Part II

Detailed Instructions for the Implementation of Subsurface Drainage Systems
General introduction to Part II

Contents

In Part I the planning of the implementation process and the organisational aspects of operation and maintenance of subsurface drainage systems were discussed. In Part II, the detailed methodologies and techniques of the implementation and operation and maintenance are dealt with. Part II is confined to the essential aspects of implementation that cannot easily be found in other literature, with the emphasis on construction, operation and maintenance of subsurface drainage systems.

Organisation

Implementation and maintenance of subsurface drainage systems is a complex process demanding the cooperation of many parties, of which the success depends entirely on the quality of the individual components. Since the responsibility is with different people and organisations, the contents of part II are presented in the form of ‘instruction sheets’, organised in subject chapters. In this way instruction sheets dealing with only one activity or sub-activity can be copied and used by the staff responsible for that particular activity. Consequently at times there are repetitions, this is done to assure that each of the instruction sheets can be used independently.

Instruction sheets

Part II contains instructions sheets for:

A Planning and monitoring of the construction of subsurface drainage systems. Although the planning methodologies described are not unique to drainage implementation and hardly useful for smaller projects, international banks sometimes insist on the preparation of such planning.

B Instructions and models for cost calculations.

C Construction of subsurface pipe drainage systems. These instruction sheets focus on the construction of pipe drainage systems with plastic drain pipes with drainage trenchers. For the sake of completeness instructions are attached for installation by hand and installation of pipes in trenches dug by excavators. Instructions for trenchless drain installation are also included.

Part C is subdivided in three sub-parts:

- Organisation of the implementation;
- Machinery and equipment;
- Installation of drain pipes.

D Quality control of pipe drainage systems and monitoring of the performance of pipe drainage Systems.

E Operation and maintenance of pipe drainage systems.
## Contents

<table>
<thead>
<tr>
<th>Instruction sheet number</th>
<th>Subject and title</th>
<th>Target groups</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Planning and Supporting Research</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1</td>
<td>Network planning for the construction of subsurface drainage systems</td>
<td>Planners, supervisor, field manager</td>
<td>189</td>
</tr>
<tr>
<td>A.2</td>
<td>Operational monitoring for machine performance</td>
<td>Researchers, planners, monitoring staff</td>
<td>197</td>
</tr>
<tr>
<td>A.3</td>
<td>Time and motion studies</td>
<td>Researchers, monitoring staff</td>
<td>201</td>
</tr>
<tr>
<td>B</td>
<td>Cost Calculations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.1</td>
<td>Methodology for the calculation of staff cost</td>
<td>Planners, contracting department, contractors</td>
<td>207</td>
</tr>
<tr>
<td>B.2</td>
<td>Methodology for the calculation of the cost of equipment and machinery</td>
<td>Planners, contracting department, contractors</td>
<td>209</td>
</tr>
<tr>
<td>B.3</td>
<td>Methodology for the calculation of the cost of transport</td>
<td>Planners, contracting department, contractors</td>
<td>213</td>
</tr>
<tr>
<td>B.4</td>
<td>Methodology for the calculation of the cost of raw material</td>
<td>Planners, contracting department, contractors</td>
<td>215</td>
</tr>
<tr>
<td>C</td>
<td>Installation of Subsurface Drainage Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.1</td>
<td>Requirements for the implementation of singular drainage systems</td>
<td>Planners, field manager, supervisor</td>
<td>227</td>
</tr>
<tr>
<td>C.2</td>
<td>Requirements for the implementation of composite drainage systems</td>
<td>Planners, field manager, supervisor</td>
<td>229</td>
</tr>
<tr>
<td>C.3</td>
<td>Task descriptions for key installation staff</td>
<td>Planners, field manager, supervisor</td>
<td>231</td>
</tr>
<tr>
<td>C.4</td>
<td>Description of trenchers</td>
<td>Planners, operators, mechanics, field manager, supervisor</td>
<td>239</td>
</tr>
<tr>
<td>C.5</td>
<td>Maintenance of trenchers</td>
<td>Planners, operators, mechanics, Field manager, supervisor</td>
<td>245</td>
</tr>
<tr>
<td>C.6</td>
<td>Adjustment of trench box and digging chain</td>
<td>Planners, operators, mechanics, field manager, supervisor</td>
<td>253</td>
</tr>
<tr>
<td>C.7</td>
<td>Minimising the operation costs of trenchers</td>
<td>Operators, mechanics, field manager, supervisor</td>
<td>259</td>
</tr>
<tr>
<td>Instruction sheet number</td>
<td>Subject and title</td>
<td>Target groups</td>
<td>page</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>---------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>C.8</td>
<td>Operation of trenchers for corrugated plastic drain pipe installation</td>
<td>Planners, operators, mechanics, field manager, supervisor</td>
<td>263</td>
</tr>
<tr>
<td>C.9</td>
<td>Working with a liftable trench box</td>
<td>Operators, mechanics, field manager, supervisor</td>
<td>267</td>
</tr>
<tr>
<td>C.10</td>
<td>Description of trenchless drainage machines</td>
<td>Planners, operators, mechanics, field manager, supervisor</td>
<td>271</td>
</tr>
<tr>
<td>C.11</td>
<td>Maintenance of trenchless drainage machines</td>
<td>Planners, operators, mechanics, field manager, supervisor</td>
<td>275</td>
</tr>
<tr>
<td>C.12</td>
<td>Operation of trenchless drainage machines</td>
<td>Planners, operators, mechanics, field manager, supervisor</td>
<td>283</td>
</tr>
<tr>
<td></td>
<td><strong>Laser equipment for grade control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.13</td>
<td>Description of laser equipment</td>
<td>Operator, surveyor, field manager, supervisor</td>
<td>287</td>
</tr>
<tr>
<td>C.14</td>
<td>Management of laser equipment for grade control</td>
<td>Operator, surveyor, field manager, supervisor</td>
<td>291</td>
</tr>
<tr>
<td>C.15</td>
<td>Determining the extension of laser mast on trencher</td>
<td>Operator, surveyor, field manager, supervisor</td>
<td>295</td>
</tr>
<tr>
<td>C.16</td>
<td>Verification of correctness of laser transmitter in the field</td>
<td>Operator, surveyor, field manager, supervisor</td>
<td>297</td>
</tr>
<tr>
<td>C.17</td>
<td>Manual grade control in absence of laser equipment</td>
<td>Operator, surveyor, field manager, supervisor</td>
<td>299</td>
</tr>
<tr>
<td></td>
<td><strong>Gravel trailers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.18</td>
<td>Description and maintenance of gravel trailers</td>
<td>Operator, mechanic, field manager, supervisor</td>
<td>303</td>
</tr>
<tr>
<td></td>
<td><strong>Installation of Drain Pipes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>General activities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.19</td>
<td>Preparatory activities</td>
<td>Field manager, supervisor</td>
<td>307</td>
</tr>
<tr>
<td>C.20</td>
<td>Sequence of drain installation</td>
<td>Field manager, supervisor, field staff 1</td>
<td>311</td>
</tr>
<tr>
<td>C.21</td>
<td>Setting out of field</td>
<td>Surveyors</td>
<td>317</td>
</tr>
<tr>
<td>C.22</td>
<td>Site preparation</td>
<td>Field manager, supervisor, field staff 1</td>
<td>321</td>
</tr>
<tr>
<td></td>
<td><strong>Installation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.23</td>
<td>Installation of drains in a straight line and with correct grade</td>
<td>Operators, surveyors, field manager, supervisor</td>
<td>325</td>
</tr>
<tr>
<td>C.24</td>
<td>Installation of drains in saturated and/or unstable subsoils</td>
<td>Field staff 1, operators, field manager, supervisor</td>
<td>331</td>
</tr>
<tr>
<td>Instruction sheet number</td>
<td>Subject and title</td>
<td>Target groups</td>
<td>page</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>------</td>
</tr>
<tr>
<td>C.25</td>
<td>Installation in fields with standing surface water</td>
<td>Field staff, field manager, supervisor</td>
<td>333</td>
</tr>
<tr>
<td>C.26</td>
<td>Installation of field drains starting from an open ditch</td>
<td>Operators, surveyors, field manager, supervisor</td>
<td>335</td>
</tr>
<tr>
<td>C.27</td>
<td>Installation of outlets of field drains into an open ditch</td>
<td>Field staff, field manager, supervisor</td>
<td>339</td>
</tr>
<tr>
<td>C.28</td>
<td>Installation of sumps at the start of collector drains</td>
<td>Operators, surveyors, field staff</td>
<td>341</td>
</tr>
<tr>
<td>C.29</td>
<td>Levels of manholes and starting levels for field drain installation</td>
<td>Surveyors, field manager, supervisor</td>
<td>343</td>
</tr>
<tr>
<td>C.30</td>
<td>Installation of manholes and preparation of start holes for field drains</td>
<td>Operators, surveyors, field manager, supervisor</td>
<td>349</td>
</tr>
<tr>
<td>C.31</td>
<td>Installation of pipe connections and joints</td>
<td>Field staff, field manager, supervisor</td>
<td>353</td>
</tr>
<tr>
<td>C.32</td>
<td>Completion of manhole/sump installation</td>
<td>Field staff, field manager, supervisor</td>
<td>355</td>
</tr>
<tr>
<td>C.33</td>
<td>Backfilling of trenches</td>
<td>Field staff, field manager, supervisor</td>
<td>359</td>
</tr>
<tr>
<td>C.34</td>
<td>Cleaning up of site after installation</td>
<td>Field staff, field manager, Supervisor</td>
<td>363</td>
</tr>
<tr>
<td>C.35</td>
<td>Application of gravel</td>
<td>Gravel manager, field manager, supervisor</td>
<td>365</td>
</tr>
<tr>
<td>C.36</td>
<td>Manual installation of drains</td>
<td>Field staff, field manager, supervisor</td>
<td>373</td>
</tr>
<tr>
<td>C.37</td>
<td>Manual installation in trenches dug by excavators</td>
<td>Field staff, field manager, supervisor</td>
<td>379</td>
</tr>
<tr>
<td>C.38</td>
<td>Wrapping a synthetic sheet envelope around the pipes in the field</td>
<td>Field staff, field manager, supervisor</td>
<td>385</td>
</tr>
<tr>
<td>D</td>
<td>Quality Control</td>
<td>Field manager, supervisor</td>
<td>391</td>
</tr>
<tr>
<td>D.1</td>
<td>Quality control of drainage materials</td>
<td>Field manager, supervisor</td>
<td>397</td>
</tr>
<tr>
<td>D.2</td>
<td>Quality control of installation of pipe drainage systems</td>
<td>Field manager, supervisor</td>
<td>397</td>
</tr>
</tbody>
</table>
### Instruction Subject and title | Target groups | page
--- | --- | ---
D.3 Checking the functionality of composite drainage systems | Field manager, supervisor, surveyors | 403
D.4 Methodology for checking the grade of installed drain and collector pipes during installation | Field manager, supervisor, surveyors | 407
D.5 Post construction verification of drain pipes | Field manager, supervisor | 413

E Operation and Maintenance
E.1 Checking the functionality of a subsurface drainage system | Maintenance staff, farmers | 421
E.2 Principles of flushing subsurface systems | Maintenance staff, farmers | 427
E.3 Management, maintenance and repair of high pressure flushers | Operators, field staff<sup>1</sup> | 433
E.4 Flushing of collector drains | Operators, field staff<sup>1</sup> | 435
E.5 Flushing of field drains from a ditch | Operators, field staff<sup>1</sup> | 439
E.6 Flushing of field drains from a manhole | Operators, field staff<sup>1</sup> | 443

---

<sup>1</sup> Field staff comprises all people involved including bulldozer operators, excavator operators and labourers.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

II-A

Planning and Supporting Research
A.1 Network planning for the construction of subsurface drainage systems

A.1.1 Introduction

To set up a network planning of the construction of subsurface drainage systems the work necessitates a detailed inventory of the processes and working methods. In Part I Chapter 1.4.4 a number of planning methods have been discussed. As indicated therein the preparation of the network planning, as sometimes required by international financiers, is a specialised job needing special software. In this instruction sheet we discuss the information that needs to be collected so that the professional can carry out the planning tasks. For the details of the network planning process see the relevant literature.

A.1.2 Information required at the start of the planning

Detailed planning of the construction can only start once the full design has been completed and technical specifications and the Bill of Quantity are available. In case of tendering the tender documents must also be available.

The information required for planning of the construction of the subsurface drainage system can be summarised as follows:

- The complete design, including:
  - Drawings of the layout of the subsurface drainage system;
  - Construction drawings of specific structures;
  - Technical specifications of all the works;
  - Technical specifications of the drainage materials;
  - The volume or quantity of work (Bill of Quantities). Table A.1-1 presents an example of the Bill of Quantities.
- The working methods and installation equipment to be used:
  - Installation methods of the pipe drains be (trenchers, trenchless, manually);
  - Installation equipment and capacity.
- The conditions under which the construction (installation) has to be carried out insofar as they influence the installation capacity and time requirements, such as:
  - Dimensions of the field;
  - Type of drains: open, subsurface, irrigation canals;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- Type of vegetation (crops, grass);
- Condition of the soil surface (trafficability, subsoil conditions);
- Water levels in open watercourse.

• The required start and end date of the construction as well as the factors affecting the time during which the fieldwork can be carried out, such as:
  - Number of working hours per day/number of working days per week;
  - Official holidays;
  - Periods during which the construction can take place (dry seasons, no crops in the fields etc.);
  - Effects of the climate on the work progress during specific periods.
• Manpower requirement and availability of manpower for each activity;
• Machinery and equipment requirement and availability for each activity;
• Responsibilities for transport of drainage materials to the site (if transport is to be included in the planning, then:
  - Availability of transport equipment;
  - Accessibility of the project area, infrastructure, roads and their quality (all-weather roads);
  - Distance of the factories to regional distribution centres and from there to the site;
  - Availability of support services;
• Time requirement for communication with the farmers and agreement with them about the schedule of construction in compliance with cropping calendars.

Now, an operational schedule for the construction of the drainage work can be prepared based on the above information.

Table A.1-1  Bill of Quantities for the construction of a composite drainage system

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Units</th>
<th>Unit cost</th>
<th>Quantity</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Field preparation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Setting out of field</td>
<td>Ha</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Accessibility of field</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>Levelling drain alignments</td>
<td>m'</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>Preparing gravel storage*)</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>Preparing pipe storage</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td>Preparing camp*)</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7</td>
<td>Transport equipment to site</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>Field drains</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>(Pre-enveloped) drain pipes</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>on site Ø (80) mm</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>(Pre-enveloped) drain pipes</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>on site Ø (100) mm</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>Connections*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>End-caps and couplers on site</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>Rigid end pipes/bridges</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Units</th>
<th>Unit cost</th>
<th>Quantity</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.6</td>
<td>Gravel envelope (if relevant)</td>
<td>m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>Installation drain pipes plus envelope</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td>Installing joints to collectors*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.9</td>
<td>Installing manholes*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.10</td>
<td>Installing end pipes*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.11</td>
<td>Installing crossings*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.12</td>
<td>Trench backfilling</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.13</td>
<td>Quality control</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subtotal

### 3 Collector drains

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Units</th>
<th>Unit cost</th>
<th>Quantity</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Collector pipes on site Ø .... mm</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>Collector pipes on site Ø .... mm</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.3</td>
<td>End-caps and couplers on site</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.4</td>
<td>Rigid end pipes/bridges</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>Installation collectors</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.6</td>
<td>Installing manholes*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.7</td>
<td>Installing sumps*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.8</td>
<td>Installing outlets*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.9</td>
<td>Installing crossings*)</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.10</td>
<td>Trench backfilling</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.11</td>
<td>Quality control</td>
<td>m'</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subtotal

### 4 Additional works*)

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Units</th>
<th>Unit cost</th>
<th>Quantity</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Construction pumping stations</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>Supply of pumps</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Installation of pumps</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>Electrical connections</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>Transformers type ...</td>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.6</td>
<td>Electricity supply lines</td>
<td>Km</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subtotal

### 5 General cost

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Units</th>
<th>Unit cost</th>
<th>Quantity</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Clearing of site</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>Final Quality Control</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>Management and accounting</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4</td>
<td>As-built drawings</td>
<td>Unit</td>
<td>LS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subtotal

**Total net cost**

<table>
<thead>
<tr>
<th>Item</th>
<th>% of total net cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead profit and risk</td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
<td></td>
</tr>
</tbody>
</table>

**Total**

*The items marked *) are not relevant to all projects.*
A.1.3  Detailed information about the activities to be carried out

For each activity an estimate needs to be made of:
- The required time to carry out the activity with the available manpower and equipment;
- The activity that must be completed before the next one can start;
- Activities that can take place at the same time;
- Which activity can succeed another upon its completion;
- The periods during which the activity can be carried out (rainfall, crops in the field etc.).

A.1.4  Activities required for the construction of subsurface systems

The activities required for the construction of subsurface drainage system are listed below. Note that not all of the listed activities are relevant to all systems to be installed:

1. Ordering/tendering machinery and equipment (if required)
   - Drainage machines;
   - Excavators;
   - Tractors;
   - Trailers;
   - Gravel trailers;
   - Low-bed trailers;
   - Trucks;
   - Mobile workshops.

2. Ordering drainage materials
   - Drain pipes;
   - Envelope materials;
   - Ordering Gravel (if required).

3. Tender and contract preparation

4. Tendering

5. Awarding of contract

6. Establishment of camp/workshops/depots

7. Transport of materials to the field

8. Field preparation and setting out

9. Installation of subsurface drainage system
   - Construction of sump (if relevant);
   - Installation of outlet structure (if relevant);
   - Construction of power lines(transformers (if relevant);
   - Construction of dewatering drain (if relevant);
   - Dewatering (if relevant);
   - Installation of collector drain (composite systems only);
   - Installation of manholes (composite systems only);
   - Installation of field drain-collector connection and flushing entrance (composite systems only);
   - Installation of field drains, if relevant with gravel envelope;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- Quality control;
- Backfill of trenches;
- Checking functionality of the drainage system;
- Cleaning the site.

10. Reception of the subsurface drainage systems

A.1.5 Network diagram

A specialist subsequently processes the activities and all the relevant information about each activity into a planning network diagram. The network diagram indicates the sequence in which the activities will be implemented and the interdependency of the activities.

In Figure A1.1 the network diagram for the construction of a subsurface drainage project with sump construction and horizontal dewatering of the collector drains is presented as an example.

![Network Diagram](image)

Figure A1.1 Network diagram for construction of a subsurface drainage system with sumps and horizontal dewatering of the collector drains

A.1.6 Results and use of network planning

A.1.6.1 Fitting the planning into the allotted times

Whether or not the construction can be completed within the allotted time period with the available means and equipment can be determined from the first result of the planning procedure. If this is not the case either the means will have to be increased or the time period will need to be extended.
Once the decision has been made about increasing the time or getting more equipment and manpower a new run of the planning process is made. The planning will need regular revision while the project is running in keeping with the actual process made.

A.1.6.2 Completion of the network

The actual time calculations can be made once agreement has been reached about the total time allotted and all the necessary means have been made available for each activity. The result is that for each activity the following will be known:

- Earliest start date;
- Latest finish date;
- The float.

The float is the difference between the period available for implementing the activity and the time required for doing it. The integration of all the activities results in the start date and earliest finish date of the project.

A.1.6.3 Determine the critical path

When the earliest start dates and latest finish dates of all the activities have been determined, the critical path - the longest path of the network in terms of time requirements where no float is available - can be identified by calculating the total float of each activity. The method for calculating the total float is presented in Table A.1-2.

Table A.1-2 Calculation of Total Float

<table>
<thead>
<tr>
<th>Activity (node no.)</th>
<th>Description</th>
<th>Latest finish time</th>
<th>(-)</th>
<th>Earliest Start time</th>
<th>(-)</th>
<th>Time estimate for Completing activity</th>
<th>= Total float</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The primary benefits to be derived from the critical path timing calculations are:
1. Establishment of the project duration for the plan;
2. Identification of the longest path through the project;
3. Identification of jobs for which there is scheduling flexibility without lengthening the project duration;
4. Identification of the activities on the critical path that do not allow any ‘float’ and therefore need to be carefully watched by the management.

The critical path activities can very well change in the course of the project when regular revisions of the planning are made based on the actual progress of each activity.

A.1.6.4   Periodic analysis of the results

Periodic analyses of the results of the regularly updated network diagram will allow the management to determine whether or not the actualised total project duration is in keeping with the allotted time for the project implementation.
- If not, the activities should be rescheduled and additional time or means will have to be made available;
- If the timing is within the allotted time the implementation can proceed without changes.

A.1.7   Simplified planning tools

A bar chart schedule can be prepared on the basis of the same information as given above. It is a simple planning tool that does not require highly specialised staff. It can be done either manually, in case of a small project, or using computer software programs, like the bar chart function of MS-project, for large-scale projects (Figure A1.2)
Figure A1.2 Example of a bar chart for the planning of a subsurface drainage system made by MS project.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

A.2 Operational monitoring for machine performance

A.2.1 Introduction

Operational monitoring is a tool to determine the realistic standard time requirements for performing installation activities. These time requirements are basic inputs for the planning process. The monitoring of the performance of drainage machines during the installation process can, over time, result in realistic information about the installation capacity of these machines. This is valuable information for planning, cost estimates and the estimates of the quantity of machines required to install drainage systems per defined time limits.

A.2.2 Terminology

The common terms used in operational monitoring are:

- **Element**: A clearly defined part of an activity;
- **Build-up Time**: The time of an element in which Time and Work Standards are built up;
- **Time Standard**: Time unit (hour, minute) per production unit (ha, km, ton, etc.);
- **Work Standard**: Production unit per time unit;
- **Capacity**: Output in production units per time unit;
- **Efficiency**: Ratio of the useful output to the total input of a system.

Time is the most decisive factor, which to be measured accurately should be divided into small time units (Figure A2.1):

- **Total Machine Time**: The number of days in a year that the machine can be made available for the work, namely, 365 (or 366) calendar days minus all weekends and public holidays in that year, and minus seasonal days during which the machine will not be operating because of harvesting or planting activities. For drainage machines the Total Time varies between 190 and 200 days, depending on local conditions;
- **Non-Available Time**: The time that the machine is unable to operate, because of bad field conditions (weather, irrigated fields or major technical breakdowns, which require extensive repairs in the workshop);
- **Available Time**: The time that the machine is actually operational. It can be really available for the actual work: Total Time minus Non-Available Time. It can be divided into Non-Effective Time and Effective Time;
There are two methods to measure these various time units: 1) time (or efficiency) studies and 2) time and motion (or capacity) studies. These two methods will be discussed in the following sections.

Important elements of the installation of drains by drainage machines are:
- Direct Effective Time
  - Laying pipe
- Indirect Effective Time
  - Support elements

Figure A2.1  Total machine time can be divided in smaller time units
- Driving back
- Lifting trench box
- Lowering trench box
- Digging connections
- Connecting outlet
- Filling water tank, if applicable

Indirect Effective Time

- Additional Elements
  - Short technical breakdown
  - Short organisational delays:
    - Laser
    - Pipes
    - Fuel
    - Field obstruction
    - Gravel
  - Field transportation

A.2.3 Time Studies

Time or efficiency studies are used to determine the total time that a machine is working such as time lost by repairs, non-working days (e.g., holidays) and lunchtime. The Total Time is divided into Non-Available Time and Available Time. The Available Time is divided into Non-Effective Time and Effective Time (Figure A2.1). To note down the time used for the various activities it is advisable to use a standard time registration form (Figure A2.2). The following data should be collected for a time study to assess the performance of drainage machines:

- General information such as the date, project, name of observer, machine and field conditions;
- Information on the working condition of the machine: time the machine was working and the time the machine was not working, including the reasons why the machine was not working.

The form should be filled in preferably by an observer or the field engineer and not by the driver. To adequately assess the performance of the machine (and its driver) the time study must cover an entire working day or a series of days. The data is used to calculate the Effective and Non-Effective Time, including the reasons for the Non-Effective Time. By making observations throughout the year, the actual available working days can also be determined. It is important to record why a machine is not working, whether this is due to holidays or stoppage due to crops, irrigation activities, breakdowns, labour disputes, and so forth. Only then can the Available Time be determined, including the length of an average working day. This type of information can be used for planning. Note, time studies do not tell us anything about the output (kilometres of drain lines installed etc.). To get to know this time & motion studies will have to be done.
### Efficiency Study on Drainage Machines

#### Time Registration Sheet

<table>
<thead>
<tr>
<th>General information:</th>
<th>Date:</th>
<th>Name of observer:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project information:</td>
<td>Directorate:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project name:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Collector number:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contractor:</td>
<td></td>
</tr>
<tr>
<td>Machine information:</td>
<td>Kind of machine:</td>
<td>Lateral / Collector</td>
</tr>
<tr>
<td></td>
<td>Manufacturer and type:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year of manufacturing:</td>
<td>Chassis number:</td>
</tr>
<tr>
<td>Conditions:</td>
<td>Crop:</td>
<td>Use of gravel: No / Yes</td>
</tr>
<tr>
<td></td>
<td>Soil type and condition:</td>
<td>Dry / Wet</td>
</tr>
<tr>
<td>Description</td>
<td>Daily hours</td>
<td></td>
</tr>
</tbody>
</table>

#### A Working

<table>
<thead>
<tr>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
</table>

#### B Not working

- **Maintenance**
- **Technical problems**
  - Engine
  - Digging mechanism
  - Hydraulic system
  - Frame
- **Organisational problems**
  - No driver
  - No labourers
  - No pipes
  - No gravel
  - No preparations
  - No fuel
- **Field conditions**
  - High water level
  - Crop damage
  - Other problems
- **Personal care**
  - Lunch break
  - Rest

#### Production of the machine: ................................ m³ / day

*Figure A2.2  Time Registration Sheet for drainage machines*
A.3 Time and motion studies

Time and motion studies are used to determine the capacity of drainage machines. The Effective Time (outcome of the time study) is divided in Indirect and Direct Effective Time. The time for each element of the work process is measured using a stopwatch in, for example, centi-minutes (0.01 part of a minute). The elements must be clearly defined, with a proper indication of the beginning and end of the elements. Again it is recommended to use standard data sheets, for time and motion studies. Two sheets are used:

- Survey Sheet Time and Motion Study to record general data: date, name of observer, project information, machine information, general working conditions, data on the drainage system and general remarks (Figure A3.1);

<table>
<thead>
<tr>
<th>Survey Sheet Time and Motion Studies</th>
<th>Drainage Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation date:</td>
<td>Name observer:</td>
</tr>
<tr>
<td>Observation number:</td>
<td></td>
</tr>
<tr>
<td>Project:</td>
<td>Directorate:</td>
</tr>
<tr>
<td></td>
<td>Project name:</td>
</tr>
<tr>
<td></td>
<td>Collector number:</td>
</tr>
<tr>
<td></td>
<td>Contractor:</td>
</tr>
<tr>
<td>Machine information:</td>
<td>Kind of machine:</td>
</tr>
<tr>
<td></td>
<td>Laterale / Collector</td>
</tr>
<tr>
<td></td>
<td>Manufacturer:</td>
</tr>
<tr>
<td></td>
<td>Type specification:</td>
</tr>
<tr>
<td></td>
<td>Year of manufacturing:</td>
</tr>
<tr>
<td></td>
<td>Chassis number:</td>
</tr>
<tr>
<td></td>
<td>General Condition:</td>
</tr>
<tr>
<td></td>
<td>Good / Moderate / Bad</td>
</tr>
<tr>
<td>General conditions:</td>
<td>Weather condition:</td>
</tr>
<tr>
<td></td>
<td>Good / Moderate / Bad</td>
</tr>
<tr>
<td></td>
<td>Soil type:</td>
</tr>
<tr>
<td></td>
<td>Heavy clay / Clay / Silty clay / Sandy</td>
</tr>
<tr>
<td></td>
<td>Soil condition:</td>
</tr>
<tr>
<td></td>
<td>Dry / Wet / Very wet</td>
</tr>
<tr>
<td></td>
<td>Crop:</td>
</tr>
<tr>
<td></td>
<td>Non / Barley / Wheat / Cotton / Rice / Potato / Barley / ...........</td>
</tr>
<tr>
<td></td>
<td>Crop height:</td>
</tr>
<tr>
<td></td>
<td>Low / Medium / High</td>
</tr>
<tr>
<td>Drainage system:</td>
<td>Distance between drains:</td>
</tr>
<tr>
<td></td>
<td>(metres)</td>
</tr>
<tr>
<td></td>
<td>Length of drains:</td>
</tr>
<tr>
<td></td>
<td>(metres)</td>
</tr>
<tr>
<td></td>
<td>Depth of drains:</td>
</tr>
<tr>
<td></td>
<td>(metres)</td>
</tr>
<tr>
<td></td>
<td>Pipe material:</td>
</tr>
<tr>
<td></td>
<td>Cement / PVC-PE</td>
</tr>
<tr>
<td></td>
<td>Pipe diameter:</td>
</tr>
<tr>
<td></td>
<td>(mm)</td>
</tr>
<tr>
<td></td>
<td>Envelope used:</td>
</tr>
<tr>
<td></td>
<td>Non / Gravel / Synthetic</td>
</tr>
<tr>
<td>General remarks:</td>
<td></td>
</tr>
</tbody>
</table>

Figure A3.1 Survey Sheet for drainage machines
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- Time and Motion Study Sheet to record time and motion, when the time (in centi-minutes) for each successive element of the machine’s working cycle is measured. The best way is to keep the stopwatch running continuously because the end-time of one element is the beginning time of the next element. Apart from general data, the following data is also recorded: the real starting time of the main elements; the name of the element or activity; length and depth of the drain trench; unusual events or incidents and changing conditions (Figure A3.2).

**Time and Motion Study Sheet**

<table>
<thead>
<tr>
<th>Drainage machine:</th>
<th>Project name</th>
<th>Collector number</th>
<th>Date</th>
<th>Sheet number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Year of manufacturing</td>
<td>Chassis number</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurement [cmin]</th>
<th>Activity</th>
<th>Lateral Depth</th>
<th>Lateral Length</th>
<th>Soil type</th>
<th>Remarks</th>
</tr>
</thead>
</table>

Figure A3.2  Study Sheet for drainage machines

The data collected with the survey and study sheets is used to calculate work and time standards. This can be done by hand (Figure A3.3) or by computerised calculation programmes. The output is the average time for each element of the work process. The output can be related to different types of machines, areas, soils, working conditions and any other variable that is important for managing the construction process. Examples are presented in Part III.
**Work Standard Calculation Form**

*Method:*
Laying plastic pipes of 80 mm diameter from both sides of the collector drain.
Average length of the drain is 200 m. Depth of trench 1.20 m. to 1.50 m.
Machine: All lateral-laying drainage machines
Envelope: None

<table>
<thead>
<tr>
<th>Elements of work process</th>
<th>Min./element</th>
<th>Total minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Laying pipes</td>
<td></td>
<td>112.0</td>
</tr>
<tr>
<td>2 Turning and driving back</td>
<td>24.7</td>
<td></td>
</tr>
<tr>
<td>Lifting shoe</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Lowering shoe</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Digging connection</td>
<td>8.7</td>
<td></td>
</tr>
<tr>
<td>Inlet outlet connection</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>Filling water tank</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>44.3</td>
</tr>
<tr>
<td>3 Short technical breakdowns</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>4 Short organisational breakdowns</td>
<td></td>
<td>25.4</td>
</tr>
<tr>
<td>- Stop for pipes</td>
<td>18.0</td>
<td></td>
</tr>
<tr>
<td>- Stop for fuel</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>- Adjustment laser</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>- Field obstructions</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>25.4</td>
</tr>
<tr>
<td>5 Transportation in the field</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>Total minutes per km of lateral drain</td>
<td>184.00</td>
<td></td>
</tr>
</tbody>
</table>

**Work norm: Metres / Hour**  \( \{ \frac{1000}{\text{total minutes}} \times 60 \} \) 326.09

**Time norm: Hours / Kilometre**  \( \{ \text{Total minutes: 60} \} \) 3.07

*Figure A3.3  Work Standard Calculation Form*
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
II-B

Cost Calculations
Part II - Detailed Instructions for the Implementation of Subsurface Drainage Systems

B.1 Methodology for the calculation of staff cost

The staff costs are calculated on a monthly or daily basis. Staff costs are generally considerably more than salary costs. It is composed of all or some of the items as given in Table B.1-1. All costs, also for tools etc., have to be calculated on a time basis (for instance, per day or per month).

Table B.1-1  Staff cost components

<table>
<thead>
<tr>
<th>Cost items</th>
<th>Explanation</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salary</td>
<td>Paid out salary plus possible withholdings for taxes and social charges</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Bonuses</td>
<td>Extra payments for special work or gratifications</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Overtime payment</td>
<td>Average overtime payments for same category staff</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Taxes paid by employer</td>
<td>Depending on national tax law</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Social charges paid by employer</td>
<td>Depending on national laws and regulations, either fixed sum or percentage of salary</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Insurance paid by employer</td>
<td>Health insurance, accident insurance, unemployment insurance, third party insurance etc., depending on national legislation and customs</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Additional allowances</td>
<td>Depending on labour contract</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Transport cost</td>
<td>Cost of transport to office or site; car allowances</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Field allowances</td>
<td>Allowance paid for work out of office, depending on national legislation and customs</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Clothing allowances</td>
<td>Depending on local customs.</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Tools and instruments</td>
<td>Essential tools that employer provides to staff for carrying out their tasks such as measuring instruments, shovels and computers</td>
<td>Monthly charge</td>
</tr>
<tr>
<td>Consumables</td>
<td>Provisions that employer provides such as paper, writing materials and lubricants for instruments</td>
<td>Amount/month</td>
</tr>
<tr>
<td>Overhead</td>
<td>See below</td>
<td>Amount/month</td>
</tr>
</tbody>
</table>

Total Cost
If costs are calculated per month, as proposed in Table B.1-1, the daily cost can be obtained as follows:

*Total monthly salary costs x 12 divided by the number of working days per year.*

**Overhead costs**

The term 'overhead cost' is a 'catch all' phrase for all costs that are not accounted for elsewhere. It often has to do with the cost that can be called 'general running cost' of an entity or establishment and can include the cost of renting offices, secretarial assistance, professional insurance, services to personnel and so forth. Most of these items provide services to or are used for a number of projects simultaneously. They can thus not be attributed to one project or contract only. A common practice is to attribute these costs to all projects or contracts served in proportion to the turnover of each. (see also Part I.7.1.5).
B.2 Methodology for the calculation of the cost of equipment and machinery

Calculation of equipment and machinery costs is complicated by the fact that these are so-called capital goods. The cost of the use of capital equipment is divided into two components:

- Fixed costs or owing costs: costs that are incurred even if the machine is not working;
- Operation costs or variable costs: costs that are incurred only if the machine is working.

A complication may occur when not all costs are incurred in the same currency. For example, if most of the fixed costs are incurred in an international currency to finance the purchase and most of the variable costs are incurred in the national currency. If this is the case, then the realistic exchange rate is to be used and the costs have to be converted into one currency.

The lifetime of capital goods, like drainage machines, is in most cases considerably longer than the time necessary to complete the installation of a drainage project. Thus:

- The cost of each activity carried out by the machinery includes part of the write-off of the investment made for the machinery. If the money destined to compensate the write-off is systematically put into a savings account, a capital will have been built up at the end of the lifetime of the machine to purchase a new one;
- The money spent for the purchase of the machine is taken out of circulation and does not accrue interest. If the machine would not have been purchased the owner could have put the money in the bank and this sum would have generated interest. Thus the purchase of the machine results in a loss of interest. This loss has to be compensated in the cost of the machine which includes an item "loss of interest". If the equipment is bought on credit (with a loan) then interest will have to be paid to the credit provider (bank). In that case the interest payments are a cost element of the machinery.

The cost calculation of machinery or equipment can be made on the basis of Table B.2-1 given below, which has been derived from the cost calculation methods of Caterpillar handbook and is one that is internationally accepted. As the table only allows for one currency, we have selected the Euro for our example.
Table B.2-1: Sample calculation method of cost of equipment

<table>
<thead>
<tr>
<th>Basic information</th>
<th>No/Item</th>
<th>Unit/formula</th>
<th>Quantity</th>
<th>No/Item</th>
<th>Unit/formula</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Purchase price</td>
<td>Euro</td>
<td>250,000</td>
<td>H. Insurance</td>
<td>% of A/year</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B. Depreciation period</td>
<td>Hour</td>
<td>10,000</td>
<td>I. Shelter</td>
<td>Euro/year</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>C. Annual use</td>
<td>Hour/year</td>
<td>1,200</td>
<td>J. Lubricants/year</td>
<td>15% of F x G</td>
<td>1152</td>
<td></td>
</tr>
<tr>
<td>D. Life time</td>
<td>Years (B/C)</td>
<td>8</td>
<td>K. Personnel cost</td>
<td>Euro/hour</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>E. Interest rate</td>
<td>%</td>
<td>9</td>
<td>L. Spare parts</td>
<td>% of A/life time</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>F. Fuel price</td>
<td>Euro/litres</td>
<td>0.50</td>
<td>M. Repair</td>
<td>% of A/life time</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>G. Fuel consumption</td>
<td>litres/year</td>
<td>15,360</td>
<td>N. Residual value</td>
<td>% of A</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Owing Costs</th>
<th>No/Item</th>
<th>Unit/formula</th>
<th>Quantity</th>
<th>No/Item</th>
<th>Unit/formula</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>O. Depreciation</td>
<td>(AN)/D</td>
<td>27,000</td>
<td>O/C</td>
<td>22.50</td>
<td>O/C*8</td>
<td>180</td>
</tr>
<tr>
<td>P. Loss of interest</td>
<td>A/2*E</td>
<td>11,250</td>
<td>P/C</td>
<td>9.38</td>
<td>P/C*8</td>
<td>75</td>
</tr>
<tr>
<td>Q. Insurance</td>
<td>H*A</td>
<td>2,500</td>
<td>Q/C</td>
<td>2.08</td>
<td>Q/C*8</td>
<td>17</td>
</tr>
<tr>
<td>R. Shelter</td>
<td>I</td>
<td>0</td>
<td>R/C</td>
<td>0</td>
<td>R/C*8</td>
<td>0</td>
</tr>
<tr>
<td>S. Total</td>
<td></td>
<td>40,750</td>
<td>S/C</td>
<td>33.96</td>
<td>S/C*8</td>
<td>272</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operation Cost</th>
<th>No/Item</th>
<th>Unit/formula</th>
<th>Quantity</th>
<th>No/Item</th>
<th>Unit/formula</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. Fuel</td>
<td>F*G</td>
<td>7,680</td>
<td>T/C</td>
<td>6.40</td>
<td>T/C*5</td>
<td>32</td>
</tr>
<tr>
<td>U. Lubricants</td>
<td>J</td>
<td>1,152</td>
<td>U/C</td>
<td>0.96</td>
<td>U/C*5</td>
<td>5</td>
</tr>
<tr>
<td>V. Spare/wear parts</td>
<td>A°L/D</td>
<td>19,500</td>
<td>V/C</td>
<td>16.25</td>
<td>V/C*5</td>
<td>81</td>
</tr>
<tr>
<td>W. Repairs</td>
<td>A*M/D</td>
<td>3,000</td>
<td>W/C</td>
<td>2.50</td>
<td>W/C*5</td>
<td>13</td>
</tr>
<tr>
<td>X. Personnel</td>
<td>K°C</td>
<td>3,000</td>
<td>X/C</td>
<td>2.50</td>
<td>X/C*5</td>
<td>13</td>
</tr>
<tr>
<td>Y. Total</td>
<td></td>
<td>34,332</td>
<td>28.61</td>
<td>143</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Cost</th>
<th>No/Item</th>
<th>Unit/formula</th>
<th>Quantity</th>
<th>No/Item</th>
<th>Unit/formula</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. Owing</td>
<td>Euro/year</td>
<td>40,750</td>
<td>S/C</td>
<td>34</td>
<td>S/C*8</td>
<td>272</td>
</tr>
<tr>
<td>Y. Operation</td>
<td>Euro/year</td>
<td>34,332</td>
<td>Y/C</td>
<td>29</td>
<td>Y/C*8</td>
<td>143</td>
</tr>
<tr>
<td>Z. Contingencies</td>
<td>(S+Y)*0.05</td>
<td>3,754</td>
<td>Z/C</td>
<td>3</td>
<td>Z/C*8</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>78,836</td>
<td>66</td>
<td>435</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explanation of the table: (for the sake of simplicity only the term equipment has been used).

**Part I - Basic information**

A. Purchase price: is the price of the equipment including all costs such as transport insurance, taxes, assembling and test runs;

B. Depreciation period (working hours): the period over which the equipment has depreciated or the technical lifetime of the equipment. The end of the technical lifetime is the moment that repair/revision of the equipment is economically more costly than purchasing a new one. The lifetime of modern machinery in the western world is estimated at 10 000 hours. In reality the lifetime may be considerably longer depending on the local cost of mechanics, spare parts and the like;

C. Annual use (working hours per year): refers to the number of hours the equipment is used annually;

D. Lifetime (years): is the lifetime of the equipment in years, which can be obtained by dividing the depreciation period by the annual use;
E. Interest rates in %: the current interest rate in the country or the expected average annual interest rate over the lifetime of the equipment;

F. Fuel price in Euro per litre;

G. Fuel consumption in litres/year. This can be obtained from the number of working hours per year (C) and the hourly consumption (The hourly consumption can be estimated from the manufacturer’s information, which if difficult to obtain can be estimated as follows: hourly consumption at full power is 200 gr./fuel per horsepower, or 0.16 litres/HP/hour. Since most of the equipment is not continuously working at full power the actual consumption is 50%-70% of 0.16 litres/HP/hour). If electrically or gas driven equipment is used, then obviously fuel will be replaced by electricity or gas;

H. Insurance (Euro per year): insurance of the equipment is often arranged to cover accidents so that the investment is not lost. The insurance rate varies per company and per country. The rates can be obtained from insurance companies and often amounts to a percentage of the insured value;

I. Shelter (Euro per year): the equipment requires storage and shelter (garage). The cost thereof depends on the local conditions and prices;

J. Lubricants (Euro per year): Lubricants are needed for most equipment. If actual costs are not known they can be estimated for diesel powered equipment as being 15% of the fuel costs. For electrically powered equipment the information can be obtained from the manufacturer;

K. Personnel costs: (Euro/hour); The costs of the personnel required to operate and do the regular maintenance of the equipment (see B.1) depends on the local cost levels, salary levels and so forth;

L. Spare parts (Euro over life time): the cost of spare parts including wear parts1 over the lifetime of equipment can be expressed as a percentage of the purchase price. The use of wear parts is especially high for drainage machines so this can be an important cost item (75-100%);

M. Repairs (Euro over lifetime). This concern the cost of mechanics and small items required for repairs, it is a local cost based on the hourly cost of mechanics. It is generally expressed as a percentage of the purchase price;

N. Residual value (in Euro): at the end of the life of the equipment it may still be of value be it second hand value, spare parts that can be cannibalised, or as scrap. The value will vary from country to country and from situation to situation and is often estimated at between 0% and 10% of the new value;

Part 2 Owing costs (in Euro per year)

O. Depreciation (Euro/year): this is calculated as the purchase price minus the residual value divided over the lifetime. (A-N)/D;

P. Loss of interest (Euro/year): is the amount of money that would be lost had the equipment been purchased as opposed to it gaining interest in the bank. Since the value of the

---

1Wear parts are parts that regularly wear out because of the activity of the equipment. With a trencher, for instance, these are the digging chains and sprocket wheels, with cars: tires and oil filters, with drain pipe production lines: needles or knives for punching the holes.
equipment depreciates every year the amount of money that could have gained interest in the bank also depreciates year by year. Thus, the loss of interest also becomes less and less. To make it simple, the average amount that could have been deposited in the bank would be 50% of the purchase price. Thus, the annual loss of interest is calculated as being 50% of the purchase price in Euro times the interest rate in percentage; 

Q. Insurance cost (Euro/year): calculated as insurance rate in % multiplied by the new value in Euro; 

R. Shelter (Euro/year): the annual cost of shelter in Euro; 

S. The total owing costs (Euro/year): addition of O, P, Q and R. The total owing costs can be calculated per hour by dividing all the costs by the number of hours the equipment is used (C). The daily price for drainage - a convenient basis for cost calculation - is the hourly cost multiplied by the daily working hours; 

Part 3  Operation costs (in Euro per year) 

T. Fuel (or energy (Euro/year): calculated as the annual fuel or electricity use multiplied by the unit cost; 

U. Lubricants (Euro/year): cost of lubricants per year; 

V. Spare/wear parts (Euro/year): Total value of spare/wear parts over the lifetime divided by the number of years; 

W. Repairs (Euro/year): Total value of repairs over the lifetime divided by the number of years; 

X. Personnel costs (Euro/year): Cost of personnel per hour multiplied by the number of hours per year; 

Y. Total operation costs (Euro per Year): addition of T, U, V, W and X. The total operation costs can be calculated per hour by dividing all the costs by the number of hours the equipment is used (C). The daily price, that for drainage a convenient basis for cost calculation, is the hourly cost multiplied by the daily working hours. 

Part 4  Total costs 

The total costs are the sum of the owning costs (S) and the operation costs (Y). For eventualities that may occur, price rises, exchange rates changes, 5 or 10 per cent is normally added for contingencies (Z). 

In Table B.2-1 a cost price has been calculated based on fictitious data for a drainage trencher, that cost 250,000 Euro, and works 1200 hours per year for 8 hours working days.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

B.3 Methodology for the calculation of the cost of transport

The transport requirements for the construction of drainage systems can be international and national or local transport.

B.3.1 International transport

International transport (sea freight or air freight) has its own particularities, which vary considerably. Since it is a question of a world market price there is no direct relationship between distance, volume and costs. Moreover charges for ports, port storage handling, insurance and paper work can be significant and out of all proportions to the actual cost of transport. The calculation of international transport costs is specialist work that can be circumvented by requesting an international supplier to do the job and quote a CIF price (Cost Insurance Freight is then included in the price). Initial quotations are often FOB (Free On Board) prices, meaning the cost of the equipment includes the transport to the harbour and the loading onto the ship.

B.3.2 Local transport costs

Local transport costs can be calculated in the following ways:

Contracted transport
If there are reliable transport companies to whom one can contract out the transport, these companies often have km/ton charges, meaning the cost of transport of one ton over one km distance. They may also have various prices for different road conditions. If light materials need to be transported (drain pipes) they may quote a price according to m³/km. Insurance for the transport is extra.

Transport by own organisation
If transport is going to be taken care of by the entity responsible for the drainage construction, the cost of transport has to be calculated in detail as follows:

- Cost of loading: is the cost of labour and possible tools, instrument lifting devices;
- Cost of transport: can be calculated in the same way as the cost of equipment presented in instruction B.2;
- Cost of discharge: is the cost of labour and possible tools, instrument lifting devices;
- Cost of Insurance: if required, to be obtained from local insurance companies;
Cost of losses and damages: losses or damages depend on what precisely is transported. Gravel will only have losses, culverts may be damaged as can happen to drain pipes. Initially an estimate can be made of the losses and damages, but as experience is gained regular corrections may be made.

B.3.3 Suppliers transport

Suppliers can be requested to take care of the transport and deliver on site. This will circumvent some of the difficulties as long as the contracts are properly drawn up. They will then be accountable for all losses and damages. The consequence is that they will include the risk of the transport in their cost.
B.4 Methodology for the calculation of the cost of raw material

Under raw material for the construction of drainage systems is understood to be materials like PVC powder, PE powder, cement and to a lesser extent fuel and electricity. The basic material for synthetic envelopes such as polypropylene, nylon thread for the windings may also be included. The cost calculation of base materials can be based on national (sometimes controlled) prices or world market prices.

B.4.1 PVC and PE powder

These materials are international commodities that are governed by world market prices. If there is a national industry that produces either one of these powders, the price is possibly a set national price. Therefore, the national price is required for the cost calculation. For the feasibility study, however, the world market (economic) price may be required. The prices of PVC and PE powder fluctuate continuously on the world market as a reaction to supply and demand. International prices can be obtained from international publications on commodity prices and national prices from the national industry. If the powder is purchased internationally the cost of transport may have to be added as well as the cost of import duties.

B.4.2 Cement

Cement prices are in most cases nationally set or have a national market price. Other raw materials have to be obtained from the national or international suppliers.
II-C

Installation of subsurface drainage systems
Preamble

The installation process starts as soon as the design has been completed and approved, the installation mode has been decided and all the relevant contracts have been signed. A prerequisite for the start of the installation in countries without an existing drainage industry is the availability of the equipment and production facilities for drainage materials in country in question or, in special cases, arrangements for the import of drainage materials. Obviously, when the installation process commences the equipment and drainage materials that will be used will already be known.

The minimum information that the organisation in charge of construction should be provided with is as follows:

- Map with the layout and levels of the drainage system relative to a benchmark and baseline;
- List of the field drains and collectors to be installed indicating: the locations, levels, lengths and diameters of the drains;
- Bill of Quantity in which the required quantities of drainage materials are listed.

Drainage materials

The procurement of drainage materials can, depending on local customs, be done directly by the implementing organisation or is included in the construction contract. Whatever method is used, the instructions sheets are based on the assumptions that:

- Drainage materials of acceptable quality has been transported to the site;
- Plastic (PVC or PE) corrugated field drain and collector pipes will be used;
- Either gravel or pre-wrapped envelope material will be used.

Installation equipment

The instruction sheets for installation are written for using trenchers with laser guided depth and grade control. Instructions for the use of trenchers can vary depending on the make of the trenchers. These are general instructions that need to be completed or modified according to the instructions provided by the manufacturers of the equipment. Instructions for manual grade control can be found in instruction sheet C.17 for the rare instances when no laser is available. For the sake of completeness a guideline is given in instruction sheet C.36 for the installation of drain pipes by hand (see also Chapter 6, Part I). In instruction sheet C.37 guidelines are given for the installation of drain pipes by hand in trenches dug by excavators (see also Chapter 6 of Part I).

Layouts

As far as the layouts are concerned the instructions are written for:

- Singular systems, which are systems in which field drains discharge into an open drain (Figure C0.1);
- Composite or collector systems where the field drains discharge into a subsurface collector drain that in turn discharges into an open ditch or a sump from where the water is pumped into an open ditch (Figure C0.2).
Organisation of the instruction sheets
The instructions only contain a limited amount of background information, they are purely and simply a practical guide to the process of drainage installation and the technical aspects of the maintenance of drainage systems. For other aspects of the implementation process reference is made to the specific Chapters in Part I.

The following groups of instruction sheets are provided:
**Sheet II.C.1 - C.3 Organisation of the implementation of subsurface drainage systems**
Provides information about the organisation required and how the organisation can be staffed and the special skills required.

**Sheet II.C.3 - C.18 Machinery and equipment**
Provides information about the machinery and equipment required, the maintenance and management thereof and, in particular, the adjustment of the trencher.
Sheet II.C.18 - C-38  Installation of subsurface drainage systems

Provides instructions on the main aspects of the implementation of subsurface drainage systems. These instructions sheets have been organised per subject as follows:

- General procedures, valid for both singular and composite layouts;
- Implementation procedures for singular systems, with pre-wrapped or gravel envelope;
- Implementation procedures for composite drainage system with pre-wrapped or gravel envelope;
- Management of gravel as an envelope;
- Installation of drain pipes by hand;
- Installation of drain pipes by hand in trenches dug by excavators;
- Trenchless installation of drain pipes.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
II-C/1

Organisation of the implementation of subsurface drainage systems
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

General

Implementation of subsurface drainage systems requires a systematic organisation. The precise form of this organisation will depend on the local customs and conditions as well on the institutional set up of the local drainage industry (see also Part I, Chapter 6). The following sections contain the requirements in terms of machinery, equipment, tools and staff for the implementation of both singular and composite drainage systems.
C.1 Requirements for the implementation of singular drainage systems

C.1.1 Required machinery equipment and tools

The following equipment and tools are required for the installation of singular drainage systems:

- Trencher(s) for installing field drains (including tools, fuel, etc.);
- At least 5 boning rods (delivered with the trenchers);
- Laser equipment;
- Levelling instrument including the measuring staff;
- Measuring tape of 2 metres;
- Measuring tape of 50 metres;
- Bulldozer;
- In some cases a hydraulic excavator.

Support equipment:

- Transport equipment material for infield transport of drainage materials (agricultural tractor with trailer);
- Fuel tanker;
- Servicing/maintenance truck (pick-up);
- Transport equipment for staff (motorcycles, cars, busses);
- Communication equipment (walky-talkies, cell phones, or other).

Additionally if gravel envelope is used:

- Three tractors and gravel trailers for each trencher, for infield transport of gravel envelope;
- Front loader for loading of gravel into gravel trailers.

C.1.2 Required staff

The following staff is required for the installation of singular drainage systems:

- Field manager for the overall organisation;
- Trencher operator (one for each trencher);
- Assistant trencher operator (one for each trencher);
- Technical assistant to assist the field manager and as deputy field manager when the field manager is absent;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- Two surveyors per trencher for setting out the field and quality control;
- Three labourers per trencher for unrolling the drain pipe (if pipes are not delivered on rolls and/or the trenchers are not equipped for handling rolls);
- One person for guiding the drain pipe on the machine (operators assistant);
- One person for installing the outlet, checking the pipe position and initial backfilling of trench;
- Tractor driver for driving the transportation material for supply of drainage material.

Support personnel:
- Mechanic for infield maintenance (depending on customs, conditions and proximity of mechanical services);
- Fuel tanker tractor driver (perhaps not full-time);
- Car driver(s) for driving transporting field staff.

In case of gravel envelope application:
- Three tractor drivers;
- Front loader driver;
- Gravel manager.
C.2 Requirements for the implementation of composite drainage systems

C.2.1 Required machinery equipment and tools

The following equipment and tools are required for the installation of composite drainage systems. The equipment is based on the use of one trencher for field drain installation and one trencher for collector installation:

- Excavator(s) for digging the starting hole of the collector trencher and for installation of collector outlet, manhole and starting holes of field drain trencher;
- Trencher for installing collector drains;
- Trencher for installing field drains;
- At least 2 x 5 boning rods (delivered with the trenchers);
- Laser transmitter (preferably 2);
- Battery charger for laser transmitter (if required);
- Levelling instrument including the measuring staff (preferably 2 sets);
- Measuring tape of 2 metres;
- Measuring tape of 50 metres;
- Mud pump.

Support equipment:

- Transport equipment material for infield transport of drainage material (agricultural tractor with trailer);
- Fuel tanker;
- Servicing/maintenance truck (pick-up);
- Transport equipment for staff (motorcycles, cars, busses);
- Communication equipment (walky-talkies, cell phones, or other).

Additionally if gravel envelope is used:

- Three tractors and gravel trailers for infield transport of gravel envelope;
- Front loader for loading of gravel into the gravel trailers;
- Transportation material for supply of drainage material;
- Transportation equipment for staff (motorcycles, cars, busses).
C.2.2 Required staff

Requirements for the staff for the installation of composite drainage systems are as follows:

- Field manager for the overall organisation;
- Trencher operator (2-4 depending on workload and customs);
- Technical assistant to assist the field manager and to be deputy field manager when the field manager is absent (depending on the size of operation);
- Two surveyors for setting out the field and quality control;
- Three labourers per trencher for unrolling the drain pipe (if pipes are not delivered on rolls);
- One person per trencher for guiding the drain pipe on the machine (operators assistant);
- One or more assistants per trencher for installing outlets making connections, checking pipe position and initial backfilling of trench;
- Tractor driver for driving the transportation material for supply of drainage material.

Support personnel:

- Mechanic for infield maintenance (depending on customs, conditions and proximity of mechanical services);
- Fuel tanker tractor driver (perhaps not full-time);
- Car driver(s) for transporting field staff.

In case of gravel envelope application:

- Three tractor drivers;
- Front loader driver;
- Gravel manager.
### C.3 Tasks descriptions for key installation staff

#### C.3.1 Field manager

**Profile**

The expertise of the field manager must cover drainage in general and the practical implementation of pipe drainage systems in particular. He needs to be conversant with the operation and maintenance of trenchers, surveying techniques and will have a clear understanding of the design principles of drainage systems. The field manager, if appointed by a contractor, represents the contractor in the field and is directly responsible to the supervising authority.

**Responsibilities**

The field manager will be responsible for the following:

- **General responsibilities**
  - Supervision and guidance of the implementation process and staff including the operator(s) of the trencher(s);
  - Assuring that the system is implemented according to the design. If local conditions require adjustment of the design, he needs to act as coordinator with the designers. If he is appointed by a contractor he will have to obtain permission from the supervisor representing the implementation authority;
  - Continuously carrying out infield quality control;
  - The total organisation of the installation process especially focused on:
    - Assuring availability of staff, pipes, fuel, trenchers + laser, excavators, transport equipment;
    - Assuring supply of materials and the availability of equipment in sufficient quality and quantities;
    - The preparation of as-built drawings.

---

1 For large projects with more than one installation unit a field manager will have a more general managerial task. Unit managers will then have the specific task of managing the unit in the field. If the installation is done by only one installation unit, the field manager will be responsible for all the tasks described.
Specific responsibilities:

- Familiarisation with the design. (Designs data, maps and sheets are to be available in the field);
- Guiding and checking the staking out in the field of the design before installation starts;
- Guiding and checking that the field is prepared for the installation (obstructions removed etc.);
- Guiding and checking that proper levels are available according to the design (benchmarks);
- Guiding and checking that the individual drain lines are properly set out;
- Guiding and checking the levels and the installation of outlets, sumps and manholes;
- Organising and checking that the drainage materials are available and properly prepared (pipes rolled out and joints correctly made);
- Guiding and checking the provision of start levels of the drains, collectors and manholes as well as the placement of the laser and settings thereof;
- Organising and checking the total installation sequence (outlets, collector, field drain);
- Assuring that the drain pipe is installed in the proper alignment and grade and that the pipe is properly entered into the trench box (limited tension);
- Checking the correct position of the drain pipe in the trench;
- Checking the preliminary backfilling of the trench (covering the drain pipe with a first layer of soil to prevent the pipe of moving and floating in the trench);
- Overall guidance and supervision the field staff, activities of the labourers;

C.3.2 Supervisor

Profile

The supervisor represents the ‘client’ in the field. In FIDIC contracts the supervisor is named: supervising engineer. In the case of important contracts the supervisor is the so-called “engineers representative”. The client (or principal) is usually the implementation authority. The main task of the supervisor is to check that the installation of the subsurface drainage system is carried out according to the design, the norms and specifications as described in the technical specifications of the contract. His powers and authority are described in the conditions of contract. The supervisor must have a good knowledge of drainage, be able to read and interpret designs, have a thorough understanding of the designs and a profound knowledge of the specifications and checking methods. For some legal details see Chapter 2 of Part I. The method for checking the quality in the field is given in Section D of Part II.

General responsibilities

This involves checking and approving all activities of the installation according to the design and specifications. If discrepancies arise the supervisor will need to take the necessary actions to assure that a good quality installation will result. The tasks include: disallowing the use of faulty materials and working with faulty machinery and equipment, order corrections for the placement of sumps and manholes, order replacement or correction of drain outlets, rejecting a faulty
altered drain line and order correction or reinstallation and so forth. His administrative authorities (including his right to stop the work) are described in the conditions of the contract.

Responsibilities for materials and equipment
- Checking and approving the drainage materials when delivered to the site;
- Checking and approving storage of the materials;
- Checking that the machinery and equipment used by the contractor/installation unit is in good condition and can be expected to install the system correctly;
- Checking and approving the certificate of the laser;
- Checking and approving the regular checking of the laser.

Responsibilities for drain installation
- Checking the setting out of the field and (levels and alignment);
- Checking the starting levels of the drainage systems;
- Checking levels, positioning, structural integrity of sumps and manholes as well as backfill;
- Checking levels and grade of installed drain pipes during/directly after installation;
- Checking damages to drain pipes during installation;
- Approving the closure of trenches;
- Checking and approving the backfill of trenches;
- Checking the functionality of the system;
- Checking the cleaning up of the site.

Responsibilities for final approval/reception of the works
This entails approval of the system and its recommendation to the implementation authority. If active supervision is carried out the supervisor must carry out all the checks in person or through a representative. If passive supervision is carried out the supervisor must verify the work carried out by the contractor/installation unit as well as carry out double checks on-the-spot.

C.3.3 Trencher operator

Profile
The trencher operator is fully trained in the operation of the trenchers and laser equipment. He is capable of carrying out or guiding the daily and regular maintenance of the trenchers. Background knowledge of drainage in general is preferred.

Responsibilities
- Daily and regular maintenance of the trencher;
- Operating of the trencher;
- Adjusting the trencher;
- Carrying out small repairs;
- Assisting with big repairs of the trencher;
- Handling of the laser equipment on the trencher;
• Reporting maintenance, and repairs and problems with the trencher;
• Filling in daily and weekly maintenance sheets (see C.5).

Observation
It is preferable to have one assistant trencher operator per trencher. In this way while one oper-
ator operates the trencher and the other one assists the operator with alignment activities such
as placing the boning or ranging rods and removing them.

C.3.4 Assistant trencher operator

Profile
The assistant trencher operator will have a basic knowledge of operating hydraulic equipment
and will be trained in the operation of the trencher and the laser equipment, and the maintenance
of the trenchers.

Responsibilities
Same as the trencher operator, but working under his guidance:
• Daily and regular maintenance of the trencher;
• Operating of the trencher;
• Adjusting the trencher;
• Carrying out small repairs;
• Assisting with big repairs of the trencher;
• Informing trencher operators of problems with the trencher during operation;
• Placing boning rods in the alignment and the timely removal of them;
• Supervising the supply of drain pipes and guiding them into the trench box.

C.3.5 Excavator operator

Profile
The excavator driver is fully trained in operating and handling of a hydraulic excavator. He is cap-
able of carrying out or guiding the daily and regular maintenance of the excavator.

Responsibilities
The excavator operator is responsible for:
• Daily and regular maintenance of the excavator;
• Operating the excavator to:
  - Remove obstructions in the field;
  - Dig starting holes up to the instructed level;
  - Place sumps and manholes.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Observation
Background knowledge of field drainage in general is preferred.

C.3.6 Surveyor

Profile
The surveyor is familiar with the setting out of lines, levels, handling of levelling instruments, laser equipment, and processing of field data in map and graphical form.

Responsibilities
- Setting out of the field with levels;
- Setting up and checking the laser transmitter;
- Providing the trencher operator with start levels;
- Providing and checking levels of manholes and sumps;
- Checking laser and level instruments;
- Assisting with staking out drain lines;
- Quality control of installed drain (checking levels of the drains directly after installation);
- Assisting with preparing as-built drawings;
- Processing field information.

Observation
Background knowledge of field drainage in general is preferred.

C.3.7 Labourers/Operators assistants

Profile
No special skills are required. However experience with soil movement is recommended.

Responsibilities
- Laying out of pipes in the field and preparing connections;
- Installing outlet;
- Connecting pipes to manholes/outlet/connector drains;
- Initial backfilling trenches, if required;
- Assisting surveyors (setting out of field and drain lines, measuring drain levels);
- Guiding the drain pipe in the trench box and checking pipe and joint quality;
- Installing the outlet, checking pipe position and preliminary backfilling of trenches;
- Clearing of field from obstacles;
- Guiding the gravel trailers/opening and closing of valves of gravel trailers (if applicable);
- Other fieldwork when circumstances demand.
C.3.8 Tractor driver/Front loader driver

Profile
The tractor driver is fully trained in driving and handling of tractors/front loaders. He is capable of carrying out or guiding the daily and regular maintenance of the tractor/front loader.

Responsibilities
The tractor driver is responsible for:
- Daily and regular maintenance of the tractor/front loader;
- Driving and operating the tractor/front loader;
- Managing/loading and unloading the gravel trailers (if applicable).

C.3.9 Gravel manager

Profile
The gravel manager is trained in handling and managing tractors and gravel trailers and furthermore is capable of judging the quality of gravel and managing relative complex situations.

Responsibilities
The gravel manager is responsible for:
- Regular, uninterrupted supply of gravel to the trenchers;
- Ordering new gravel (if circumstances demand);
- Selecting the best location of field depots of gravel;
- Controlling/correcting proper supply of gravel to and placement of gravel around the drain pipes;
- Managing the loading and unloading the gravel trailers (if applicable).
II-C/2

Machinery and Equipment
C.4 Description of trenchers

C.4.1 General

In the following instructions sheets reference is often made to components of the trencher and commands to be given to the trencher. A schematic drawing of the trencher and its main components is presented (Figure C4.1). The figures presented in this section are based on a commonly used trencher. The different makes of trenchers differ in detail. The manuals and technical information provided by the manufacturers with the drainage trenchers will give the exact information about the particular trencher used.

![Figure C4.1 Schematic drawing of a trencher](image)

C.4.2 Trencher

In Figure C4.1 is a schematic drawing of a drainage trencher. The following components of the trencher require additional comments:
Press pulley
For the installation of corrugated plastic pipes the trench box is equipped with a press pulley above the outlet opening for the drain pipe in the trench box (Figure C4.2). The press pulley pushes the drain pipe towards the bottom of the trench, which is the designed level for the pipe. Because the drain pipe is relatively light, installing it without this press pulley can cause the soil to slip underneath the pipe. This might result in differences in level.

The press pulley should not be used when a gravel envelope is applied, because a space for the gravel is required between the bottom of the trench and the bottom of the drain pipe. The pulley can be either removed or fixed in an upward position.

The auger
Most of the lateral drainage machines are equipped with an auger, which is meant to move the excavated soil sideways. If an auger is not used there will be a larger friction area (Figure C4.3).
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Water tanks

If installation takes place in sticky clay the friction between the sides of the trenches and the trench box can be significant, slowing down the speed of the trencher. This requires extra power. The friction can be significantly reduced by spraying water along the sides of the trench box and on the digging chain. Therefore, trenchers for use in clay soils can be equipped with a water tank (Figure C4.4). The need of such a tank should be stipulated in the purchasing contract or in the contract with drainage contractors.

Figure C4.3 Use of auger reduces friction

Figure C4.4 Trencher with water tank
C.4.3 A model of a operators command panel of a trencher

Below, in Figure C4.5, is a schematic layout of the driver’s console from which the operator gives the required commands. The various command buttons/handles are referred to in the instruction sheets that follow:

Figure C4.5 Operators command panel of a trencher
<table>
<thead>
<tr>
<th>No.</th>
<th>Function of command</th>
<th>No.</th>
<th>Function of command button/handle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Engine speed</td>
<td>11.</td>
<td>HI and LO position of the crawler drive motors</td>
</tr>
<tr>
<td>2.</td>
<td>Left-hand crawler drive pump</td>
<td>12.</td>
<td>Floatation of slew cylinders</td>
</tr>
<tr>
<td>3.</td>
<td>Right-hand crawler drive pump</td>
<td>13.</td>
<td>Slew cylinders</td>
</tr>
<tr>
<td>4.</td>
<td>Floatation of lifting cylinder</td>
<td>14.</td>
<td>Selection lever for speed of digging chain</td>
</tr>
<tr>
<td>5.</td>
<td>Overrule button</td>
<td>15.</td>
<td>Warning horn push button</td>
</tr>
<tr>
<td>6.</td>
<td>Battery charge lamp</td>
<td>16.</td>
<td>Lifting cylinder trench box</td>
</tr>
<tr>
<td>7.</td>
<td>Key starter lock</td>
<td>17.</td>
<td>Emergency stop</td>
</tr>
<tr>
<td>8.</td>
<td>Engaging oil cooler</td>
<td>18.</td>
<td>Foot pedal for uncoupling gearbox from engine</td>
</tr>
<tr>
<td>9.</td>
<td>Depth regulation cylinders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Lifting cylinder digging boom</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
C.5 Maintenance of trenchers

C.5.1 General

Maintenance of a trencher consists of:

- Daily maintenance, including the starting up procedures;
- Weekly maintenance;
- Regular maintenance: maintenance needing to be done after every 100 hours of operation;
- Yearly maintenance and storage.

In the following sections simplified checklists and action lists are given. However, it is of great importance that the people in charge of the machines have knowledge of and access to the manuals. Sample forms that need to be filled in by the persons responsible for the daily maintenance and for the weekly maintenance are provided at the end of this instruction sheet. These forms can serve as maintenance records or logs.

C.5.2 Daily checks and maintenance

Daily checks and maintenance includes the starting up procedures.

C.5.2.1 Before starting engine

Engine

Check:

- Water level (if too low: add water);
- Oil level (if too low: add oil);
- Hydraulic oil (if too low: add hydraulic oil).

---

1 Instructions are based on a trencher of a specific manufacturer, which generally applies to trenchers of other manufacturers as well. However, for other trenchers the manufacturers instructions in the manuals must be checked and adjustments made (if required).
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Cleaning and draining:
- Drain the water separator so that the water is removed;
- Clean pre-air filter (by hand).

Other parts of the trencher

Greasing:
- All cardan shafts;
- Final drive digging chain;
- The nipples of the auger should be greased after every 500 m of drain installation.

Check and repair:
- Broken or loose bolts (tightly or replace);
- Oil leaks (tighten couplers if necessary);
- Fuel leaks;
- Digging chain (Figure C5.1):
  - Tightness of bolts and broken knives (tighten bolts and replace knives if necessary);
  - Digging chain tension;
  - Difference between scraper blades and trench box;
  - Lubricate rotating points every 1 or 2 hours.

Figure C5.1   Check blade wear, nuts, digging chain tension and lubrication
C.5.2.2 After starting the engine

Wait five to ten (5-10) minutes until engine is warmed up (length of time depends on the outside temperature).

After that check on dashboard:
- Oil pressure engine indicator (if too low, call mechanic!);
- Fuel level indicator (if too low: add fuel);
- Air filter indicator (if flashing: clean filter);
- Hydraulic filter indicator (if flashing: check vacuum gauges on machine);
- Hydraulic oil tank.

Check on the machine: Vacuum gauges of the hydraulic drive.

C.5.2.3 Re-fuelling

Re-fuelling the trencher should preferably be done after work, not in the morning (to prevent condensation forming in the tank).

C.5.2.4 General

- During the checking and starting up procedures a general cleaning of the machine is recommended;
- The daily maintenance should not take more than 30 minutes.

C.5.3 Weekly maintenance of trencher

- Perform daily maintenance (see C.5.2);
- Check acid levels in the batteries (if too low: add distilled water);
- Check oil levels of all the gearboxes in the machine (if too low: add oil);
- Grease all grease nipples on machine;
- Check tightness of duplex or triplex chain in chain case¹ (tighten if necessary, see manual);
- Change the fuel filters if the engine power had been noticeably less;
- Clean machine and make intensive checks for:
  - Fuel leaks;
  - Oil leaks;
  - Water leaks.
- Carry out repairs, if necessary.

¹ Only in case of mechanical driven digging chain.
**C.5.4 Regular maintenance of trencher**

Carry out the following activities after every 200-300 running hours of the engine:

- Change engine oil and oil filter;
- Clean bleeder of crankshaft;
- Check tension of V belts and tension if necessary.

**Other parts of the trencher:**

- Adjust digging chain (Figure C5.2)

---

![Digging chain adjustment](image)

**Figure C5.2 Digging chain adjustment**

**C.5.5 Annual maintenance and winter storage**

- Check and if necessary adjust valves (see manufacturers manual);
- Clean and grease whole machine, and check for leaks;
- Repair leaks before the winter storage of the trencher;
- Drain cooling water from engine;
- Put tracks of machine on wooden beams;
- Change engine oil and oil filter;
- Change oil in gear boxes (every 1000 hours or once a year; check the manufacturers manual);
- Change filters of hydraulic system; (every 500 hours or once a year; check the manufacturers manual);
- Cover machine against dust.
C.5.6 Replacement of digging chain, digging knives, sprockets and auger blades

The digging assembly of a trencher is subject to wear and tear, requiring regular checks and replacement of digging knives, auger blades, sprocket wheels and the chain itself. The digging chain and sprocket wheels are the parts that suffer the most wear and tear (see also C.7). Figure C5.3 shows the digging boom with the digging chains, knives, auger and the position of the sprockets.

Digging chain
Digging chains and the two sets of digging knives have to be replaced when they are worn out. The replacement depends on the soil texture. On average the replacement takes place after 60 km of drain pipe installation. But situations are known where this has to be done after 40 km (sandy soils) or 80 km (clay soils).

Digging knives
The wear of the digging knives depends on the soil conditions, for instance, in sandy soil the wear is much faster than in clay soil. On average, the knives need to be welded after some 10-15 km of drain installation, depending on the soil texture and the installation speed. The welding of the knives can be done twice. For the welding of each knife one electrode is used to create a 1.5 cm wear strip.
Sprockets
The drive sprocket at the top of the digging boom needs to be replaced after approximately 60 km, so at the same time the digging chain and digging knives are also renewed. The bottom sprocket and the auger sprocket should be replaced after approximately 120 km.

Auger blades
The wear of the auger blades also depends on the type of soil in which the trencher is operating. On average the auger blades have to be welded at the same time as the digging knives. After 10-15 km of drain pipe installation, wear strips are welded on the auger blades.

C.5.7 General warning for trencher

- If welding is done on the machine disconnect three (3) cables from control box and disconnect the battery;
- Do not drive the machine at high speed over long distances!!

C.5.8 Model maintenance record

On the following pages examples of daily and weekly maintenance records for drainage trenchers are given.
### DAILY MAINTENANCE OF TRENCHER: (type en number)

**Report no:**

**Daily Record**

<table>
<thead>
<tr>
<th>Working area</th>
<th>Drains installed (no)</th>
<th>Metres installed</th>
<th>Fuel use (litre)</th>
<th>Work hours</th>
<th>Time</th>
<th>hours counter of the machine</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Start:</th>
<th>End:</th>
<th>Total</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour</td>
<td>Hour</td>
<td></td>
<td></td>
<td>hours</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------</td>
<td>------------------</td>
<td>----------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>hours</td>
</tr>
</tbody>
</table>

#### DAILY MAINTENANCE CARRIED OUT

**Before starting engine**

**Engine**

<table>
<thead>
<tr>
<th>Water level:</th>
<th>Checked</th>
<th>Yes/no</th>
<th>Water added:</th>
<th>Litre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil level:</td>
<td>Checked</td>
<td>Yes/no</td>
<td>Oil added:</td>
<td>Litre</td>
</tr>
<tr>
<td>Water drained in fuel:</td>
<td>Checked</td>
<td>Yes/no</td>
<td>cm</td>
<td></td>
</tr>
<tr>
<td>Air filter:</td>
<td>Cleaned</td>
<td>Yes/no</td>
<td>Water drained:</td>
<td></td>
</tr>
</tbody>
</table>

**Greasing**

| Cardan shaft 1, .. nipples | Greased | Yes/no |
| Cardan shaft 2, .. nipples | Greased | Yes/no |
| Final drive digging chain | Greased | Yes/no |
| Auger                   | Greased | Yes/no |

**How many times:**

**Checking/ repairing**

<table>
<thead>
<tr>
<th>Result OK</th>
<th>Activity</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolts</td>
<td>Checked</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Oil leaks</td>
<td>Checked</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Fuel leaks</td>
<td>Checked</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Digging chain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolts</td>
<td>Tightened</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Knives replacement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**After starting engine 5-10 minutes**

<table>
<thead>
<tr>
<th>Result OK</th>
<th>Activity</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil pressure</td>
<td>Checked</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Fuel level</td>
<td>Checked</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Air filter indicator</td>
<td>Checked</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Hydraulic filter indicator</td>
<td>Checked</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Hydraulic oil indicator</td>
<td>Checked</td>
<td>Yes/no</td>
</tr>
</tbody>
</table>

**Observations**

Operator: Supervisor:
### WEEKLY MAINTENANCE OF TRENCHER: (type and number)

<table>
<thead>
<tr>
<th>Report no:</th>
<th>Weekly Record</th>
<th>Week</th>
<th>Start:</th>
<th>End:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working area:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drains installed: (no)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metres installed:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel use (litres)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Maintenance record

<table>
<thead>
<tr>
<th>Date:</th>
<th>At: ......................... hours (reading on the hours counter of the machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Previous weekly maintenance:</td>
</tr>
<tr>
<td></td>
<td>100 hours maintenance carried out:</td>
</tr>
</tbody>
</table>

#### WEEKLY MAINTENANCE

Carried out at ................................ Hours (Reading on the hours counter of the machine)

<table>
<thead>
<tr>
<th>Batteries</th>
<th>Checked</th>
<th>Yes/no</th>
<th>Water added:</th>
<th>Yes/no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil in gearboxes of:</td>
<td>Checked</td>
<td>Yes/no</td>
<td>Oil added</td>
<td>Quantity</td>
</tr>
<tr>
<td>Pump case</td>
<td></td>
<td></td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Main gearbox</td>
<td></td>
<td></td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Angle gearbox</td>
<td></td>
<td></td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Chain drive gearbox</td>
<td></td>
<td></td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Final drive track L</td>
<td></td>
<td></td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Final Drive Track R</td>
<td></td>
<td></td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Grease nipples greased</td>
<td></td>
<td></td>
<td>Yes/no</td>
<td>Number:</td>
</tr>
<tr>
<td>Fuel Filter changed</td>
<td></td>
<td>Yes/no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duplex chain checked</td>
<td></td>
<td>Yes/no</td>
<td>Tightened: Yes/no</td>
<td></td>
</tr>
<tr>
<td>V belts tension checked</td>
<td></td>
<td>Yes/no</td>
<td>Tightened: Yes/no</td>
<td></td>
</tr>
<tr>
<td>Wear plates checked</td>
<td></td>
<td>Yes/no</td>
<td>Replaced: Yes/no</td>
<td></td>
</tr>
<tr>
<td>Trencher cleaned</td>
<td></td>
<td>Yes/no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil leakage checked</td>
<td></td>
<td>Yes/no</td>
<td>Leakage found: Yes/no</td>
<td></td>
</tr>
<tr>
<td>Oil and filters</td>
<td></td>
<td>Last time</td>
<td>This week</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Engine oil changed every 250 hours</td>
<td></td>
<td>Date</td>
<td>Hours</td>
<td>Yes/no</td>
</tr>
<tr>
<td>Hydraulic oil changed every 1000 hours</td>
<td></td>
<td></td>
<td></td>
<td>Yes/no</td>
</tr>
<tr>
<td>Engine oil filter changed every 250 hours</td>
<td></td>
<td></td>
<td></td>
<td>Yes/no</td>
</tr>
<tr>
<td>Hydraulic oil filters changed every 500 hours</td>
<td></td>
<td></td>
<td></td>
<td>Yes/no</td>
</tr>
</tbody>
</table>

#### Other repairs carried out:

Observations:
C.6 Adjustment of the trench box and digging chain

C.6.1 General

The trench is dug to the required depth by the digging chain and the trench box mounted immediately behind the digging chain (see schematic layout of trencher in Figure C4.1). The function of the trench box is to:

- Keep the trench walls apart and prevent collapse during the process of positioning the drain pipe in the trench. This also facilitates the checking of the installation depth of the pipe;
- Guide the drain pipe from the top of the trencher towards the bottom of the trench;
- Make a V-profile in the bottom of the trench in order to position the drain pipe in a straight line;
- Act as float for the whole rear end of the trencher.

The depth of the trench box can only be adjusted when the machine is moving and digging. When the trench box is pointed upwards, it will result in a lifting of the trench box and a shallower trench. When the trench box is pointed downwards, it will result in a lowering of the trench box and a deeper trench. This adjustment is done by retracting or expanding the depth regulation cylinder B using the command button no.9. The lifting cylinder A (with command button no.4) should be in the floating position, so that the trench box rests on the trench bottom (Figure C6.1). If the lifting cylinder is not in the floating position, the trench box will not rest on the trench bottom and the drain pipe alignment will be incorrect (Figure C6.2). An exception is the installation in unstable soil (see C.24).

C.6.2 Adjustment of the trench box in relation to the digging chain

The bottom of the trench box must be in a horizontal line with the lowest point of the digging chain if the soil is soft and stable but not very hard or stony. When the trench box is lower than the chain, the machine will require much power and the trench box might get damaged. When the trench box is higher than the bottom end of the digging chain, the V-profile in the bottom of the trench is not created. The result is that the drain pipe cannot be installed in an absolute straight line. In the case of a hard and stony soil the digging chain has to be adjusted in such a
way that it is 5-10 mm under the trench box. The adjustment of the digging chain relative to the trench box, for different soil conditions, is given in Figure C6.3.

C.6.3 Adjustment of the knives on the digging chain

The knives on the digging chain vary in size. The number of different sized knives to be used on the digging chain depends on the width of the trench to be dug. The trench width, in turn, is dependent on the width of the trench box. The diameter of the drain pipe to be installed, and, if required, provisions for the application of gravel around the drain pipe determine the width of the trench box.

Sizes of the knives to be used also depend on the soil conditions. Generally, the following sizes are used:

- Sand: 16 cm, 24 cm, 30 cm, 38 cm, 46 cm, 50 cm, and 60 cm
- Clay: 16 cm, 24 cm, 30 cm, 40 cm, 50 cm, and 60 cm

The sizes and intervals can be adjusted, if required.

In sandy soils the interval will be smaller than in clay soil. In clay soil the larger intervals of diameter facilitates the loosening of the clay from the knives. In sandy soils the smaller intervals prevent the soil from falling back into the trench. The knives are fixed to the digging chain in a V-shaped pattern, as presented in Figure C6.4 on the outer links of the chain on the left and right side, starting with the smallest size (forerunner). The digging width of the forerunner is 16 cm, then comes the next size and so on until the width of the trench is reached. The forerunner digs a V-shaped groove in the bottom of the trench.
Figure C6.4a shows the digging chain and the positions of the different sized knives of a trencher digging a trench of 24 cm width, for field drain pipe installation. Figure C6.4b shows the digging chain and knives of a trencher digging a trench of 50 cm width for collector drain pipe installation.

a. Trenchbox will dig deeper

b. Trenchbox will be lifted slowly out of the soil

Figure C6.2  If the lifting cylinder is not in the floating position, the trench box will not rest on the trench bottom and the drain pipe alignment will be either too deep (a) or too shallow (b)
### Table: Height of Trench Box for Different Soil Conditions

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Height of Trench Box</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard stony soil</td>
<td>10 mm</td>
</tr>
<tr>
<td>Stones and hard layers</td>
<td>5 mm</td>
</tr>
<tr>
<td>Some stones</td>
<td></td>
</tr>
<tr>
<td>Soft soil</td>
<td></td>
</tr>
<tr>
<td>Never above the bottom of the trenchbox</td>
<td></td>
</tr>
</tbody>
</table>

![Diagram](image)

Adjust height of trench box by loosen or tighten nut 1 and 2.

**Figure C6.3** Adjustment of the trench box and digging chain under different soil conditions
Figure C6.4a  Digging chain with positions of the knives for a trench width of 24 cm
Figure C6.4b  Digging chain with positions of the knives for a trench width of 50 cm
C.7 Minimising the operation costs of trenchers

C.7.1 General

Trenchers are expensive items of equipment with many so called “wear parts” (parts which will wear out with use). The main wear parts are the digging chain and sprocket wheel. The quantity of wear parts used per km of drain installed is an important cost factor in the total cost of the installation. Increasing the lifetime of wear parts results in minimising the cost of installation. Taking special care when operating the trencher can extend the life of the wear parts. In the following sections the methods to reduce wear and tare and thus costs, are discussed.

C.7.2 Reduction of wear on the digging chain and sprocket wheel

C.7.2.1 If the machine is digging: reduction of wear of the digging chain

The digging chain of the trenchers wears out regularly because of the abrasive working of the soil on the digging knives. The wear can be reduced, thus extending the lifetime, by installing the drains more quickly. The reasons are as follows:

- If the chain is digging (in the ground) it wears out with the same velocity, no matter how fast the chain is digging;
- The faster the machine is driven, the quicker a drain is installed and the less the wear per km of installed drain. The wear of the chain is a function of the hours of working and thus digging by the chain. The wear can be calculated as follows:

Examples of how much a chain can dig in a certain soil for a period of 100 hours before being worn out:
- If the installation speed is 600 m/h a drain of 1200 m can be installed in 2 hours.
  A chain can then install a total of 60 km drain;
- If the installation speed is only 400 m/h a drain of 1200 m will be installed in 3 hours and the chain can then only install 40 km of drain. Thus, the cost per metre of drain installed in this case is higher.

The conclusion is that fast work when digging reduces the cost of drain installation! Fast digging is also recommended for the cleaning of the knives, because if too slow the mud will stick to the knives and digging will be less efficient.
C.7.2.2 If the machine is not digging: reduction of wear on the sprocket wheel

- The sprocket wheels that drive the chain are expensive spare parts;
- The sprocket wheels wear out quickly when the chain turns around without digging;
Thus:
- To prevent wear and tear do not run the chain at fast speed when not digging.

C.7.3 Reduction of wear on the engine

- The engines of most trenchers have been designed and built to perform under maximum power;
- The engine has the longest lifetime if it is run at around 2150 RPM (on most engines);
Thus:
- Try to keep the engine speed always between RPM 2000 and 2150;
- Drive, during installation, as fast as possible for reduced chain cost and wearing of the engine.

C.7.4 Reduction of wear during transport of the trencher

C.7.4.1 In field transport

1. Drive from one drain to the next preferably in reverse because turning around costs time and wears the tracks (this only for short drains);
2. Drive to the following drain in second gear;
3. During transport to new fields, drive in second gear.

C.7.4.2 Transport to other areas

The trenchers are not built and equipped for driving fast over long distances (distances of more than 1 km). Therefore, always use a low loader to travel to other areas or other parts of a drainage area!
If low loaders are not available, drive and transport the trencher at "low speed" (low gearing) with a speed of not more than 1.5 km/hour. After every 30 minutes stop for a while (5-10 minutes).

*If the trenchers are driven at too high a speed for too long a time the under-rollers in the tracks become too hot and the seals will be damaged so that it loses oil. Then, the only repair possible is replacement of the under-rollers, which is very expensive!*
C.7.5 Concluding recommendations to reduce cost of trenchers

- Dig as fast as possible;
- Do not run chain at high speed when not digging;
- Do not transport trencher over long distances under its own power, use a low loader (Figure C7.1);
- If it is necessary to drive over longer distances then drive slowly and stop for cooling every half hour.

Figure C7.1 Trencher on low loader
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
C.8 Operation of trenchers for corrugated plastic drain pipe installation

C.8.1 General

The procedures for operating the trencher for the installation of drain pipes are given below as a sequence of events for installing a field drain, starting with a trencher at an open drain. The principles apply also when starting at either a manhole or a piped collector drain, in a starting hole previously dug. The procedure needs to be adjusted if the drain trencher, equipped with a liftable trench box, digs its own starting hole (see C.9).

C.8.2 Procedures

1. Reverse the trencher until the trench box and digging chain are above the open drain. When doing so, the operator must take care that the vertical direction rod is exactly in line with the boning or ranging rods that mark the drain line;
2. Lower the trench box and digging chain with the lifting cylinder (see C.4, command button 16) until the top of the trench box is horizontal, and the bottom of the trench box is at the starting level of the pipe drain;
3. Adjust laser mast so that the top orange light is flashing (see C.15);
4. Insert the drainage pipe into the trench box, extend it so far that the rigid pipe can be connected to it (see also C.27);
5. Shift the digging chain into gear and drive forward slowly, while manually adjusting the depth to keep the top orange coloured light flashing. Stop the trencher at the moment that all of the trench box is inside the side slope of the drain;
6. Switch on slew (see C.4, command button 12) and lift “float” (see C.4, command button 4) and set laser to “automatic”;
7. When digging starts, the trench box and digging chain will automatically rise a bit until the green light flashes;
8. As the machine starts moving forwards the pipe should be kept in place by hand, so that the end that has been fitted with the rigid pipe is pulled to its final position. Release the pipe when the rigid pipe is in the correct position and immediately fix it in this position by backfilling and carefully compacting the soil over the rigid pipe;
9. To prevent the drain pipe from being displaced, preliminary backfilling could be done by throwing some soil on the pipe at regular intervals;

C.8.3 Accidental stopping of engine

Sometimes (if hard objects or clay layers are encountered), the engine may stop running when laying pipes and the gearbox is still in gear. At the moment it stops, considerable friction will occur on the gear sprockets as the trencher will have been working under full load conditions, making it very difficult to shift the gear into neutral. It requires strength and parts may break or be damaged. So, two persons will be required to solve the problems. The operator should start the engine while at the same time the assistant operator pulls the gear stick into neutral.

C.8.4 Changing the trench box

Some trenchers are equipped with the facility to remove with a quick release system the trench box from the intermediate frame so that another trench box can be attached to the trencher. This quick release system may be necessary if:
- Trench boxes of different width have to be used;
- The trencher operates in stony soil.

If a different sized trench box has to be mounted the following actions are to be taken:
1. Lift the trench box so that a transport trailer can be moved under the trench box;
2. Lower the trench box so that it rests on the transport trailer;
3. Remove the safety pin and unlock the upper trench box clamp;
4. Lift the digging mechanism and remove the transport trailer with trench box from the trencher;
5. Drive the transport trailer with the other trench box to be used near the trencher;
6. Lower the digging mechanism so that it slides into the bushing of the trench box;
7. Remount the upper bushing and safety pin;
8. Lift the trench box and remove the transport trailer.

C.8.5 Operating in stony soil

If a digging mechanism is blocked by an obstruction, for example stone or stump (Figure C8.1a), then the operator has to act as follows:
1. String out or cut off the flexible drain tube (Figure C8.1b);
2. Remove the safety pin and unlock the upper trench box clamp (Figure C8.1c);
3. Lift the digging mechanism and drive forward until the obstruction can be removed (Figure C8.2d);
Obstruction

a.

b.

c.

d.

Figure C8.1  Obstruction in the field
4. Drive the trencher backwards again and lower the digging mechanism so that it slides into the bushing of the trench box;
5. Remount the upper bushing and safety pin;
6. Roll up the flexible tube again or reconnect the tube.
C.9 Working with a liftable trench box

C.9.1 General

Some trenchers are equipped with a liftable trench box. The trench box can then slide upwards along the digging boom. With this attribute of the trencher it is possible to start installing field drains and connect them to manholes without a starting hole. The maximum depth to which a machine with liftable trench box can dig without a starting hole is approximately 1.25 m in stable soils. If a deeper start is needed and/or the installation has to be done in unstable soils, it is better and faster to dig a starting hole using an excavator.

Reference is made to C.4 for the commands on the drivers command panel.

C.9.2 Operation of the liftable trench box

1. Switch the float of the lifting cylinders to “off” (button 4, C.4);
2. Lift the trench box completely (Figure C9.1a);
3. Extend the trench box cylinder completely (if this is not done there is a risk that the trench box starts bouncing on the soil surface);
4. Start digging the starting hole (Figure C9.1b):
   - Start the digging chain, let the engine run at approx. 1500 rpm;
   - Lower the digging boom with the lift cylinder until the trench box (or cabin platform if the cabin platform is attached to the digging boom) is completely horizontal;
   - Start digging slowly;
   - Advance slowly with the machine approx. 3 m, so that a trench is dug that is long enough to accommodate the full length of the trench box;
   - After the 3 m are dug, lift the digging boom out of the trench and drive 3 m backwards;
   - Lower the digging boom with the depth regulation cylinder some 50 cm and start digging;
   - Lower the digging boom every run (3 m) 50 cm deeper until the desired depth is reached (Figure C9.1c)
5. After the start hole has been dug return the trench box to its original position (in lock position) in the following way:
   - Keep the digging chain running (to prevent soil from falling in between digging boom and trench box);
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Digging mechanism as flat as possible

Figure C9.1  Operation of a liftable trench box
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

• Lower the trench box with trench box cylinder. Be sure that the trench box hook is secured;
• If trench box hook is not automatically secured:
  - Lift digging boom with lift cylinder;
  - Lift trench box with trench box cylinder again and lower it completely so that trench box hook is secured. Repeat this until there is certainty that trench box hook is in place.
6. Lower the digging boom with trench box in the trench (Figure C9.1d);
7. Connect the drain pipe;
8. Switch the float lifting cylinders switch to “on” and start installing.
C.10 Description of trenchless drainage machines

C.10.1 General

Two types of drainage machine machines have been developed for trenchless drain installation:

- Vertical plough;
- V-plough.

The main components of the vertical plough and the V-plough are presented in Figure C10.1 and C10.2. The major difference compared to a trencher is that the digging mechanism and the trench box are replaced by a plough-type assembly with a guidance tube/box for the drain pipe. No engine power has to be transferred to moving parts at the rear end. So, the operating panel for the operator (Figure C4.5) does not have the functions no. 10 (lifting cylinder digging boom), no.14 (selection lever for speed of digging chain) and no.16 (lifting cylinder trench box). This is replaced by one new function for lifting of the plough assembly.

The drain pipe is guided through a pipe box behind the plough (vertical plough-type) or through a tube in one of the legs of the plough (V-plough).

An iron flap with knives at both sides is attached to the rear-end of the V-plough (Figure C10.3), near the outlet of the drain pipe. This has the same function as the press pulley in a trench box. It cuts soil on both sides of the drain pipe to keep the drain pipe in the correct position.

In principle, the installation of drains by a trenchless drainage machine is not very different from installation by trenchers. The major differences are:

- Only field drains can be installed (the size of the drain pipes should not exceed 125 mm (V-plough) and 200 mm (vertical plough));
- A gravel envelope cannot be used, only pre-wrapped drain pipes;
- In stony soil the vertical plough should be used;
- Laser has to be used for grade control. The laser set-up is the same as for a trencher (C.11);
- Installation speed is much higher speed. Logistics (supply of drainage materials in the field) have to be very well organised;
- In the case of installation of composite systems, starting holes have to be pre-excavated. An excavator should be available.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Figure C10.1  Schematic drawing of a vertical plough

Figure C10.2  Schematic drawing of a V-plough
Figure C10.3 Iron flap with knives at the rear end of the V-plough
C.11 Maintenance of trenchless drainage machines

C.11.1 General

Maintenance of a trenchless drainage machine consists of:
- Daily maintenance, including the starting up procedures;
  - Weekly maintenance;
  - Regular maintenance: maintenance needed to be done after every 100 hours of operation;
  - Yearly maintenance and storage.

In the following sections simplified check and action lists are given. It is however of great importance that the people in charge of the machines have knowledge of and access to the manuals. For the daily maintenance and for the weekly maintenance sample forms to be filled in by the responsible persons are provided at the end of this instruction sheet. These forms can serve as maintenance records or logs.

C.11.2 Daily checks and maintenance

Daily checks and maintenance includes the starting up procedures.

C.11.2.1 Before starting the engine

*Engine*

Check:
- Water level (if too low: add water);
- Oil level (if too low: add oil);
- Hydraulic oil (if too low: add hydraulic oil).

Cleaning and draining:
- Drain the water separator so that the water is removed;
- Clean pre-air filter (by hand).
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Other parts of the trenchless drainage machine

Greasing:
- All cardan shafts;

Check and repair:
- Broken or loose bolts (tighten or replace);
- Oil leaks (tighten couplers if necessary);
- Fuel leaks;

C.11.2.2 After starting the engine

Wait five to ten (5-10) minutes till engine is warmed up (length of time depends on the outside temperature).

After that check on dashboard:
- Oil pressure engine indicator (if too low, call mechanic!);
- Fuel level indicator (if too low: add fuel);
- Air filter indicator (if flashing: clean filter);
- Hydraulic filter indicator (if flashing: check vacuum gauges on machine);
- Hydraulic oil tank.

Check on the machine: vacuum gauges of the hydraulic drive.

C.11.2.3 Refuelling

Refuelling the trenchless drainage machine should preferably be done after work, not in the morning (to prevent condensation forming in the tank).

C.11.2.4 General

- During the checking and starting up procedures a general cleaning of the machine is recommended;
- The daily maintenance should take not more than 30 minutes.

C.11.3 Weekly maintenance

- Perform daily maintenance (see C.11.2);
- Check acid levels in the batteries (if too low: add distilled water);
- Check oil levels of all the gearboxes in the machine (if too low: add oil);
- Grease all grease nipples on machine;
- Change the fuel filters, if it was noted that engine power is less;
• Clean machine and make intensive checks for:
  - Fuel leaks;
  - Oil leaks;
  - Water leaks.
• Carry out, if necessary, repairs.

C.11.4 Regular maintenance

Carry out the following activities after every 200-300 running hours of the engine:
• Change engine oil and oil filter;
• Clean bleeder of crankshaft;
• Check V belts and tension if necessary.

C.11.5 Annual maintenance and winter storage

• Check and if necessary adjust valves (see manufacturers manual);
• Clean and grease entire machine, and check for leaks;
• Repair leaks before the winter storage of the trenchless drainage machine;
• Drain cooling water from engine;
• Put tracks of machine on wooden beams;
• Change engine oil and oil filter;
• Change oil in gear boxes every 1000 hours or once a year (check manufacturers manual);
• Change filters of hydraulic system every 500 hours or once a year (check manufacturers manual);
• Cover machine to protect against dust.

C.11.6 General warning for trenchless drainage machines

• If welding is done on machine disconnect three (3) cables from control box and disconnect the battery;
• Do not drive the machine at high speed over long distances!!.

C.11.7 Replacement and welding of plough parts

The wear and tear of the plough parts is much less than that of the digging assembly of a trencher.
C.11.7.1 V-plough

The wear parts on the trenchless drainage machines that have to be replaced are: the knives at the front, the inner plates of the plough and the tip (Figure C11.1). The time after which these have to be replaced depends on the soil characteristics. The average length of drain pipes installed after which replacement is required, is:

- The knives at the front (both sides) that are fixed with bolts: 150 km or earlier if the knives are damaged by stones;
- The inner plates of the plough: 250 km;
- The tip: 150 km. The lifetime of the plough tip can be extended by welding;
- The V-shaped bottom profile: 250 km. The underside of the plough has a V-shaped metal reinforcement that generally needs to be changed together with the plough plates. This V-shaped metal part has to be attached in such a way that the bottom front of the plough is 2 cm higher than the bottom end (i.e., the plough has to be tilted upwards slightly).

![Diagram of V-plough parts](image)

Figure C11.1 Parts of a V-plough that are subject to wear and tear

C.11.7.2 Vertical plough

After installing 150-250 km (depending on the soil characteristics) of drain pipes the following parts have to be replaced or re-welded (Figure C11.2):

- Leading edges;
- Nose;
• Bottom profile part;
• Pipe box: the lifetime can be extended by re-welding the lower part of the pipe box.

![Diagram of a vertical plough showing parts subject to wear and tear](image)

*Figure C11.2  Parts of a vertical plough that are subject to wear and tear*

**C.11.8 Model maintenance record**

On the following pages examples of daily and weekly maintenance records for trenchless drainage machines are presented in Table C.11-1 and C.11-2.
# DAILY MAINTENANCE OF TRENCHLESS DRAINAGE MACHINE: (type en number)

<table>
<thead>
<tr>
<th>Daily record</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working Area</td>
<td></td>
</tr>
<tr>
<td>Metres installed</td>
<td></td>
</tr>
<tr>
<td>Fuel use (Litres):</td>
<td></td>
</tr>
<tr>
<td>Start:</td>
<td>Hour</td>
</tr>
<tr>
<td>End:</td>
<td>Hour</td>
</tr>
<tr>
<td>Total hours</td>
<td></td>
</tr>
</tbody>
</table>

## DAILY MAINTENANCE CARRIED OUT

### Before starting engine

<table>
<thead>
<tr>
<th>Water level:</th>
<th>Yes/no</th>
<th>Water added</th>
<th>Litres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil level:</td>
<td>Yes/no</td>
<td>Oil added</td>
<td>Litres</td>
</tr>
<tr>
<td>Water drained in fuel:</td>
<td>Yes/no</td>
<td>cm</td>
<td></td>
</tr>
<tr>
<td>Air filter:</td>
<td>Yes/no</td>
<td>Water drained</td>
<td></td>
</tr>
</tbody>
</table>

### Greasing

<table>
<thead>
<tr>
<th>Cardan shaft 1... nipples</th>
<th>Greased</th>
<th>Yes/no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardan shaft 2... nipples</td>
<td>Greased</td>
<td>Yes/no</td>
</tr>
</tbody>
</table>

### Checking/repairing

<table>
<thead>
<tr>
<th>Activity</th>
<th>Result OK</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolts</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Oil leaks</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Fuel leaks</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Plough parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knives replacement</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Inner plates</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Tip</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>V-shaped bottom plate</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Repaired</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Couplers tightened</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaks repaired</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knives replaced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner plates replaced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tip replaced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-shaped bottom plate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### After starting engine 5 - 10 minutes

<table>
<thead>
<tr>
<th>Activity</th>
<th>Result OK</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil pressure</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Fuel level</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Air filter indicator</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Hydraulic filter indicator</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Hydraulic oil indicator</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Corrected</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Fuel added</td>
<td>Litres</td>
<td></td>
</tr>
<tr>
<td>Cleaned</td>
<td>Yes/no</td>
<td></td>
</tr>
<tr>
<td>Oil added</td>
<td>Litres</td>
<td></td>
</tr>
</tbody>
</table>

### Observations

Operator: Supervisor
# WEEKLY MAINTENANCE OF TRENCHLESS DRAINAGE MACHINE: (type en number)

## WEEKLY MAINTENANCE OF TRENCHLESS DRAINAGE MACHINE: (type and number)

<table>
<thead>
<tr>
<th>Report no:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly record</td>
<td>Week</td>
</tr>
<tr>
<td>Working area:</td>
<td>Work hours during past week</td>
</tr>
<tr>
<td>Drains installed: (no)</td>
<td>Start:</td>
</tr>
<tr>
<td>Metres installed:</td>
<td>End:</td>
</tr>
<tr>
<td>Fuel use (litres)</td>
<td>Total</td>
</tr>
</tbody>
</table>

## Maintenance record

<table>
<thead>
<tr>
<th>Date</th>
<th>At.........................hours (reading on the hours counter of the machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous weekly maintenance:</td>
<td>hours</td>
</tr>
<tr>
<td>100 hours maintenance carried out:</td>
<td>hours</td>
</tr>
</tbody>
</table>

## WEEKLY MAINTENANCE

<table>
<thead>
<tr>
<th>Carried out at ................hours (Reading on the hours counter of the machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batteries</td>
</tr>
<tr>
<td>Oil in gearboxes of:</td>
</tr>
<tr>
<td>Pump case</td>
</tr>
<tr>
<td>Main gearbox</td>
</tr>
<tr>
<td>Angle gearbox</td>
</tr>
<tr>
<td>Final drive track L</td>
</tr>
<tr>
<td>Final drive track R</td>
</tr>
<tr>
<td>Grease nipples greased</td>
</tr>
<tr>
<td>Fuel filter changed</td>
</tr>
<tr>
<td>V belts tension checked</td>
</tr>
<tr>
<td>Wear plates checked</td>
</tr>
<tr>
<td>Trenchless drainage machine cleaned</td>
</tr>
<tr>
<td>Oil leakage checked</td>
</tr>
</tbody>
</table>

## Oil and filters

<table>
<thead>
<tr>
<th>Interval</th>
<th>Last time</th>
<th>This week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine oil changed every 250 hours</td>
<td>Date</td>
<td>Hours</td>
</tr>
<tr>
<td>Hydraulic oil changed every 1000 hours</td>
<td>Yes/no</td>
<td>Litres</td>
</tr>
<tr>
<td>Engine oil filter changed every 250 hours</td>
<td>Yes/no</td>
<td>Litres</td>
</tr>
<tr>
<td>Hydraulic oil filters changed every 500 hours</td>
<td>Yes/no</td>
<td>Litres</td>
</tr>
</tbody>
</table>

## Other repairs carried out:

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations:</td>
</tr>
</tbody>
</table>
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
**C.12 Operation of trenchless drainage machines**

### C.12.1 Installation of field drains starting from an open ditch
(singular system)

1. Reverse the machine until the V-plough is above the open drain. When doing so the operator must take care that the vertical rod is exactly in line with the ranging rod that marks the drain line (Figure C12.1);
2. Lower the V-plough so that the bottom of the V-plough is at the starting level of the pipe drain;
3. Adjust the laser mast so that the top orange light is flashing (C.15);
4. Insert the drain pipe through the pipe guidance in the leg of the V-plough until it is so far out that the rigid pipe can be connected to it;
5. Drive forwards slowly while manually adjusting the depth to keep the top orange coloured light flashing. Stop the machine at the moment that all of the V-plough is inside the side slope of the drain;
6. Switch on the lift and slewing "float" and set laser to "automatic";
7. Start moving the machine forwards slowly to allow time for the hydraulic system to build up enough pressure;
8. Once the green light on the laser indicator starts flashing the speed can be increased;
9. The drain pipe is placed at the correct level as the machine advances and the green light keeps on flashing;
10. When crossing ditches with high embankments drive extremely slowly and help the plough by making manual adjustments;
11. Lift the plough slowly at the end of the drain line;
12. Once the drain line has been completed the machine is driven backwards with one track over the uplifted soil to press the topsoil down (only in case of the V-plough);
13. If a roller is attached to the front of the machine, the roller is lowered and the machine driven backwards (Figure C12.2);
14. Backfill of the starting hole is best done the same day.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Figure C12.1  V-plough starting installation of a field drain from an open drain

Figure C12.2  Roller in front of trenchless drainage machine
C.12.2 Installation of field drains starting from a collector drain
(composite system)

The installation of a field drain starts with digging a starting hole near the manhole or collector using an excavator.
1. Manoeuvre the V-plough into position by driving backwards towards the starting hole until the plough is above the starting hole;
2. Lower the V-plough so far that the bottom of the V-plough is at the starting level of the pipe drain (Figure C12.3);
3. Adjust the laser mast so that the top orange light is flashing (C.15);
4. Insert the drain pipe through the pipe guidance in the leg of the V-plough until it is far enough for the drain pipe to be connected to the manhole;
5. Drive forwards slowly while manually adjusting the depth to keep the top orange coloured light flashing. Stop the machine at the moment that the V-plough is completely inside the side slope of the starting hole;
6. Switch on the lift and slewing "float" and set laser to "automatic";
7. Start moving the machine forwards slowly to allow time for the hydraulic system to build up enough pressure;
8. Once the green light on the laser indicator starts flashing the speed can be increased;
9. While the machine advances and the green light keeps on flashing, the drain pipe can be placed at the correct level;
10. When crossing ditches with high embankments drive extremely slowly and help the plough by making manual adjustments;
11. At the end of the drain line lift the plough slowly;
12. Once the drain line has been completed the machine is driven backwards with one track over the uplifted soil to press the topsoil down;
13. If a roller is attached to the front of the machine, the roller is lowered and the machine driven backwards;
14. Backfill of the starting hole is best done the same day.
C.13 Description of laser equipment for grade control

C.13.1 General

Installing a drain or collector pipe at the proper grade (slope) is essential for the functionality of the drain. The laser is the precision tool used for assuring that the pipes are installed at design levels and grades (slopes). There to the laser requires a correct management, handling and control.

The laser equipment consists of:

- Transmitter (modern transmitters are equipped with rechargeable batteries) that is transportable and can be stored in a special case;
- Tripod (transportable);
- Battery (on old models only);
- Receiver (mounted on mast on trencher);
- Expandable/retractable mast for receiver (mounted on trencher);
- A so-called beeper rod, which is a staff gauge with a movable receiver on it. The receiver "beeps" when it is in the plane of the laser beam.

C.13.2 Principles of the laser

The principles of the laser are given in Figure C13.1. Laser equipment for drainage basically consists of two components:

- The laser transmitter (Figure C13.2), which is positioned in the field on a stable tripod that is some 2.5 m high, emits through a rotating prism a beam of invisible light that forms a plane. This plane can be a horizontal or at an angle (slope-grade). This plane serves as reference for the level and depth of the trench box of the trencher and consequently for the drain to be installed;
- The laser receiver (Figure C13.3) is mounted on the trench box of the trencher and receives the beams of (invisible) light coming from the transmitter. The receiver is fixed on a mast that can be raised and lowered. It contains 3 groups of photocells one above the other: a top group, a middle group and a bottom group.
The receiver is electrically connected to the hydraulic system of the lifting cylinders of the trencher and is programmed in such a way that:

- If the bottom cells receive the laser beam light then it means that the trench box is too high and the trench box is automatically lowered until the middle group of cells receive the laser beam;
- If the top cells receive the beam light, then the trench box is too low and the trench box is automatically raised;
- When the middle cells receive the laser beam, the trench box is at the correct height and no change occurs.

There are indicator lights for the photocells on the operator’s display (receiver display): when the level is correct the light is green, too high or too low the red or orange indicator lights flash above or below the green indicator.

As is indicated in Figures C13.1 and C13.3, the drain will be installed at the same grade (slope) as the laser beam, as long as the middle cells receive the laser beam.

**Figure C13.1  Principles of laser**

**Figure C13.2  Laser Transmitter**
Figure C13.3 Laser Receiver
C.14 Management of laser equipment for grade control

C.14.1 Tips for operating

Maximum distance during good weather conditions

The 'safe' maximum distance (in good weather conditions) between the transmitter and the receiver (trencher) is 300 m (thus a drain length of approx. 600 m). For a drain of 400 to 600 m, place the transmitter tripod halfway along the length of the drain.

In the case of a drain of > 600 m in length:

- Place the transmitter at a distance of about 250 m from the start of the drain;
- Stop the trencher once the trencher has installed about 500 m of drain;
- Switch the control on the trencher from automatic to manual. (The reason for switching from automatic to manual is to prevent undesired reactions on the receiver when replacing the transmitter);
- Now, replace the transmitter at a distance of about 750 m from the start of the drain (right direction, right slope!);
- Adjust the transmitter to a level to where it can be assumed that the laser beam will be within reach of the receiver;
- Switch the laser to automatic and wait for a green light to appear on the display. During the levelling the mast of the receiver extends or shortens so that the receiver is in the laser beam of the transmitter. The left lamp on the display will flash red during the levelling, which may last for 1 to 2 minutes;
- Continue with drain installation.

Poor weather conditions

During humid weather (hazy, misty, rain) the laser beam will be scattered by the water particles in the air. The safe distance for working with laser will then be reduced, even in extreme cases to < 100 m.

Drain direction - Direction of the slope of the laser beam

The slope or grade of the laser plane has to be in the same direction as the designed slope of the drain to be installed.
C.14.2 Possible problems with the operation of the laser

- **Wind.** The transmitter is mounted on a tripod and is sensitive to wind. If there is a strong wind the transmitter will vibrate, which may result in a flashing indicator light on the receiver display/control box and cause inaccurate levels of the drain. The deviations increase with increasing distance from the transmitter. If the wind is strong the following measures can be taken:
  - Erect the tripod as indicated in Figure C14.1;
  - Limit the distance between the transmitter and the receiver (< 300 m);
  - Put weight in the form of sandbags on the legs of the tripod;
  - Decrease the height of the tripod as much as possible;
  - Limit the height of the base of the transmitter in relation to the tripod;
  - Tighten all the bolts of the tripod;
  - Be sure that the legs of the tripod are as far away from each other as possible (chains not fully stretched);
  - Place, if possible, a car in front of the transmitter/tripod as windbreak.

*Figure C14.1 Positioning and anchoring the tripod legs of the laser transmitter to minimize the effect of wind*
• **Sunlight.** Sunlight and high temperatures may cause inaccurate laser performance; 
  Action: shorten distance between transmitter and receiver.
• **Fog/Mist.** Fog can influence laser performance; 
  Action: In the case of fog shorten the distance transmitter to receiver.
• **Vibrations of the soil.** Especially when the soil is soft at the place where the transmitter is placed prevent vibrations caused by machines;
  Action: This can be done by making sure that no machines or vehicles are driven close to the transmitter and/or by placing the tripod as far away as possible from the drain line.
• **High-tension lines.** When the laser beam passes a (high-tension) electric line it is possible that the beam is disturbed. If the lights on the machine’s display will flash, the depth of the trencher is not correct;
  Action:
  - Do not place the transmitter underneath the electric line and/or;
  - Place the transmitter so that transmitter and trencher are on the same side of the line.
• **Radar.** Nearby radar may disturb the laser beam, which makes its use impossible. Sometimes, in the case of strong radar (e.g., airport), the influence is noticeable over a large distance.

### C.14.3 Laser use when two trenchers work side by side in the same field

It is quite possible that two drainage trenchers work in tandem for installing field drains in the same field with the same slope. For the operation of the laser the following aspects have to be taken into account:

- The trenchers operate with one transmitter. In this case only one person is to be responsible for the transmitter. Using one laser transmitter prevents interference between two transmitters. If two transmitters are used, one of the trenchers can after some length of installation start to receive the laser beam of the other transmitter, which would make it suddenly alter the depth of the drain;
- Using one transmitter is only possible if:
  - The two drains are designed with the same slope and run parallel;
  - The drain lines are not more than 300 m from each other.
- During installation, one trencher should not be between the transmitter and the other trencher. Therefore, it is preferable that the trenchers operate on both sides of the transmitter as indicated in Figure C14.2;
- In practice it means that only one drain on both sides of the transmitter can be installed with the same transmitter position;
- The maximum distance between the transmitter and the receiver(s) should not exceed the safe maximum distance as discussed above;
- In the presence of (high) tension lines, both the trenchers and the transmitter should operate on the same side of the (high) tension line.
C.14.4 Maintenance of the laser equipment

In general the laser can be used without any specific maintenance. Dust and mud spots should however be removed as soon as possible from all parts including the tripod. Batteries (this only for the older models that have non built-in rechargeable batteries): should be recharged regularly (every two days). It is advisable to keep one extra, charged battery close to the laser for quick replacement.

Winter storage
Store receiver, transmitter, mast, survey rod and control box after cleaning in a heated room; every month switch laser on for about 3 hours, recharge the batteries afterwards (this heats the transmitter somewhat and the condense moisture will be expelled).
C.15 Determining the extension of laser mast on trencher

C.15.1 General

The laser beam gives a plane with a certain slope (grade) with a level in the middle of the beam at the level of the transmitter. To install the drain at the right level, the receiver of the laser beam on the mast of the trencher should be set so that the trench box bottom is at the design start level for the drain and the middle cell of the receiver is in the middle of the laser beam.

C.15.2 General procedures

Start
1. Read manual, surveyor should be familiar with the contents of the manual;
2. Place tripod at a maximum distance of 300 m from trencher some metres left or right from the drain line;
3. Be sure that tripod is stable (wind direction!);
4. Put transmitter on tripod, adjust to direction of drain;
5. Switch on self level switch;
6. Adjust required slope setting on transmitter (see design and the manual);
7. Open windows of the laser.

Level of laser beam (transmitter)
Determine the level of the laser beam (LBL) relative to the reference level used in the design of the drainage system (this can be the national datum (sea) level or a local reference level) as follows (Figure C15.1):
1. Set beeper rod on peg with known absolute level (peg level = PL);
2. Extend beeper rod until the beep is heard;
3. Measure beeper rod height ("Y");
4. Calculate the absolute level of the laser beam ("LBL") as follows:
   Absolute level of peg (PL) + beeper rod height (Y), or LBL = PL + Y
C.15.3 Determine the required mast extension (ME)

1. Determine desired absolute drain pipe bottom level from design, DL;
2. Calculate the depth of drain below laser beam: DD = LBL (-) DL;
3. Calculate the extension of the receiver mast: "ME" = DD - Machine Constant (HM).
   
   The machine constant is the vertical distance between bottom of trench box and the lowest point of the receiver mast.
   
   The machine constant for each trencher is different and should be determined separately for each machine (normally between 4 and 5 metres);
4. Give mast extension information to operator who will extend the mast accordingly;
5. Installation can begin.
C.16 Verification of correctness of laser transmitter in the field

C.16.1 General

In principle, the laser is a precision tool that is sensitive to rough handling and rough transportation. Its proper functioning should be regularly (monthly) checked, or more often when its proper functioning is doubted. An easy field test to check the performance of a laser transmitter is described below.

C.16.2 Methodology for testing

There are 2 aspects to test:
- The horizontal adjustment of the laser beam or plane;
- The functioning of the grade control.

C.16.3 Testing horizontal adjustment of laser beam

1. Erect the tripod and transmitter and adjust the laser plane to horizontal position;
2. Place pegs in a straight line on both sides of the tripod at a distance of 100 and 200 m. Determine the levels of the pegs with a levelling instrument;
3. Though not necessary, for easy comparisons later on it will be useful if the pegs were placed at the same absolute level (Figure C16.1);
4. Set a rod with beeper on pegs 1 and 4, and later on pegs 2 and 3. Calculate for each peg the level difference between the top of the peg and the laser plane. If the level of the 4 pegs is the same (see 3), and the level difference with the laser plane is the same, then the laser plane is horizontal and functions correctly;
5. If the readings between pegs 1 and 2 or between 3 and 4 are different, then there is a deviation in the laser plane related to horizontal adjustment;
6. For adjustment to the correct setting see the instruction book of the laser equipment.
C.16.4 Test for grade control

1. Position the transmitter in the same way as described above. Adjust the grade of the laser plane to 1 \(\frac{1}{100}\) pointing upwards in the direction of pegs 1 and 2;
2. Be sure that the 4 pegs have all the same absolute level. Set the beeper rod on pegs 1 and later on pegs 4 and 3. Calculate for each peg the level difference between the top of the peg and the laser plane. If the transmitter performs correctly then the readings on pegs 1 and 2 should be: \(0.001 \times 100\) m = 10 cm (peg 2) and \(0.001 \times 200\) m = 20 cm (peg 1) more than the reading of the levels measured in C.16.3. The readings for pegs 3 and 4 should read 10 cm and 20 cm lower than the readings of the levels measured in C.16.3;
   If this is not the case then the grade control of the transmitter is not correct: either the angle of the slope is not according to the angle of 1 \(\frac{1}{100}\), or the direction of the slope is not according to the direction of the alignment pegs 14.

C.16.5 Observation

If the deviations are considerable and the cause is unclear the transmitter should be sent to the supplier for adjustment. It is advisable to get the laser transmitter regularly checked and certified by the manufacturer or the local representative.
### C.17 Manual grade control in the absence of laser equipment

#### C.17.1 General

If no laser equipment is available or if the trencher is not electrically equipped for laser guided grade control, the grade of the drain to be installed has to be checked manually. Manual control can only be practised if\(^1\) the driver cabin is mounted on the trench box and the trencher is equipped\(^2\) with a so-called ‘sighting bar’.

#### C.17.2 Preparation for manual grade control

Boning rods are used for manual grade control (Figure C17.1). A boning rod is a ‘double’ sighting rod - a tube with two cross bars (one at the top and one at the bottom, at a fixed distance) that can be moved over a stake and fixed by bolts. The two parts can move in relation to each other so that the total height of the cross bars can be adjusted. The cross bars are painted red on one side and white on the other. Besides the horizontal alignment of the drain to be installed they also indicate the level and the grade thereof.

**Procedures**

- Calculate the required level of the top of the boning rods (see C.17.3);
- Place pegs at intervals of 25 m in the centre of the alignment of the drain to be installed and place two pegs at 5 and 15 metres beyond the end peg (Figure C17.2);
- Place the boning rods beside the pegs and extend the cross bar to the desired height using a levelling instrument, taking into account the slope of the drain;

**Observations**

- Boning rods are best placed every 25 metres (or less in the case of limited visibility) in the alignment of the drain;
- The last boning rod but one is placed 5 metres further than the end of the drain. The last one is placed 15 beyond the end of the drain;

---

\(^1\) As indicated in Chapter 5 of Part I manual depth control on trenchless machines is not practicable.

\(^2\) In the case of manual control the presence of the sighting bar has to be specified when ordering a trencher.
The highest point of the boning rods is a fixed height above the desired level of the drain pipe to be installed;
The boning rods are to be placed in such a way that the red coloured cross bars are all facing the same direction, namely, either facing the driver or facing away from the driver depending on the colour that best contrasts with the background.

Figure C17.1 Ranging rod, boning rod, peg and sighting rod

Figure C17.2 Placing of pegs
C.17.3 Determining the required level of the cross bars of the boning rod

The location and elevation of the sight bar of trenchers varies from model to model. The sighting bar must be adjusted to "eye level height" of the operator in such a way that he can sit in a comfortable upright position (Figure C17.3a).

Once the sighting bar is adjusted:

- Measure the distance from the sighting bar to the shoe (bottom) of the trench box in centimetres. The cabin must be in an exact horizontal position and the digging mechanism just touches the ground. This distance is called \( H_m \) and is a machine constant;
- The height of the first boning rod is \( H_t \). The drain depth = \( D \). So, the height of the first sighting stake \( H_t = H_m - D \) (Figure C17.3b);
- The height of the last boning rod at the end of the drain line depends on the slope of the drain: \( H_t + H_s, H_s = \) height caused through slope (Figure C17.3c).

The thus created line of boning rods runs parallel to but at a level of \( H_t \) above the designed drain line. Once installation starts, the operator has to keep the sight bar level in line with the levels of the first two visible boning rods by manually adjusting the level of the trench box. Since the boning rods are installed in the line of work of the trencher, as the trencher approaches a boning rod the operator changes his sighting on the following two boning rods while at that moment the nearest boning rod is removed by the operator’s assistant. The boning rods are then to be loaded on the trenchers as soon as they have been taken way.

The accuracy of the depth of installation is determined by:

- The visibility of distance between the boning rods and the sight bar;
- The speed of installation;
- The experience and fatigue of the operator (change operators regularly to avoid fatigue factor).
Figure C17.3 Setting up the manual grade control system of the trencher

- Horizontal adjustment
- Height adjustment
- Vertical visor

View from the rear end

100 cm

L

D

X

Hm

Ht

Ha

Hi
C.18 Description and maintenance of gravel trailers

C.18.1 General

Gravel trailers are only needed when gravel is used as an envelope material for drains. A tractor pulls the most commonly used type of gravel trailer. There are also self-propelling gravel trailers. The capacity of gravel trailers varies between 2 and 10 m$^3$. Gravel trailers with a capacity of 2, 4 and 6 m$^3$ are mounted on an undercarriage consisting of an axle and wheels. Gravel trailers with a capacity larger than 6 m$^3$ are provided with crawler tracks and are self-propelling.

The main elements of a commonly used gravel trailer (Figure C18.1) are:

- Undercarriage consisting of a frame with an axle and wheels;
- Hopper with a capacity of 4 m$^3$;
- Conveyor belt for unloading the gravel into the container on the trench box of the trencher.

The main functions are operated hydraulically by the driver of the tractor or the driver of the self-propelling unit and consist of:

- Lifting and lowering of the conveyor belt;
- Running of the conveyor belt;
- Adjusting of the outlet gate of the gravel.

The maintenance is basically only carried out weekly.

C.18.2 Weekly maintenance

On gravel trailers only "weekly" maintenance has to be done. This consists of checking:

- Tyre pressure, adjust if necessary;
- Tightness of belt (see manual), adjust if necessary;
- Bearings, add some grease if necessary;
- Hydraulic system for leakage, repair if necessary;
- Hydraulic oil.
C.18.3 Storage of the gravel trailer/winter storage

- Store the trailer preferably in a dry place;
- Protect the hydraulic hoses from strong sunlight;
- Take the weight of the tyres.

After storage: check the hydraulic oil and replace if necessary
II-C/3

Installation of pipe drainage systems
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
C.19 Preparatory activities

C.19.1 General

Installation of subsurface drainage systems can start once the design is completed and approved, contracts have been signed (orders to start have been issued), materials have been ordered and the site is handed over to the contractor or to the installation unit. If the implementing authority provides the drainage materials then the drainage materials need to be on site.

The process of handing over the site to the contractor or installation unit requires:

- Verification of the site to assure that the conditions allow proper installation. This is to be carried out by the implementation authority usually represented by the supervisor or supervising engineer (the client or principal);
- Installation and/or verification of the existence and levels of benchmark, and levels at places as indicated in the specifications, terms of contract and design;
- Handing over the necessary information to the contractor or implementation unit;
- Making the necessary arrangements with other parties who have activities or rights in the area.

Most of these activities are stipulated in the contract and/or specifications or instructions to installation units.

C.19.2 Arrangements to be made by the implementation authority

These include arrangements:

- With the owners and the users of the land to secure the rights of way at the required moments;
- For removal of unforeseen and foreseen obstacles along the drain lines that have not been prescribed in the contract or instructions. The organisation responsible for removal and the unit prices as well as payment conditions are normally stipulated in the contract or the instructions to the installation unit;
- To secure permission for the removal of obstacles;
- For disposal sites for the removed obstacles and indication of the organisation responsible for the removal;
For the removal of the crops either by the farmers or by the contractors in case crops are grown on the field during the approved installation period. Thus, this should be done before the work starts as well as compensation arrangements;

- For regulating the irrigation in the area. To provide workable conditions for installation, the field should not be irrigated for a period that allows proper drying of the soil before actual installation operations start. Timely and regular contacts with the farmers are required to ensure that the irrigation schedule and the construction schedule do not interfere with each other. The farmers should know the schedule of construction well in advance;
- With the design groups, if as a result of the field verification drain alignments or other parts of the designs have to be changed.

### C.19.3 Right of Way

Verification that the rights of way have been secured is necessary. (The right of way is to be secured by the principal or implementation authority, not by the contractor or installation unit). The right of way should preferably be a right to the entire area affected by the drainage system to be installed, which in practice is not always possible. The minimum right of way needed is as follows:

- Along the drain pipes to be installed (a minimum of 5 metres for installation of drain pipes without envelope material or drain pipes with pre-wrapped envelope material, and 12 metres if gravel is used as envelope material);
- Access to the fields where drain lines are to be installed;
- Access to places where pumping stations/sumps/drain outlets are to be constructed;
- Places for storage of materials;
- Place(s) for building construction camp.

### C.19.4 Site verification

The implementation authority and contractor/installation unit can best carry out the site verification simultaneously.

The verification consists of checking if the information provided in the designs about the site conditions are (still) correct and complete, and includes:

- General topography (topography as indicated on the maps as issued by the designers);
- Location of the existing infrastructure (such as the irrigation and drainage networks, road networks and buildings);
- Existence and location of overhead lines (electric/power/telephone lines)\(^1\);
- Existence and location of underground pipelines or cables\(^2\);

\(^1\) Overhead lines can be too low to allow passage of the machinery and can influence the functioning of laser.

\(^2\) Underground pipes, for example, if above or just below drain depth can get damaged during drain installation, and can damage the drain installation equipment.
• Location of other above or underground (potential) obstructions;
• Conditions of open drains, surface drain and outlet points, etc.;
• Design (layout) of the drainage system and confirmation that no unknown obstacles have to be crossed or are in the way;
• Whether or not there is enough unobstructed access along the drains to be installed (5-6 m for installation without gravel, 12 m for installation with gravel);
• Verification of the designs in the field and the correct location of all drains and ancillary works and confirmation that no (unexpected) obstructions are in the way;
• Verification of the existence of benchmarks with known height to which the systems to be installed can be related;
• Readily recognisable points (benchmarks) in the field from which the layout can be staked out in the field;
• Checking that all approvals of rights of way for the contractor/implementation unit have been obtained (see C.19.3);
• If relevant, checking that all relevant authorisations have been obtained of the utility companies (electricity, water gas) for the installation of the drainage system as designed;
• If relevant, checking whether the instructions to the contractor/implementation unit for contacting the utility companies prior to actual installation have been clearly issued.

The handing over of the field to the contractor/installation unit takes place after all parties concerned are satisfied that all above-mentioned points are in order.

Any obstructions in the field that are not on the topographic map should be removed, or in case this is not possible the layout of the drain should be adjusted accordingly. No work may commence until the utility and contractor are mutually satisfied that all requirements and safety precautions have been met.
C.20 Sequence of drain installation

C.20.1 General

- All activities are designed to support the trenchers. Trenchers are the most expensive single items of machinery and should work continuously if they are to be cost effective;
- As with all drainage works, for both singular and composite systems, it is essential to start from the downstream end of the system and work towards the upstream end. In this way, water can be discharged as the system construction progresses;
- For composite systems, the field drains govern the level of the collector system. If the field drains are placed first and too deep, then the collector system will need to be deeper still and more costly than necessary. Therefore, for composite systems, first construct the pumping station (if applicable), next the collector system, and after these have been completed, the field drains (see C.28, C.29 and C.30);
- In case gravel is used as an envelope the supply and management of gravel is required in a specified sequence of events (see C.35). In case a pre-wrapped envelope is used, the activities for gravel application will not be relevant;
- In the case of unstable subsoil, high-speed work is essential for easy and good quality work. In reality the work must be completed before the soil has had time to collapse (see C.24).

C.20.2 Preparations shortly before installation

- Discuss activities, required labour and responsibilities with representatives of landowners;
- Have design (setting out sheet) available;
- Set out drains by placing pegs at start and end of drain (see C.21);
- Review field for obstructions, remove obstructions and if necessary smoothen alignment of collector and/or field drain (see C.22);
- Measure field level near sump, near every collector manhole and/or start of every field drain and place a reference peg (see C.29);
- Dry/drain off standing water in the field (see C.25);
- Construct a camp if necessary.
C.20.3 Preparations the day before installation

- Prepare all equipment and staff;
- Place gravel in field (when a gravel envelope is used);
- Place rolls of pipes in field;
- Place manholes and sump in field near location of the installation.

C.20.4 Installation of singular system

(See also C.26 and C.27).
1. Have design information with levels available in the field;
2. Assure that all equipment is ready (as needed: trenchers, gravel trailers, excavator, bulldozers, laser equipment);
3. Have all required drainage materials available;
4. Roll the pipe out in the field, make connections (if no prefabricated couplers are available: be sure to have (iron) wire and filter cloth or plastic!), or;
5. If pipes are delivered on rolls and the trencher is equipped with places to store the rolls and hydraulics to load the rolls on the trencher, place the rolls in the field along the drain pipe alignment at distances equal to the length of the rolls;
6. Place boning rods (red poles) in line in the field (see C.21);
7. Install laser transmitter (see C.13, C.14);
8. Determine starting level of the drain, calculate depth of pipe below reference peg (see C.26);
9. Pass the blind drain pipe through the trencher and extend it some 1.5 metres outside the trench box. Make sure the pipe remains in position over the roller at the bottom of the trench box by attaching a wire and holding it firmly;
10. Dig start hole with trencher (liftable trench box) in side slope, if required;
11. Lower the trench box into or along side slope;
12. Check level of bottom of trench box and adjust this to the required starting level;
13. (Have gravel ready);
14. Extend laser mast so that upper red light is flashing;
15. Start trencher (and gravel supply);
16. Start installing field drain;
17. (Apply gravel, manage gravel supply);
18. Control check levels of the pipe every 10 metres;
19. Control continuous pipe and envelope material for damages;
20. At end of field drain block end;
21. Install drain outlet;
Preferably a few days later when the soil from the trench is dry:
22. Backfill trench (see C.33).
C.20.5 Installation of composite (collector) systems

C.20.5.1 Installation of the Collector

1. Have design information with levels available in the field;
2. Have all machinery and equipment available in field:
   - Trencher;
   - Excavator;
   - Bulldozer;
   - (Gravel trailers);
   - Laser equipment.
3. If collector pipes are not mounted as rolls on the trencher - lay the pipes out in the field, make connections (be sure to have iron wire and plastic!);
4. Install laser transmitter with correct slope (see C.13, C.14);
5. Determine level of bottom of the sump - calculate level below the reference peg, based on the design (see C.29);
6. Determine level of the bottom of the collector at the sump connection;
7. Dig hole for sump (fast!) (if necessary stabilise soil with filter);
8. Put sump in place (see C.28);
9. Check level and straightness of the sump;
10. Make trencher ready;
11. Fill hole for sump up around sump up to the level of connection of the collector and compact (see C.28);
12. Connect collector to sump;
13. Dig start hole for trencher;
14. Put trencher at start level;
15. Determine level of bottom of trench box;
16. Calculate required length of mast and inform driver;
17. Start installing collector;
18. Finalise connection of collector to manhole (watertight);
19. Fill up hole around manhole;
20. Control levels of collector installed every 10 metres;
21. At end of collector block the end;
22. Install (temporary) pump in sump;
23. Start pumping in sump;
24. Check if collector flows;
   After soil from the trench is dry:
25. Backfill trench: how and when to do this is to be determined in the field.
C.20.5.2 Installation of additional manholes in collector line

1. Determine the exact location of the manhole in the collector line;
2. Dig out a hole for placement of the manhole up to level of collector;
3. Dig out by hand around collector up to the required depth of the manhole;
4. Regularise hole to accommodate the manhole;
5. Cut a piece of the collector drain pipe. The length of the cut pipe is equal to the diameter of the manhole minus 20 cm;
6. If water is flowing out, block the now open part of the manhole using cloth or other material;
7. Bend outwards the two ends of the collector, be sure not to disturb the levels;
8. Hoist the manhole into the hole to a level just above its installation site;
9. Put the ends of the collector through the holes in the manhole;
10. Place the manhole in its permanent site;
11. Level manhole so that ends of collector do not bend up or down;
12. Secure both collector ends with cement in manhole;
13. Remove the blockage of the collector;
14. Fill in hole up to bottom level of field drain;
15. After starting field drain, complete filling up of hole.

C.20.5.3 Install field drain starting from manhole

1. Lay the pipe out in the field and make connections (be sure to have iron wire and plastic!);
2. Be sure sump is pumped so that little or no water is in the collector or manhole;
3. Dig start hole for trencher;
4. Put up laser transmitter;
5. Put trench box at the level of the hole in the manhole for the field drain;
6. (Have gravel ready);
7. Connect field drain to manhole - first length of the field drain should be "blind" (no holes);
8. Measure level field drain and compare actual level of field drain with design level;
9. Give difference between actual level and design level (if any) to operator;
10. Start trencher (gravel supply) start installing field drain;
11. Finalise manhole, filling up in layers up to the top, placing rings as necessary;
12. Put lid on manhole;
13. Continue installing field drain;
14. (Apply gravel, manage gravel supply);
15. Control check levels of the pipe every 10 metres;
16. At end of field drain block end;
17. Preferably a few days later when soil from trench is dry;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

C.20.6 Check functioning of system
(See section D)

C.20.6.1 Singular system

- Check alignment of all drains (see D.4);
- If there are problems with the quality/level control of field drains, correct them immediately;
- Check whether all drains are flowing;
- If there are manholes in the drains check if the parts upstream of the manhole are flowing.

C.20.6.2 Composite systems

- Check alignment of collectors and drains (see D.4);
- If any problems with the quality/level control of field drains are discovered, correct them immediately;
- Clean out silt from all manholes/sumps by hand;
- Pump in sump;
- Check water levels in collector manholes, check if water level is logical and collectors are flowing;
- If the obstruction can be pinpointed try to remove (flusher? digging up?);
- Check water flow in field drain manholes;
- Check for obstructions and if found, remove.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
C.21 Setting out of field

C.21.1 General

Setting out of the field, based on benchmarks with known levels as placed or identified by the designers and the baseline as defined by the designers, consists of setting out the:

- Reference level per field in a permanent benchmark;
- Alignment of collectors (check that there are no obstacles such as electricity posts and culverts in the alignment);
- Alignment of field drains (check that there are no obstacles such as electricity posts and culverts in the alignment);
- Location of manholes;
- Levels of manholes (only sumps and collector manholes).

C.21.2 Reference level per installation area: “benchmark”

A benchmark with a known level per installation area is to be placed in a spot that cannot be damaged by the installation. The level is based on the same reference as the design and preferably related to the national standard. This benchmark will in the future help with repairs and diagnosis of faults in the system.

A benchmark (Figure C21.1) can be made of concrete with some reinforcement iron dug firmly into the soil (dimensions for example: 0.2 x 0.2 x 0.5 m). The best thing to do is to write the level on the benchmark.

Figure C21.1 Benchmark
C.21.3 Alignment of collectors and field drains

C.21.3.1 Alignment of collectors or baseline for the start of field drains

The alignment of the collector drain (Figure C21.2) or the downstream end locations of the field drains must be marked in the field. This alignment is usually either parallel or perpendicular to the baseline. The collector line should be marked in the field by placing pegs at the centre of the spot where the future manholes/sumps will be installed and/or where the field drains will start. Since these pegs will be destroyed during installation, it is advisable to install reference pegs in a spot adjacent to the alignment of the collector and/or start of field drains that will not be destroyed during installation. In this way one can always trace the alignment and thus locate drains and manholes if flushing becomes necessary.

C.21.3.2 Alignment of field drains

The general alignment of the field drains is derived from the design. Once the downstream end (start end) of the drains has been marked in the field as described in C.21.3.1, the upstream end can be similarly marked (make a line perpendicular to the baseline at the top end of the field and use pegs to mark the end of the field drains). Next, a straight line is pegged out in between the start and end peg of the field drain and along this line is where the field drain will be installed (see C.21.3.3).

C.21.3.3 Staking/pegging out a straight line

Required tools
- Ranging rods/sighting rods (5);
- Spirit level (preferably).

Methodology (Figure C21.3)
1. Place ranging rods at the place of the start peg (A) and end peg (B);
2. Place the ranging rods vertically (verify by spirit level if available);
3. One person stands 3 to 5 metres behind the start ranging rod (A) and views the end ranging rod;
4. Place in the line at regular distances, which do not exceed the easy view from the previous sighting rod, the other sighting rods (maximum distance 75 m). The distance between two rods must not be too great and must not exceed the view of the workers and machine operator;
5. A second person aligns the intermediated ranging rods in the line starting 75 metres from the rod on the other end of the line;
6. Person (2) holds the rod between thumb and forefinger while person (1) sights the ranging rod in line;
7. Place a peg just behind or in front of the thus placed sighting rod.

### Tip: Setting out a perpendicular line

In most cases the line is situated parallel to another natural line like a canal, ditch or agriculture road. If this is not the case a line must be set out perpendicular to an existing baseline and if there are no instruments available this can be done as follows:

Using the properties of a triangle (Pythagoras law) lay a triangle of rope with sides measuring 3, 4 and 5 metres, respectively. Place an iron ring at each of the three corners and place in every ring a ranging rod. Then place one of the sides of the triangle parallel to the base or reference line. Put another ranging rod in the remaining corner. The other side of the triangle is now perpendicular to the base line.

**Required tools:**
- Three ranging rods;
- A rope of 12 metres;
- Three iron rings.
C.21.4 Location of manholes

If the collector and field drains are set out as given in section C.21.3, the location of the manholes will automatically be known. Since the pegs will be destroyed during drain installation, a second peg will need to be placed outside the alignment to be able to trace the centre after the drain has been installed (Figure C21.4).

![Figure C21.4 Location of the alignment peg and reference peg](image)

C.21.5 Levels of manholes

Levels are very important for collector manhole and sump installation and to save time during the installation of the manhole a level is required close to the installation pit. The level of the reference peg outside the alignment, as mentioned under section C.21.4 can therefore best be determined and implies that the level is measured in accordance with the benchmark (see C.21.1). The best thing to do is to write the level on the peg, and if the peg is in a permanent secure place, it will also help to relocate the manhole when repairs or cleaning needs to be done (Figure C21.4).
C.22 Site preparation

C.22.1 General

After the general staking out of the drain alignments the site preparation can start, which consists of:

- Removal of obstruction in the alignments, including trees, shrubs, crops and structures (if still there);
- Smoothing of the path of the trenchers with bulldozers (graders can also be used);
- Temporary filling in of ditches and removal of bunds or dykes to provide a smooth path for the trenchers;
- Temporary filling in or making bridges over ditches for access of the equipment;
- Preparation of storage places for gravel envelope, if required.

C.22.2 Smoothing of the alignments

The alignment of the drains has to be smooth to allow smooth passage of the trencher. Although trenchers can cross ditches and climb over minor bunds and so forth, this will only slow down the operation and can negatively affect the grade and depth control. The laser can of course correct the level difference within a limited range, but the reaction of the hydraulics to bumps in the field as instructed by the laser will be too slow because the hydraulic system has certain inertia (see C.23.2). Consequently, this will result in "bumps" in the level of the installed drain (Figure C22.1). This will happen if the subsoil is unstable, the float control is switched off and the laser receiver is mounted on the lifting cylinder. In stable subsoil a bump in the drain level can be avoided by driving slowly over the water course bund and keeping the float control switched on.

C.22.3 Crossing of small canals or surface drains

Whenever the drainage trencher has to cross a small canal or surface drain, these can best be levelled and smoothed by a bulldozer or excavator and reconstructed after the passage of the trencher. Getting past these obstructions, especially if this has to be done at an angle causes problems as indicated in Figure C22.2. First, one track of the machine will enter the small...
irrigation canal and the machine will tilt. The trench box will then get stuck in the soil, and more power will be needed to move forwards. This will cause the track to dig itself into the bottom of the small canal and will only make things worse and finally the machine could come to a complete standstill or the boom of the trench box might break.

Depending on the depth of the canal and the depth of the drain, it is often advisable to make a drain bridge (Figure C22.3) or a blind pipe (drain without holes) under the canal. In this way the irrigation water will not be able to seep into the drain. If temporarily filling in is not an option the canals/drains will have to be crossed at as large an angle as possible, preferably 90°. In that case it would be better to place blind pipes or rigid pipes under the crossing.
C22.2 Crossing of irrigation
a. Drain bridge

b. Rigid pipe under road, or canal

c. Crossing at larger angle

Figure C22.3 Drain bridge (a), use of ridged pipes to cross a road or a canal (b) and crossing at a larger angle (c)
C.23 Installation of drains

C.23.1 General

A subsurface drain or collector can only function correctly if installed straight, without horizontal curves, and at a correct straight grade, with minimal deviations.

C.23.2 Depth/grade control

The depth and grade of a drain line during installation can be controlled manually and automatically using a laser. Since most of the trenchers are equipped with a laser, manual control will not be further elaborated.

Laser equipment has its limitations for controlling the grade and correcting the depth of installation. A laser can very well compensate for gradual changes in field level, but not for sudden changes, because:

- One of the limitations is the speed at which the depth control is automatically corrected by the laser beam if confronted with a sudden obstruction in the field. The operator will have to slow down the speed if:
  - A sudden obstruction (small dike or dip in the field level) is encountered. (It is better before installation starts to level these using a bulldozer, for instance);
  - A hard layer in the soil is encountered. Apart from slowing down the float control will also need to be (temporarily) switched off (button 4, C.4).
- If the subsoil is unstable or if soft layers occur in the soil, the deviation of the grade over short distances can be substantial. Under these conditions the float switch will need to be switched off and the speed increased to the maximum. Even under these conditions the installation process should not be interrupted. If an interruption is really necessary, the engine and the laser will have to be kept running (see C.24).
C.23.3 Alignment control

The drain line needs to be pegged out carefully to facilitate alignment control, as described in C.21. Ranging rods will have to be placed if there are no boning or ranging rods anymore on the line at the places of the alignment pegs. There should be at least one ranging rod at the end peg and always at least two, preferably 3 boning or ranging rods in front of the trencher (Figure C23.1).

![Alignment control diagram](image)

Figure C23.1  Alignment control

The trencher operator can then align the vertical indicator rod on the trencher with all the boning or ranging rods that have been set out in the field. A frequently observed mistake is that the operator only aims at the nearest boning or ranging rod. As a result the installed line will not be straight and this in turn will lead to difficulties when locating the drain in the future.

C.23.4 Handling and installation of the corrugated plastic drain pipe

The installation of corrugated plastic drain pipes if the pipes are delivered on coils and click couplers are available, is done as follows:

- Corrugated plastic drain pipes of diameters up to 200 mm can be delivered in coils. The maximum diameter up to which delivery on coils is possible depends on the manufacturer. Generally speaking field drains up to 100 or 125 mm are delivered on coils by all manufacturers. The coils can be placed on reels that are mounted on the trenchers and gradually unwound when installation starts. The pipe is guided through the trench box into the drain trench via the pipe guidance rollers;
• The press pulley at the end of the trench box has to be lowered on top of the drain pipe to keep the drain pipe in the right position at the bottom of the trench;
• During installation the free unwinding of the pipe has to be checked. One labourer is responsible for the connection of the pipes and the unobstructed unwinding and guiding of the drain pipe;
• The coils have to be connected to each other by click couplers, if these are available. Both ends of the pipes are to be put firmly in the click coupler. This has to be done in such a way that the lips of the click coupler are firmly behind the ridges of the corrugated pipe;
• Be sure that there is no undue stress on the drain during the full installation time;
• When the trencher approaches the end of the drain line the drain pipe is cut off from the coils at approximately 2.5 m before the end. The end of the drain pipe is plugged (Figure C23.2);
• The backfilling of the trenches has to be done carefully as described in C.33.

In case larger diameter corrugated drain pipes (which are often delivered in lengths of 6, 9 or 12 m), or drain pipes that are not (properly) coiled, or in case no quick couplers are available, the pipes have to be laid out in the field parallel to the drain alignment. At the downstream end of the pipe an extra length of pipe is required of some 5-7 m to allow for the for the length required to lift the pipe over the trencher at the start of the installation The pipe sections can then be connected before installation starts. Connecting drain pipe sections can be done as follows:
• The connections can be done by prefabricated plastic couplers (Figure C23.3) or the connections can be made by hand as is indicated in Figure C23.4;
• The hand-made couplers consist of 1 or 2 pieces of corrugated drain pipe of approx. 30 cm length, slit open longitudinal;
• The two ends of the drain pipes are put pushed together and then one connection piece is put over the drain pipe in such a way that it covers both sides of the remaining gap between the drain pipes. The corrugations of the connection piece fits tight into the corrugations of the drain pipe. However, the hand-made connection piece has the same diameter as the drain pipe, and there will be a small longitudinal gap, which does not hinder the proper functioning of the drain pipe. The connection will be stronger if a second connection piece is put over the first one, covering the small longitudinal slit of the first connection piece;
• The couplers should be well fitted and if necessary additional iron wire is used for securing the connection. In case there is a fear of openings in the connection which could allow soil to enter the pipe a sheet of plastic can be fastened around the pipe.

At the start of the installation the end of the pipe is lifted over the front top of the trencher and inserted into the pipe guidance system on top of the trencher. Special rollers have to be constructed on the trencher to make it possible that the pipe is smoothly guided towards the tube guidance in the trench box. The trencher drives under the pipe (see also Part I, Figure 56).
C.23.5 Handling and installation of concrete/and or clay drain pipes

The concrete or clay drain pipes are loaded on a platform on the machine and then put along the chute in the trench box to the bottom of the trench. In case collector drains are installed as closed conduit-pipe, the installation requires one labourer on the platform to put the pipe in the chute and one labourer in the trench box to put cloth or other sealing around the joints (Figure C23.5)
Figure C23.4  Hand made connection for small diameter drain pipes

Figure C23.5  A labourer in the trench box to put cloth around the joints
C.24 Installations drains in saturated and/or unstable subsoils

C.24.1 General

Installation of drains with trenchers in unstable soils that loose all cohesion and become liquid if saturated, require special installation procedures and attention of management and operators.

C.24.2 Installation methodology

The installation method that has the highest chance of success in unstable, saturated subsoils incorporates the following elements:

- Fast driving. If the trencher drives fast the drain pipe is put in its correct place quickly and can be fixed in its place, before the soil has time to become liquid or the trench collapses;
- Fixing the drain pipe quickly in its place by loading soil on the drain pipe at the moment that is leaves the trench box. This can be done by:
  - Pushing with a spade a quantity of excavated soil into the trench immediately behind the trench box, and/or by;
  - Mounting a 'plough like' device on the back of the trench box that scrapes a quantity of soil from the walls of the trench, while at the same time making a "break mark" in the trench wall, which prevents dislodging of the drain pipe in case of collapse (Figure C24.1).

C.24.3 Observations

When working in this type of soil, operators should (Figure C24.2):

- Avoid to leave the trench box in the trench when the trencher stops for a longer pause (e.g. lunch or overnight), because its weight will make it sink into the ground and the level will be lost;
- If it is unavoidable and the trencher is left for a longer period with its trench box in the trench, sand and water will settle between the chain links and the sprocket and the chain will be fixed in the ground. In this case do the following:
  - Start the engine and let the chain turn a while in first gear before shifting to higher gears. (If you start immediately in sixth gear the engine may stall, parts may break or be damaged).
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Figure C24.1 Use of scrapers to cover the drain pipe in unstable soils

Figure C24.2 Trencher operating in unstable soil
C.25 Installation in fields with standing surface water

C.25.1 General

Any standing surface water on the field in the lines of installation must be removed before the installation starts. In principle, no drains should be installed under wet surface conditions. This is specifically true for field drains.

C.25.2 Effects of standing water on quality of drains

If a drain trench is made in an area with standing water, the water will immediately flow into the trench. This water is usually mixed with mud. The muddy water will during installation flow to or fall on the drain pipe with envelope and will disturb the envelope. The effect is that muddy water will flow into the drain and fill the drain pipe with mud. Consequently the drain will not function as intended. A secondary effect is that installation will be difficult because the gravel trailers will sink or slip. In most cases, however, the trencher is capable of working under wet conditions.

C.25.3 Preventive measures

If there is standing water in the field, a shallow trench must be dug before installation commences to channel the water towards the open drain. This can be done with an excavator, a bulldozer or even a plough. It is best to do it a few days before drain installation so that the surface can dry out and if gravel is used the gravel trailers will have little or no problems.
Inflowing water
Pipe and gravel envelope
Trench
Muddy water
Excavated soil

Figure C25.1   Effects of standing surface water
C.26 Installation of field drains starting from an open ditch

C.26.1 Procedures

1. Reverse the trencher until the trench box and digging chain are above the open drain taking care that the vertical direction rod is exactly in line with the ranging rods that mark the drain line (Figure C26.1a);
2. Lower the trench box and digging chain with the lifting cylinder (Button 16, C.4) until the top of the trench box is horizontal and the bottom of the trench box is at the starting level of the pipe drain (Figure C26.1b);
3. Adjust laser mast so that the top orange light is flashing (C.13);
4. Insert the drainage pipe into the trench box until it is so far out that the rigid end-pipe can be connected to it;
5. Shift the digging chain into gear and drive forwards slowly while manually adjusting the depth to keep the top orange coloured light flashing. Stop the trencher at the moment that the trench box is completely inside the side slope of the drain (Figure C26.1c);
6. Switch on slewing (C.4, no 12) and lift "float" (C.4, no.4) and set laser to "automatic";
7. When digging starts, the trench box and digging chain will automatically rise a bit until the green light flashes;
8. As the machine moves forwards the pipe should be kept in place by hand, so that the end fitted with the rigid pipe is pulled to its final position. Release the pipe when the rigid end-pipe is in the correct position and immediately fix it in this position by backfilling and carefully compacting the soil over the rigid pipe;
9. While the machine advances, the drain pipe is placed at the correct level in the trench. To prevent it from being displaced some backfilling ("blinding") can best take place instantly at regular intervals.

C.26.2 Trench box too long for width of open ditch

If the open drain is too narrow to fit the trench box and digging chain the procedure is as follows:
1. Lift the trench box with the trench box cylinder (C.4, no.16) (Figure C26.2a);
2. Lower the digging boom with its lifting cylinder (C.4, no.10) until the trench box is horizontal (Figure C26.2b);
3. Lower the digging boom further with the depth control, until the top orange laser light starts flashing;
4. Shift the digging chain into gear and move forward slowly until there is enough space to lower the trench box (Figure C26.2c). While moving forward, adjust the depth manually to keep the

---

Figure C26.1  Installation of field drains starting from an open ditch
top orange coloured light flashing. Usually, it will be necessary to lift the digging chain to be able to position the trench box in the correct place;
5. Important: make sure that the hook between trench box and digging boom is secured properly, if not, switch on the trench box (see C.9);
6. If, during this exercise, the trench box has completely entered the side slope of the drain channel, the lift and slewing "float" can be switched on (Figure C26.2d);
7. Continue as described previously.

Important: The pipe should never be moved after it has been placed in position. Moving it will cause a change in bottom level so that the drain may not be able to function properly.
Figure C26.2  Installation of field drains starting from a narrow open ditch
C.27 Installation of outlets of field drains into open ditches

If a field drain discharges into an open ditch the following provisions have to be made:

- The drain has to start with a rigid pipe of 3-5 metres in length. This length is necessary to ensure that the pipe is clearly anchored in the side slope of the drain to prevent water leaking out of the pipe and wetting and weakening the soil body of the side slope. The rigid pipe also serves to prevent the drain pipe from bending downwards after some time;
- Preferably, behind the rigid pipes are at least five metres of "blind" drain pipe (pipe without perforations). The "blind" pipe serves to prevent water from flowing out of the drain pipe into the surrounding soil causing weakening of the soil body which may lead to collapsing of the slope;
- After installation of the rigid end pipe and the blind pipe that is partially pushed into the rigid pipe, backfill the end part of the drain immediately. Backfilling should be done in layers of 30 cm and each layer should be well compacted. Compacting of this first section, especially around the rigid pipe, is essential to prevent the slope from collapsing and to securely anchor the pipe (Figure C27.1);
- The connection between the "blind" pipe and the rigid pipe should be as watertight as possible so that water from the open drain cannot flow into the soil of the side slope. This can be done by:
  - Tying a sheet of plastic firmly around the connection between the pipes;

![Image of outlet of field drain into open ditch](image_url)
- Extending the “blind” pipe into the rigid pipe almost to the end (a pipe in a pipe) and wrapping a plastic sheet firmly around the connection.
- The connection between the “blind” pipe and the “normal” perforated pipe can be made just like the usual pipe joint.
C.28 Installation of sumps at the start of collector drains

C.28.1 General

Installation of a sump at the start of a collector drain corresponds to installation of a manhole. The installation level for a sump is derived and defined by the level of the collector at the place of installation. The description of the installation of sumps is for prefabricated sumps. If the sump has to be constructed onsite in the excavated pit, the pit will need dewatering over a longer period of time.

C.28.2 Preparation

For the installation of a prefabricated sump the following preparations are to be made:

- The location of the sump will be indicated by a peg;
- The sump unit should be available near the location;
- Be sure that suction pumps are available;
- Excavator available;
- Surveyors and labourers available;
- Survey equipment available;
- Carpenters level available.

In case no prefabricated sump will be used and the sump will be constructed on site dewatering equipment is to be available.

C.28.3 Installation of prefabricated sump

1. Position the excavator (perpendicular to the drain line on the side where the field drain is planned) and start digging;
2. Excavate the hole for the sump fast and be sure no to dig too deep. If necessary remove the last layers by hand;
3. If the hole fills up with water, pump this out with the suction pump. If the hole is at the required depth and seemingly dry but muddy, throw a thin layer of gravel or course sand on the bottom;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

4. When the bottom is prepared properly (right alignment, right depth, horizontal line), use the excavator to hoist the sump unit and with help of the labourers place the sump in the pit in the correct position (use carpenters level). For determining the right level see C.29;

5. After placing the sump unit prepare the connections with the collector and make connection watertight with cement. Check (carpenters level) the horizontal position of the collector connections;

6. Fill the hole with dry soil up to the level of the lower side of the holes for the collector drain in the sump’s wall. Labourers compact the soil, especially immediately around the sump, and at the place of the (future) collector drain;

7. Connect now the collector pipe to the sump (see C.29).

C.28.4 Installation of sump built on site

1. If the sump has to be built onsite, install dewatering equipment (vertical well pointing), if needed, and operate pumps. Operation of the pumps should start well in advance of the digging of the hole for the construction of the sump. The groundwater table should be lowered to a level below the base of the sump;

2. Start pumping;

3. If ground water has locally been pumped out to bottom level of future sump start digging, by hand or with excavator;

4. Be sure that hole dug is 0.5-1 m wider and larger than required for sump to be built;

5. Start building sump at correct level (see C.29);

6. If sump is completed connect the collector pipe(s);

7. Fill the hole with dry soil up to the level of the lower side of the holes for the collector drain in the sump’s wall. Labourers compact the soil, especially immediately around the sump, and at the place of the (future) collector drain.

C.28.5 Starting hole for collector drain.

- If there is no certainty that the collector drain will be installed immediately, then close the opening in the sump with filter sheet or plastic sheet and fill up and compact with dry soil to a higher level. In this case the starting hole will be prepared later just before installation of the collector drain. It will need a little more manual work;

- If the collector is installed immediately after the sump has been installed (which is preferable in the case of prefabricated sumps), the starting hole for the collector is dug at the same time as part of the hole for the sump.
C.29 Levels of manholes and starting levels for trencher for field drain installation

C.29.1 General

Sumps, collectors, manholes in collector lines and field drains have all to be installed at the correct level. To provide the correct level for installation and for checking if the levels are correct it is necessary to have a reference peg with a known level (PL) near every manhole to be installed. Moreover, the reference level must be related to the same basis as used in the design.

C.29.2 Determining the level of the levelling instrument

For determining the so called “instrument level” of the levelling instrument (Figure C29.1):

1. Install the levelling instrument in a strategic place;
2. Determine on the basis of the reference peg with known height the level of the instrument;
3. The instrument level is: \( IL = PL + \text{Reading} \).

![Figure C29.1 Determining the level of the levelling instrument](image)
C.29.3 Determine the level of the sump or manhole (Figure C29.2)

1. Take from the design the level of the bottom of the lowest collector to be installed in the sump (DL); 
2. Calculate on the basis of the design information the difference in level between the bottom of the lowest collector and the instrument level (IL-DL). The result (IL-DL) is the bottom level below the instrument level; 
3. Measure with a measuring tape the distance between the bottom part of the collector entry hole and the bottom of the sump/manhole (SD = Sump Depth); 
4. Add this value (SD) to the difference in level between instrument and bottom lowest collector (IL-DL); 
5. The result is the installation depth of the sump/manhole below the instrument level (IDS = Installation Depth Sump).

\[ IDS = IL-(DL-SD) \]

(Sumps, but not manholes, can better be placed 5-10 cm lower, to be on the safe side)

---

C.29.4 Level for collector manhole installation

Theoretically, the depth of installation of the collector manhole can be determined in the same way as the sump. In practice, however, the manhole is installed in the already installed collector line. Therefore, the level is determined in the field on the basis of the actual level of the collector. The bottom level of the manhole (BLM) is thus:
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

BLM = Top level collector - Ø collector - MD (Manhole Depth = difference between level of the bottom of the manhole and the bottom of the hole for the collector)

Be careful that the manhole is not placed too high or too deep, but at the right level. The reason why and how it differs from a sump is explained in the following drawing (if there is choice, never install too high rather a few centimetres deeper). However, if the manhole is placed too deep the downstream collector will not flow properly because the water cannot flow with the slope. This reduces the effective slope of the collector and thus the capacity.

![Figure C29.3 Determining the level of collector for manhole installation](image)

The difference between a manhole and a sump is given in the following figures:
- C29.4a: A manhole should not be installed too deep because this will interrupt the flow downstream;
- C29.4b: A sump that receives water from both sides can be installed deeper, since this will only increase the slope and will not interrupt the flow towards the sump.

**C.29.5 Levels for field drain manhole installation**

The depth of the field drain determines the depth of installation of the field drain manhole. No other level is involved. In practice one has to align the manhole with the existing field drain. The level is thus to be determined in the field on the basis of the actual level of the field drain. Therefore, the bottom level of the manhole (BLM) is (Figure C29.5):

BLM = Top level field drain - Ø of field drain - MD (Manhole Depth = difference between level of the bottom of the manhole and the bottom of the hole for the field drain)

Be careful that the hole is not dug too deep, but at the right level. (See C.29.4).
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Figure C29.4  Effects of too deep installation of a manhole and sump

Figure C29.5  Determining the level for field drain manhole installation
C.29.6 Level to be given to trencher operator for collector drain at sump

After the sump has been installed and the starting hole made the following procedure needs to be followed for the installation of collectors (Figure C29.6):

1. Connect collector pipe to the sump;
2. Drive trencher forwards approximately 2 m;
3. The operator extends the laser mast until the green light appears on the display;
4. Determine the instrument level (IL) of the level instrument (see C.29.2);
5. Take the level at the top of the pipe at two places:
   - At the top of the collector pipe close to the sump;
   - At the top of the collector pipe where it comes out of the trencher.
6. Subtract from these levels the diameter of the collector;
7. Compare the values with the design level for the collector. If:
   - Level (2) is higher than level (1) but at or below design level, determine how much below design level and give this value to the operator. He can then, while installing slowly, raise the trench box to the desired level;
   - Level (2) is lower than level (1), determine how much (2) is below level (1) and ask operator to raise the trench box so that it is at least at level (1). Give the operator the number of centimetres the box should be raised. The operator then adjusts the mast length to come again in the green (This action will lift the collector pipe somewhat thus fill soil will need to be put under the pipe to support it).

![Figure C29.6 Schematic configuration of sump, collector and starting hole for trencher](image)

C.29.7 Start Level for field drain to be given to trencher operator

After installing the collector a hole has to be dug at the place where the manhole is to be installed (Figure C29.7):

1. Dig the hole carefully so as not to disturb the pipe (see C.29.4);
2. Install the manhole at the same level as the pipes and be sure this is properly aligned (if the manhole is too high lower it, it is better that the manhole is a few centimetres too low, this is
acceptable, too high is not acceptable). Thus, the level of the openings in the manhole for
the collectors is the actual level of the collector pipe;
3. Connect the collector pipes to the manhole and secure them;
4. Fill the manhole to a level above the collector pipes (up to the bottom opening for a field
drain);
5. Dig a starting hole for the trencher;
6. Connect the field drain to the opening in the manhole;
7. Drive trencher approximately 2 m forwards;
8. The operator then extends the laser mast to the height until the green light appears on the
display;
9. Determine the Instrument Level (IL) of the level instrument (see C.29.2);
10. Take the level at the top of the field drain at two places:
   • At the top of the field drain close to the sump;
   • At the top of the field drain where it comes out of the trencher;
   Subtract from these levels the diameter of the field drain;
11. Compare the values with the design level for the field drain. If:
   • Level (2) is higher than level (1) but at or below design level, determine how much below
     design level and give this value to the operator. Then, while installing slowly he will be
     able to raise the machine to the desired level;
   • Level (2) is lower than level (1), determine just how much this is and ask operator to raise
     the trench box so that it is at least at level (1). Give the operator the number of
     centimetres so that the box can be raised appropriately. The operator then adjusts the
     mast length to come again in the green (As the field drain pipe would have been lifted
     somewhat by this action fill soil will need to be put under the pipe to support it).

In some cases the level of the field drain will be higher than the start level at the opening in the
manhole; the operator will raise the level gradually until it is at design level by gradually lowering
the mast.

Figure C29.7  Schematic configuration of manhole, field drain and starting hole for trencher
C.30 Installation of manholes and starting holes for field drains

C.30.1 General

The installation of a manhole in a collector or a field drain is very similar to the installation of a sump. The installation level for a manhole in a collector is derived and defined by the level of the collector at the place of installation.

C.30.2 Preparation

- The place of the manhole is pegged out;
- The manhole is at the spot;
- If necessary, the collector is pumped dry at the sump (just before installation of the manhole);
- Excavator available;
- Labourers available;
- Detection rod available. A detection rod is a rod made of concrete reinforcement steel of about 1.5 - 2 m in length with a handle (Figure C30.1);
- Carpenters level available.

C.30.3 Digging the hole and installing the manhole and collector

1. Position of excavator. For easy operation it is recommended that the excavator is positioned perpendicular to the collector;
2. Measure in the prefabricated manhole the distance between the bottom of the hole for the collector and the base of the manhole (see C.29 and C.29.7; SD and MD);
3. The excavator excavates a hole above the collector;
4. While excavating, a labourer timely starts to detect with a detection rod the place and the depth of the collector and gives the information to the operator. So the excavator can excavate safely the maximum quantity of soil without damaging the collector;
5. When the excavator has almost dug up the collector, the labourers dig the collector free over a length of about 1.50 m;
6. Cut out of the collector (using iron saw) a piece equal to the outside diameter of the manhole minus 40 cm;
7. When water flows from the collector the collector must be plugged instantly;
   (Possibility: Use a soft ball with a diameter of about 2 cm more than the inner diameter of the collector);
8. The soil to about the desired depth is excavated between both ends of the collector (see point 2 above);
9. Using the carpenters level the labourers smoothen the spot where the manhole will be installed while the manager indicates the depth of the bottom in relation to the bottom of the collector (see 2);
10. When the bottom is prepared properly (right alignment, right depth, horizontal), the excavator hoists the manhole and with help of the labourers places the manhole in the hole in the correct position (carpenters level);
11. In most cases the collector can be connected at one side of the manhole straightaway;
12. After placing the manhole prepare the collector connections and make them watertight using cement. Check (carpenters level) horizontal position of the collector connections;
13. Fill the hole with dry soil up to the level of the lower side of the holes for field drain in the manhole wall. Labourers compact the soil, especially immediately around the manhole and at the place of (future) field drain.

C.30.4 Observations

C.30.4.1 Manholes in field drains

The same working sequence as in C.30.3 applies to the installation of manholes in field drains. It is advisable to replace a part of the field drain that is connected into the manhole (approx. 1 m length) by a so-called blind pipe (pipe without perforations). Directly after the pipes are connected, the manhole can be completed by placing the top rings on the lower rings (if applicable) and the hole can be filled straightaway.

C.30.4.2 Starting hole for field drain

- If there is uncertainty about the immediate installation of the field drain following installation of the manhole, close the opening in the manhole with filter sheet and fill up and compact with dry soil to a higher level. In this case the starting hole will be prepared later just before installation of the field drain, which will require a limited amount of extra manual work;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- In case the field drain is installed immediately after the sump or collector manhole has been installed (which is preferable in the case of prefabricated sumps), the starting hole for the field drain is dug at as part of the hole for the manhole.

C.30.4.3 Inserting the trencher for field drain

As the collector and the manholes are designed and installed in such a way that the lowest field drain can discharge to the collector system, some field drains may have a higher starting level than the level of the entrance hole in the manhole to which they are connected. The procedure in that case is as follows:

- Connect the field drain to the manhole at the level of the entrance hole;
- Advance a few metres with the trencher;
- Measure the actual top level of the field drain;
- After correcting the level by subtracting the Ø of the drain pipe compare the measured level with the design level + the diameter of the drain;
- Inform the operator of the difference between the actual and the design level (in cm);
- Proceed with installation and instruct the operator to gradually shorten his laser mast with the length equal to the level difference;
- Be sure that the difference in level is corrected very gradually otherwise maintenance of the drain may become problematical.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
C.31 Installation of pipe connections and joints

C.31.1 General

Connections between field drains and collector drains are preferably made inside a manhole as described in the previous instruction sheets. In some cases the design prescribes direct connections. A direct connection can be made by a rectangle joint or a T-joint. The so-called T joint allows, although complicated and cumbersome, access to the field drain for a flusher. Rectangle joints do not have such provisions. This T-junction will need to be equipped with an access pipe with and end cap for the objective in mind (Figure C31.1). The access pipe should be installed in such a way that its upper part remains under plough depth (> 0.6 m depth). A reinforced concrete tile can be used to cover the end of the access pipe, which in theory can be detected underground with a metal detector in case flushing is required. However, in practice this does not always function easily.

C.31.2 Installation of connections (Figure 31.2)

- Joints should be installed in the starting hole dug for the field drain as soon as possible after the field drain installation has started;
- If the groundwater is above the collector pipe the hole needs to be pumped out to ensure work under dry conditions;
- The joint should is to be installed on the centre line on top of the collector pipe (the starting level of the field drain is the top level of the collector drain or higher);
- A hole needs to be drilled in the collector with a diameter equal to the outer diameter of the joint;
- The joint is then inserted into the hole and fixed with iron wire or plastic wire around the collector;

1 The advantage of a connection inside a manhole is that it provides relatively easy access to the field drain for cleaning and a way of inspecting the flows from field drains into collectors.

2 This allows the field drain to flow immediately and to discharge its water into the collector. The longer the wait the higher the risk that the water starts flowing and the connection hole will be inundated, thus vastly complicating the activity.
- The lateral is then inserted firmly into the open end of the joint up to the tab stops;
- The hole is filled by hand in layers that are compacted up to just above the level of the joint, taking care that the field drain does not sag and has no reverse slopes.

![Diagram of a T-joint with flushing provision](image1.png)

**Figure C31.1** Example of T-joint with flushing provision

![Images of installation steps](image2.png)

**Figure C31.2** Installation of a lateral collector junction
C.32 Completion of manhole/sump installation

C.32.1 General

The installation of sumps and manholes has been discussed in C.28, C.29 and C.30. Completion of the installation is discussed below.

C.32.2 Aboveground or underground manholes

Manholes can be installed aboveground as well as underground. An aboveground manhole, which is an obstruction in the field, has to be clearly marked so that a tractor is not driven over it. Also, surface water has to be prevented from freely flowing into it, so it is advisable that the top of the manhole is 0.6-1 m above ground level. Conversely, the top of underground manholes has to be at least 0.6 m below ground level so that no damage is caused to the manholes by soil cultivation activities like ploughing.

C.32.3 Backfilling methods

C.32.3.1 Background

A manhole is installed in a rather large pit. The pit is filled up later, but the soil is disturbed and has different characteristics than the original undisturbed soil. If the soil is not completely compacted then:

- It will subside in time;
- The soil will become more permeable and water will flow easily downwards towards the drain, which could cause piping and disturbance of the manhole;
- When wetted the disturbed soil will easily become muddy. If tractors work close to the manhole the soil may become boggy and disturb the manhole.
C.32.3.2 Solution

Backfilling the construction pit around the manhole can be done according to the following procedure (Figure C32.1):

- Fill up in layers of some 0.3 m;
- Compact each layer;
- Fill up the next layer and repeat the procedure;
- Continue filling up to a level above some 0.3 m of field level, so that the manhole seems to stand on a hill.

This will be minimising the risk of piping, inflow of water and muddy soil and disturbance by tractors.
C.32.4 Joints of rings of manholes and joints of drain pipes with manholes

C.32.4.1 Background

The function of manholes is to provide access for inspection and cleaning of the collector and field drain pipes. Dirt (mud) should be prevented from entering the drainage system through joints of the manhole. Prefabricated manholes are often composed of rings which can be piled on top of each other to create a manhole of the desired height. If the joints of these rings are not properly sealed and watertight, muddy water may easily flow into the manhole and cause siltation of the drainage system.

C.32.4.2 Preparing water tight joints

Make the joints watertight even though the contact surfaces between rings are never perfectly level. The solution is to put cement on it repairing at the same time any damage to the rings. If available, asphalt-based joining kits are better than cement. The rings may be off-set from the perfect alignment by side way pressure during filling or shocks with agricultural equipment. A second defence to prevent water from entering through the off set joints is to wrap a plastic sheet around the joints and fix these with iron wire. The best is agricultural (black) plastic of a minimal thickness. Agricultural plastic is both watertight and less expensive than other geotextiles.

C.32.4.3 Making joints of drain pipes with manholes watertight

The joints of the drain pipes with the manholes can be made water tight by putting (on the outside) mortar around the pipe and fill up the space in between the pipe and the manhole. If asphalt based kits are available these can also be used. As a second security some plastic sheets with iron wire can be used.

C.32.5 Lids/covers of manholes

Upon completion of the construction lids and covers of the manhole should be placed as soon as possible to avoid dirt from falling or being thrown into the manhole. The joints of the lid and top of underground manholes should be better protected using plastic sheeting as discussed in C.32.4.2, to avoid inflow of muddy water.

C.32.6 Pump house

If other than submersible pumps are used a pump house is to be installed for the protection of the pumps. For the protection of small pumps a pump box is to be installed.
For diesel driven pumps in most cases a full fledged pump house is required. The pump house is constructed either above or close to the sump. The pump house can be a simple brick building with a door that can be locked. For small drainage units a prefabricated pump house can be installed. In case submersible pumps are installed, a locked cover for the sump has to be installed.

C.32.7 Connection to the power grid system

In case of electrically driven pumps the connection to the power grid system has to be made prior to the installation of the drains, so that pumping can start already during installation of the drain pipes. The switch board for the pump operations is either put inside the pump house, or in a sturdy locked switch board box attached the electricity pole.
C.33 Backfilling of trenches

C.33.1 General

After the drain pipes have been installed (C.23) the trenches have to be backfilled. Backfilling should be carried out according to the right methodology because if this is not done correctly it may have a negative impact on the performance of the drain, especially in the case of field drains. Ideally, all the excavated soil should be returned to the trench. If the backfilling is not correctly done there is a risk that soil lumps will form bridges in the trench and so-called "tunnels" will be formed (Figure C33.1). The formation of bridges or tunnels should be prevented at all cost because of the high risk that the muddy water will flow directly through the hollows in the trench towards the pipe and cause irreparable damage to the envelope. Figure C32.2 shows the erosion ("piping") that can occur in case of unconsolidated trench fill.

Figure C33.1 Bridges in the trench after incorrectly backfilling of the trench
C.33.2 Backfilling methodology

Backfill of the drain trench is a three-step operation:

- Blinding;
- Backfill;
- Compaction.

Blinding

An initial backfill of 15 to 30 cm of soil is placed around and over the drain pipe. This is done to ensure that the drain pipe will remain in line when the remaining excavated material is placed in the trench.

Blinding may be done by shaving off the topsoil at the top of the trench with a spade (Figure C33.3), or with an attachment (scraping knife) to the trench box.

Backfilling

The best method for backfilling depends on the characteristics and the condition (wetness) of the soil.

- If the soil is dry, the trench can be closed almost immediately after installing the drain;
- If the soil is wet or unstable, it is preferable to wait a few days until the excavated soil is dry before commencing with backfilling.
Compaction
Compaction is required to avoid serious problems arising in irrigated areas when water moves rapidly through the unconsolidated trench fill causing severe erosion.

C.33.3 Instructions for backfilling of trench

C.33.3.1 Dry soil

- Directly after installation of the pipe the excavated soil can be pushed back into the trench using a bulldozer (or angle dozer). First the soil on one side of the trench is pushed in the trench and thereafter the soil on the other side of the trench. This will give the soil “time” to fall into the trench and thus prevents the formation of bridges. The soil can be pushed into the trench by hand, by tractor with a front end bulldozer blade, by tractor with a levelling blade, by bulldozer, by angle dozer or by grader;
- If available, a double V-shaped blade for a bulldozer can also be used. The bulldozer drives over the trench and pushes the soil deposited at both sides into the trench. The blade should be set in such a way that it does not touch the original field level. In a second go, after the soil is dried, the remaining soil can be pushed into the trench;
- After backfilling in this way the remaining ridge of soil on the trench must be pushed on top of the trench and compacted later. This compaction can be done with the wheels of a tractor that is driven over the trench.

C.33.3.2 Wet soil

In wet conditions the excavated soil is mostly wet, muddy and sticky. Collapse of drain trenches and formation of bridges are likely to have occurred during the installation of the drain. The following procedures are recommended:

- Let the excavated soil dry before backfilling starts;
- After a few days make push with the bulldozer the excavated soil on one side of the trench, as much as possible, in the trench. After some days push the soil from the other side into the trench;
C.33.3.3 Trenches and irrigation

It is advisable for all the remaining soil to be heaped on the trench alignment, which in time will subside and compact. At the same time a small ridge on the trench will partly prevent the direct flow of irrigation water into the trench.
C.34 Cleaning up of site after installation

The following actions need to be taken upon completion of the drain installation in an area:

- The original conditions should be restored: farm ditches, fences, roads and so forth should be able to function as before;
- Surplus soil that is not of an injurious nature should be spread over the surrounding field;
- Materials such as large stones and roots likely to damage implements or livestock, or of a size and character abnormal to material found on the surface of the field, should be removed;
- The contractor has to arrange for the removal of surplus pipe material, bands and ties, wood, glass, metal cans, and containers and other rubbish from the installation work;
- The ditches that were temporarily closed are to be opened and restored again;
- Canals that were cut by the drains are to be repaired and restored;
- The roads that were cut by the drain lines have to be restored to their original state;
- Bench marks and other permanent reference points should be protected, made clearly visible and marked correctly on the as built drawings.
C.35 Application of gravel

C.35.1 General

For proper performance of the drainage system, the quality of the gravel envelope and the even application of a layer of about 7.5 cm of gravel around the pipe is of paramount importance. The quantity of gravel required is considerable and depending on the diameter of the pipe amounts to 4-5 m³ per 100 m of field drain.

The objective of the management of the gravel supply is to supply timely good quality gravel to the trencher so that it can work continuously and does not have to wait or slow down. A slowing or stopping of the trencher because the gravel hoppers run empty can disturb the grade of the drain. The supply should also be gradual since suddenly filling of the hoppers with gravel will add a considerable weight to the trench box. The resulting weight shock can push the trench box down so that the even grade of the drain pipe is disturbed. Best is that the degree of filling of the gravel hoppers is continuous and fluctuates between ¾ of the capacity and full capacity. This creates a constant pressure on the gravel and a regular flow of gravel in the chutes and, to some extent, prevention of clogging.

The quality of the gravel itself is important. Dirt or sand or clay in the gravel will clog the chutes and prevent a regular flow, apart from the fact that the filter function will then not be optimal. Constant quality control of the gravel is of great importance for these two reasons and all the more because gravel is a natural product that is rather variable by nature.

Activities
Gravel supply consists of the following activities:
- Selecting storage sites;
- Quality control of the gravel upon delivery;
- Loading the gravel into gravel trailers;
- Infield transport of gravel by gravel trailers from storage site to trencher and back;
- Unloading the gravel into the trencher hoppers;
- Gravel management on the trencher.
C.35.2 Equipment and staff requirements

Equipment
- One front loader for loading the gravel at the storage sites into the gravel trailers;
- Three gravel trailers pulled by tractors.

Staff
- Operator front loader;
- Three tractor drivers;
- One gravel assistant.

C.37.3 Selecting a storage site

The location of the gravel storage in the field is important for logistic reasons. The storage site location must fulfill the following conditions:
- Sites need to be located as close as possible to the drains to be installed so that travel distances (time) are minimal;
- Cross field travel for the tractors plus gravel trailers should be minimised (slows down speed and increases travel time);
- Sites should be easily accessible to the supply trucks and gravel trailers;
- The gravel must be stored on a flat place, which if not flat should be levelled beforehand;
- A sandy place for storage free from coarse stones is preferred over a place with clay;
- Mixing of the lowest part of the gravel heap that is in contact with the soil is unavoidable and results in loss of this layer of the heap of gravel. Therefore, the surface of the storage area needs to be kept as small as possible and to achieve this the gravel should be stored in heaps as high as possible;
- Unloading of trucks arriving with gravel should be done as directed, preferably on top of an already existing heap.

Thus, to save gravel a small number of storage places with high heaps of gravel are best, but to minimise infield transport time a large number of heaps close to the drain alignments is preferable. Obviously, a compromise has to be made. If transport distances become too great and three gravel trailers cannot supply the trencher in time additional gravel trailers will have to be used.

C.35.4 Quality control

Quality control on the graduation and the cleanliness of the gravel should be carried out in the quarry before transport (see D.1.3). In the field quality control starts at the moment of reception of the transport, with a visual check: the gravel should not contain any coarse stones (>Ø 3-4 cm), or silt or mud. If there are doubts about the presence of mud and silt (for instance, when the gravel is dry) a simple test can be carried out. Mix a small sample with fresh, clear water. If
there is mud and silt in the sample this will immediately be visible in the water. If the gravel contains dirt, too coarse stones, mud or silt, the gravel is not acceptable and should be rejected. If such problem occurs the gravel must be sieved again. If the gravel is acceptable, care should be taken to ensure that the quality of the gravel does not deteriorate while storing and loading on the site (see above for the different precautions).

C.35.5 Loading

Loading of the gravel into gravel trailers is best done by a front loader (Figure C35.1). The larger the capacity of the front loader the faster the loading and the less time lost during loading. To limit the dirt that is mixed with the gravel while loading:

- The operator of the (front) loader should take care that he keeps the bucket of the loader above the original field level to avoid loading soil as well;
- When new trucks with gravel arrive the storage manager should dictate the place of unloading, preferably on top of already existing heaps.

C.35.6 Infield transport and unloading

The basics of the gravel transport and unloading are:

- Gravel trailer 1 has to drive alongside the trencher and unload the gravel gradual by way of the conveyor belt into the hoppers of the trenchers (Figure C35.2). The gravel assistant’s job is to guide the process, swivel the transport belt between the front and back
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

hopper, manipulate the valve on the gravel trailer and indicate to the driver the required speed of unloading and the starting and the stopping thereof;

- Gravel trailer 3 has to be loaded and after loading it should be driven as fast as possible towards the trencher behind gravel trailer 1, wait until this trailer is empty and then replace it;
- Gravel trailer 2 has to travel from the trencher towards the loading place and when loaded travel to the trencher and relieve trailer 3;
- A new cycle starts.

The unloading should be regular, meaning that the unloading begins when the hoppers are ¾ full (of the load supplied by the previous trailer). During the unloading (approx. 10 min) the filling grade of the hoppers should remain at the same level. Towards the end of the unloading the unloading speed is increased somewhat so that the hopper is fully filled when the trailer is empty and drives away. (The speed of unloading can be regulated by the speed of the transport belt and the valve on the gravel trailer). In the time lapse necessary for the replacement of the empty trailer with the fully loaded waiting trailer, the load of the hopper will decrease again to ¾, the starting point for the following trailer. The time required for return travel, loading and travel toward the trencher increases (or decreases) in accordance with the distance of the trencher from the gravel depot. The location of the storage site determines the travel distances and whether a continuous supply of gravel can be guaranteed with three trailers.

Trailers with a full load of gravel (> 8 tons) can only slowly travel over uneven ground. The easiest is to travel parallel to the trench, where the path is smoothed somewhat. Travelling long distances crosswise to the field is to be avoided (Figure 35.3).
Figure C35.3  Schematic representation of infield gravel transport
C.35.7 Gravel management of the trencher

The gravel management on the trencher is partly carried out by the gravel assistant partly by the operator of the trencher or the person in charge of checking the quality of the pipe and guiding the pipe into the pipe guidance tube. The management consists of:

- Adjusting the gate on the trench box so that the appropriate cover of gravel over the pipe is obtained;
- Assuring that the degree of filling of the hoppers stays more or less constant (3/4 full - full);
- Making sure that the gravel floats smoothly into the chutes;
- Checking that the pipe is homogeneously covered with gravel when it comes out of the trencher.

The gate at the end of the trench box should be adjusted so that the opening at the end of the trench box is: 7.5 cm + Ø pipe + 7.5 cm (Figure C35.4).
C.35.8 Possible problems

- The flow of gravel from the gravel trailer onto the conveyor belt is not regular:
  - Push the gravel with a stick and/or poke the gravel with the stick around and above the outlet of the trailer until the flowing resumes;
  - Beat with a stick against the outside of the hopper of the gravel trailer. (Not a very elegant solution).

- The gravel in the hopper of the trencher is sticky and/or does not flow down the chute towards the pipe, or obstructions have formed in the chute:
  - Push the gravel with a stick into the chute until the regular flow is re-established;
  - Beat with a stick against the side of the hopper;
  - If serious, stop the trencher and remove the gravel so that a possible obstruction can be removed.

- If the supply by the gravel trailers stagnates and the hoppers run the risk of running dry an undesirable situation occurs. To make the best of it one can do the following:
  - Stop the trencher when the hoppers are still ½ full;
  - Put the float control lock on just before the trencher stops;
  - Be sure the laser is in the green;
  - When a full gravel trailer is available again, bring it into position;
  - Start the trencher engine and manipulate the trench box height manually so that the laser is in the green;
  - Start filling the hoppers very slowly;
  - Start driving with the trencher;
  - Gradually fill the hoppers up to the normal level.
Installation of Subsurface Drainage Systems | Installation of Drain Pipes | Instruction sheet
---|---|---
Manual Installation of drains and envelope materials | C.36 | 

Subject: Manual installation of drains

Target group: Field staff, field manager, supervisor

C.36 Manual installation of drains

C.36.1 General

Installation of drain pipes with trenchers is in most cases the most cost effective and quality secure method. Even in low labour cost countries, especially in large-scale projects, the total cost of mechanical installation often turns out to be less than the cost of manual installation. However, there may be situations where equipment is not available, where it is not economically justified to invest in equipment or where the equipment cannot access the site. Under these circumstances manual installation may be the only option. So, for the sake of completeness, an instruction for manual installation is given below.

C.36.2 Procedure and method for manual installation

The procedure for installing pipe drains manually consists of the following steps:

- Setting out alignments and levels;
- Excavating the trenches;
- Placing the drain pipes and envelopes;
- Backfilling of the trenches.

C.36.3 Setting out alignments and levels

Setting out the alignment and the levels of the drains is to be done as follows:

1. Mark the start or downstream end of the drain by placing a peg at the designated place of the outlet or at the connection point with a collector drain;
2. Then, mark the centre line of each drain by placing a peg at the upstream end (Figure C36.1a) of the drain;
3. These pegs are placed in such a way that the level of the top of the peg is at a fixed height above the planned trench bed, whereby the slope of the drain line is implicitly indicated (Figure C36.1b);
4. Draw a chalk line between the two pegs to mark the centre line of the future drain and place a row of sighting rods on the line at 10 m intervals. Next, fix a rope along the sighting rods at the level of the start peg and the end peg. This rope shows the slope of the proposed drain,
not at its actual level but at a fixed height above the design level (e.g., drain depth + the height of the top of the pegs above trench bottom).

**Figure C36.1  Setting out alignments (a) and levels (b)**

### C.36.4 Manual excavation of the trench

**Tools**
Special tools have been developed for manual installation of pipe drains. These tools can facilitate the work considerably. The tools consist of (Figure C36.2):
- Normal and long-blade spades. The blade of the long-blade spade is concave and approximately 70 cm long;
- Drain scoop to smoothen the trench bottom;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- A laying hook to place clay or concrete pipes (only if these are used);
- Auxiliary tools:
  - Correction hook (to correct the alignment of the pipes, only for concrete or clay pipes);
  - Pipe tongs (to remove broken concrete or clay pipes);
  - Soil pincer (to remove earth or debris from the trench bottom);
  - A hoe (to remove hard soil lenses/layers).

If these tools are not available, installation will require some more work, but installation with normal digging spades if the drains are not deep (50-80 cm) is quite possible.

Excavation

Excavation starts from the downstream end so that excess rain or groundwater can be discharged immediately. Excavation should preferably be carried out under dry conditions so that a smooth trench bottom with a uniform gradient can be made. It may be advantageous to wait a few days for favourable weather conditions rather than to install the pipes in muddy soil.

The top part of the trench up to a depth of about 0.5 m can be dug using a normal spade. Best would be a width of about 0.3 to 0.4 m for this upper part of the trench so that a man can stand in the trench to dig the remaining part. The excavated topsoil must to be placed at least 0.5 m away from the trench. This is because this soil often contains organic matter (remains of the crop, roots, etc.) and using it for backfilling immediately on top of the installed drain pipe should be avoided.
The long-blade spade can be used to dig this remaining part of the trench up to the design depth, thereby reducing the amount of earth moving (Figure C36.3). The last 5 cm or so should be removed with care to ensure that the pipes will be laid at the exact slope. If, by accident, part of the trench has been excavated too deep, it should be backfilled and compacted before the pipes are installed. The excavated soil from below 0.4 m must be kept separately from the excavated soil from the upper part. Special care needs to be taken to ensure that the trench bottom is dug at the correct grade, so that the pipe can be installed at the correct grade.

Figure C36.3   Digging a drain trench by hand

C.36.5 Manual installation of drain pipes

Concrete or clay drain pipe installation
If available, a drain scoop and a laying hook can be used to place the drain pipes (length +/- 30 cm) correctly on the bottom of the trench. The other auxiliary tools can also be very useful in this process. Clay or concrete pipes should be laid in such way that they are in line with no gaps left between the pipes.

Plastic pipe installation (pre-wrapped or without envelope)
- Roll the plastic pipes out parallel to the trench;
- Fix the downstream end of the pipe (roll) in the trench by putting some soil on it and hold in place preferably manually - one person;
- A second person carefully puts the pipe in the trench while walking backwards through the trench and keeping a limited tension on the pipe, taking care that the pipe is not twisted or over stressed;
To fix the pipe in place at regular intervals (10 m) put some soil on it; 
At the end of each working day, the upstream open end of the installed drain pipe should 
be protected so that no debris or rodents can enter the pipe overnight.

During installation of pre-wrapped pipes the pipe should be lifted in its totality and not lifted by 
grabbing the envelope to avoid tearing the envelope.

Application of gravel envelope
If a gravel envelope is to be installed the trench needs to be over-excavated (made deeper) equal 
to the thickness of the envelope (7-10 cm).

- After excavation put a layer of gravel on the trench bottom. The thickness of this layer 
  should be in accordance with the design thickness;
- Then, install the pipes on top of the gravel bed as described above, taking care not to 
disturb the envelope;
- Finally, put a second layer of gravel equal the design thickness along the sides and on top 
of the pipes to cover the pipes.

C.36.6 Manual backfill of the trench

To avoid damage it is preferable not to leave open trenches overnight, instead, immediately 
backfill the drain or the part of the drain that has been dug and installed. Before backfilling starts 
the elevation, grade, alignment, thickness of envelope and joints must be verified and broken or 
cracked pipes replaced.

Start backfilling with a layer of about 25 cm to secure the pipe using dry and friable soil. Care 
should be taken to ensure that the drain pipe is not disturbed by the backfill soil either vertically 
or horizontally. For the remainder of the backfill the trench is filled in layers of about 25 cm, with 
light compaction (spreading the backfill and walking over it) in between. Use the topsoil that was 
laid aside during the excavation of the trench for backfilling the last (top) 0.5 m. All debris that 
is not used for backfilling such as larger stones, boulders, plant and root remains must be 
removed from the site.

Backfill and compaction can also be done mechanically by using a tractor, in which case for 
compaction it is sufficient to drive over the trench a number of times with the wheels of a tractor.
C.37 Manual installation in trenches dug by excavators

C.37.1 General

Installation of drain pipes with trenchers is generally considered to be the most cost effective and quality secure installation method. There may, however, be situations where trenching equipment is not available or where large diameter collector drains need to be installed that cannot accommodate the available trenchers. Under such circumstances manual installation of the drain pipes in trenches dug by excavators can be a functional alternative.

C.37.2 Procedure and method for manual installation in trenches dug by excavators

The procedure to install pipe drains manually in trenches dug by excavators consists of the following steps:
1. Setting out alignments and levels;
2. Excavating the trenches with excavators;
3. Placing the drain pipes and envelopes in the trench;
4. Backfill of the trenches.

C.37.3 Required equipment and material

The following equipment and material is required:
- Excavator with the capacity to dig to the required depth;
- Digging buckets for the excavator with widths suitable for the diameter of pipes to be installed;
- Measuring equipment (measuring tapes 50 or 100 m, measuring tapes 5 m, levelling instrument with staff gauge);
- Pump (suction pump preferable);
- Ranging rods and pegs;
- Hand tools (spades, etc.);
- Hoist material if heavy concrete pipes are to be installed;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- Drain pipes, joints, caps, etc.;
- Drain scoop and laying hook, correction hook, pipe tongs and soil pincer if small diameter, 30 cm long concrete or clay pipes are to be installed (Figure C36.2).

C.37.4 Setting out alignment and levels

Setting out of the location and alignment of the drain lines takes place as follows:

1. Ranging rods are placed at the start (downstream) and at the end (upstream) of the alignment of the drain and the locations of the ranging rods secured with pegs;
2. Pegs are placed in the centre line every 10 - 25 m in between the two extreme ranging rods, with the aid of other ranging rods;
3. A second row of pegs spaced around 25 m (or less) is placed parallel to the centre line at a distance of about 10 m from the centre line, either to the left or right;
4. Place a marker peg or benchmark near the downstream end of the drain and determine the level thereof in centimetres in relation to the base level used in the design;
5. Calculate the level difference between the top of the marker peg (or benchmark) and the design level of the bottom of the trench (= depth of the drain) at the downstream point (start point) of the drain line;
6. Determine the level of the top of the pegs in a line parallel to the centre line;
7. Calculate the required bottom depth of the trench below the head of each peg;

\[(\text{Level peg head (cm)} - \text{level of benchmark (cm)}) - (\text{level of drain trench at start (cm)}) + (\text{Distance between peg and start of drain line (m)} \times \text{required slope (cm/m)})\]

8. Clearly note the level (cm below top of peg) of the trench bottom near each peg.
   (It is also possible to place all the pegs on the parallel line at a prefixed level, for instance, 2 m above the desired bottom of the trench. This requires a considerable amount of work that can be avoided if a levelling instrument is available during construction.)

C.37.5 Organisation of the process

The installation process is to be organised in such a way that the installation of a drain or a part thereof is completed in one day, meaning that the excavation, installation and backfilling are all completed in the same day. If the full drain line is not completed in one day, the installed drain pipe must be capped so that no dirt or water can enter it.

\[^1\]

\[^1\] If laser equipment is available a laser reception mast can be mounted on the bucket of the excavator. The operator of the excavator can monitor the digging depth, in which case the laser transmitter has to be set at the appropriate slope and the mast on the bucket extended so that when the bottom of the bucket is at the required depth of bottom of the trench a green light lights up on console of the laser.
C.37.6 Excavation of the trench

1. Select the required digging bucket (width as close as possible to diameter of drain + 10-20 cm);
2. Make arrangements so that water flowing in the trench can be removed, either through an outlet by gravity flow or by pumping (if groundwater is expected);
3. Place the excavator at the downstream side of the drain line in the centre line so that it can be driven backwards to excavate the trench;
4. Place a levelling instrument in the parallel line of the pegs and regularly check to see that the trench is at the required depth making use of the levels of the pegs in the parallel line;
5. Start digging: deposit the excavated soil of +/- the top 40 cm on one side of the trench and the remainder on the other side of the trench;
6. Removal of the bottom layers is to be done carefully to avoid over excavation;
7. If water starts flowing let it flow out of the trench immediately or pump it out;
8. Move the excavator backwards to dig the next part and repeat the process;
9. Verify with the levelling instrument the level of the trench bottom every 5 m or more often;
10. If by error the trench bottom is over excavated, the over excavated part must be filled up again to the right level with dry soil in thin layers that are carefully compacted.

C.37.7 Manual installation of drain pipes

Installation of small diameter 30 cm concrete or clay field drain pipes
The installation must be commenced from the downstream end and the first part of the drain directly connected to the outlet, be it a direct outlet, a manhole that connects to a collector drain or a sump.
The drain scoop and laying hook, if available, are used to place the drain pipes in the trench. If available, auxiliary tools can be used like: (i) a correction hook to correct the alignment of the pipes; (ii) pipe tongs to remove broken pipes; and (iii) a soil pincer to remove earth or debris from the trench bottom. Clay or concrete pipes should be laid in the trench in such way that they are in one straight line with no gaps left between the pipes.

Installation of plastic field drain pipes installation (pre-wrapped or without envelope)
1. Roll the plastic pipes out parallel to the trench;
2. Fix the downstream end of the pipe (roll) in the trench by putting some soil on it and preferably manually hold it in place - one person for the job;
3. A second person carefully puts the pipe in the trench while walking backwards through the trench and keeping a limited tension on the pipe, taking care that the pipe is not twisted or over stressed;
4. Put some soil on the pipe at regular intervals (10 m) to keep it in place;
5. At the end of each working day, the upstream open end of the installed drain pipe should be protected so that no debris or rodents can enter the pipe overnight.
During installation of pre-wrapped pipes the pipe should be lifted in its totality and not lifted by grabbing the envelope so as to avoid tearing the envelope.

C.37.8 Installation of large diameter concrete collector pipes

Larger concrete collectors in lengths of 0.8-1.0 m are also installed starting from the downstream end in an upstream direction.

- The bottom of the trench should be nominally dry and stable. If the bottom is muddy first place a layer of 5 cm of gravel or sand on the bottom of the trench;
- If the pipes cannot be manually handled they need to be hoisted with a hoist on the digging bucket of the excavator and lowered into the trench. When this is being done a person needs to stand in the trench to guide the pipe to the right spot;
- If the pipes are equipped with spigot and groove joints, the pipes should be firmly pushed together. If an asphalt based kit is available this could applied in the grooves before the pipes are pushed together;
- If there is no special provision at the joints and to avoid leakage, a burlap or jute cloth can be put over the joint and fixed with asphalt;
- Immediately after installation partly backfill the trench by carefully filling up the bottom part and thus fixing the pipes in place.

C.37.9 Application of gravel envelope

If a gravel envelope is to be installed the trench should be over excavated (made deeper) equal to the thickness of the envelope (7-10 cm).

1. After excavation put a layer of gravel on the trench bottom. The thickness of this layer needs to be the design thickness;
2. Pipes are installed on top of the gravel bed as described above, taking care that the envelope is not disturbed;
3. Put a second layer of gravel applied along the sides and on top of the pipes so that there is a cover over the pipes equal to the design thickness.

C.37.10 Backfilling and compaction

The trench can only be backfilled after verification that the levels, grade, alignment, joints and thickness of the envelope comply with the norms and/or specifications. Moreover, a check is to be done to see that there are no broken or cracked pipes.
Quality of backfill soil
Backfilling can best be done by dry, friable soil. Stones, wood, trunks or soil clogs in the excavated soil should not be used for backfilling and can best be removed from the site. Start the backfilling with the soil that came from the bottom part of the trench that was kept separate. Once all this soil has been used up finish the backfill with the soil excavated from the upper surface.

Backfill method
Backfilling can be done both mechanically and manually. In the case of large collector drains the first part of the backfilling up to the top level of the pipe should be done manually. Initially, the bottom sides of the pipes have to be filled, carefully avoiding the displacement of the pipe.

For all pipes
- The initial backfilling is considered to be backfill up to 30 - 50 cm above the pipe. This backfill needs to be placed in thin layers (15 cm) that are carefully compacted by hand, while avoiding the displacement of the pipe or damage/disturbance to the envelope;
- Backfilling of the top part starts 30 - 50 cm above the top of the pipe. The top part can be backfilled mechanically preferably also in layers of 15 - 20 cm that are individually compacted. The wheels of a tractor driven over the trench can do compaction of the last layer.

All available soil (suitable) is to be used for backfilling. Overfill of the trench resulting in a small bund or hill on top of the drain line will compensate for the inevitable subsidence that will eventually occur.
C.38 Wrapping a synthetic sheet envelope around the pipes in the field

C.38.1 General

If synthetic envelopes are used, these are usually pre-wrapped in the factory. If the need arises (experimental fields) and the so-called ‘nylon sock envelopes’ can be used, these can be wrapped around the drain pipes with simple tools in the field. If the envelope is in the form of sheets, these can be folded around the pipe with a longitudinal overlap of at least 15 cm and later sown or fixed by thread.

C.38.2 Wrapping at the site

The wrapping of around synthetic fabric material around the pipe in the field is done as follows (Figure C38.1):

- Check the fabric material visually for any cuts, tears or other damage;
- Testing of envelope material is required periodically in the laboratory to make sure it complies with the specifications. A record should be maintained of the brand name, nominal weight per square metre and date and time of receiving. Tests for other specifications are expensive and require specialised equipment that may not be available locally but should, however, be performed for each supply received;
- The seam of non-woven fabric should be lapped, folded and stitched properly with polyester thread;
- The fabric should be loose enough around the pipe to avoid stretch, yet tight enough to ensure it does not restrict pipe travel through the installation equipment;
- Before pulling the fabric around the pipe check the pipe for damages. If necessary remove the damaged parts of the pipe;
- The actual hand wrapping is to be done by pushing the sock over the pipe, not by pulling it. Pulling can cause excessive stretching and consequently damage of the sock. In the process the pipe is to be properly fixed;
- Fabric should not be installed on non-perforated or damaged pipe.
Figure C38.1  Wrapping of drain pipe at the site
II-D

Practical aspects of quality control
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

General

The practical aspects of quality control during and directly after the installation process are discussed in the following sections. It includes what needs to be checked, when to check and the consequences if deficiencies turn up. The sections have been written under the assumption that the supervisors directly or indirectly carry out the checks passively or actively. The responsibilities of all persons involved in the quality control process is not dealt with here but in Part I, Chapter 8 of this handbook.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

D.1 Quality control of drainage materials

D.1.1 Quality control of corrugated plastic drain and collector pipes

Quality control of corrugated drain and collector pipes consists of at least 5 checks during the installation process:

<table>
<thead>
<tr>
<th>Check</th>
<th>Where</th>
<th>What to check</th>
<th>Consequence if deficient</th>
</tr>
</thead>
</table>
| 1     | In factory before transport (note) | a) Pipes against norms  
b) Pipes stored in shade  
c) Supply conform order | a) Reject total lot  
b) Reject total lot  
c) Reject bad pipes only |
| 2     | On site in depot after transport | Damage during transport  
Storage in shade | Take out damaged pipes return to factory or repair immediately |
| 3     | In the field after distribution | Damage during transport | Take out damaged pipes or repair small damages |
| 4     | Just before installation on machine | Small damage, and strength at the connections | Stop machine, repair or replace |
| 5     | After installation in trench | Small damage  
Lose connectors | Dig up and repair damage or connection |

Note: The check in the factory consists of:
- Checking whether the pipes have been produced according to the specified norms (ISO, NEN, DIN, ASTM or other) and if a certificate of an independent entity is available. If there are no independent entities find out who can professionally do the checking and issue certificates, and check the internal production quality control reports of the factory;
- Verification during the production that the checks and tests are carried out according to the norms may be called for. Detailed descriptions of the checking procedures are given in the norms (see Part I, Chapter 4).

A visual check in the factory of the produced pipes can consist of:
- Evenness of thickness (discolorations);
- Perforations;
- Dimensions;
- Stiffness/flexibility;
- The production date of the pipes (not older than approx. 3 months);
- Storage of pipes after production away from sunlight;
- Check lot against order (quantity, length of perforated, non-perforated pipes, etc.).
D.1.2 Quality control of cement or clay drain and collector pipes

Quality control of cement or clay drain and collector pipes consists of at least 5 checks during the installation process:

<table>
<thead>
<tr>
<th>Check</th>
<th>Where</th>
<th>What to check</th>
<th>Consequence if deficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In factory before transport or on the site after production (note)</td>
<td>a) Pipes against norms</td>
<td>a) Reject total lot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Pipes not broken or chipped</td>
<td>b) Reject damaged pipes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Supply conform order</td>
<td>c) Instruct to correct before acceptance</td>
</tr>
<tr>
<td>2</td>
<td>On site in depot after transport</td>
<td>Damage during transport</td>
<td>Take out and destroy damaged pipes or return to factory</td>
</tr>
<tr>
<td>3</td>
<td>In the field after distribution</td>
<td>Damage during transport</td>
<td>Take out damaged pipes</td>
</tr>
<tr>
<td>4</td>
<td>Just before installation on machine</td>
<td>Small damages</td>
<td>Take out damaged pipes</td>
</tr>
<tr>
<td>5</td>
<td>After installation in trench</td>
<td>Damage</td>
<td>Dig up and correct connections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loose connections</td>
<td>Replace damaged pipes</td>
</tr>
</tbody>
</table>

Note: The check in factory consists of:
- Checking to see if the pipes have been produced according to the specified norms (ISO, NEN, DIN, ASTM or other) and if a certificate of an independent entity is available. If there are no independent entities find out who can professionally do the checking and issue certificates.

The following checks are required during production process:
- For cement pipes: the dosage, the mixing/vibration process and the curing process;
- For clay pipes: mixing and wetting of the clay, extrusion of the clay, cutting of the ends of pipes (straight!), baking process time and temperatures. Detailed descriptions of the checking procedures are given in the norms.

A visual check in the factory of the produced pipes can consist of:
- Evenness of thickness of pipes;
- Round form of pipe (not oval!);
- Straightness and smoothness of the ends;
- Dimensions;
- Breakage, cracks and chippings;
- Check lot against order (quantity, packing, etc.).
D.1.3 Quality control of gravel envelope

Quality control of the gravel envelope material consists of at least 3 checks during the installation process:

<table>
<thead>
<tr>
<th>Check</th>
<th>Where</th>
<th>What to check</th>
<th>Consequence if deficient</th>
</tr>
</thead>
</table>
| 1     | In quarry before transport | a) Grading (note 2)  
b) Quantity  
c) Cleanliness | a) Grading: reject until re-graded  
b) Quantity: correct, or pay less  
c) Cleanliness: reject until cleaned |
| 2     | On site in depot | a) Unloading & storage  
b) Cleanliness (note 6)  
c) Grading (note 1.3)  
d) Quantity (note 4)  
e) Loading (note 5) | a) Correct (note 5)  
b) Clean, remove dirt  
c) Remix and try to correct  
d) Note and report adjust payment |
| 3     | In the field on trailer before application | Cleanliness | Remove dirt |

Notes:
1. **General.** The grading of the gravel is extremely important. The mixing of the gravel may be undone by vibration during transport (larger particles separate from smaller particles). This may be corrected by remixing the gravel.

2. **Inspection at quarry**
   - **General inspection**
     - Check the results of the quality control (sieving curves) of the supplier.
   - **Visual inspection on all loads before transport**
     - If particles larger than the maximum allowed or smaller than the minimum allowed (dust) are present, the loads should be sieved again;
     - Check cleanliness of the loads.
   - **Detailed inspection at random**
     - Take a 1 kg sample of each 100 m³ of gravel (approximately 25 truckloads), and carry out a sieve analysis in the laboratory;
     - Compare the gradation curves against the given specifications;
     - If grades do not comply with specifications sieving of the gravel should be done again before transport.

3. **Inspection at field depot**
   - **General inspection on all gravel**
     - Inspect visually before unloading. If visually not according to standards (cleanliness) reject the load;
     - After unloading inspect that all gravel is graded as when loaded in the quarry (no clear separation in coarse and fines as a result of transport) this can be checked by eye;
     - Cleanliness of gravel should be inspected to see:
       * Whether contaminated by dust (if so, change transport procedures and clean affected loads);
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

• Whether clay or organic material has entered (clean this by hand).
• Quantity of gravel by: number of trucks and filling level of the trucks.

- Detailed inspection
  - For analysis in the laboratory, take samples randomly over time approximately 1 sample every 100 m³ after normal deposit procedures, and two samples in bottom and top of deposited pile;
  - Compare grading of the two samples;
  - If there are discrepancies in consistency, improve field-mixing procedures.

4. Quantity. The quantity of gravel loaded in the quarry and the quantity on arrival needs to be checked and recorded. This can be done by counting truckloads and by measuring the contents of the truck. Payment should be either:
   - Against quantity loaded in the quarry, client is responsible for transport, or;
   - Against quantity received in the field, if supplier is responsible for transport.

5. Cleanliness. If there is a doubt about the presence of mud and silt (for instance, when the gravel is dry) a simple test can be carried out: mix a small sample with fresh, clear water. If there is mud and silt in the sample, this will float on the water and will be visible immediately.

D.1.4 Quality control of synthetic envelopes

Quality control of synthetic envelopes should take place simultaneously with the control of the pipes. The quality control is to be carried out with at least 5 checks during the installation process:

<table>
<thead>
<tr>
<th>Check</th>
<th>Where</th>
<th>What to check</th>
<th>Consequence if deficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In factory before transport (note 1)</td>
<td>a) Material used complies with specifications/norms&lt;br&gt;b) Enveloping is done according to norms with specified thread&lt;br&gt;c) Supply against order</td>
<td>a) Reject total lot&lt;br&gt;b) Reject total lot&lt;br&gt;c) Reject total lot or insist on correction</td>
</tr>
<tr>
<td>2</td>
<td>On site in depot after transport (note 2)</td>
<td>Damage during transport</td>
<td>Take out pipes with damaged envelop, return to factory or cut out damaged parts</td>
</tr>
<tr>
<td>3</td>
<td>In the field after distribution</td>
<td>Damages during transport</td>
<td>Take out pipes with damaged envelopes, or cut out damaged parts</td>
</tr>
<tr>
<td>4</td>
<td>Just before installation on machine</td>
<td>Small damage</td>
<td>Stop machine, repair or replace</td>
</tr>
<tr>
<td>5</td>
<td>After installation in trench</td>
<td>Damage</td>
<td>Dig up and correct or repair damage</td>
</tr>
</tbody>
</table>

Notes:
1. The check in the factory consists of: Checking whether the manufactured envelope and the enveloping process comply with the specified norms (See Part I, Chapter 4) and if a certi-
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Each check of an independent entity is available. If there are no independent entities that can professionally do the checking and issue certificates, then check:

- The specifications of the material and the guarantees of the producers of the base material;
- The specifications of the fixing thread and the guarantees of the producers of the thread;
- Evenness of thickness of the envelop;
- Tightness of the fixing thread;
- The date of enveloping the pipes (not older than approx. 3 months);
- Storage of pipes after enveloping away from sunlight;
- Check lot against order.

2. Check whether storage in the field is done in the shade.

D.1.5 Quality control for prefabricated structures

Quality control of prefabricated structures should consist of at least 3 checks during the installation process:

<table>
<thead>
<tr>
<th>Check</th>
<th>Where</th>
<th>What to check</th>
<th>Consequence if deficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In factory before transport</td>
<td>a) Dimensions (note 1)</td>
<td>a) Reject</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Concrete quality (note 2)</td>
<td>b) Reject</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Chipping/broken</td>
<td>c) Reject</td>
</tr>
<tr>
<td>2</td>
<td>On site at arrival</td>
<td>a) Breakages</td>
<td>a) Return or refuse to accept</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Chippings</td>
<td>b) Small chippings acceptable</td>
</tr>
<tr>
<td>3</td>
<td>After installation</td>
<td>a) Breakages</td>
<td>a) Remove and install other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Chippings</td>
<td>b) See if repair is possible, repair with cement</td>
</tr>
</tbody>
</table>

Notes:
1. Dimensions: Includes checking of dimensions, holes made for field drain and collector pipes. Compare against specifications and orders;
2. Compare quality with specifications.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS
D.2 Quality control of installation of pipe drainage systems

D.2.1 Field layout and levels

What to control
Before installation, check that pegs have been placed at the start and end of the drain lines (field drains and collectors) in accordance with the design. Pegs with known levels should be placed at crucial points (downstream end of field drains and collectors). These level pegs form the basis for the design start levels of the drains. The location of the future drains and the levels must both be checked.

How to check
The check can be carried out by verifying if the staked out layout is in agreement with the design and by checking the levels.

Observation
If discrepancies are observed (drains not located in logical places) and levels do not turn out to be realistic, corrections must be made immediately and before construction starts, preferably together with or by the design group. It is better to double-check the corrections to ascertain that the result does not interfere with the logic of the design or the design criteria.

D.2.2 Installation of plastic field and collector pipes

What to control and norms
Quality control of the installation of field drains and collector pipes consists of control of:

- Levels: check starting levels (downstream) of the pipes against the design allowing for minimal deviations. This is especially important for composite systems since a mistake in one level can have repercussions on the levels of the whole system;
- Grade: the grade set at the laser must agree with the design;
- Connections: pipe sections must be properly connected for obvious reasons. During installation if too much tension is exerted on the pipe and/or if the connections are not properly made, the connections may become undone;
- Alignments: must be in accordance with the design, small deviations do not normally cause much problems;
• Horizontal straightness: the pipes should not zigzag in the trench as this will hinder flow and entrance of the flusher for cleaning;
• Vertical grades and levels: should be conform the design with a maximum deviation from the straight line of approx. 0.25 x the pipe diameter and no negative slopes;
• If a gravel envelope is used: check correct application of gravel around the pipe/adequate coverage on top of the pipe;
• For synthetic envelopes: check for damage to envelope during installation.

How to control
During installation: A thorough check during installation is the most effective. All discrepancies can then be seen and corrections can still be made relatively easily. After installation the only way of correction is mostly by reinstalling the drain. The simplest and most practical control during installation is to check:
• The levels (starting level) using a levelling instrument just before the trencher starts installation;
• By hand the strength of the connections of the pipe sections;
• The alignment and the horizontal straightness visually (Figure D2.1a):
  - Alignment by verifying the start and end from the maps or specifications;
  - Horizontal straightness during installation by checking if the pegs have been properly placed and that the operator follows the staked line. After installation check the straightness of the trench.
• The vertical grades and levels by measuring the elevation of the installed pipe every 5-10 m with a levelling instrument, directly behind the trencher\(^1\) (see D.4, and Figure D2.1b);
• The gravel envelope application visually, by direct observation in the trench of the outflow of gravel and the coverage of the pipe and, indirectly, to see if there is a regular flow of gravel from the hopper;
• Synthetic envelope application visually in the trench, looking for damage.

Corrective measures and prevention
• Horizontal straightness: If (plastic) drain pipes meander in the trench this can be caused by:
  - Not enough stress on the pipe during installation. More stress must be maintained on the plastic pipe during installation because horizontal straightness cannot be corrected once pipe is installed;
  - Quality of the pipe (extensibility, straightness: if during production process pipe is not cooled enough before it is coiled or stored). Improve quality control of pipe. No correction possible.
• Vertical grade: If excessive deviation of the prescribed grade is noted the only solution is to dig up the section and correct it manually. To prevent deviations:
  - Adjust digging chain/trench box;

\(^1\) Can only be done if trenchers are used.
- Adjust slip clutch;
- Laser management (closer spacing of the transmitter, prevention of wind impact on transmitter);
- Operator management (adjust speed of installation in case of hard layers, unevenness of field, gravel supply. No stopping during installation).

Gravel envelope: Correct inadequate application of gravel around the pipe by digging up and applying gravel by hand. If there is too much gravel around the pipe, adjust the gates for the gravel supply (above and below the drain). To prevent problems with gravel application:
- Correct adjustment of gravel gates depending on size of gravel and speed of installation;
- Improve cleanliness of gravel;
- Improve regular supply of gravel to hoppers.

### D.2.3 Installation of concrete collectors

Quality control for the installation of concrete collectors is basically the same as for plastic collectors, with the following adjustments:

#### Levels
Since the pipe sections are prepared in lengths of 0.75-1.0 m, the control of the levels needs to be intensified, meaning that the level needs to be measured at both sides of each pipe section using a levelling instrument.
Alignment
Since with concrete pipes the number of joints per drain line is considerably larger than with plastic pipes, the alignment of the pipes must be checked carefully with regard to water tightness of the joints. This can be checked visually to ascertain whether the top levels of the end of the earlier section and the start of the new section are the same. The visual check should also focus on the underside of the pipes.

Stability of the pipe sections
Concrete pipes are heavier and require stable bedding in the alignment otherwise the individual pipe sections can easily become dislocated during backfilling. Check this visually and do a second check during backfilling after the backfilling has been completed up to half the Ø of the pipe, to be sure that no dislocation of the pipes had occurred as a result of backfilling.

D.2.4 Backfilling of trenches
What to control:
Check if all the trenches are properly closed and if there is some extra soil heaped on the alignment of the trenches to allow for subsidence.

How to control:
Visual control and testing of compaction by pushing a testing rod or ranging rod into the trench.

Corrective measures:
Extra compacting with extra soil on top of former trench, very slow application of irrigation water, especially during the first irrigation.

D.2.5 Quality control installation of prefabricated manholes and sumps
What to control
• The levels of the entry holes for collector and drain pipes
  Norms: Maximum deviation from design 1-2 cm - measure with levelling instrument.
  Correction: Dig under the manhole or pushing down the manhole with the excavator. If the manhole is too low: push soil or gravel under the manhole (lift first the manhole with the excavator).
• The level of the manholes/sumps
  Norms: Maximum deviation on the ring: 1-2 cm - measure with carpenters level.
  Correction: Dig under the manhole or push down with excavator.
• The integrity of the manholes/sumps (no breakage, no excessive chipping)
  Norms: No breakage allowed, chippings should not threaten structural strength or expose reinforcement steel - visual inspection.
  Corrections: Repair with cement or replace.
• Water tightness of the connections of field drains/collectors to manholes/sumps
  Norms: No water may enter the manholes otherwise than through the collector pipes/field drains. Check: (i) Visual check for flow; (ii) indirect: check if silt on top of pipes; (iii) manholes fill up with water if field drains are not running.
  Correction: Repair with sleeve of cement around pipe. Try first to repair on the inside if it does not work, dig out and repair on the outside with cement sleeve.

• Water tightness of the joints of rings of concrete manholes/sumps
  Norms: No water may enter through joints. Check: (i) visually for flow; (ii) indirectly to see if much silt is in manhole/sump; (iii) to see if manhole fills up with water if field drains are not running.
  Correction: Make watertight using cement.
  Prevention: During installation, place sheet of plastic around joint and tighten with iron wire.

• Aboveground manhole/sump placed well above field level
  Norm: > 50-60 cm above field level - visual inspection.
  Correction: Increase level with one ring - keep rings of approx. 50 cm height in stock.

• Belowground manhole placed well below field level
  Norm: Below at least the ploughing depth (as per specification) below field level - visual inspection.
  Correction: Remove rings or replace rings with rings of less height.

• Protective soil hill above ground around manhole/sump (Figure D2.2)
  Norm: A soil hillock around manhole/sump to prevent damage by tractors - visual check.
  Correction: Add soil.

• Cover in place and not broken
  Norm: Cover to be in place and stably installed - visual check.
  Correction: Place, repair or replace cover.

• End of plastic collector/drain pipes inside manhole/sump smoothened and cut off at acceptable length
  Norm: Length of pipes inside manhole approx. 10 cm and smooth to prevent cutting of hose while flushing - visual check (Figure D2.2).
  Correction: Cut to length and smoothen by filing.

• Manhole clean, no silt
  Norm: Clean and no silt inside.
  Correction: Clean out.
D.2.6 Quality control of installation of pumps

Quality control of the installation of pumps depends very much on the quality norms of the manufacturer. Items needing attention too are:

- Pump installation level;
- Electric connection protected against water;
- Electric lines safely installed;
- Switches in place and well adjusted;
- Outlet protected.
D.3 Checking the functionality of composite drainage systems

D.3.1 What to Check

Once a composite drainage system has been installed in its entirety including the whole system of field drains, collector drains, manholes and sumps and pumps, its functioning requires to be checked as soon as possible. The methodology for the checking is described in the sections below.

D.3.2 Principles of the checks

In first instance one has to check in the manholes if all the collector drains and field drains are flowing at capacity\(^1\). If there is no flow or only a limited flow, first check the quality control of drain installation to verify that the grade of the drains have been installed at the correct grade. If not, first repair the location where the grade is not acceptable. When done and corrected:

- Check if there is a silt build-up in the sumps;
- Check water levels in manholes (Figure D3.1). If the water is high in a manhole and not in the manhole situated downstream of it, there must be an obstruction in the stretch downstream of the manhole where there is no flow. Then,
  - If the water is high in the field drain manhole and the water is flowing at the end of the field drain, there is an obstruction in the field drain between the collector and the field drain manhole, in which case flush out the field drain;
  - If no water is running from the field drain in the collector manhole or the field drain manhole and there is a high groundwater table, flush out the upstream end of the field drain first and later the bottom end.

---

\(^1\) If groundwater is below drain level there will generally be no flow. Verify if the groundwater level is below drain level. If this is the case the check should be done during the following irrigation season or wait for rain.
D.3.3 Methodology for checking the functionality of collectors

Checking procedures
1. Open all collector manholes and the sump (in case of a pumped outlet);
2. If not yet installed, put a pump in the sump and start pumping (if the drains are flowing start pumping the day before). In case of a gravity outlet be sure that the outlet can flow freely.

Figure D3.1 Principles of checking functioning collector system

Figure D3.2 Example of water levels in collector line in case of proper functioning
3. Wait till the water is in balance (if pumping, then keep pumping);
4. Measure in each manhole the bottom level of each collector pipe (top level minus outside diameter of the collector pipe);
5. Check if the bottom levels of the collector pipes are in a regular line. The slope of the line should approximate the design slope of the collector;
6. Measure the water levels in each manhole;
7. Plot the water levels and the pipe levels in the manholes as absolute levels:
   - If the field drains are flowing and the water level is as indicated in Figure D3.2 there are no problems and the system is functioning properly;
   - If the water level is as indicated in Figure D3.3, there is an obstruction between manhole 2 and 3.

If there is no water flowing from the field drains:
   - And the water level is almost horizontal or in line with the slope of the collector, most likely there is no obstruction in that part of the line;
   - And the water level shows a discontinuity it also implies that there is an obstruction upstream of this discontinuity.

**Correction of collectors**

If there is an obstruction:
1. Flush upstream with the flusher from the downstream manhole and clean the collector pipe.
   - If the flusher hose cannot proceed, then you know where the obstruction is. If it cannot be cleared by flushing, mark the location (measure the length of hose in the collector pipe);
2. The only solution now is to dig up the collector and try to remove the obstruction by hand.

---

**Figure D3.3  Example water levels in collector line in case of obstructions.**
D.3.4 Checking field drains

Observations
1. Open the manholes (field drain manhole and collector manhole);
2. Start pumping (in case of a pumped outlet). In case of a gravity flow outlet be sure that the outlet can flow freely;
3. Wait till the water is in balance (if pumping, then keep pumping);
4. Measure in each manhole the top level of each field drain pipe;
5. Check if the bottom levels of the field drain pipes show a regular line. The slope of the line should approximate the design slope of the drain;
6. Measure the water level in each manhole;
7. Plot the water levels and the pipe levels in the manholes as absolute levels.

Interpretations
Interpretation of the observations for field drains is similar to the methodology for collector drains.

Corrections
If there is an obstruction:
1. Flush upstream with the flusher from the downstream collector manhole and clean the drain pipe. If the flusher hose cannot proceed, then you know where the obstruction is. If it cannot be cleared by flushing, mark the location (measure the length of hose in the field drain pipe);
2. Repeat the activity stream upwards from the field drain manhole;
3. If the flusher cannot clean out the drain and/or clear the obstruction, the only solution is to dig up the drain and try to remove the obstruction by hand.

Note:
In case there are no field drain manholes, only the flow of those field drains discharging into the collector manholes can be checked visually. If no water is running from the field drain into the collector manhole and there is a high groundwater table, flush out the field drain.

D.3.5 Final field check before completion

All is complete only after a final field check has been performed and includes checking that:
• All trenches are properly closed and soil of starting holes levelled;
• All remaining materials have been removed from field (pipes, manholes, broken manholes etc.);
• Functioning of the field drains have been checked;
• Functioning of the collector system have been checked;
• All manholes cleaned and closed;
• Pump functioning and well adjusted;
• Farmers instructed in maintenance.
D.4 Methodology for checking the grade of installed drain and collector pipes during installation

D.4.1 General

The field drain and collector pipes are installed with the trenchers using laser control for assuring the design slope/grade of the pipes. Installing the drain pipes at the right grade is essential to assure a correct functioning drainage system. Deviations from the grade may result in reduced or no flow in pipes, air locks and so forth.

Based on extensive research the maximum acceptable deviation from the design grade has been determined as follows:
- \( \pm \frac{1}{4} \) or \( \pm \frac{1}{3} \) of the diameter of the drain pipe;
- No negative slopes.

Should there be faults outside the tolerances stated above, repairs have to be carried out only if:
- Deviation is more than \( \frac{1}{4} \) of the diameter (thus \( >20 \) or \(-20 \) mm of the design grade in case of an 80 mm \( \varnothing \) pipe);
- Negative slope shows a deviation of more than \( \frac{1}{2} \) of the \( \varnothing \) (thus \(+40 \) mm of the design grade in case of an 80 mm \( \varnothing \) pipe).

From the point of view of flow it can be stated that the pipe is functional:
- As long as the pipe has an average slope that is at or higher than the design slope;
- If there are no negative deviations of more than \( \frac{1}{4} \) of the \( \varnothing \) of the pipe.

Since the laser is an aid and does not provide absolute security and the installation may be less than ideal especially in unstable subsoils, a continuous check on the grade and slope of the pipe is recommended. If, as a result of the check, it turns out that there is a serious problem, corrective measures need to be taken immediately. If the problem is not detected at an early stage, it will be considerably more troublesome to correct later when the drain will need to be dug up.
D.4.2 Methodology

D.4.2.1 General

Quality control on drain slopes is carried out during or immediately after installation by measuring the level of the top of the drain every 5 m. This means that the surveyor’s measurements are done directly behind the trencher.

D.4.2.2 Placing of the levelling staff

If the drain pipe is covered with gravel measuring on top of the gravel may give uneven results. Digging with the levelling staff in the gravel may leave the surface of the pipe at that particular spot uncovered by gravel, which can cause inflow of silt into the pipe later on. To avoid this fit the bottom of the levelling staff to a special shoe (Figure D4.1). In this way the gravel cannot be disturbed.

![Figure D4.1 Placing of the levelling staff](image)

In the case of trenchless drain installation a detection probe can be used (Figure D4.2). The levelling staff is put on top of this drain probe.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Placement of levelling instrument
The levelling instrument should be placed as close to the trench as possible and measurements taken first backwards then forwards (Figure D4.3). When the levelling staff is out of sight replace the instrument forwards and maintain, in the meantime, the level with the levelling staff.
Measuring at every 5 or 10 m
This can be done by measuring with the levelling staff.

Reporting
A reporting form model is attached (Table D.4-1)

Table D.4-1 Reporting form

<table>
<thead>
<tr>
<th>Field: Drain no: Manhole/sump</th>
<th>Date: Drain machine Driver:</th>
<th>Surveyor: Page 1/2/3/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start from:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level at:</th>
<th>Reading</th>
<th>Level at:</th>
<th>Reading</th>
<th>Level at:</th>
<th>Reading</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 m+</td>
<td>100 m+</td>
<td>200 m+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>30</td>
<td></td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>40</td>
<td></td>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td></td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>55</td>
<td></td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>65</td>
<td></td>
<td>65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>70</td>
<td></td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>75</td>
<td></td>
<td>75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>80</td>
<td></td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>85</td>
<td></td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>90</td>
<td></td>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Processing of data
Process the results the same day in a spreadsheet and make a graph, marking on it the design slope and the upward and downward deviations. In this way one can see directly if the drain has been properly installed. A sample of the results of quality checking of the grade of drains is presented in Figure D4.4. The graph shows that the drain level fluctuates up to 200 m from the start within the acceptable range. After 200 m the slope becomes steeper but there is no negative slope and the flow will not be interrupted. However, the drain depth is 5 cm less than designed. The drain is of acceptable quality. The operator must take care in the future not to start lifting the trench box too early and only during the last 10 m or so of the drain.

Figure D4.4 Example of result quality checking of the grade of the drains
D.5 Post construction verification of drain pipes

D.5.1 Introduction

Once a drain is installed and covered with backfill, no visual inspections are possible. The same is true for drain pipes installed with trenchless drainage machines. The two techniques developed for checking the correct installation of drains under these conditions are Rodding, Continuous depth recording and Video inspection. As described in Part I Chapter 7.5 these checking methods are rather complicated and time-consuming and more suited for research purposes and pilot projects than for routine installation. Instructions for the rodding and continuous depth recording are given in the sections below.

D.5.2 Rodding

D.5.2.1 General

Rooding is a technique to check whether there are abrupt disturbances in the drain line, such as broken pipes, loose couplings and sharp changes in the slope. Besides checking for problems with functioning of the drain, the technique can also be used to determine if the drain will be accessible for flushing. The rodding method cannot be used to check the grade of the drain line. Rodding was developed to test drains in a singular drainage system, but the technique can also be used in composite systems with special arrangements for access to the field drain (Figure D5.1).

D.5.2.2 Testing protocol

In principle, every single drain can be tested, but this will be rather expensive. Hence, it is advisable to randomly test only a limited number of drains, for example, 10% of the drains. Testing can be increased if the number of drains that fail the test exceed a prescribed percentage. The number of drains to be tested, the method and whether or not the malfunctioning drains have to be replaced can be specified in the contract or instructions.
D.5.2.3 The rodding equipment

The rodding systems consist of a steel rod with a torpedo shaped tip. The steel rod is screwed to a long fibreglass rod. The length of the fibreglass rod is 300 - 400 m. A probe for radio detection can be attached to the tip of the steel rod. The fibreglass rod is wound on a reel. The reel can be transported, attached to a tractor or it can be rolled over the ground surface on the outer ring of the cage with the coiled rod (Figures D5.2).

Use:
- The reel should be put in the correct position at the beginning of the drain line which will be checked;
- The top end of the fibre-glass rod is put through the white plastic rings;
- During transportation of the reel by rolling, the rodding head and/or probe cannot be attached to the fibreglass rod, and the rod should be out of the white plastic rings;
- A piece of metal pipe with screw-thread is attached to the tip of the fibreglass rod;
- Torpedo-shaped tips of different diameter can be attached to the rod;
- The screw-thread should be clean and not damaged;
- The torpedo-shaped tips have screw-thread on both sides;
- The screw-thread at one side can be used for attaching a probe for radio detection;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- The rod is pushed manually into the drain pipe over its entire length starting at the outlet (Figure D5.2a).

Figure D5.2 Rodding equipment attached to the tractor (a) and transported in the field by hand (b)
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Location of a disturbance
Locating aboveground the spot where the rodding head came up against an abrupt disturbance can be done by:
- Fitting a counter on the fibreglass rod for distance measurement, or;
- Fitting a probe to the rodding head when the location of the probe can be measured directly via a radio detection device.

The site of the disturbance has to be marked in the field and/or on a map. Its location can then be traced later on for the purpose of excavation and repair.

D.5.2.4 Functioning of the rodding systems
If the drain has been correctly installed, the rod can pass unhindered but the required pushing force increases slightly with the length of the drain. If the drain spirals, however, the required pushing force increases considerably with the length of the drain. The required force should not exceed a pre-set limit¹ (Table D.5-1), because the misalignment of the drain will mean that cleaning the drain using a flusher will not be possible (Figure D5.3). Consequently, the quality of the drain installation will not be acceptable and the drain will need to be reinstalled. The same applies if the rod cannot pass a particular point in the drain because there is a fault in the installation, when the drain will have to be excavated at this point. The maximum drain length that can be checked by rodding is 400 m.

¹ The norms have been developed for singular drainage systems. For composite drainage systems no norms have been developed, and rodding is used to check abrupt disturbances in the drain line.
D.5.3 Continuous depth recording

D.5.3.1 General

Continuous depth recording provides a good picture of the actual alignment of the drain line. It enables more accurate checking of the quality of different installation methods than by using traditional levelling. The equipment is very useful for measuring the grade of drains installed by trenchless drainage machines. It can be used to check whether the quality standards set for drain installation have been achieved.

D.5.3.2 The equipment

Collins at the Leichtweiss Institute of the University of Brunswick, Germany has developed a method for continuous depth recording based on a water level gauge. One end of a hose is connected to a special open container, the water surface of which serves as a reference level (Figure D5.4). A pressure transducer is fitted to the other end of the hose. This transducer transforms the hydrostatic pressure into an electric signal, which is proportional to the hydrostatic pressure over the reference level.

Table D.5.1 Maximum permissible forces for rodding

<table>
<thead>
<tr>
<th>Distance from outlet (m)</th>
<th>Maximum permissible force (N) With drain discharge</th>
<th>Without drain discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 100</td>
<td>20 - 30</td>
<td>20 - 40</td>
</tr>
<tr>
<td>100 - 200</td>
<td>30 - 60</td>
<td>40 - 80</td>
</tr>
<tr>
<td>200 - 300</td>
<td>60 - 90</td>
<td>- -</td>
</tr>
<tr>
<td>300 - 400</td>
<td>90 - 120</td>
<td>- -</td>
</tr>
</tbody>
</table>

Figure D5.4 Level recording instrument for continuous depth recording
D.5.3.3 The use

- The hose with the pressure transducer is pushed into the drain. The transducer can be inserted into the drain to a maximum length of 200 m;
- The hose is withdrawn at a constant speed;
- Measuring takes place while the hose is being withdrawn from the pipe. The hydrostatic pressure can be measured with an accuracy of less than 2 mm;
- The data can be recorded in digital form and plotted graphically (Figure D4.4).

D.5.3.4 Comments

This method is quite costly (the cost per metre amounts in the Netherlands to about 50% of the total costs of pipe drainage system). Because of its limitation of length and cost, the system can only be used in exceptional cases and for pilot areas or research. The equipment should only be used for random checks on a limited number of drains, for instance, 1-2% of the drains.
II-E

Maintenance of drainage systems
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Operation and Maintenance

Instruction sheet E.1

Subject: Checking the functioning of subsurface drainage systems
Target group: Maintenance staff, farmers

E.1 Checking the functioning of subsurface drainage systems

E.1.1 General

A subsurface drainage system can have a singular (Figure E1.1) or composite layout (Figure E1.2).

The components of the systems are:
- Singular system: field drains, in some cases manholes and outlet pipes;
- Composite system: field drains, collector drains, manholes and sumps (possibly with pumps) and outlets.

Regular checking of the system is required to see if the system functions and/or if repairs and/or maintenance is required. The methodology for the routine checking of the system and the techniques for cleaning and repairing parts of the system is given in the following sheets.

E.1.2 Checking the functioning of a singular system and minor repairs

Activity 1: Visual checks
Visual checks that can be routinely carried out (Figure E1.3):
- Flow of drains;
- Flow of drains into manholes (if any);
- Condition of outlets;
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

- Adequate depth of open drain;
- Silt in manholes;
- Silt flowing out of the pipe.

Activity 2: Carry out minor repairs and cleaning
- Outlets: replace or rearrange outlet pipes. If required, remove the silt around the outlet;
- Manholes (if applicable): remove silt from the manholes.

Activity 3: Reporting
If problems surpass the capacity of the farmers to correct them, the problems should be reported to the responsible entity so that they can take action. In all cases reporting is necessary if:
- A drain does not flow while the other drains are flowing;
- The open drain is too shallow;
- Drain outlets are under water or silted up;
- The drain flow of one or more pipes has been slowly decreasing over the years;
- Drain water is muddy;
- There is a high water level in the manholes (if there are manholes).
E.1.3 Checking the functioning of composite systems and minor repairs

Activity I: Visual checks of functionality
The following visual checks can be routinely carried out (easily done by the farmers):

- Is there a flow from outlet or pump;
- Is there a flow from the field drains into the manholes;
- Water level in manholes above field drains or below field drains;
- Is there a silt built-up in the manholes;
- Is there a leakage from outside water into manholes;
- Flow of field drain into field drain manholes (if any);
- Condition of outlets;
- Silt in manholes.

![Figure E1.4 Checking for leaks in a manhole](image)

Activity 2: Carry out minor repairs and cleaning

- Outlets: Rearrange outlet pipe of pump or gravity flow;
- Manholes: Close covers and/or repair covers or manholes (restore ground cover);
- Manholes: Remove silt from the manholes;
- Manholes: If possible repair leaks in the manholes.
Activity 3: reporting

If problems surpass the capacity of the farmers to repair them, the problems should be reported to the responsible entity so that they can take action. In all cases reporting is necessary if:

- A drain does not flow while the other drains are flowing;
- There is a sudden build-up of silt in the manholes;
- The drain flow of one or more pipes has been slowly decreasing over time;
- The drain flow of the entire system is getting less and less;
- The drain water is muddy;
- There is a high water level in the manholes;
- The pumps are not functioning.

E.1.4 Checking the functioning of a composite system (Figure E1.5)

E.1.4.1 Detailed monitoring to pinpoint location of obstruction in composite systems

If there is no flow in part of the collector the location of the obstruction or damage to pipes has to be pinpointed, this can be done in the following way:

1. Open all collector manholes and the sump (in case of a pumped outlet);
2. Start pumping (if the drains are flowing start pumping the day before) or in case of a gravity outlet be sure the outlet can flow freely;

![Figure E1.5 Schematic layout of collector drain](image-url)
3. Wait till the water is in balance (if pumping, then keep pumping);
4. Measure in each manhole with the levelling instrument the bottom level of each collector pipe (top level minus the outer diameter of the collector pipe);
5. Check if the bottom levels of the collector pipes are in a regular line. The slope of the line should approximate the design slope of the collector;
6. Measure the water levels in each manholes;
7. Plot the water levels and the pipe levels in the manholes as absolute levels.

Under normal conditions the water level plot should look as is given in Figure E1.6. If the water levels are as indicated in Figure E1.7, there is an obstruction between manhole 2 and 3. If there is an obstruction:
1. Flush upstream with the flusher from the downstream manhole and clean the collector pipe. If the flusher hose cannot proceed, then you know where the obstruction is. If it cannot be cleared by flushing, mark the location (measure the length of hose in the collector pipe);
2. The only solution now is to dig up the collector and try to remove the obstruction by hand.

![Figure E1.6 Water levels in a properly functioning collector drain](image-url)
Figure E1.7 Water levels in a collector line with an obstruction in the section between manhole 2 and 3.
E.2 Principles of flushing of subsurface drains

E.2.1 General

Maintenance of subsurface drainage systems consists of the removal of silt from the field and collector drains by flusher. Silt removal from manholes is done manually.

A flusher basically consists of a pump, reel, hose and a “jet head” at the end of the hose. Water is pumped into the hose and leaves the hose through the jet head. The hose with jet head can be pushed into the drain pipe to a maximum distance of some 300 m for ‘high-pressure flushers’. Once the hose has reached the end it is pulled back and rewound on the reel. On the basis of the pressure developed by the pump three types of flushing units can be distinguished:

- Low-pressure: up to 20 bar;
- Medium-pressure: 20-50 bar;
- High-pressure: 50-100 bar.

The differences between the first two types and the high-pressure flushing unit are:

- High-pressure flushing units are mounted on a chassis with wheels and pulled by a tractor. The hose reel is driven from the tractor with Power Take Off (PTO) or engine when fitted on the chassis;
- Medium and low-pressure flushing units are directly connected to the PTO of an agricultural tractor and is attached on a frame to the tractor;
- The hose of the high-pressure unit moves into the pipe through the reaction force of the backward directed jets coming out of the nozzle;
- The hose of low-or medium-pressure flushing units needs to be pushed into the drain pipe;
- Length of drains to be flushed by medium and low-pressure flushing units is limited as the hose can only be pushed to a limited length (approximately 150 m);
- Length of drain that can be flushed by a high-pressure unit is 300 m.

As discussed in Part I the pressure of a high pressure flushing unit can be reduced by reducing the speed of the engine. In any case the loss of pressure in the longer hoses of the high pressure flushers reduces the pressure at the jet head already considerably (with a pressure of 85 bar at the pump and a hose of 300 m length, the pressure at the jet head is some 30 bar). In the following paragraphs the flushing with a high pressure unit is described. The high and medium-pressure flushing units are presented in Figure E2.1.
E.2.2 Required equipment

For flushing one requires:

- One flusher;
- One tractor (about 75 HP) with Power Take Off (PTO);
- If no water is available: one tractor plus tanker (4 m$^3$) - for flushing one drain of 500 m one needs about 3 m$^3$ of water thus an almost full tank.

If flushing is done from a manhole or sump, additionally requirements are as follows:

- One hose guidance for manhole;
- One mud pump with a capacity of at least 100 litres/min (for pumping out the return flow from the manhole and to fill the tank).

The hose guidance equipment (ladder) can be made locally. The hose guidance (ladder) (Figure E2.2a) is made of angular steel 1 x 1 inch of some 3.5 or 4 metres in length with steps 50 cm apart. In the lowest metre of the "ladder" holes are made at intervals of 10 cm to fix a system with a moveable roller. The top roller is fixed near the top. The diameter of the roller is at least 0.40 m. The movable roller is similar in size. The hose guide (ladder) is placed inclined in the manhole. Another more sophisticated type of hose guidance is presented in Figure E2.2b.

E.2.3 Cleaning

The cleaning action of the jet head at the end of the hose is achieved through the outlet holes, three directed backwards and one forward (Figure E2.3). The backward force of the three high-velocity waterholes in the jet head combined with the pulsation of the pressure make the jet head and hose move or jump forward into the drain pipe. This force is sufficient to penetrate into the drain over a length of some 300 metres. The cleaning consists of:
The hose is first pushed into the drain pipe from the downstream end by the force of the water pressure directed backwards. During this inward movement of the hose with jet head, the dirt and sediments are loosened up and partly flushed out;

When the end of the drain or drain section is reached the pumping is continued but the pulsation is stopped and the hose is pulled backwards. During the pulling back action the backward holes act as a sweeper and sweep the loosened sediments towards the downstream end of the pipe. The hose is pulled back by the pulling power of the then activated reel on which the hose is rewound.

During the inward movement the coupling in the driveline should be disengaged. During the pulling out action the hose reel can be activated from the cardan shaft via the pump’s gear case. The hose is then automatically rolled on the reel and pulled out from the drain pipe (the driveline to the hose reel is engaged when the hose is pulled out, and disengaged when the hose pushes itself into the drain).
E.2.4 Conditions for flushing

Flushing is not a solution to correct badly installed drains, because the flushing action may cause damage to the pipe and filter. The following rules apply:

- Only flush drains when they are giving real problems or are not flowing;
- Starts flushing only if field drains are flowing. If a dry drain is cleaned the envelope will be damaged;
- Do not enter a (field) drain with the flusher twice during one cleaning session because this may damage the filter;
- Flushing of field drains should be done preferably at about 12-15 bar at the jet head. Higher pressure will damage the filter. In case the hose cannot enter the drain pipe, the pressure may be increased temporarily. For un-perforated collector drain flushing there is no limit to the amount of pressure you can use;
- Flushing must always be done downstream in an upstream direction. In case of a collector or field drain consisting of several sections, the flushing starts in the downstream part (in upstream direction) of the most upstream section;
- For collector systems the sequence of flushing is:
  - In the case of dirty collector drains: first collector drains, next field drains and then a second cleaning of the collector drains to remove any silt that has entered from the cleaning action of the field drain;
  - In the case of slightly dirty collector drains: first field drains and then collector drains.
E.2.5 Flushing water

For flushing, use water from a nearby drain or canal. If no open water is available a tank with approx. 4 m³ of water will be required.

E.2.6 Flushing methods

Depending on the local conditions flushing can be done according to the following methods:

- Flushing of collector drains;
- Flushing of field drains from an open ditch;
- Flushing of field drains from a manhole.

The details of the methods are given in instructing sheets for maintenance: E.3, E.4, and E.5.

E.2.7 Possible problems with flushing

Flushing may not be possible and the jet head may be lost if the installed drain:

- Is not straight;
- Not at a proper grade;
- Is damaged or pipes have got flattened.

If a drain is broken the jet head will sometimes leave the drain pipe and penetrate into the surrounding soil. If the jet head has left the drain pipe to either side of it or downward it will be almost impossible to recover the hose and jet head.

If a drain has not been installed in a straight line or the pipe has got flattened, the jet head may get stuck in the bends of the drain against the corrugations. Often the only way to recover the jet head is to estimate the place where the jet head is stuck from the length of hose that has entered the drain, then dig up the drain, cut it and recover the head by cutting it off from the hose.

If the drain has not been installed straight or at a straight grade, it may happen that the jet head still passes, but because the resistance is so great the jet head and hose will only partly penetrate. Withdrawing the hose will be troublesome and the jet head may get stuck.
E.3 Management, maintenance and repair of high pressure flushers

E.3.1 General

The flusher referred to in the following sections is a high-pressure flusher produced by a specific manufacturer. Similar rules apply to other flushers, but the details have to be checked with the relevant instruction manual of the manufacturer.

E.3.2 Safety rules

The flusher is entirely safe when used properly. For the safety of the personnel read the instructions below first.

- The chief operator has the responsibility for the safety of the individuals around the flushing machine;
- Check every day after use the rubber hose and nipples for external damage and repair any damage before use;
- Check daily if the pressure relief valve is properly adjusted;
- Check steel cable of hose guide wheel for signs of damage and deterioration and if damage is detected replace immediately before use;
- Do not drive over the hoses of the flusher with any vehicle, especially the suction hose, because this will damage the hoses;
- Always have at least two persons available for the operation of the flusher;
- When connecting flusher to the tractor, the hinge-pin should be secured firmly so that it cannot loosen during transport.

E.3.3 Preventive maintenance

- Change the oil in the pump crankcase every 1000 working hours or every 6 months.

E.3.4 Regular maintenance

E.3.4.1 Weekly maintenance

Actual maintenance only needs to be done once a week though continuous checks should be made during operation.
• Grease nipples;
• Grease the bearing and the spiders of the cardan shaft every week during operating periods;
• Check for loosened bolts (tighten);
• Check oil in the sump of the pump;
• Check tyre pressure and adjust if necessary.

E.3.4.2 Verification during operation

• Check and if necessary clean suction filter;
• Pressure valve should be adjusted to a maximum of 80-85 bar at the pump. If the pressure increases to over 80-85 bar, it means that one of holes in the jet head is blocked. Stop pumping and clean the jet head immediately;
• Prevent pump from running without water;
• Water leaking out of pump through holes behind pistons indicates that seals are rotten. Replace seals;
• Protect the hose from the sun.

E.3.5 Repair of the hose repair using hose clamp device

1. Cut out the damaged part of the hose with a hacksaw;
2. Slide the hose clamp into the hose;
3. Position the hose over the connector pipe;
4. Put the complete assembly in the clamp device (pay attention that the proper size of clamp elements is used);
5. Position the clamp rings properly over the hose ends and tighten the clamp elements again. Repeat this over the total hose circumference and in the same way for the other rings;
6. Open the clamp device and remove the hose.

E.3.6 Storage of the flusher/winter storage

• Store the flusher in a place preferably free from frost;
• Drain water from pump cylinder body by opening the two plugs;
• Remove the 3 pump valve covers and lift the ball valves to release the water from the cylinders;
• Take the hose off the reel connection and blow the water out of the hose using a compressor;
• Grease the ball valves of the pump and its seating when extended storage is expected;
• Protect the hose from strong sunlight;
• Take weight off the tyres.
E.4 Flushing of collector drains

E.4.1 General

Flushing of a collector drain is always done from a manhole, usually requiring specific equipment for the job and a water tank.

E.4.2 Required equipment

For flushing one requires:

- One flusher;
- One tractor (about 75 HP) with Power Take Off (PTO);
- If no water is available: one tractor plus tanker (4 m³) - for flushing one drain of 500 m one needs about 3 m³ of water thus an almost full tank.

Since flushing is done from a manhole or sump, additionally one needs to have:

- One hose guidance for manhole;
- One suction pump capacity of at least 100 litre/min (for pumping out the return flow from the manhole and to fill the tank).

E.4.3 Sequence of flushing

E.4.3.1 General

For the flushing of collector drains there are no limits to pressure and time, which means that flushing can also be done when there is no natural drain flow.

E.4.3.2 Sequence

The sequence of cleaning is as follows (Figure E4.1):
1. Clean out the mud from all the manholes, if necessary with a mud pump;
2. Start cleaning at the downstream end of the upstream section side of the collector.
   Be sure that in each manhole the downstream pipe is closed off.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

Be sure that the field drain pipe is closed off;
3. Flush out with the highest possible pressure.

E.4.4 Flushing water

- If there is an open drain or canal nearby that has clean water at least 20 - 25 cm deep, one can use water from the drain or canal for cleaning. In that case:
  - Dig a hole in the open drain and put a bucket or other metal container in the hole. The rim of the bucket should be at least 10 cm above the bottom of the drain and the water level should be about 10 cm above the rim of the bucket;
  - Put the suction valve of the pump in the bucket.
- If no water is available in the drain, one can use a tank, in which case put the suction part of the flusher in the tank.

E.4.5 Flushing action

E.4.5.1 General

- Flushing is done from the sump or a manhole;
- Flushing is always done in an upstream direction;
- Be sure there is always plenty of water;
- Never leave the hose in the drain without pumping, the head may get stuck and it may be lost;
- During the pulling back action the pumping (flushing) has to continue otherwise the jet head may get stuck.

E.4.5.2 Entering the hose into the collector drain

1. Put the flushing machine downstream of the manhole or near the end pipe so that one can guide the hose straight into the drain;
2. Close off all the inlets/outlets to the manhole or sump, with the exception of the part to be cleaned, with a cloth plastic ball or other material;
3. Install the mud pump close by and put the suction of the mud pump into the manhole/sump. Start the engine of the mud pump as soon as the manhole fills up with water;
4. Put the suction hose of the flusher into the water of the ditch or into the tank;
5. Use hose guidance to protect the hose from wear on the edges of the manholes (Figure E4.2);
6. Check the tightness of the jet head on the high-pressure hose;
7. Insert the hose by hand about 2-3 metres into the collector pipe;
8. Start the engine of the tractor and run the pump at low speed. Open the relief valve on the pressure side so that the water runs off of the bottom of valve (this relief valve opens automatically when its pressure is released);
9. Open the valve fitted on the first cylinder (this valve should always be in the open position when pulling out the cleaning hose);
10. Open the valve fitted under the pressure gauge;
11. Now close the relief valve by pulling lever upwards. The pressure will now build up in the pressure line;
12. Increase the engine speed until pressure gauge on the pump indicates the pressure at which the hose is entering the drain pipe (for collectors 65 up to 85 bar). Close the pressure gauge valve to protect the gauge. During normal operation check the delivery pressure twice per day;

Figure E4.2  Correct (right) and faulty (left) way of entering the hose pipe through a manhole
13. During the first fifty metres of penetration, the cleaning hose will tend to run too fast into the pipe due to low friction. Thus, decrease the speed of the penetration by decreasing the engine speed of the tractor so that the entry speed is no more than 30 m/min.

14. Continue with the flushing until the jet head has reached the upstream manhole.

E.4.5.3 Withdrawing the hose from the collector drain and rewinding it onto the reel

During the pulling back action the pumping (flushing) has to continue otherwise the jet head may get stuck, thus:

1. Decrease the engine speed to half speed;
2. Close the valve on the first cylinder;
3. Move the engaging lever of the reel drive system to the right so that the V-belt drive is engaged and the hose reel starts to turn. Pulling out of the hose is to be done at moderate speed (20-25 m/min) to achieve the extra benefit of the second cleaning;
4. Keep pumping with the mud pump;
5. Take care that the hose is properly rewound on the reel. Cross winding of the hose might lead to disconnection of the hose connections. The last metres of the hose should be pulled out very carefully and at low engine speed of the tractor to prevent the hose from swinging dangerously. The hose filled with water should always be wound on the reel;
6. When the jet head is about to leave the drainage pipe the relief valve should be operated by hand in order to relieve the water pressure as soon as the jet head leaves the drain pipe. Open the valve on the first cylinder again before closing the relief valve and increasing the engine speed of the tractor;
7. Pump out with the mud pump all the remaining water and clean out all the silt from the manhole by hand (if necessary);
8. Remove all the closures of other inlet and outlets.

E.4.6 What to do in the case of damaged pipes or faulty drainage system

To follow the progress and/or to detect the location of a problem in the drain, it is recommended marking off every 20 m of the drain, so that at all times one knows how far the hose has penetrated.

If there is a damaged drain the jet head will sometimes leave the drain pipe and penetrate into the surrounding soil when a considerable amount of cleaning water will be injected into the surrounding soil. This problem will be indicated by a decrease of the out flowing cleaning water, and the out coming water will suddenly carry a lot more dirt. The place where the jet head has left the drain pipe may be deduced from the measurement marks on the length of the hose. If the jet head left the drain pipe to either side of it or downwards, it will be almost impossible to recover the hose and jet head. When a drain has not been installed in a straight line the jet head may get stuck in the bends of the drain against the corrugations. Often the only way to recover the jet head is to estimate the place where the jet head is stuck from the lengths of hose which has entered the drain, dig up the drain, cut the drain and recover the head by cutting it from the hose.
E.5 Flushing of field drains from a ditch

E.5.1 Required equipment

For flushing one requires:
- One flusher;
- One tractor (about 75 HP) with Power Take Off (PTO);
- If no water available: one tractor plus tanker (4 m³) plus pump for filling the tank - it will take 3 m³ of water thus an almost full tank to flush one drain of 500 m.

E.5.2 Conditions for flushing

- Only flush drains when they give real problems or are not flowing;
- Start flushing only if field drains are flowing. If a dry drain is cleaned the envelope will be damaged;
- Do not enter a (field) drain with the flusher twice during one cleaning, this may damage the filter;
- Flushing of field drains should be done preferably at about 12-15 bar at the jet head. With the high-pressure flusher the pressure at the pump (see on the pressure meter) should be no more than 50 bar. Higher pressure will damage the filter. If the hose is unable to enter the drain pipe, the pressure may be increased temporarily;
- Flushing must always be done downstream in an upstream direction.

E.5.3 Flushing water

- If there is an open drain or canal nearby which has clean water and where the water depth is at least 20 - 25 cm, one can use water from the drain for cleaning. In that case:
  - Dig a hole in the open drain and put a bucket or other metal container in the hole. The rim of the bucket should be at least 10 cm above the bottom of the drain and the water level should be about 10 cm above the rim of the bucket;
  - Put the suction valve of the pump in the bucket.
- If no water is available in the drain, one can use a tank, in which case put the suction part of the flusher in the tank.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

E.5.4 Flushing action

E.5.4.1 Entry of flusher hose into the drain

1. Put the tractor and the flusher on the opposite bank of the open drain. In this way the hose can enter the drain very easily and runs smoothly off or on the drum over its entire width (Figure E5.1a);
2. If the flusher cannot be positioned on the bank opposite the drain the reverse roller can be used (Figure E5.1b). In that case position the flusher in such way that the hose runs off from the bottom side of the drum. Lower the reverse roller far enough into the ditch so that the hose running off the drum can move in a straight line into the drain pipe;
3. Put the suction hose into the water of the ditch or tank as described above;
4. If necessary protect the hose from wear on the edges of the pipe;
5. Check the tightness of the jet head on the high-pressure hose;
6. Insert the hose by hand about 2-3 metres into the drain pipe;
7. Start the engine of the tractor and run the pump at low speed. Open the relief valve on the pressure side so that the water runs off of the bottom of valve (this relief valve opens automatically when its pressure) is released;
8. Open the valve fitted onto the first cylinder (this valve should always be in an open position during pulling out of the cleaning hose).
9. Open the valve fitted under the pressure gauge;
10. Now close the relief valve by pulling lever upwards to let the pressure build up in the pressure line;
11. Increase the engine speed until pressure gauge on the pump indicates the pressure at which the hose is entering the drain pipe (preferably not exceeding 50 bar, but if necessary 65 up to 85 bar). Close the pressure gauge valve for protection of the gauge. During normal operation check the delivery pressure twice per day;
12. During the first fifty metres of penetration, friction will tend to cause the cleaning hose to run too fast into the pipe. Therefore, decrease the speed of the penetration by decreasing the engine speed of the tractor. Speed should be limited to 30 m/min;
13. Continue with the flushing until the jet head has reached the end of the pipe.

E.5.4.2 Withdrawing the hose from the drain and rewinding it onto the reel

During the pulling back action the pumping (flushing) has to continue otherwise the jet head may get stuck.
1. Decrease the engine speed to half speed;
2. Close the valve on the first cylinder;
3. Move the engaging lever of the reel drive system to the right so that the V-belt drive is engaged and the hose drum starts to turn. Pulling out of the hose is to be done at a moderate speed (20-25 m/min) to achieve the extra benefit from the second cleaning;
4. Ensure that the hose is properly rewound on the reel. Cross winding of the hose might lead to disconnecting of the hose connections. The last metres of the hose should be pulled out.
Figure E5.1  Tractor with flusher cleaning from an open drain
very carefully and at low engine speed of the tractor to prevent the hose from swinging
dangerously. The hose filled with water should always be wound on the reel;
5. When the jet head is about to leave the drainage pipe the relief valve should be operated by
hand in order to relieve the water pressure as soon as the jet head leaves the drain pipe.
Open the valve on the first cylinder again before closing the relief valve and increasing the
engine speed of the tractor;
6. Pump out with the mud pump all the remaining water and clean out all the silt from the
manhole by hand (if necessary);
7. Remove all the closures of other inlet and outlets.

E.5.5 What to do in case of damaged pipes or faulty drain system

To follow the progress and/or to detect the location of a problem in the drain, we recommended
marking off every 20 m of the drain, so that at all times one knows how far the hose has
penetrated.

If there is a damaged drain the jet head will sometimes leave the drain pipe and penetrate into
the surrounding soil when a considerable amount of cleaning water will be injected into the
surrounding soil. This problem will be indicated by a decrease of the out flowing cleaning water,
and the out coming water will suddenly carry a lot more dirt. The place where the jet head has
left the drain pipe may be deduced from the measurement marks on the length of the hose. If
the jet head left the drain pipe to either side of it or downwards, it will be almost impossible to
recover the hose and jet head.

When a drain has not been installed in a straight line the jet head may get stuck in the bends of
the drain against the corrugations. Often the only way to recover the jet head is to estimate the
place where the jet head is stuck from the lengths of hose which has entered the drain, dig up
the drain, cut the drain and recover the head by cutting it from the hose.
E.6 Flushing of field drains from a manhole

E.6.1 Required equipment

To flush a field drain from a manhole one requires:
- One flusher;
- One tractor (about 75 HP) with Power Take Off (PTO);
- One tractor plus tanker (4 m³) - for flushing one drain of 500 m one needs about 3 m³ of water thus an almost full tank;
- One hose guidance for manhole;
- One mud pump capacity of at least 100 litre/min (for pumping out the return flow from the manhole and to fill the tank).

E.6.2 Conditions for flushing

- Only flush drains when they give real problems or are not flowing;
- Start flushing only if field drains are flowing. If a dry drain is cleaned the envelope will be damaged;
- Do not enter a (field) drain with the flusher twice during one cleaning, this may damage the filter;
- Flushing of field drains should be done preferably at about 12-15 bar at the jet head. With the high-pressure flusher the pressure at the pump (see on the pressure meter) should be no more than 50 bar. Higher pressure will damage the filter. If the hose is unable to enter the drain pipe, the pressure may be increased temporarily;
- Flushing must always be done downstream in an upstream direction.

E.6.3 Flushing sequence

Flushing a field drain from manhole may only be done in an upstream direction! Thus, if there are field drain manholes start in the downstream field drain manhole, clean the upstream field drain and after that the next one, then the next and so forth.
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

E.6.4 Flushing water

- If there is an open drain or canal nearby which has clean water that is at least 20 - 25 cm deep, one can use water from the drain for cleaning. In that case:
  - Dig a hole in the open drain and put a bucket or other metal container in the hole. The rim of the bucket should be at least 10 cm above the bottom of the drain and the water level should be about 10 cm above the rim of the bucket;
  - Put the suction valve of the pump in the bucket.
- If no water is available in the drain, one can use a tank, in which case put the suction part of the flusher in the tank.

A tank is almost always required for flushing from manholes.

![Figure E6.1 Direction and sequence of flushing of a field drain from a manhole](image)

E.6.5 Flushing action

Flush only in an upstream direction (otherwise the out coming dirt which flows downstream through the still dirty drain can clog up the drain!).

E.6.5.1 Preparation

1. Put the flushing machine downstream of the manhole or near to the end pipe so that one can guide the hose straight into the drain;
2. Open the manhole;
3. Cleanout the silt of the manhole by hand;
4. Close off all the downstream outlets of the manhole with a cloth, plastic ball or other material;
5. Install the mud pump close by and put the suction of the mud pump into the manhole/sump and start the engine of the mud pump if the manhole fills up with water;
6. Install the hose guidance to prevent damage to the pipe.
E.6.5.2 The entry of the flushing hose into the field drain

1. Put the suction hose of the flusher into the water of the ditch or into the tank;
2. If necessary protect the hose from wear on the edges of the pipe;
3. Check the tightness of the jet head on the high pressure hose;
4. Insert the hose by hand about 2-3 metres into the drain pipe;
5. Start the engine of the tractor and run the pump at low speed. Open the relief valve on the pressure side so that the water runs off of the bottom of valve (this relief valve opens automatically when its pressure is released);
6. Open the valve fitted on the first cylinder (this valve should always be in open position during pulling of the cleaning hose);
7. Open the valve fitted under the pressure gauge;
8. Now close the relief valve by pulling the lever upwards when the pressure will build up in the pressure line;
9. Increase the engine speed until pressure gauge on the pump indicates the pressure at which the hose is entering the drain pipe (preferably not exceeding 50 bar, but if necessary temporarily 65 up to 85 bar). Close the pressure gauge valve for protection of the gauge. During normal operation check the delivery pressure twice per day;
10. During the first fifty metres of penetration, friction will tend to cause the cleaning hose to run too fast into the pipe. Therefore, decrease the speed of the penetration by decreasing the engine speed of the tractor the entry speed should not be more than 30 m/min;
11. Continue with the flushing until the jet head has reached the upstream or the end of the drain.

Figure E6.2 Correct (right) and faulty (left) way of entering the hose pipe through a manhole

Use hose guidance to prevent hose damage on sharp edges!

Cost saving by:
- increase lifetime hose
- faster operation
- less water needed
PART II - DETAILED INSTRUCTIONS FOR THE IMPLEMENTATION OF SUBSURFACE DRAINAGE SYSTEMS

E.6.5.3 Withdrawing the hose from the drain and rewinding it on the reel

During the pulling back action the pumping (flushing) has to continue otherwise the jet head may get stuck.

Actions
1. Decrease the engine speed to half speed;
2. Close the valve on the first cylinder;
3. Move the engaging lever of the reel drive system to the right so that the V-belt drive is engaged and the hose reel starts to turn. Pulling out of the hose is to be done at a moderate speed (20-25 m/min) to achieve the higher benefit of the second cleaning;
4. Take care that the hose is properly rewound on the reel. Cross winding of the hose might lead to disconnecting of the hose connections. The last metres of the hose should be pulled out very carefully and at low engine speed of the tractor to prevent the hose from swinging dangerously. The hose filled with water must always be wound on the reel;
5. When the jet head is about to leave the drainage pipe the relief valve should be operated by hand in order to relieve the water pressure as soon as the jet head leaves the drain pipe. Open the valve on the first cylinder again before closing the relief valve and increasing the engine speed of the tractor;
6. Pump out with the mud pump all the remaining water and clean out all the silt from the manhole by hand (if necessary);
7. Remove the closures of other outlets.

E.6.6 What to do in the case of damaged pipes or faulty drain installation

To follow the progress and/or to detect the location of a problem in the drain, we recommended marking off every 20 m of the drain, so that at all times one knows how far the hose has penetrated.

If there is a damaged drain the jet head will sometimes leave the drain pipe and penetrate into the surrounding soil when a considerable amount of cleaning water will be injected into the surrounding soil. This problem will be indicated by a decrease of the out flowing cleaning water, and the out coming water will suddenly carry a lot more dirt. The place where the jet head has left the drain pipe may be deduced from the measurement marks on the length of the hose. If the jet head left the drain pipe to either side of it or downwards, it will be almost impossible to recover the hose and jet head.

When a drain has not been installed in a straight line the jet head may get stuck in the bends of the drain against the corrugations. Often the only way to recover the jet head is to estimate the place where the jet head is stuck from the lengths of hose which has entered the drain, dig up the drain, cut the drain and recover the head by cutting it from the hose.