21.4 Installation of Pipe Drains

The classical method of pipe installation comprises marking the alignments and levels, excavating the trenches, placing the pipes and envelope material, and backfilling the trenches. Field drains nowadays are installed by drainage machines, either by trenchers or by trenchless machines, whereas concrete collectors are often installed with excavators. In addition to the mechanics of installation, the work planning, the working conditions, and supervision and inspection are important.

21.4.1 Alignments and Levels

The classical method of marking alignments and levels is by placing stakes in the soil at both ends of a drain line, with the top of the stakes at a fixed height above the future trench bed. The slope of the drain line is thereby implicitly indicated. A row of boning rods is placed in line (both vertically and horizontally) between the stakes, with an extension at the upstream end of the drain line, where the run of the drainage machine ends (Figure 21.18). The boning rods are thus in a line parallel to the trench bed, and

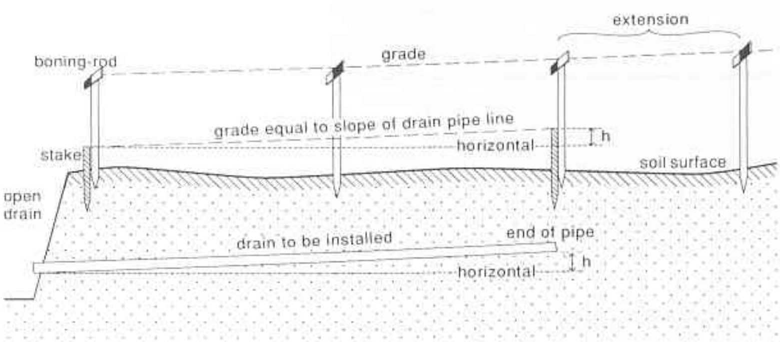

Figure 21.18 Staking out for grade control of drain pipe line

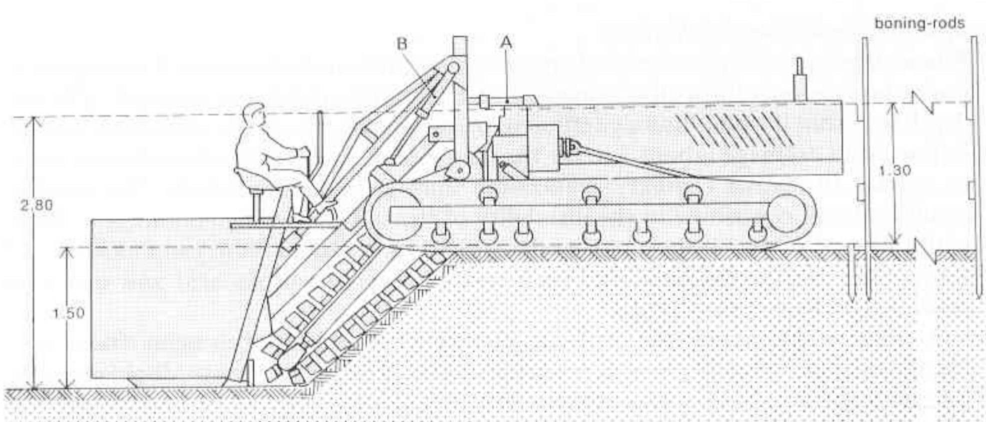

Figure 21.19 Grade control by the operator

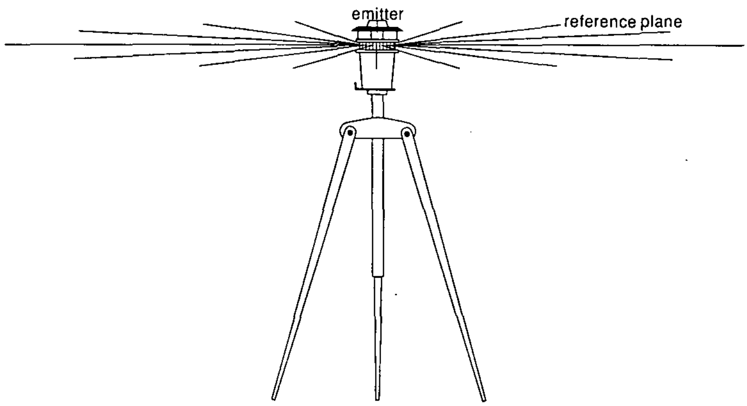

Figure 21.20 Laser emitter establishes a reference plane

grade control can be achieved through sighting by the driver of the drainage machine (Figure 21.19). The same principle can be applied when drains are installed manually.

Nowadays, most drainage machines have grade control by laser. An emitter, placed on a tripod near the edge of the field, establishes an adjustable reference plane over the field by means of a rotating laser beam (Figure 21.20). A receiver, mounted on the digging part of the drainage machine, picks up the signal (Figure 21.21). The control system of the machine continuously keeps a fixed mark in the laser plane. One position of the emitter can serve the installation of a fairly large number of drains.

21.4.2 Machinery

The most common types of machines for installing field drains fall into two main categories: trenchers and trenchless machines.

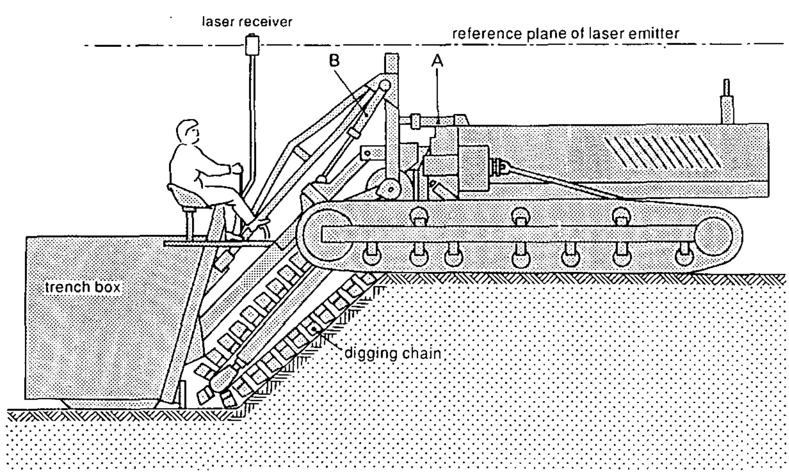

Figure 21.21 Trencher equipped with laser-grade control

Trenchers
Trench-excavating drainage machines vary from attachments to a wheel tractor, suitable for installation depths of up to 1 m, to heavy-duty machines, suitable for installing large-diameter collector pipes to a depth of about 3.5 m.

Most machines move on tracks, but especially the lighter ones may have rubber tyres. The digging implement is commonly a continuous chain with knives (Figure 21.19 and 21.21). The excavation depth and trench width of a machine can be varied through interchanging digging attachments. The maximum depth of a trencher is somewhere between 1 and 3.5 m. The trench width varies roughly between 0.12 and 0.65 m, a standard width for field drains being 0.20 to 0.25 m. The engine power ranges from 75 to 300 kW (100 to 400 HP), and one machine weighs between 10 and 50 tons. The grade-control system is optional for most machines: either by the driver or by laser.

The corrugated plastic pipe for small-diameter field drains is carried on the machine on a reel and is fed into the trench. Larger-diameter corrugated pipes (e.g. for collectors) are usually laid out and coupled in the field beforehand. The continuous tube is subsequently picked up by the machine as it moves along. Clay tiles and concrete pipes move down a chute behind the digging chain.

Synthetic and organic envelopes are usually pre-wrapped around the corrugated pipe. For gravel envelopes, a hopper can be fitted into which the gravel is fed from a trailer moving alongside the drainage machine. For a complete gravel surround, two gravel hoppers can be installed: one before and one after the point where the pipe is fed in.

Special trencher-machine attachments are a water tank with a spraying nozzle to wet the chain (in sticky clay), and a scratcher at the back of the machine for blinding the pipe with soil from a pre-selected layer (mostly well-structured top soil).

In view of the wide variety of machine types and working conditions, it is difficult to give meaningful data on the output rate. A typical average output for a 160 kW trencher installing field drains at 1.5 m depth would be approximately 500 m per hour.

Trenchless Drainage Machines
Trenchless drainage machines have been used since about 1965, after flexible corrugated plastic pipe appeared on the market. Two main types of trenchless devices are the vertical plough (Figure 21.22) and the 'V-plough' (Figure 21.23).

The vertical plough acts as a subsoiler: the soil is lifted and large fissures and cracks are formed. If these extend down to the drain depth, the increased permeability leads to a low entrance resistance and an enhanced inflow of water into the pipe. Beyond a certain critical depth, however, the soil is pushed aside by the plough blade, instead of being lifted and fissured. This results in smearing, compaction, and a destruction of macropores, so that the permeability is reduced and the entrance resistance is increased. The critical depth depends mainly on the soil texture and on the water content during pipe installation.

The V-plough, which lifts a triangular 'beam' of soil while the drain pipe is being installed, has a hazard of deforming the corrugated pipe under the weight of the soil beam. This problem was found to occur in heavy alluvial clay soils in The Netherlands, but it can be solved by simple adjustments to the plough.

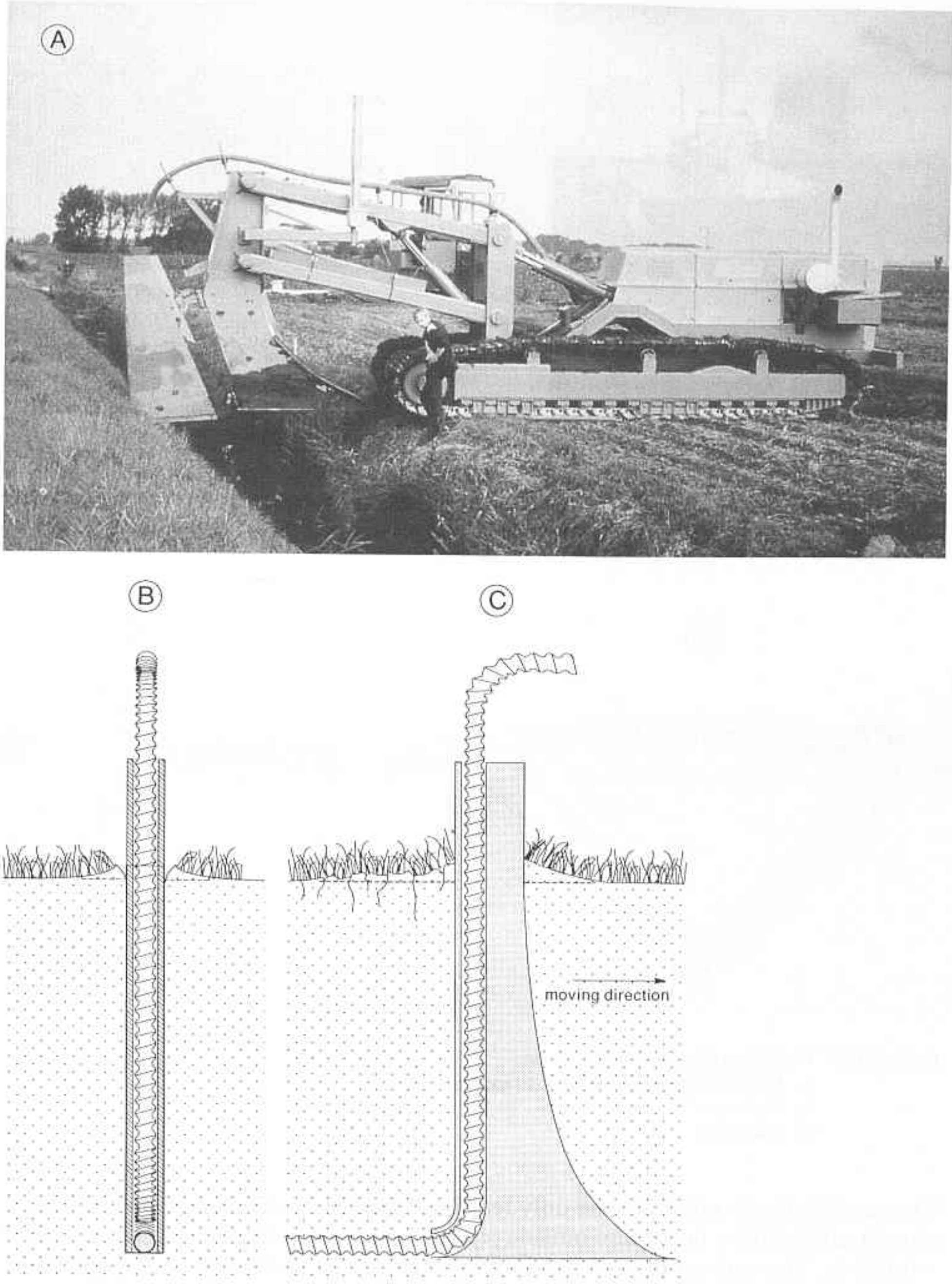

Figure 21.22 Trenchless pipe drain installation
A: Machine equipped with a vertical plough
B: Rear view
C: Side view

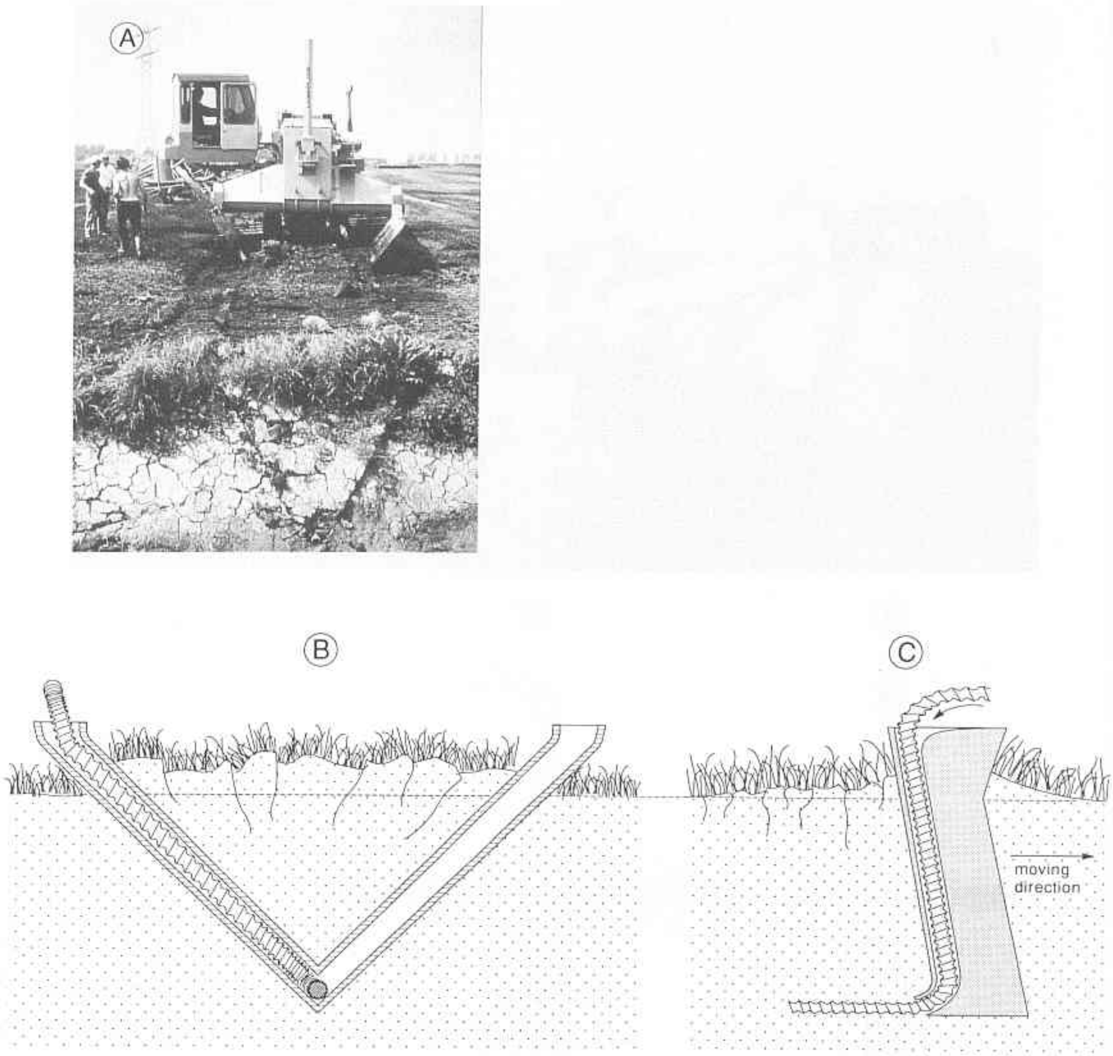

Figure 21.23 Trenchless pipe drain installation
A: Machine equipped with a V-shaped plough
B: Rear view
C: Side view

Corrugated plastic pipes are the only feasible pipes for trenchless machines. The V-plough can handle a maximum outside pipe diameter, including the envelope, of 0.10 – 0.125 m. The vertical plough can handle much larger diameters. Although gravel envelopes would be possible with trenchless drainage, it is not recommended because of the risk of a clogged funnel and because of the difficulty of supplying gravel to a comparatively fast-moving machine. The only practical option is to use pre-wrapped envelopes.

Table 21.6 Example of the capacity (m/h) of a trencher (160 kW) and a trenchless machine with a V-shaped plough (200 kW) for the installation of field drains in singular systems in The Netherlands (after Van Zeijts and Naarding 1990)

Soil type	Drain depth (m)	Capacity (m/h)		Ratio Trenchless/Trencher
		Trencher	Trenchless	
Sand	1.00	700	840	1.2
	1.30	600	600	1.0
	1.60	520	430	0.8
	1.90	475	-	-
Clay loam and clay	1.00	620	1150	1.9
	1.30	540	1050	1.9
	1.60	470	800	1.7
	1.90	420	-	-

Because of the high speeds, depth regulation by laser is the only practical method for trenchless machines. Moreover, because of the absence of an open trench, visual inspection is impossible.

Comparison of Trencher and Trenchless Installation

Experience in Western Europe and North America has shown that, for drain depths up to some 1.3 to 1.4 m, the cost of trenchless drain installation is lower than trencher installation, mainly because of a higher speed. In The Netherlands, with drain depths of mostly 1.0 to 1.2 m and pipe diameters of up to 0.08 m, the difference is 15 to 25%. The advantage of trenchless installation decreases rapidly with greater drain depth and with higher soil resistance (Figure 21.24). Soil resistance is higher in fine-textured soils than in coarse-textured ones, as illustrated in Table 21.6.

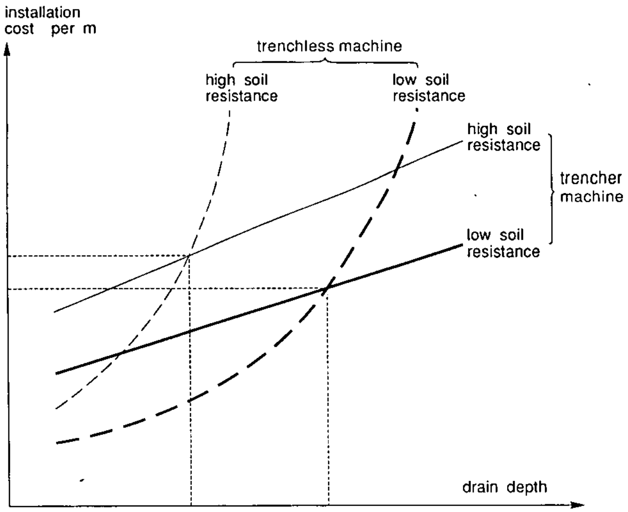

Figure 21.24 Cost comparison between a trenchless machine and a trencher machine (Van Zeijts and Naarding 1990)

Trenchers mainly use energy for digging and only a small portion for traction. Power requirements increase approximately linearly with depth, (i.e. proportional to the amount of excavated soil). Trenchless machines use energy almost exclusively for traction, and power requirements increase with the square of the installation depth. Because of the higher draught requirements, the grip of the tracks on the land surface is more critical for trenchless machines. The grip decreases rapidly with increasing water content of the top soil, especially in fine-textured soils. Trenchless machines therefore need to be heavy and require large tracks. They are also sooner unable to work under wet soil conditions caused by rain or untimely irrigation.

The trencher usually causes more disturbance to the crops and to the land surface than the V-shaped plough, but less than the vertical plough. The disturbance of the vertical plough can partly be redressed by running one track of the machine over the drain line on its way back.

21.4.3 Collector Installation

Concrete pipes are installed either by trencher or by hydraulic excavator (backhoe). As a safeguard against siltation, the collector is commonly constructed as a closed conduit. Thus, the joints between pipe sections are sealed with either mortar or close-fitting rubber rings.

The larger corrugated plastic pipes ($>$ 0.20 m diameter) need to be embedded in gravel as a protection against deformation, and are comparatively expensive, although their use is increasing. They are the only alternative if a de-watering collector is needed. The installation of such a collector is commonly done by a trencher. The gravel bed also has a hydraulic and a filter function.

Installing a deep collector in an unstable soil well below the watertable is a difficult job, because of the sloughing conditions during pipe installation. Installing concrete pipes is then only possible after the soil has been de-watered (i.e. by lowering the watertable to below the installation depth of the collector). This can be achieved by the classical well-pointing technique or, alternatively, by horizontal de-watering.

Horizontal de-watering was originally developed to de-water the installation sites of oil and gas pipelines, as a lower-cost alternative to vertical well-pointing. It consists of installing a pre-wrapped perforated corrugated pipe, well below the future excavation depth, and connecting it to a pump (Figure 21.25). The pipe is installed by a machine that resembles a trencher, but with a vertical digging chain and no trench box. Installation depths of over 6 m are possible. The trench usually collapses immediately behind the machine.

A different approach to dealing with sloughing conditions is to install a de-watering collector, which will lower the watertable above it. Corrugated pipe and gravel should be installed in one and the same run of a trencher machine. In very unstable soil, it is essential that the entire collector line be installed in one continuous run, otherwise the machine will get stuck. The advantage of a de-watering collector is that, by lowering the watertable, it facilitates field drain installation later on.

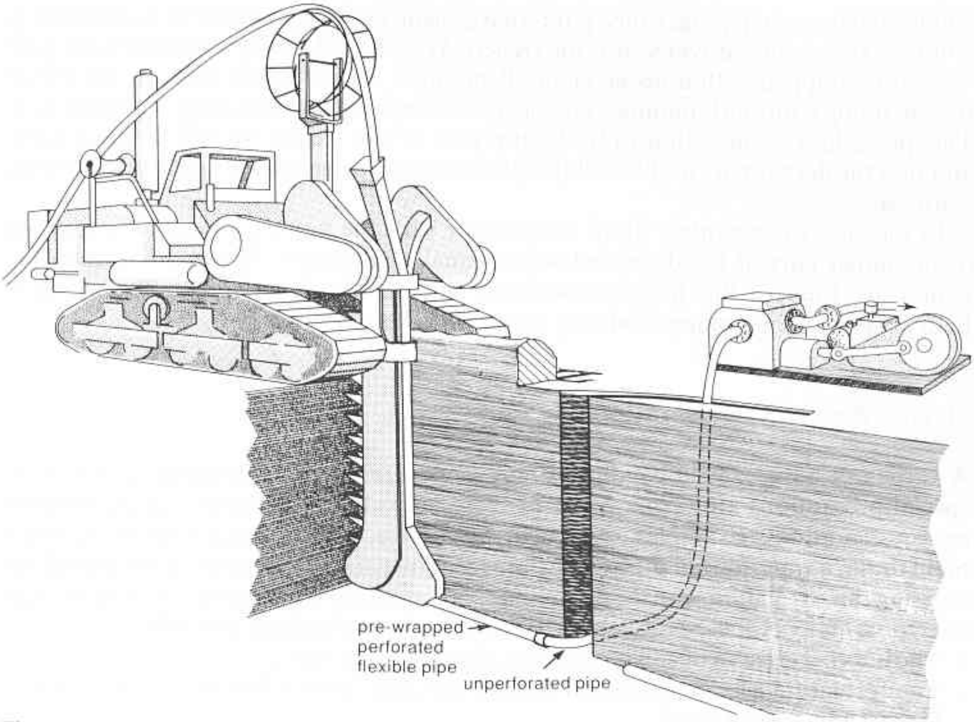

Figure 21.25 Principle of horizontal de-watering to lower the watertable for collector installation

21.4.4 Logistics, Auxiliary Work, and Equipment

The bottleneck for the speed of pipe installation is usually not the capacity of the drainage machine, but the organization and logistics connected with keeping the machine going. The preparation of the site (e.g. setting out, removing obstacles) is important, as is the operation and maintenance of the drainage machine (fuel supply, spare parts). In addition, the supply of pipe and envelope material needs to be properly organized.

A gravel envelope requires a considerable fleet of extra equipment to ensure a continuous supply to the machine (e.g. lorries, front loaders, and tractors with trailers). The latter move alongside the drainage machine and unload the gravel into the hopper(s) on the machine. Field drains require roughly 1 m^3 of gravel per 25 m of drain. A machine output of 3 km per day thus needs 120 m^3 (i.e. 180 tons) of gravel per day.

A hydraulic excavator (backhoe) is often needed as a standby for digging pits in which to connect collector and field drain, or for removing boulders in stony soil.

Trenches are preferably back-filled the same day as they are dug to avoid a possible destabilization of soil under wet conditions (irrigation, rain, high watertable). Only in unripened soil is it recommendable to leave the trenches open for some time to initiate ripening. In irrigated land, the upper part of the trench backfill should be compacted to avoid piping, which is internal erosion of trench backfill by water flowing from the soil surface directly into the trench. Trench backfilling is usually done with a tractor equipped with a dozer blade. Running a tractor wheel over the backfilled trench, filling it up, and running over it again will take care of the required compaction. This procedure ensures that only the top part of the trench backfill is compacted, and that the deeper part of the backfill retains a good permeability and a low entrance resistance.

In the case of trenchless drain installation with the vertical plough, compaction of the upper part of the disturbed soil is equally important. A common procedure is that one track of the drainage machine runs over the drain line on its way back. In dry clay soil, this compaction may not be sufficient.

21.4.5 Special Considerations

A variety of adverse field conditions may jeopardize the pipe drainage system if no special precautions are taken. Most of these hazardous conditions can be grouped as wet conditions. Examples are a high watertable, a high water level in the open main drain, a waterlogged top soil due to recent irrigation or rainfall, and a pipe drain crossing an irrigation canal. Sometimes, an appropriate choice of season may overcome many of these problems. The hazards of wet conditions include:

- The internal erosion of soil resulting in siltation of the pipe;
- The formation of a puddled soil around the pipe, with a low permeability and a high entrance resistance;
- The dislocation of pipe and envelope material in the case of sloughing conditions.

A general principle of drain installation is to start at the downstream end, so that any free water can drain away immediately. Thus a good drainage base should be secured, which implies that the collector should be in place and should be functioning before the start of the field drain installation. Also, the water level in the open drain should be below the pipe outlets, and the connection with the collector should be made before a field drain is installed.

When the land surface is waterlogged, pipe installation should be avoided, especially in medium-textured soils. The dry season should be selected, if possible, and it should be arranged that the land is not irrigated shortly before installation. Trenches need to be backfilled and compacted before the land is irrigated again.

When open canals have to be crossed, these should be dry during pipe installation. Temporary dams should be made on either side of the crossing, and water should be pumped out, after the necessary arrangements have been made with the farmers and the responsible authorities. Especially at these crossings, it is important to compact the trench backfill and to seal the bed of the canal in order to avoid piping. If necessary, a closed pipe section should be installed at the crossing.

At the outlet of a pipe drain into an open drain, there is an extra risk of erosion of the trench backfill. As a precaution, the last few metres of the drain before the outlet should consist of unperforated pipe without envelope material, while over the same distance the trench backfill should be compacted over its entire depth.

Wherever trees or shrubs are growing in the vicinity of drainage pipe lines, there is a risk of roots penetrating into the pipes (Section 21.7.4). Recommended precautions are to keep drain lines away from trees wherever possible (while even considering the probability of future tree planting), and to use unperforated pipe where strips of trees or shrubs must be crossed.

Subsurface obstacles may be stones, tree stumps, and solid rock. The vertical plough is the best in dealing with loose stones and tree stumps, as long as they are not too big. If obstacles are too big, they will have to be removed with a hydraulic excavator. Solid rock can, under certain conditions (not too hard; shallow penetration), be dealt with by a special type of trencher.

21.4.6 Supervision and Inspection

Inspection and supervision of drain installation are required for several reasons:

- To ensure that design specifications are complied with;
- To handle unforeseen conditions during installation;
- To check the quality of the materials used (pipes, envelope), which includes certification and a site-check on possible damage during transport and handling;
- To ensure good workmanship, including the proper alignment of pipe lines, which should be straight and according to the design slope, within an accepted tolerance (e.g. half the inside pipe diameter for field drains), and with proper joints;
- To see that the trenches are properly backfilled and compacted;
- To assess the need for any extra work or modifications, which implies that the supervisor should be a well-qualified person.

Inspection Methods

When clay or concrete pipes are installed with a trencher, supervision is comparatively simple and straightforward because it can be done visually. Checking the gradient can be done with a levelling instrument and a staff gauge in the open trench behind the machine. With the introduction of pre-wrapped corrugated pipe, however, and the consequent trenchless pipe installation, visual inspection and levelling have been made virtually impossible. One must therefore resort to other checking methods such as rodding and level recording.

Rodding is done by pushing a rigid steel rod through the pipe outlet into the drain pipe over its entire length (Van Zeijts and Zijlstra 1990). The steel rod has a torpedo-shaped tip, and a glass fibre rod to assist in the pushing (Figure 21.26). If the drain

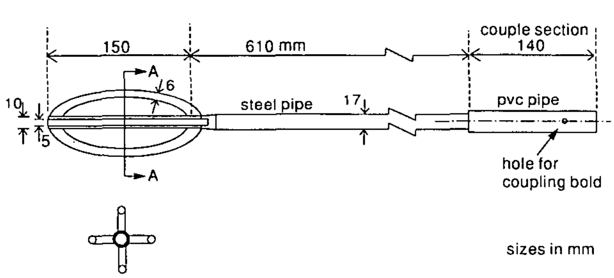

Figure 21.26 Drawing of the rodding head

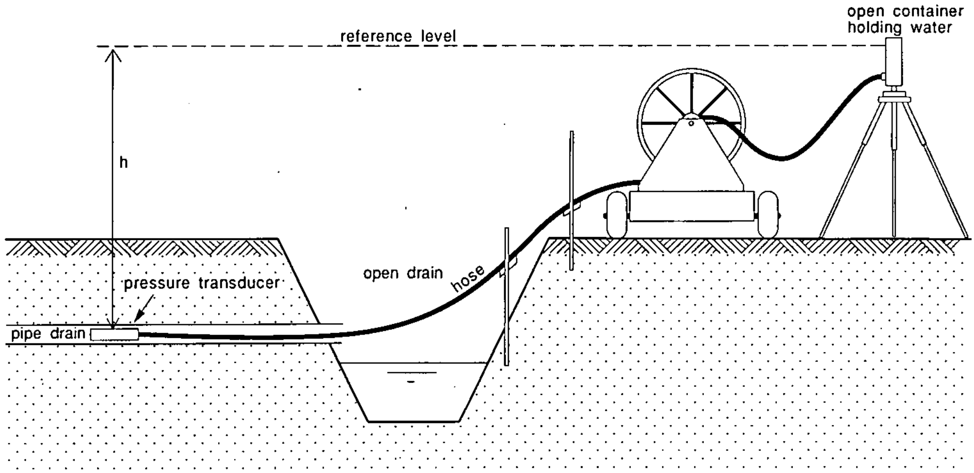

Figure 21.27 Level recording instrument for continuous depth recording (Van Zeijts 1987)

has been correctly installed, the rod can pass unhindered. The required pushing force increases slightly with the length of the drain. If the drain spirals, however, the required pushing force increases with the length of the drain. The required force should not exceed a pre-set limit. If the rod cannot pass a particular point in the drain, there is a fault in the installation, and the drain has to be excavated at this point. Rodding is also a useful way to make sure that the drain will be accessible for flushing (Section 21.5.3).

Another method is to use a level recording instrument, based on the ancient water-level gauge (Van Zeijts 1987). One end of a hose is connected to a special open container, the water surface of which serves as a reference level (Figure 21.27). A pressure transducer, fitted to the other end of the hose, slides into the drain. This

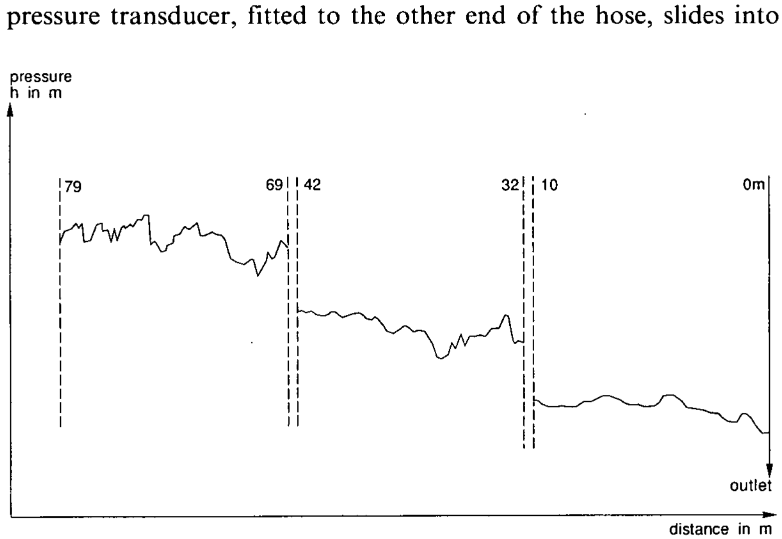

Figure 21.28 Graph representing drain depth as recorded during retraction of the transducer (Van Zeijts 1987)