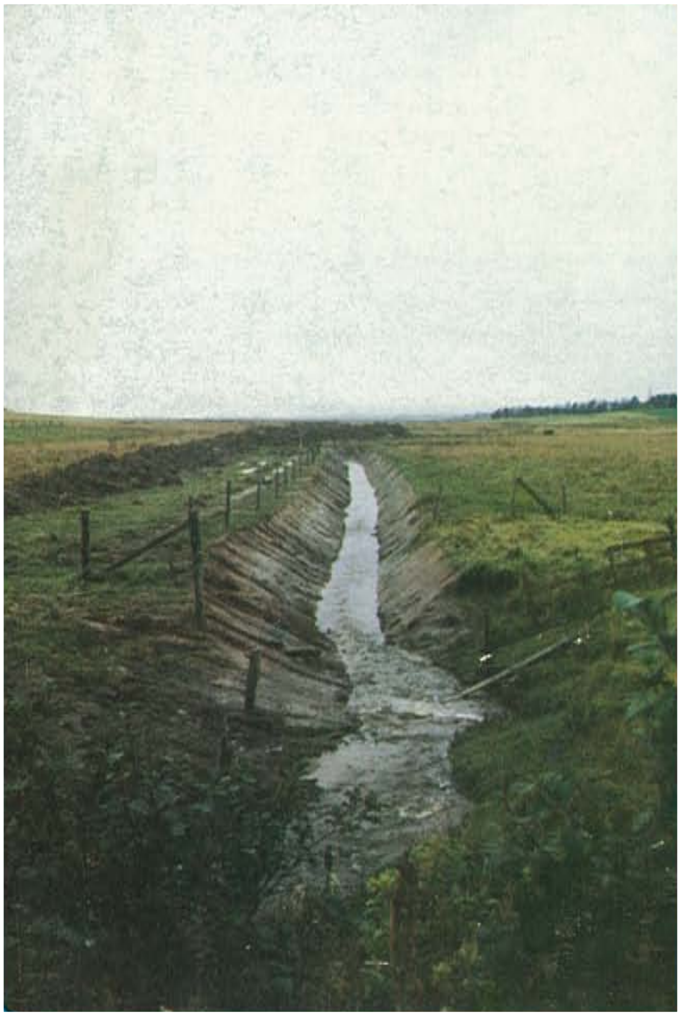
FARM DRAINAGE

IN THE ATLANTIC PROVINCES



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I. INTRODUCTION

Adequate drainage is essential to the proper management of agricultural soils in the Atlantic Provinces.

The purpose of agricultural drainage in humid areas is to provide an aerated plant root environment suitable for crop production and to ensure trafficable conditions for field operations such as cultivation and harvesting.

Several factors may create excess soil water which interferes with crop growth and the timely performance of field operations. Many of our agricultural soils are fine textured with a massive or dense subsoil which causes slow, downward movement of water. The situation is further aggravated by annual precipitation of approximately 1000 mm (40 in.) which is 50% in excess of crop needs. Also, soils in low areas are often poorly drained because of a natural high water table. In all cases, provisions should be made for the timely removal of the excess water if the soil is to be agronomically productive.

In the Atlantic Provinces, approximately 4,000 hectares (10,000 acres) of farm land are being improved annually by the removal of excess water. This is especially important since present farm trends are toward more intensive production of high value crops.

This publication is intended to provide farmers, land improvement contractors and the public with a basic understanding of the importance of good agricultural land drainage, and of design, construction and maintenance considerations common to drainage systems in the region.

II. UNDERSTANDING DRAINAGE

A. Hydrologic Cycle

The earth's water in its various forms is in a continuous circulation called the hydrologic cycle as shown in Figure 1. Radiation from the sun evaporates water into the atmosphere; this water vapor rises, and is condensed to form clouds, which in turn results in precipitation in the form of rain, snow, sleet or hail. Water may be evaporated from the surface of the ground, from free water surfaces, or from the leaves of plants through transpiration. A portion of the total precipitation may move over the soil surface as runoff while another portion may infiltrate into the soil to be used by vegetation, to become part of the deep ground water supply, or to seep slowly to streams, rivers and the ocean.

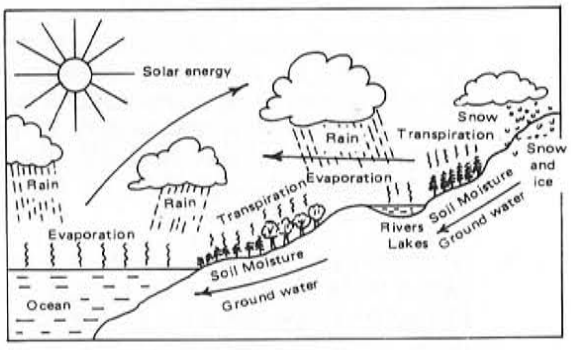


Figure 1. The Hydrologic Cycle [schematic]

B. Water Balance

Any attempt to control the quantity and availability of soil moisture to plants must be based on a thorough understanding of the balance of water in the soil. The field water balance, like a financial statement of income and expenditures, is an account of all quantities of water added to, subtracted from and stored within a given volume of soil during a given period of time. The various items entering into the water balance of a hypothetical root zone are shown in Figure 2.

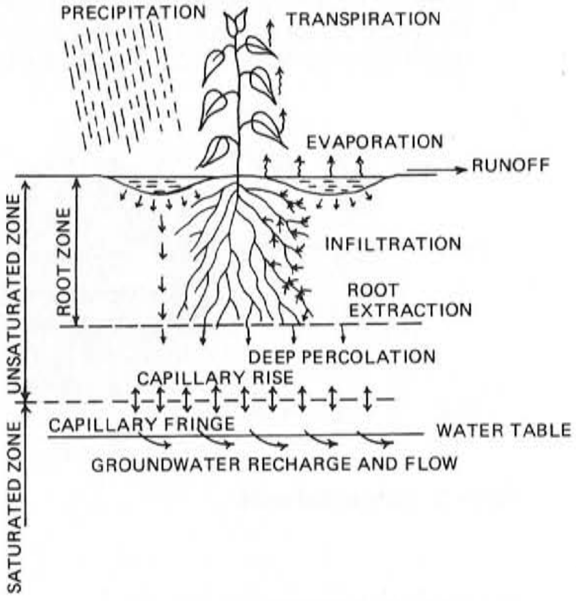


Figure 2. The Water Balance of a Root Zone.

To itemize the additions and subtractions from the soil storage reservoir, we must consider the disposition of precipitation reaching the soil surface. For example, rain may infiltrate into the soil as fast as it arrives, or some of the water may pond over the surface. Depending on the slope, a portion of this water may run off while the remainder will be stored temporarily as puddles in surface depressions. Some of this water evaporates and the rest eventually infiltrates into the soil. Of the water infiltrated, some evaporates directly from the soil surface, some is taken up by plants for growth or transpiration, some may drain downward beyond the root zone, and the remainder accumulates within the root zone and adds to soil moisture storage.

There are two basic soil-water conditions of importance to drainage; saturation and field capacity. When water fills all the spaces between the soil particles, the soil is saturated. If the saturated soil is allowed to drain for a few days, the soil water content will decrease to field capacity. Water has drained out of the larger pore spaces due to the action of gravity, and air has taken its place. Field capacity is characterized by the following phenomena:

1. Only the water that will drain due to the action of gravity is removed. This "gravitational" water is of no use to the plant. Therefore, the main purpose of drainage for crops in Atlantic Canada is to remove the gravitational water to allow adequate aeration of the root zone.
2. The water remaining in films around the soil particles, called capillary water, is the water utilized by plants. It is replaced by rainfall or capillary rise from the water table. Gravitational and capillary water is shown in Figure 3.
3. Further moisture depletion occurs through the plant's root system (root extraction), or by direct evaporation from the soil surface.

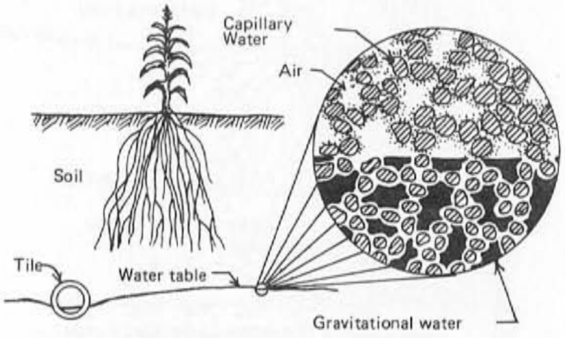


Figure 3. Types of Soil Water

C. Drainage Benefits

Drainage affects both plant growth and overall farm management. The major benefits of good drainage area:

1. Drainage promotes earlier warming and drying of soil in the spring. Seed can be planted earlier (better trafficability) and can germinate earlier (higher temperature). This is very important in areas with short growing seasons and where early harvests may bring higher prices.
2. Drainage removes the excess (gravitational) water from the root zone leaving only the capillary water which is required for plant growth.
3. The removal of excess water is also essential to maintain a continuous supply of oxygen to the root zone. A lack of oxygen discourages the growth of beneficial soil micro-organisms and the formation of useable forms of plant nutrients. Fertilizer applied to a poorly drained soil may only be partially used by the plant due to the lack of oxygen.

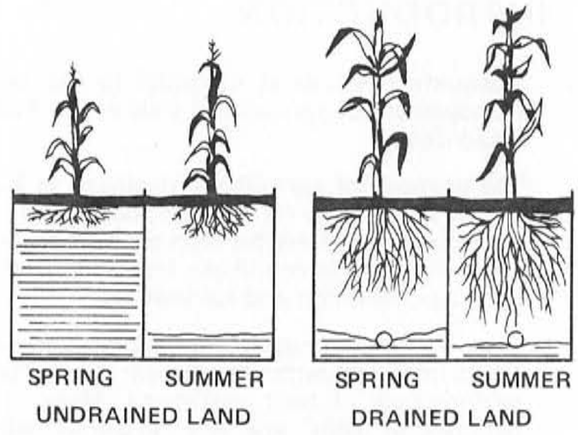


Figure 4. Root Development on Drained and Undrained Soil

4. Plant roots will penetrate more deeply into a drained soil, thus enlarging the supply of plant food which produces healthier, more vigorous growth (Figure 4). Deeper roots also help the plant to withstand drought and strong winds. Most plant root systems will not penetrate into a water table. In poorly drained soils, the plant root system will be shallow and more susceptible to disease.
5. Drainage promotes conditions that maintain soil structure and workability while reducing compaction. Well drained soils are essential to efficient field operations throughout the season. Poorly drained soils adversely affect planting, cultivating, and harvesting operations.
6. Drainage can increase infiltration and reduce surface runoff. On fields susceptible to soil erosion, subsurface drainage can help to control soil loss caused by the runoff of surface water. Also, surface drainage techniques such as diversion ditches and grassed waterways can control runoff and reduce soil erosion.
7. Less soil heaving and root damage will occur during winter on drained land.
8. Drainage enhances farm productivity and net returns by adding productive areas without extending farm boundaries, and by increasing the yield and quality of crops. Increased crop yields of 10 - 25% or greater can be expected, depending on the initial drainage status of the land.
9. Good drainage provides the farm manager with a wider range of crop choices and an increased scope for crop production planning.

III. TYPES OF DRAINAGE SYSTEMS

The following discussion outlines a variety of techniques that are used to drain the most common mineral soils in Atlantic Canada. If drainage of peat soils is being considered, variations or different techniques may be required. Professional assistance should always be requested before commencing drainage projects.

A. Surface Drainage

Surface drainage is the removal of excess water from the land surface through improved natural channels, constructed open ditches or shaping of the soil surface.

1. Open Ditching

Open ditches are the most widely used form of surface drainage in the region. Open ditches generally provide an economic solution to conveying large volumes of water. They act as field perimeter drains, cut-off drains (collecting water from an upslope wooded or other area) and outlets for other drainage systems. Open ditches also have disadvantages. They may take some land out of production and they require considerable maintenance. Field ditches may also interfere with farm equipment operations. These considerations notwithstanding, it should be realized that few drainage systems can be constructed without some form of open ditching to provide an outlet.

When planning an open ditch system there are a number of items which should be considered:

(a) volume of water to be drained.
(b) topography.
(c) type of soil.
(d) depth requirements.

The volume of water to be drained by an open ditch is a function of the size, length, slope, vegetation, soil type and hydrologic condition of the affected watershed.

The slope of a ditch is determined by the area's topography. Slopes as little as 0.05% or 0.5 m / 1000 m (0.5 ft. / 1000 ft.) may be used. In situations where open ditches are required to transport large volumes of water on steep slopes, they should be carefully planned to avoid ditch bottom and side slope erosion. If high water velocities are expected, the open ditch should be rock lined or water control structures installed to prevent erosion.

Open ditches require adequate side slopes to prevent eroding and sloughing of ditch banks. Table 1 indicates the recommended side slopes for various soil types. A typical open ditch cross-section is shown in Fugure 5. Note that the minimum ditch bottom width for soils susceptible to erosion is 1.0 m (3.3 ft.).

Table 1. Recommended Open Ditch Side Slopes [Horizontal [x] : Vertical]

Soil	Shallow Channels ‹ 1.2 m [4 ft.]	Deep Channels ›1.2 m [4 ft.]
Peat and Muck	Vertical	0.25:1
Heavy Clay	0.5:1	1:1
Clay or Silt Loam	1:1	1.5:1
Sandy Loam	1.5:1	2:1
Loose Sandy	2:1	3:1

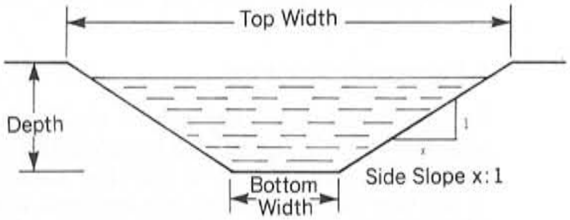


Figure 5. Typical Open Ditch Cross-Section

An open ditch should be planned in conjunction with the other drainage systems discharging into it. For example, if an open ditch is to serve as an outlet for a subsurface drainage system, the ditch depth should be 0.3 m (1.0 ft.) greater than the outlet depth of the subsurface system. Perimeter cut-off ditches should have a depth of 1.0 m (3.3 ft.). Other ditches should have sufficient depth to provide an adequate outlet for all field drainage systems to be constructed.

The ditch banks should be seeded with a recommended grass mixture as soon as possible after construction. This will help stabilize the ditch bank and prevent bank erosion. Also, sediment control structures such as settling ponds and check dams may be required to prevent sedimentation of downstream watercourses. **Watercourse Alteration Permits** are required before constructing ditches that discharge into brooks, streams and other watercourses.

2. Land Levelling

The purpose of land levelling is to grade or level the surface of a field to eliminate areas where surface water may pond. Land levelling is commonly used to drain dykeland fields where it is generally referred to as land forming (see Dykeland Drainage). But the technique may also be used to improve surface drainage on upland fields.

Perennial forage crops and fall seeded cereals may not survive winter as a result of ponded water. Crops may also be negatively affected during the growing season when ponding occurs after heavy rains. Thus, eliminating areas subject to ponding can improve crop production.

To level upland fields, where topsoil is often shallow, the topsoil should be removed and piled both from the higher field areas and from the lower ponding areas with earth moving equipment. The ponding areas are then filled with subsoil and the topsoil replaced. This extra movement of topsoil is expensive but necessary to provide the best conditions for crop production.

3. Land Smoothing

Land smoothing is the process of eliminating minor surface irregularities or the finishing operation in land levelling. Smoothing is usually performed by farm tractor powered land levellers after the bulk of the soil has been moved by larger equipment.

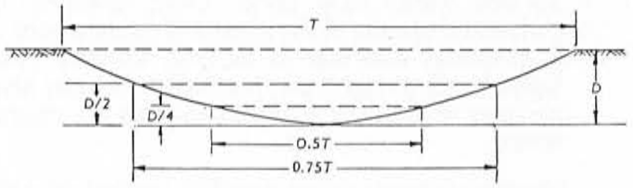
4. Grassed Waterways

Grassed waterways are broad, shallow vegetated channels designed and constructed to carry natural concentrations of surface water runoff or the discharge from terrace systems, diversion channels or farm pond emergency spillways. Grassed waterways help to prevent gully erosion and are normally constructed in depressions where water can collect and flow to an outlet.

Grassed waterways should not be used for continuous flows, such as may discharge from subsurface drains, since prolonged wetness in the waterway will result in poor vegetative cover. If they must be used under these circumstances, special supplemental treatment should be considered such as grade control structures, stone centers or subsurface drainage.

Grassed waterways should be designed to transport peak runoff volumes at low velocities. Figure 6 shows a typical grassed waterway cross-section. The shape and dimensions of a waterway are dependent upon the design peak flow, the type of vegetative cover or channel bottom material required, and the waterway slope. The cross-section should be designed to permit crossing of equipment where necessary and to allow for easy mowing and maintenance of the waterway.

Grassed waterways usually discharge into a ditch or stream and it is important to construct non-erodable outlets at these points. A rock chute spillway or a drop inlet structure may be used. Subsurface drains should be offset from the centreline of a waterway by at least 25% of the total waterway width.



T = design top width

D = design depth

Figure 6. Typical Parabolic Grassed Waterway Cross-Section

5. Dykeland Drainage

For many years, difficulties have been encountered in farming dykeland soils due to their poor drainage condition. In the past, numerous shallow ditches were excavated resulting in small field sizes and little drainage improvement. To overcome this problem, many farmers have successfully used the surface drainage method of land forming to improve drainage and to make larger fields.

Two principle methods of dykeland forming have been developed:

(a) Forming with open ditches - In this method, an area between shallow open ditches is crowned or formed so that the cross-section midpoint slopes from 1 to 2% to the ditches. This sloping of the land causes more rapid movement of surface water from the field to the ditches. The distance between these ditches is normally 35 - 60 m (115 - 200 ft.), the actual distance depending on depth to subsoil and the length and size of the field to be formed. Since the ditches between the crowns cannot be easily crossed with farm equipment, each crowned area is farmed separately.

(b) Forming with "runs" - This method is similar to (a) above, except that water drains from the crown to a "run" or low area formed between the crowns rather than a shallow ditch. A run usually has a gradient of 0.1 - 0.4% to an open collector ditch. The advantage of this system is that much larger areas can be worked as one field since the runs, when dry, may be crossed with farm equipment. The disadvantage is that more earth movement may be required to grade the runs to a collector ditch. To reduce earth movement, run lengths are usually less than 150 m (500 ft.).

Forming has been widely accepted by the farming community and in some dykeland areas all of the fields are drained by this method. Installations of subsurface drainage in combination with land levelling also may be an effective method of dykeland drainage and could be considered prior to draining some areas.

B. Subsurface Drainage

Subsurface drainage, commonly called tile drainage, is the removal of excess water below the ground surface. Subsurface drainage lowers high water tables caused by precipitation, irrigation water, seepage from higher lands and ground water under artesian pressure.

As previously mentioned, a high water table damages most crops to varying degrees. The optimum depth of the water table is not constant for all areas, but varies with soil texture, depth of soil and subsoil layers and crops grown. Table 2 indicates the recommended **minimum** water table depths for various crops (deeper water tables are preferable).

Table 2.
Minimum Water Table Depths for Various Crops

Water Table Dept m (ft.)			
0 - 0.30 (0 - 1.0)	0.30 - 0.40 (1.0 - 1.3)	0.40 - 0.5 (1.3 - 1.6)	0.5 + (1.6 +)
Tolerant Species	**Shallow Rooted**	**Medium Rooted**	**Deep Rooted**
Rushes Sedges Reed Canary Grass Water Fox Tail	Cranberries Forage Grasses Red Top Ladino Clover White Clover Vegetable Leaf Crops Spinach Lettuce Cabbage	Strawberries Blueberries Black Currants Nursery Crops Red Clover Alsike Clover Vegetable Root Crops Carrots Parsnips Potatoes Beets Bulbs	Alfalfa Raspberries Red Currants Nuts Tree Fruit Asparagus Corn Grapes

With subsurface drainage, excess water moves through the soil and enters drainage pipe through perforations spaced around the pipe. The water then flows along the pipe by gravity and is discharged into an open ditch, watercourse, or other low point in or near the field.

1. Types of Subsurface Drainage

Subsurface drainage systems generally are of the random or systematic types (Figure 7). The topography, slope, and drainage condition of the field determine the type of system that should be installed.

(a) Random

A random system is used to drain isolated wet spots caused by springs or ponding. Although this approach works well for the wet spots, as a rule it does not benefit the other areas of the field. Since many of our soils in Atlantic Canada are not naturally well drained, random drainage may only provide a partial answer to the total problem. Quite often fields drained with a random system will be re-drained several years later in a systematic fashion.

(b) Systematic - Gridiron and Herringbone

A systematic system results when drainage lines are planned and installed to control excess subsurface water over all of the field.

The gridiron system is used to drain fields with uniform slopes in one direction. The main collector line is installed along one side of the field and lateral lines are connected perpendicular to it. A herringbone system is used to drain fields in which a narrow depression is near the centre of the field. The main is installed in the depression with angled laterals connecting on both sides.

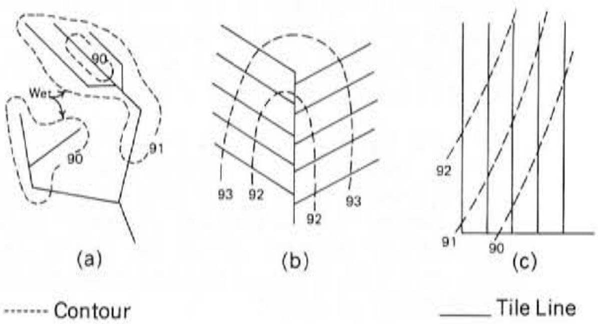


Figure 7. Common Types of Subsurface Drainage Systems: (a) Random; (b) Systematic Herringbone; (c) Systematic Gridiron.

2. The Interceptor Principle

Wet spots on a hillside may appear as a line of seepage along the upper surface of a clay or compact layer. To correct this situation, the water must be intercepted by a subsurface drain installed across the slope above the seepage area (Figure 8). Since Atlantic Canada has many rolling fields, this interceptor principle should be recognized when designing a subsurface drainage system.

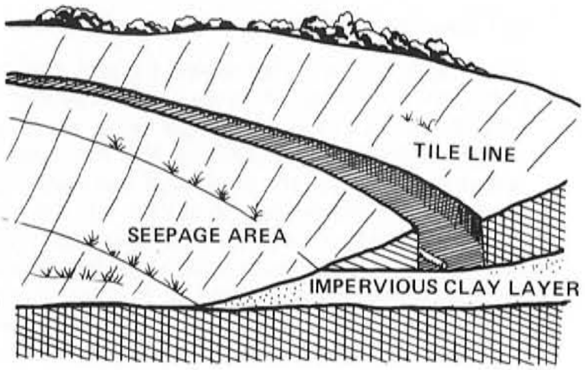


Figure 8. Proper Location of an Interceptor Drain

3. Design of Subsurface Drainage Systems

To design an effective drainage system, a field investigation is necessary. Information on excess water problems and crop production plans,in combination with soil and topographical survey data is required.

A soil investigation is important to determine the hydraulic conductivity (rate of water movement through the soil), texture of the soil (clay, silt, and sand content), soil profile characteristics, and the location of impermeable layers. These factors affect the depth and spacing of drains. Generally, the lower the hydraulic conductivity the closer the required drain spacing. A topographic survey is required to determine outlet locations and drain sizes, depths and gradients. These investigations contribute to the final design and preparation of plans for the proposed drainage system. Proper investigation and planning will help to ensure the optimum performance of the system.

Whatever the combination of drain depth and spacing, subsurface drainage systems should remove gravitational water to a depth of 0.3 m (1 ft.) below the soil surface at a point midway between the laterals within 24 hours after a heavy rain. This is a general recommendation for a wide range of crops.

The following important points should be considered when planning a subsurface drainage system:

(a) Depth of Drains

Drain depth is controlled by soil hydraulic conductivity, depth to the impermeable layer, depth of the outlet and machine limitations. Subsurface drains should have at least 0.6 m (2.0 ft.) of soil cover to protect them from damage by equipment travelling over the field. Generally, subsurface drains are installed at a depth of 1.0 m (3.3 ft.) which may vary depending on the topography and soil. Where impermeable subsoil layers exist, the pipe should be placed on or above the impermeable layer if possible.

(b) Spacing of Drains

Drain spacing is determined by soil hydraulic conductivity, type of crop, drain depth, the extent of surface drainage and depth to impermeable layer. Generally, the narrower the spacing, the better the control of the water table (Figure 9). However, selection of the most economic system calls for determination of the maximum drain spacing which can be tolerated by the crops to be grown. In Atlantic Canada, most subsurface drainage laterals are spaced at 9 - 18 m (30 - 60 ft.).

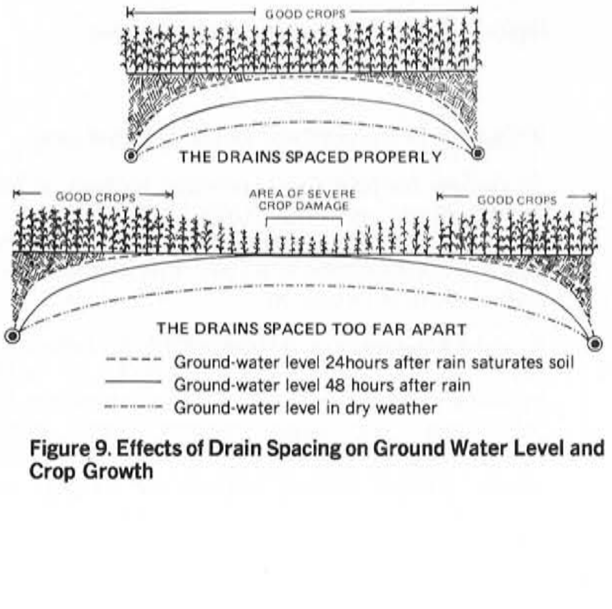


Figure 9. Effects of Drain Spacing on Ground Water Level and Crop Growth

(c) Grade

Subsurface drains are normally placed on uniform grades and as close to uniform depth as topography permits. Usually a grade of at least 0.3% is desired on the laterals. Where sufficient slope is not available, the grade should not be less than the minimum, unless special precautions are taken during construction to prevent reverse-grade conditions.

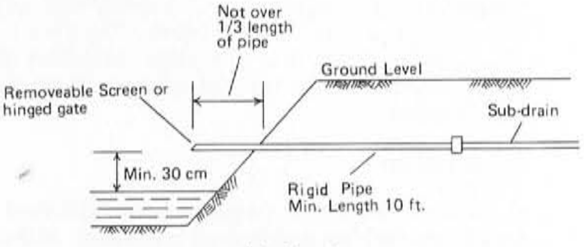
Table 3
Minimum Grades for Subsurface Drains

Pipe Diameter mm (in.)	Minimum Grade %
75 (3)	0.2
100 (4)	0.1
150 (6)	0.05

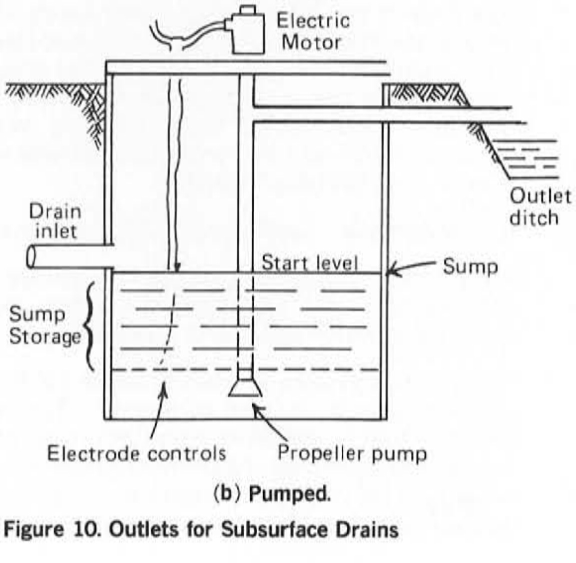
Maximum grades are limiting only when drains are designed for near maximum capacity or are embedded in unstable soil. The maximum grade of lateral drains should not exceed 2%.

(d) Outlets

The most important part of a drainage system is the outlet. The outlet must be deep enough to provide free flow of water from subsurface drains. The outlet should have adequate flow capacity to accept and safely dispose of all the water delivered by the drainage system. The two main types of outlets for subsurface drains are gravity and pumped (Figure 10). The type of outlet used for a particular area depends on the existing conditions.



(a) **Gravity;**



(b) **Pumped.**

Figure 10. Outlets for Subsurface Drains

Gravity outlets, which are the most common, are usually natural channels (brooks) or constructed waterways and open ditches.

An outlet pipe of corrugated metal or other rigid pipe, about 3 m (10 ft.) long and extending into the bank, is recommended. The bottom of the outlet pipe (pipe invert) should be above the high water mark where possible, and at least 0.3 m (1.0 ft.) above the normal water level in the ditch. Submergence for an extended period of time could cause silting in the pipe.

Pumped subsurface drainage outlets are required when the normal water level at the outlet location is higher than the bottom of the outlet pipe, resulting in the system being unable to adequately drain the field only by gravity flow of water. Pump installations should have facilities for storing water, such as a sump or an open ditch, to reduce the frequency of pump starts and stops.

(e) Filter Requirements

Filters for subsurface drains are permeable materials placed around the drains for the purpose of preventing fine grained materials in the surrounding soil from being carried into the drain by groundwater. The commonly used filter material is a factory pre-wrapped synthetic envelope. A filtered pipe should be used in uniform soils where most of the particle size is from 0.01 - 0.25 mm (fine sands-silty soils). A soil may be sandy but have a wide range of particle size, with the larger acting as filters for the smaller sizes. In these cases, a filter is not required. Also, filters may not be required if grades are great enough to create water velocities that will flush sediment out of the drain lines.

(f) Surface Inlets

Surface inlets may be used to collect and drain excess surface water when other surface drainage methods are not practical. A surface inlet is a structure used to divert surface water into an open ditch or a tile line. They may be constructed from concrete, metal, or prefabricated plastic materials (Figure 22, page 15). The size and / or type of inlet required depends on the flow volume and whether or not suspended sediment will be allowed to pass through it. Trash racks or screened inlets should be used to prevent debris from entering the inlet structure. Surface inlets should be inspected several times each year to ensure performance during heavy rainfall and spring runoff periods.

4. Subsoiling

Subsoiling is applicable to soils in which the hydraulic conductivity in the entire root zone, or of layers within the profile, is very low. There are soil types in Atlantic Canada with the above conditions; subsoiling may be required to improve response to subsurface drainage by loosening and shattering the compacted soil. Subsoiling without subsurface drainage may create a "bath tub" with the excess water readily sinking into the loosened soil but being unable to drain away. Subsoiling should normally be performed perpendicular to the drainage laterals to improve water movement to the drains. Also, the response to subsoiling is improved if performed when the soil is dry (Figure 20, page 14).

5. Mole Drains

Mole drains are unlined, cylindrical channels artificially produced in the subsoil by a moling plow without excavating a trench from the surface. The moling plow has a long blade-like coulter to which is attached a cylindrical bullet-nose plug, known as the mole (Figure 11). As the plow is drawn through the soil, the mole forms a cavity at a set depth, 0.4 - 0.6 m (1.3 - 2.0 ft.) below the ground surface. Mole channels usually range in diameter from 50 - 100 mm (2 - 4 in.) and are spaced 2.5 - 3 m (8 - 10 ft.).

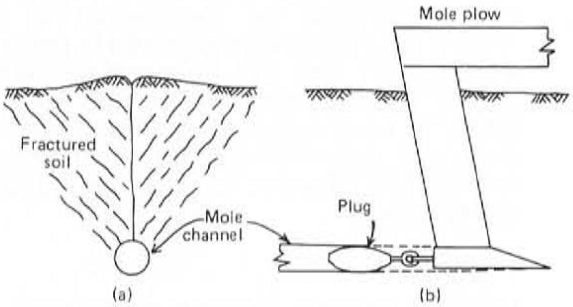


Figure 11. Mole Drainage: (a) Cross-section of Mole Channel; (b) Method of Forming a Mole Drain.

Heaving and fracturing of soil by the mole provides drainage pathways for water trapped at or near the soil surface. Moling is normally employed on heavy clay land. The optimum ranges of clay content and soil moisture which produce stable, long-lasting mole channels are still being investigated.

Mole drains should be on grade and have a suitable outlet. In areas of the world where mole drains are commonly used, they are generally pulled across and over subsurface drains. These subdrains have a permeable gravel backfill which provides an outlet for the intersecting mole drains. The frequency of remoling is dictated by the drainage response and may be from one to five years. Mole drainage is not a common practice in Atlantic Canada.

IV. DRAINAGE EQUIPMENT AND MATERIALS

This section presents a brief outline of the specialized equipment and materials commonly used for agricultural land drainage in the Atlantic Provinces. Since these items are available through drainage services provided by land improvement contractors, farmers do not need to be greatly concerned with their operation, handling, and/or installation.

A. Drainage Equipment

1. Draglines

Cable operated, crawler mounted shovels or draglines are often used to construct large open ditches and main outlet drain systems (Figure 12). Draglines are also used for dyke construction because of their long reach and deep excavating capabilities.

2. Excavators

Hydraulically operated, crawler or wheel mounted excavators (Figure 13) have gained wide acceptance for construction of farm ditches. Excavators have good reach, speed and trafficability and can efficiently construct ditches ranging from shallow field perimeter drains to main outlet drains. Specialized "V" ditch and side ditching bucket attachments improve the efficiency of excavators used for open ditching.

3. Backhoes

Industrial loader / backhoe combination machines are commonly used for secondary open ditch construction, placement of culverts, and installation of subsurface drainage tubing. With the advent of specialized drainage installation equipment, the backhoe alone is rarely used to excavate trenches for placement of drainage tubing. Rather, it is used for excavating outlet ditches and making connections between main and lateral drainage lines while the drainage machine performs the tubing installation work.

Figure 12. A Dragline Excavating a Large Open Ditch.

Figure 13. A Typical Excavator that was used to Construct the Open Ditch in the Right of the Figure.

4. Crawler Tractors

Shallow ditch excavation, levelling of spoil material from ditches, and land levelling are the most common drainage jobs performed by crawler tractors. On the dykelands, crawler tractors of 75 kw (100 hp) or greater, perform most of the land forming / surface drainage construction work (Figure 14). Large crawler tractors may also be used to pull drainage plow attachments for installing subsurface drainage tubing.

Figure 14. Dykeland Forming Using a Crawler Tractor.

5. Rotary Ditchers

Powered by farm tractors of 30 kw (40 hp) or more, rotary ditchers have gained acceptance for constructing small field ditches, primarily on the dykelands (Figure 15). Rotary ditchers can excavate several kilometers of ditches in one day while spreading the spoil at the same time. Rotary ditchers are used in rock-free soil where surface drainage improvement is the primary concern.

6. Subsurface Drainage Trenchers

Trenchers are used to install subsurface drainage tubing or clay tile (Figure 16). Basically, the trencher's digging wheel excavates a rectangular ditch or trench with a groove in the center of the trench bottom. The trencher then places the tubing or tile in this groove and covers it with several centimeters of topsoil. In good conditions, light trenchers of 60 - 90 kw (80 - 120 hp) can install drains at depths to 2.0 m (6.5 ft.) at speeds of 200 - 300 metres per hour (650 - 1000 feet per hour). Grade control may be achieved by using an engineer's level and stakes (manual system) or a laser grade system.

7. Subsurface Drainage Plows

In agricultural areas where the annual installation rate of subsurface drainage is high, trenchless drainage plows have become popular drainage machines. Available in self-propelled or crawler-mounted models, the trenchless plow does not excavate a trench; rather, a large blade or tine is pulled through the soil and the drainage tubing is placed in a hollow chute at the back of the blade. As the plow moves, the tubing is drawn through the chute into the soil at the bottom of the blade (Figure 17). Connections between drainage laterals and mains are made using a backhoe. No backfilling of drains is required except at lateral connections. Trenchless plows have the potential to work 2 - 3 times faster than trenchers and are more suited to installing drains in stony soils. The most common drainage plows have approximately 150 kw (200 hp), a maximum installation depth of 1.6 - 2.0 m (5.2 - 6.5 ft.) and are equipped with a laser grade control system.

Figure 16. A Subsurface Drainage Trencher Preparing to Install Drainage Tubing.

Figure 17. Laser Receiver Mast Mounted on a Trenchless Drainage Plow, 100 mm (4 in.). Filtered Tubing Being Installed.

Figure 15. A Rotary Ditcher Excavating a Shallow Open Ditch on Dykeland.

Both the trencher and trenchless plow can perform quality drain installations over a range of soil conditions when properly maintained and skillfully operated.

8. Laser Grade Control Systems

Laser equipment is used with most subsurface drainage machines to automatically control installation depth and grade. Variations of subsurface drainage laser equipment may also be used for aiding excavator operation or for performing field level surveys.

The subsurface drainage machine laser system consists of an emitter and a receiver. The emitter (Figure 18) is usually located in the field about midway between the main collector and the ends of the lateral drainage lines.

Figure 18. Laser Grade Control Emitter Tower. Note the Drainage Machine in the Background.

It establishes a pre-determined sloping reference plane over the field by means of a rotating laser ray. The receiver, located on the machine (Figure 17), detects this plane of reference and transmits a signal to the machine's hydraulic system. The drain depth in relation to the reference plane is monitored five or more times per second, allowing drains to be installed with great accuracy. The machine operator can adjust the drain slope using a control panel in the cab or by changing the emitter settings.

9. Land Levellers

These machines are pulled by farm tractors of greater than 35 kw (47 hp) and vary in size from the smaller single blade levellers (Figure 19) to large multi-blade levellers up to 12 m (40 ft.) in length. Land levellers are designed to smooth and plane the soil surface to eliminate minor surface irregularities without changing the general contours of the land. Levellers are normally used as part of the finish operation in a land levelling or forming project. They may also be used to smooth the land after land clearing or subsurface drainage installation.

Figure 19. A Land Leveller Implement Performing Land Smoothing.

10. Subsoilers

These are specialized machines with one or several tines pulled through the soil to cause lifting, shattering, and loosening in compacted soil layers (Figure 20).

Light Duty

Heavy Duty

Figure 20. Typical Light and Heavy Duty Subsoiler Implements.

For shallow subsoiling, 4 or 5 tines spaced 50 cm (20 in.) apart may be used. For soil loosening at a depth of 60 - 80 cm (24 - 30 in.), 2 - 3 tines spaced about 80 cm (30 in.) apart may be used. An effective subsoiler tine should be rather robust and its foot or tip should have an inclination of not less than 25 - 30° to produce good lifting and loosening of the soil. Proper side wing attachments to the foot of the subsoiler tine will increase the area of soil loosening. Generally, power requirements for subsoiling are considerable, depending on the soil condition, the desired subsoiling depth, and the spacing and configuration of the subsoiler tines.

B. Drainage Materials

1. Culvert Pipes

Culverts are used for the construction of road and other crossings over ditches and for transporting drainage water in areas where open ditches or waterways are not practical or feasible. Most culverts are constructed of corrugated steel pipe but concrete and corrugated plastic pipes are also used. 150 - 1500 mm (6 - 60 in.) diameter culvert pipes, 6 - 18 m (20 - 60 ft.) in length, are used for most agricultural applications. Culvert pipe should be sized and installed properly to ensure adequate discharge of peak water flows.

2. Subsurface Drainage Tubing

Perforated, corrugated polyethylene or polyvinyl chloride plastic tubing has become the most commonly used subsurface drainage material because of its light weight, ease of handling, bearing strength, cost, and availability. Normally, lateral drains are 100 mm (4 in.) and main collector drains are 100 - 150 mm (4 - 6 in.) tubing. Larger or smaller sizes are also available but are not commonly used.

Tubing connections are easily made using manufactured plastic fittings (Figure 21). Also, tubing is available covered with filter material to prevent drain plugging in fine sandy loam and some silty soils (Figure 17, page 13).

3. Subsurface Drainage Outlets

Subsurface drainage outlets should be protected by a 3 m (10 ft.) length of continuous, rigid, non-perforated corrugated steel or plastic pipe (Figure 21). A hinged rodent grate or flap is attached to the outlet pipe to prevent rodents from entering and / or causing damage to the drainage tubing. The inside diameter of the outlet pipe should not exceed the outside diameter of the drain pipe by more than 50 mm (2 in.).

Figure 21. Rolls of Corrugated Plastic Subsurface Drainage Tubing, Molded Plastic Connections and a Corrugated Steel Outlet Pipe with a Hinged Rodent Flap.

4. Surface Inlets

Manufactured plastic surface inlet riser pipes (Figure 22), are used occasionally to provide entry of excess surface water into a subsurface drainage pipe. Surface inlets should be equipped with screens or trash racks, or manufactured with smaller diameter inlet holes to prevent debris entry into the drainage system. The drainage system capacity should be large enough to allow entry of the excess surface water. Manufactured plastic inlets may vary in diameter from 150 - 250 mm (6 - 10 in.) with 25 mm (1 in.) inlet holes or slots. They may be adjusted to pond the water before entering the inlet causing the silt to deposit, or to allow free flow of water into the subsurface drainage system.

Figure 22. Surface Inlet Riser Pipe Installed in a Surface Water Collection Area.

V. SUCCESSFUL FARM DRAINAGE

A. Planning and Construction

Agricultural land drainage is a significant investment and should be properly planned, constructed, and maintained if optimum value for the drainage dollar is to be achieved.

Before commencing drainage work, careful consideration should be given to assessing drainage priorities and alternatives on the farm. For example, drainage improvements generally should be made on the higher quality land where the major limitation to crop production is wetness. Poorer quality land with a variety of other limitations such as stoniness, steep slopes, poor soil structure, etc. may not give an acceptable economic return on the drainage investment.

Once the area to be drained has been chosen, proper planning and scheduling of the work is necessary. It is always advisable to contact the local Department of Agriculture drainage engineer to obtain assistance in planning drainage projects as outlined in Section III of this booklet. The following general outline should be followed when draining a typical farm field in Atlantic Canada:

1. Open ditches should be constructed first. This would include perimeter and cut-off ditches and outlet ditches for subsurface drainage. Open ditches should be constructed before September 1, if ditch bank seeding is required to prevent erosion and sedimentation.
2. Land forming or levelling should be performed in conjunction with or after open ditch and or surface waterway construction. Excess spoil can be used to fill low areas or blended with other forming work. The ditches and waterways will also provide some topographic relief to facilitate land forming.
3. Subsurface drainage normally should be installed after open ditch and or other surface water control structures are in place. This eliminates damage to drainage lines which could occur if ditching and other excavation work is performed after subsurface drainage installation.

   Where subsurface drains are to be installed on fields which are susceptible to soil erosion (row crops, steep slopes, etc.) planning should encompass both drainage and erosion control measures. For example, if grassed waterways and / or diversion terraces are required, subsurface drainage should be planned in conjunction with these erosion control structures. It may be necessary to locate main collector lines and outlets to one side of waterway locations and/or to install subsurface drains after soil erosion controls are constructed. Drainage lateral locations should also be adjusted to the location of diversion terraces.
4. Subsoiling may be performed on compacted soil after subsurface drainage installation if it is determined that additional crop production improvements will result. If required, subsoiling may also be performed prior to subsurface drainage installation provided field conditions are sufficiently dry.
5. Mole drainage, if used, should be performed after the subsurface drainage tubing is installed so that an outlet is available for the mole drains.
6. To eliminate minor field surface irregularities remaining after the drainage work and to provide an even seed bed, the final drainage operation should be land smoothing.

Drainage construction should not be undertaken when the field is excessively wet or frozen. Working in wet soil leads to compaction and reduces construction efficiency. Working in frozen soil is usually not practical as the soil shears in large chunks which are difficult to form or shape.

Drainage construction should be performed by experienced land improvement contractors with the proper equipment and trained operators. For large drainage projects, requiring several weeks of construction, it is wise to leave the field fallow and have the work done during the summer months when conditions are drier and contractors may be more available than during the early spring or late fall.

When drainage projects are planned that will alter watercourses, it is necessary to check with Provincial Environment authorities before proceeding with construction. Every precaution should be taken to control erosion of soil from ditch banks and fields that may result in sedimentation damage to a watercourse. Also, open ditches should be properly located to serve the maximum possible area to be drained, thereby reducing the number and length of ditches required.

B. Field Management After Drainage

Generally, it is difficult to immediately grow a valuable cash crop on recently drained land that has a history of poor productivity. This land may have a shallow rooting zone, poor pH and or low natural fertility. The soil fertility and pH should be monitored and amended. Also, it may be advisable to grow a grain or hay crop for several years following initial drainage. This will help improve the soil structure which in turn improves soil drainage and aeration. The performance of the drainage system should improve over time as the crop rooting zone extends deeper into the soil profile.

A good crop rotation, including grains and forages, will benefit the long term performance of the drainage system. High value cash crops generally require more intensive machinery use leading to an increased risk of soil compaction. Continuous row crops may lead to a degraded soil structure adversely affecting downward mobility of water and reducing the effectiveness of the drainage. The field should not be worked too early in the spring or immediately following a rainfall. The soil should be allowed time to dry and strengthen to avoid soil compaction problems. Drainage reduces the time required for this but some evaporation of water from the field's surface is still necessary.

Contact the local Department of Agriculture Soil and Crop Specialist for advice on soil management and crop production.

C. Inspection and Maintenance

Properly planned and constructed drainage systems normally require very little maintenance. Any deficiencies will usually appear in the first two years after construction. If minor repairs are promptly carried out, future major and costly damage can be avoided.

It is important to preserve good plans of the drainage system if proper maintenance is to be provided. These plans should be revised and updated as repairs and extensions are made. "As-built" drainage plans should indicate the field area; the locations of field boundaries, roads, open ditches, waterways, subsurface drains and outlets; and the size and length of subsurface drainage lines.

Inspections of the drainage system should be made in the spring, fall, and after heavy rainfall events. Debris and other obstructions should be removed from open ditches, waterways, and culverts to maintain their capacity. Grassed waterways and open ditch banks should be mowed at least once annually. Adequate side slopes should be maintained to prevent bank erosion. Grass buffer strips approximately 3 m (10 ft.) wide should be maintained on both sides of a ditch to minimize siltation.

Water holding depressions in landformed fields caused by settlement or machine operation should be filled in and levelled immediately to ensure long-term successful operation of the system.

If soils are compacted or have poor permeability in the area of a subsurface drain line, but surface water does eventually disappear, a closer drain spacing or more permeable backfill may be required in this area. However, if water remains on the surface for extended periods while the rest of the field has dried, a drainage line may be damaged, or a connection may have separated during installation. The drain should be exposed at the seepage area and checked for blockage with a plumber's "snake". When the damaged section of pipe is found, it should be repaired as soon as possible with pipe of equal diameter.

Blockage of subsurface drains can be caused by a number of factors including roots, sedimentation, ochre formation, or as a result of organic wastes entering drains. Consider the following points when inspecting a drainage system:

1. Tree Roots

Water loving trees, such as willows, elms and poplar, growing near drains may extend their root system to the drain in search of water during dry periods. Roots can enter the drains via the preforations in the drain side wall reducing the effectiveness of the drains in conveying water. The area upstream of the blockage may experience ponding and remain wet for extended periods of time. If blockage by root growth is confirmed, the trees should be removed within a distance of 30 m (100 ft.) from the drain and the section of blocked pipe replaced. If the tree is considered valuable and is to be retained, the affected section of pipe should be replaced with a continuous length of non-perforated pipe or moved to another location.

2. Sedimentation

Soils with a high content of fine sand and silt can pose a hazard to subsurface drainage systems. The fine soil particles can flow into the drains and cause blockage. Drainage blockage by sedimentation can be detected by initially checking at the outlet. If there appears to be a significant accumulation of fine sand or silt and the drainage system had performed satisfactorily for a period of time after installation, a portion of the system may be blocked. Exposing the main line at lateral connections where the drainage system's performance seems to be impeded will indicate whether the main or a lateral is blocked. If blockage is detected, it may be possible to flush out the drains with a high pressure water jet, but it may be more desirable and less expensive to replace the blocked pipe with a new filtered pipe of equal diameter.

3. Iron Ochre

Iron ochre is a tan to red-colored, gelatinous deposit containing extensive amounts of iron in association with bacterial slimes. It is formed by an oxidation reaction involving iron laden groundwater and bacteria. Ochre deposits can block perforations in drains and or drain filters, eventually leading to reduced flow rates and in severe cases, complete blockage. Only isolated cases have been reported in the Region. The exact conditions under which ochre formations occur are complex and it is difficult to predict whether ochre will be a problem in any particular field prior to drainage. The presence of ochre can be detected by checking for a reddish deposit at the outlet. If a neighbour has experienced problems with ochre and a large subsurface drainage system is being planned on a similar soil type, it may be advisable to install a few check lines through the field that could later be incorporated into a complete system. If after a couple of years no problem is evident, it should be safe to complete the job.

If a field has a severe ochre problem, it is debatable whether subsurface drainage is practical. Flushing of problem lines with high pressure water, acid treatments, liming of trenches to increase pH and a number of filter treatments have been tried without long lasting success. Judicious use of surface drainage techniques may provide a workable alternative.

4. Organic Wastes

A household or barn waste disposal system should never be connected to a subsurface drainage system. Waste water solids may settle out and the nutrients in the waste may encourage the growth of organisms which can cause blockage and deterioration of drains very quickly. Manure, if spread on the field in extremely high concentrations, can also create organic growths in drains.

5. Blowouts

Water may be present on the soil surface over a drainage line as the result of a blowout. Blowouts most commonly occur with lines flowing at high capacity on steep grades. Failures usually occur at drain connections or at a change in grade to a more moderate slope. Relief wells can be used to relieve the pressure in a drain which might cause a blowout. The relief well, consisting of a vertical riser to the surface, should be located at points where the drain may become overloaded for brief periods of time such as where the grade changes from steep to flat. Where possible, relief wells should be located at fence or property boundaries.

6. Erosion Over Drainage Lines

The backfill over drain lines should also be inspected, especially after installation and following the first winter. Deep holes in the backfill may indicate that a drain is broken and that surface water is entering the drain at this point. The drain should be dug up and repaired immediately before too much silt enters the subsurface drainage system. If the backfill has settled below the original grade, additional backfilling is required. All drains should be checked for this condition prior to winter. If there is any surface flow through the winter months, the water could travel down the inadequately backfilled trench causing severe erosion problems over the drainage lines. If drainage is installed with a trencher or backhoe, the backfilled grade over the trench should be higher than the surrounding grade to allow for settling. In severe cases of trench washout, the drainage lines may be partially or totally exposed and or washed out. If severe washout has occured, repairs should take place in a relatively dry period. Debris should be cleaned from the trench, and exposed pipe examined and discarded if damaged. New pipe of equal diameter should then be placed on firm footing at the bottom of the trench at an adequate grade and backfilled.

Drainage pipe should never be installed in a natural watercourse without adequate erosion protection.

7. Outlets

The outlet is the single most important aspect of the subsurface drainage system. The location of the outlet should be clearly marked with a stake so that it can be easily located. All outlets should be protected with a 3 m (10 ft.) length of corrugated metal or rigid plastic pipe at the end of the drain line where it discharges into the ditch.

The stability of the ditch bottom and banks at the outlet should be regularly inspected. If erosion is occurring, stone rip-rap underlain by a suitable filter mat should be placed on the ditch side slope and bottom.

Surface water should not be permitted to enter a ditch at a subsurface drainage outlet. If water tends to flow into a ditch at this point, a small dam or berm should be constructed on the ditch bank such that surface water is diverted into the ditch at some other location.

If the color of water flowing from an outlet is cloudy, it may indicate that surface water is directly entering the drain. Surface water should only enter a drain by seepage through the soil or through a properly designed surface inlet.

Any debris or silt that is present at an outlet should be removed so that the outlet is kept flowing freely.

For further information on agricultural land drainage, contact the Provincial Department of Agriculture or your local drainage contractor.

SUGGESTED READING

Interested readers are directed to the following bulletins on regional soil and water topics, published by authority of the **Atlantic Provinces Agricultural Services Co-ordinating Committee** and available through your local agricultural office.

Soil Erosion. Pub. No. 9, 1982 Advisory Committee on Soil and Water of the Atlantic Committee on Agricultural Engineering, 11 pp.

Farm Ponds. Pub. No. 6, 1984 Advisory Committee on Soil and Water of the Atlantic Committee on Agricultural Engineering. 19 pp.

Land Clearing for Agricultural Production. Pub. No. 7, 1985. Advisory Committee on Soil and Water of the Atlantic Committee on Agricultural Engineering. 17 pp.

Tillage and Working the Land: Tool Depth. Pub. No. 8, 1986 (leaflet) Advisory Committees of Power and Machinery, Soil and Water of the Atlantic Committee on Agricultural Engineering.

The Climate for Agriculture in Atlantic Canada. Pub. No. ACA 84 - 2 - 500, 1984 Advisory Committee on Agrometerology of the Atlantic Committee on Soil and Climate. 19 pp. plus maps.

Spring Field Workdays in the Atlantic Provinces. Pub. No. 1, 1978 Advisory Committee on Agrometeorology of the Atlantic Committee on Soil and Climate. 43 pp.

Soil Fertility Guide. Pub. No. 535-81, 1981 Advisory Committee on Soil Fertility of the Atlantic Committee on Soil and Climate. 23 pp.

Soil and Fertilizer Nitrogen in Atlantic Canada. Pub. No. 536-84. Advisory Committee on Soil Fertility of the Atlantic Committee on Soil and Climate.

Atlantic Soils Need Lime. Pub. No. 534-84 Advisory Committee on Soil Fertility of the Atlantic Committee on Soil and Climate.

Crop Micronutrients in Atlantic Canada. Pub. No. 537-86 Advisory Committee on Soil Fertility of the Atlantic Committee on Soil and Water.

Soil Management in Atlantic Canada. A series of bulletins by the Advisory Committee on Soil Resource Management of the Atlantic Committee on Soil and Climate which includes:

- Soil Physical Requirements for Grain Production (in review).
- Soil Physical Requirements for Apple Production (in review).
- Soil Physical Requirements for Potato Production (in review).