OPINNÄYTETYÖ - **AMMATTIKORKEAKOULUTUTKINTO**
TEKNIIKAN JA LIIKENTEEN ALA

THESIS

Horizontal directional drilling

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Kauko-ohjattu suuntaporaus on Suomessa suhteellisen uusi tekniikka asennettaessa maanalaisia rakenteita. Avokaivuu ja auraus ovat perinteiset tavat maanalaisten rakenteiden asentamisessa. Suuntaporaus tuo uusia mahdollisuuksia maanalaisten rakenteiden asennukseen, koska perinteisistä asennusmenetelmistä poiketen pintamaata ei työvaiheiden aikana rikota, vaan porausta ohjataan maanpinnalta käsin. Tämän tekniikan avulla saadaan kustannustehokkaampia tuloksia maanalaisten kaapeleiden asentamisessa. Kauko-ohjattu suuntaporaus on myös ympäristöystävällinen asennusmenetelmä. Lisäksi kauko-ohjattu suuntaporaus on tuonut uuden markkina-alan suomen yrityksille ja tämän myötä uusien asennusmenetelmien käyttö on alkanut nostaa päätään perinteisten menetelmien tilalle. Uudet vaihtoehtoisen maanalaisten rakenteiden asennusmenetelmät kehittävät kilpailun myötä tekniikoita paremmaksi, nykyaikaisemmiksi sekä ympäristöystävällisimmiksi.

Tämän opinnäytetyön tavoitteena on tarkastella suuntaporauksessa käytettäviä menetelmiä, tarkastella sen ympäristövaikutuksia, työturvallisuutta sekä maaperän vaikutuksia työkapasiteetin. Tarkastelen maanalaisten kaapeleiden Suomessa käytettäviä asennusmenetelmiä ja vertailen niiden kustannustehokkuutta, sekä hyötyjä ja haittoja. Tarkoituksenani on luoda selkeä kokonaiskuva maanalaisten kaapeleiden asennusmenetelmistä. Tarkastelen kauko-ohjattua suuntaporausta vaihtoehtoisena menetelmänä vanhojen kaapelinasennusmenetelmien rinnalla. Tavoitteenani on löytää tämän opinnäytetyön myötä uusia näkökulmia maanalaisten kaapeleiden asennusmenetelmien rinnalle, sekä korostaa kauko-ohjattua suuntaporausta kustannustehokkaana sekä ympäristöystävällisenä menetelmänä. Toimeksiantaja tulee markkinoimaan kauko-ohjattua suuntaporausta maanalaisten rakenteiden asennusmenetelmänä, tätä opinnäytetyötä hyväksikäyttäen.

Avainsanat
Kauko-ohjattu suuntaporaus, avokaivu.

SAVONIA UNIVERSITY OF APPLIED SCIENCES	THESIS Abstract

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Abstract

In Finland horizontal directional drilling (HDD) is a relatively new technology when installing underground structures. Conventional excavation and cable ploughing are the traditional ways of installing underground structures. Horizontal directional drilling brings new opportunities for the installation of underground structures because, unlike the traditional methods, breaking of the surface of land is not infringed during the drilling stages, but drilling is controlled from the ground. This technology provides a cost-effective results in the installation of underground cables. The remote controlled horizontal directional drilling is also environmentally friendly method of installation. In addition, the horizontal directional drilling has brought a new market sector, for Finnish companies and that the use of new methods of erection has begun to raise its head in place of traditional methods. New alternative methods for installing underground structures develops competition of the techniques, and also brings the techniques more modern and more environmentally friendly.

The aim of this thesis was to examine the methods used in horizontal directional drilling, look at its environmental impacts, work safety, and the impact of soil on the working capacity.

Firstly the methods used for installing underground structures in Finland were examined closely in this thesis. After this I looked closely horizontal directional drilling as a method, compared it to the alternative used methods and discussed about its opportunity as an alternative method for installing underground structures in Finland.

As a result of this thesis was to find the right place for HDD in Finnish construction work when installing underground structures. The client organisation of this thesis will use it for marketing HDD method in Finland.

Keywords
Horizontal Dricectional Drilling, Conventional Excavation

FOREWORD

Working with this thesis was a huge challenge, but anyhow very interesting. Special thanks to you who believed in me and never had doubts about my capability of managing this.

Kuopio 28.3.2016

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1 INTRODUCTION

In directional drilling, a guided bore is made and a carrier pipe is pulled into the wanted location. Directional bores have been used worldwide for the installation of pressure pipes. For these pipes grade is nor critical. However, until very recently it was impossible to make an installation with sufficient accuracy to meet gravity sewer requirements. With the refinement of guidance methods, this has become feasible. Directional drilling is a trenchless method and should be considered where surface disruptions would be unacceptable. Although it is more costly as a method than open-cut installation and it is also more cost-effective than microtunneling.

The development of alternative cost-effective installation methods is slow. Especially operators are keen to explore if the methods used outside Finland are usable. Especially the methods used on paved street areas need attention, where the traditional conventional excavation is very expensive. For example, the percentage of paving work is about 40-70% of the cost of installing telecommunication network.

The aim is to study the methods used in installing underground structures. The most common installation methods used in Finland will be studied, and the advantages, disadvantages, costs and impacts to the environment will be evaluated. After this the horizontal directional drilling takes the attention. The aim is to find all the benefits of this method so that the use of HDD would rise in Finland. To find all needed information scientific articles will be used as well as interviews with persons working with HDD. Connections with the persons working across the Europe related with HDD are also useful when finding information from this relatively new method.

The client organisation will use this thesis for marketing, so this is why the information is focused on the cost-effectivity of HDD compared to the alternative methods.

2 STRUCTURES PLACED UNDERGROUND

In this chapter the aim is to research literature facts from horizontal directional drilling. There are no laws from directional drilling, but the laws on civil engineering are researched. There are also some scientific documents on directional drilling that have statistic information about directional drilling.

2.1 Laws and regulations

Installation and maintenance of cables, wires and pipes underground on the road area always requires a permission from the maintenance organisation of the road (ELY Centre 2012). The streets and roads, maintained by municipal administration, demand licenses given by the respective municipality. Street maintenance includes street planning, construction, maintenance and renovation, as well as other measures that are necessary to the street area, as cables, components and structures. Organizing street maintenance pertains to the tasks of municipality. (Land Use and Building Act 1999)

Placing telecommunication cables to the road area is mainly related to the Communications Market Act (393/2003), as well as the Highways Act (503/2005) and the Land Use and Building Act (132/99). According to Communications Market Act, 101 § 1 section, wherever it is possible, a telecommunications cable shall be installed in a highway area referred in the Public Roads Act (243/1954) or in a public area as referred in the Act on Real Estate Formation (554/1995).

In accordance with the Highways Act 42 § section 1, "the permission of the road management authority is required for work on the road area as well as placement of structures, wiring, pipes and other equipment in the road area. Such permission may be granted if the measure does not constitute a hazard to road safety or an impediment to road management."

When planning a telecommunications network, road management shall be contacted. For the most cost-effective solution, transport and structural factors, as well as the factors affecting to the road maintenance have to be taken into account. (Finnish Road Administration 2009)

Municipalities act as the licensing authority in the areas, owned or controlled by them, namely the streets and other public areas. The telecommunication operators are responsible for planning cable routes. The licensing authority and operator will work closely together so that the cable route is the most appropriate for both sides. Streets and other public areas obey the same procedures in principle as the roads in the area.

The placement of cables and other equipment requires a permit or agreement for location and also a separate license in addition to work on the street and public areas (street permit decision or excavation permit). Policies vary by municipality. Electricity and telecommunication cables are mainly located in municipal and state-owned areas - mainly in the street and the road area. When planning the placement of cables, the following factors must be considered:

- instructions by authorities
- structural factors
- the effects of the construction of the network on the surroundings of the work area and the usability of it
- the effects of the investments and construction to the maintenance of the network and the region
- impacts on future restructuring and additional construction

In practice, this means that the investment has to be designed so that work causes as little harm as possible to the users of the region, to the existing devices as well as to reconstructing in the future. When placing cables belonging to an area owned by some other, license / agreement under the law is referred. (InfraRYL 34-710102 Televerkon kaapelien asennusmenetelmät 2012)

2.2 Environmental factors and sustainable development

Examining the subject of this thesis from the environmental and sustainable development view, one can observe how many different aspects can be obtained by comparing the advantages and disadvantages of underground electrical and telecommunication cables to the traditional aerial cables. Underground structures such as drainage ditches and water supply network, have been installed through times, but installing electrical and telecommunication cables underground in Finland is still in its infancy. When underground networks constructing is becoming more common, selecting a suitable method for installing underground structures is important for the developer and the purchaser.

Every year aerial electrical and communication cable networks suffer from thousands of damages, such as trees falling over the aerial network, either because of heavy snow or strong winds. The clearing work of trees below an aerial network causes also high costs for the network manager. These costs directly affect to the user fees paid by customers. Underground cables usually includes only the cost of installation. The aerial line also have a negative impact on the landscape, as well as the poles passing over fields makes it difficult to work out in the fields. Also, the aerial network in a forest makes forestry, such as cutting and thinning difficult.

The harm caused by the underground network installation for the environment is very limited because the installation does not cause significant harm to the environment. Environment is loaded only once during the installation work and when the maintenance of air lines requires the use of machinery below the aerial network at regular intervals. Underground cables do not cause harm to flora or fauna, whereas the aerial lines may be fatal for example for squirrels or birds. (M. Parviainen, personal communication 22.3.2015)

Underground cable network benefits compared to the aerial network are, that underground network

- have lower transmission losses;
- can absorb emergency power loads;
- have lower maintenance costs;
- emit no electric field and can be engineered to emit a lower magnetic field than an overhead line;
- require a narrower band of land to install, and;
- is less susceptible to the impacts of severe weather.

Major transmission projects require careful analysis and specific solutions. Unless an acceptable overhead route can be found, the underground cables are an appropriate solution for the sections of a line. (Leonardo energy, 2015)

2.3 The investing process

In general, when working in public areas, permission and contract for investment are needed, as well as the management report, excavation permit and, if necessary, temporary traffic arrangement permit. Occupational safety issues are also explained in a separate document. Before starting the work, initial inspection is carried out at the work site. When the work is complete, the final inspection is carried out at the work site. Sometimes, especially in the larger construction sites before work is started, a kick-off meeting, as well as follow-up meetings will be held. The property owner is required to let cables serving the society, as well as the installation of minor equipment's and plants to the areas owned or controlled by it, unless the placement cannot be arranged satisfactorily and at a reasonable cost in some other way. Because there is not a general rule of investing cables, and other technical equipment of municipal streets and other public areas, instructions for siting must be applied for separately from the owner or holder of the property. (Highways Act (503/2005), Communications Market Act (393/2003), Land Use and Building Act (132/1999), Real Estate Formation (554/1995)) In figure 1 there is an example of the administrative process for investing a telecommunication cable. (InfraRYL 34-710102 Televerkon kaapelien asennusmenetelmät 2012)

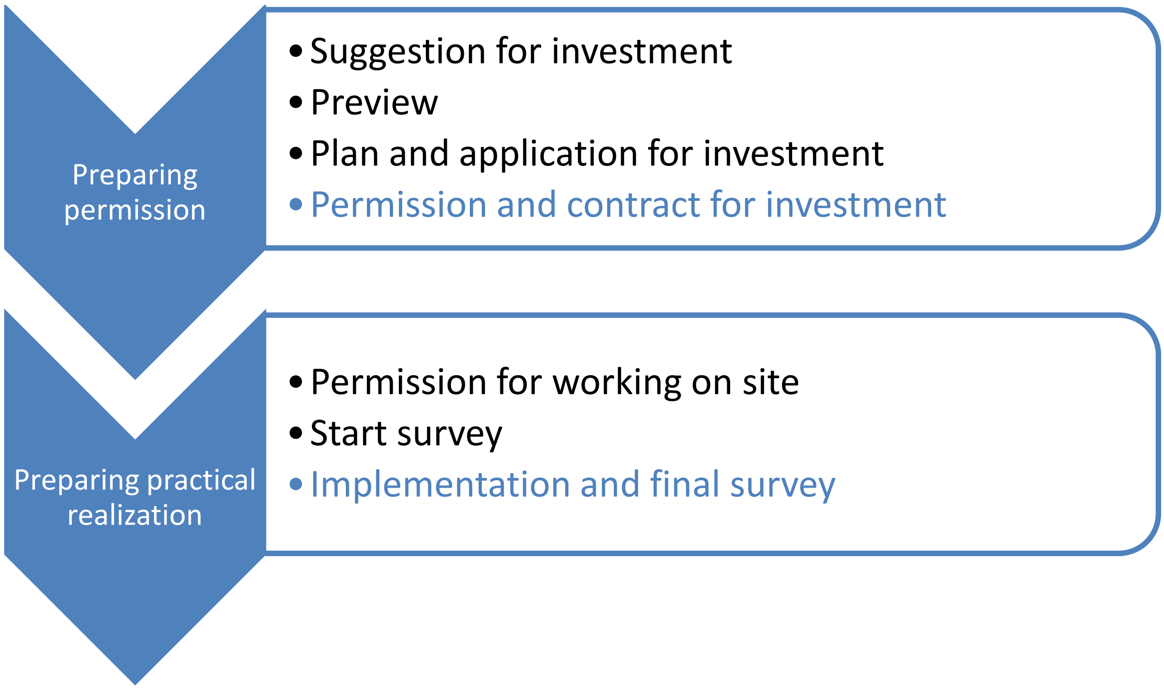


Figure 1 The process of investing a telecommunication cable. (InfraRYL 34-710102)

2.4 Traditional methods for installing underground structures

Underground constructions in this thesis stand for electrical cables and telecom cables, as well as community development. Traditionally, the cable installation is done in the ground, either in conduit or ground protected. The installation method for the ground-mounted cables is usually either conventional excavation or cable ploughing. Alternative low-installation methods and excavation methods have been paid into account among the operators, when applying more cost-efficient as well as more modern network construction techniques. Finland is still in its infancy of using these new methods, but the rest of the world already has a lot of experience in these working methods and machines.

Traditional construction methods bring a number of challenges for the contractor. Construction work is often concentrated for the summer season, when the soil is unfrozen. This leads to the fact that the builder should concentrate year’s budgeted constructions for these months when contractors, supervisors and planners are extremely occupied. This rush may cause unnecessary damage and haste at the site, which causes a slowdown of work. Instead, during the winter months the contractors have to fill their schedule with a replacement job. When annual work peak would not happen, the all year round feasible network building technologies would be more cost-effective for the contractor, management and designers.

The majority of construction costs consists of excavating and paving work. The costs consists of machinery, personnel, as well as the cost of the working hours. The costs of the network construction mostly consists of the unit price, in which case a fast work speed is always good for the contractor.

From the unit price work, the compensation represents the so-called hard values of currency. Almost all the machine work that is carried out almost always leads to the soft values representing the disadvantages to the third parties. These are for example traffic and road network harm to the environment caused by noise and landscape disadvantages. These soft values are very difficult to evaluate in terms of money, because these costs are usually indirect costs and therefore often difficult to measure. New alternative methods reduce suspense-harm for third parties, compared to traditional methods. For example, the Centre for Economic Development requires that the work in the roads that are managed by them, cannot harm third parties. In practice, this means that roads managed by the Centre for Economic Development are not allowed to dig open. (M. Parviainen, personal communication 22.03.2015). In figure 1 there is an example of the process for investing a telecommunication cable.

In traditional excavation work in built up and urban environment, daily work capacity varies from tens of meters to hundreds of meters. In an open field or on the side of the road the daily work capacity varies between five hundred meters up to five kilometres by ploughing. The working group consists of a minimum of two staff members, as well as suitable digging machine. Suitable digging machine is either an excavator or a backhoe.

The network construction is often done in building stock and infrastructure which already has underground structures. Often roadsides, as well as intersections already have underground structures. These structures must be taken into account in preminary examination, wherein the system operator is requested to report on pre-existing structures. In addition, various scanning devices are used to reveal the location of underground cables. In some situations, damage can arise, when the inflicted damage varies from hundreds of euros up to tens of thousands of euros. Traditional methods used in network construction arise the risk of damage. (M. Parviainen, personal communication 17.02.2015)

2.4.1 Conventional excavation

Underground cable laying by conventional excavation is used as an installation method usually in the case when, for example, cable ploughing cannot be implemented for the terrain reasons. Traditional conventional excavation is well suited to situations in which there are existing underground structures, because the method is reasonably accurate. Conventional excavation is also a safe method when there is no accurate information of the areas cabling or other underground structures. In urban areas, or in regions where underground structures are abundant, conventional excavation is still the most common method of network construction.

Work is done by suitable device for digging, either an excavator or a backhoe. The contractor will select the best available excavator on the basis of each workplace. The excavator is selected for its size, the power and the platform used. Excavating platform types are either a wheeled or tracked excavator. The size and power of the excavator is directly proportional to the extent of the work site, the soil structure as well as the type of terrain. In excavation work the excavator dugs the ground underneath the rollers or wheels, when the main boom is bent forward. This allows a longer working distance. A smaller excavator is chosen on construction sites with low-mass amounts and in confined spaces and the larger machines have more power to dig hard soil types such as tight clay and have the capacity to dig large mass amounts effectively. Simply it can be said that the heavier the machine, the better it is suitable for heavy construction work and correspondingly a lighter and more delicate machine is suitable for smaller construction work.

A track excavator (Figure 2) is stable and balanced when working because the machine tracks distribute the machine weight over a large area and the machine gets a good grip to ground with track shoes, which contributes to the movement in difficult and poor-bearing terrain. Also, hydraulic dozer blades stabilizes the machine. Track excavators are generally selected for long-term construction sites, as they need to be transported between sites. The transportation requires different kind of transport equipment depending on the machine weight and width.

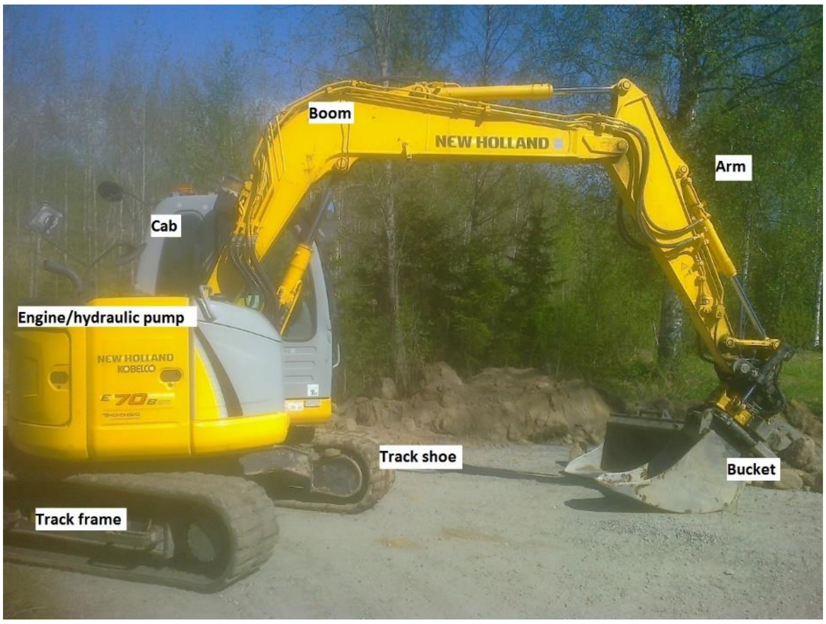


Figure 2 Parts of a track excavator (Miettinen, 22.6.2014)

Wheeled excavators (Figure 2) and backhoes are best suited for sites where the soil is not suffering from capacity problems. A wheeled excavator is not suitable for soft and poorly bearing terrain because of the high surface pressure and bad off-road characteristics. They are common in short-term work, where a transporting track excavator is not profitable because of high transport costs. It is also common to choose a wheeled excavator for the urban area where it is allowed to drive in public roads if it is registered for traffic use. Wheeled excavators are stabilized before digging by using the dozer blade and / or stabilizer legs, paws. Also, the frame is lockable. It is possible to equip the wheels or chains with pins in winter conditions. (A. Kananen, personal communication 02.03.2015)

Figure 3 Parts of a backhoe (How stuff works, Science 20.3.2015)

The work group includes the excavator driver and a shovel man. The network construction by conventional excavation starts by exploring the sites existing underground structures. The existing underground structures are usually marked on the site maps. If necessary, the system operator does a cable screening and marks on the ground the location and depth of the existing structures. In most cases, the underground structures are explained in site maps. If the new excavator track intersects or overlaps already existing structures before digging, a cable radar is used. Excavator bevels thin layers after ensuring with a spade that the cutting edge from the bucket does not cause damage to the structure. Underground cables are usually marked with warning tape, which is placed 5 to 20 centimetres on top of the structure. It helps to notice the existing structure. When the excavator has removed most land masses around the structure, the end of the excavation is done by shovelling. The depth instructions are given by the customer and the holder of the authorization.

When the excavation is done, it is ensured that the bottom of the trench is relatively flat, and there should not be any larger rocks that could damage the cable being installed. If the trench is too shallow, for example because of the bedrock, the cable will be protected with the conduits or cable ducts. Also in stony terrain cable must be protected with cable ducts. Cable ducts are classified according to their strength. At underflow sections of the roads, the cable is usually installed in conduit. When installing more cables at the same time in the ditch, there should be between a minimum of 5 cm interval or they must be separated with the cable ducts as seen in picture 1. On top of the cable / cables, a 20 cm protective layer of fine soil is placed and the warning tape is placed on top of the protective layer. Warning tape protects the cable / cables in case of new excavations. After the warning tape is being installed, the trench is being filled so that the terrain would be at the same condition as before the work began. (M. Parviainen, personal communication 23.02.2015)

Picture 1 When installing more cables at the same time in the groove, there should be a minimum of 0.05 meters interval between the cables or they must be separated with the cable ducts. (Miettinen, 19.08.2013)

2.4.2 Cable ploughing

Compared to conventional excavation, cable ploughing is a very fast underground network installation method. Either only a cable or conduit, where the cable is pulled later, can be installed to the ground. Conduit’s typical size is 40-50 mm in ploughing method. (Onninen, 2008, 129.) The installation depths are the same as with the conventional excavation method.

The cable ploughing is usually done with an excavator, either a tracked or wheeled excavator. Picture 2 shows a tracked cable ploughing excavator. When using a tracked excavator, tracks must be either smooth surfaced or equipped with rubber track shoes to prevent damaging surface material, usually asphalt. The plough can also be attached to the rear of the tractor, but it is not so common. The plough is installed on the excavator boom and its position is controlled either with a hydraulic cylinder or with a rotator attached to the boom. Steer ability can be improved by connecting the plough with a hydraulically reversible part which functions like a ship rudder. When the cable or conduit is installed in the ground, at the same time also a warning tape is installed a little higher up from the cable or pipe. The groove made by the plough is pressed shut and the surfaces will be corrected to match the original condition. When ploughing, the groove is not separately filled because the soil is not actually removed but is displaced momentarily after which it will become almost back to normal very quickly.

Picture 2 A tracked excavator for cable ploughing (Geograph, Bron V250 Cable Plough)

There are two types of cable ploughs; either conventional cable ploughs or trembling ploughs. Trembling plough’s advantage compared with the cable plough is that the cable plough can use lower power and size, when trembling improves cutting the ground in front of it. Trembling separates also soil materials from each other, when the fine grained soil is gathered around the cable or conduit, forming a protective layer. The fine soil is also separates the cables when installing several cables at the same time. The trembling also reduces friction between the control stand and cable / conduit, so that the cable slips through the plough better. This trembling ploughs structure is much more complicated, the price more expensive and compared with conventional ploughs they are more susceptible to interference. However, the use of trembling ploughs is becoming more common, because of the benefits.

When installing the cable, or conduit, they are passed through the guide wheel through a hollow, splitted cable plough to the bottom of the groove. The cable is usually led from the cable reel attached to the machine. Otherwise, the cable or the conduit is led into the groove, for example, from a cable trailer or different kind of input devices for cable ploughs. The last alternative is to lead the cable or conduit by hand to the groove, but this slows down the work significantly. (Lancier Cable gmbh 2012)

The cable groove width and the form has a significant impact on the required power because the cable plough is pulled inside the ground. The cable plough is selected as narrow as possible depending from the cable or conduit. The width of cable plough varies from 75 mm to 160 mm. (POME 2015.) The groove can be widened by adding to the plough extension parts. The depth of ploughing can be changed by raising and lowering the plough.

The good properties of the soil makes the plowing possible. For example stony, clayey or already underground structures containing ground makes the plowing slow and in some cases impossible to do. The most effective plowing is done in fine grained soil, for example, unobstructed sandy road, where the daily work capacity can reach up to five kilometres. (Lancier Cable gmbh 2012)

2.5 Some alternative methods for installing underground structures

Installing telecommunication and electric power network underground is going to be frenetic in the near future. It is important to aim for more cost-effective actions. Efficiency can be improved by

- using methods, that have less environmental harms;
- using methods that can be used around the year;
- constructing structures that meet the functional requirements for a long time;
- using heavy-duty materials.

Development of new methods must happen in such a way that everyone at the industry gets benefits, not only the operator or contractor. The building costs can be reduced by choosing the most suitable method. There can also be provisos for the licenses given by the authorities. To ensure all the methods are treated fairly and equitably, the guidance is updated at regular intervals.

The road and street maintenance needs information about the impacts of low-installation methods to street structures. The following aspects must be followed:

- How does the road and street structures withstand the possible water entering the groove?
- How does the telecommunications, electricity and district heating structures carry the increased stress caused by the new structures?
- How to deal with the maintenance of the existing telecommunications, electricity and district heating structures? In particular, the potential cost distribution between different actors must be investigated. (ELY Center)

2.5.1 Microtrenching

In micro-trenching technique a small top or side-controlled machine (picture 3), which is equipped with a cutting disc, is used for making a groove for cable conduit. The method uses conduits, which are installed in the cut. The groove is approximately 300 - 400 mm deep and 24-32 mm wide. In figure 4 a micro trench can be seen. In a sawn groove micro tube, or a number of separate micro tubes, are being installed. A micro-ditched network is located in the load-bearing structure of the street, in a depth of a 300-400 mm. Therefore, the installation method does not have to look out for the water supply network equipment, except for cross sections, because they are located deeper in the street structure.

Picture 3 Microtrenching (Microtrenching system, Vermeer)

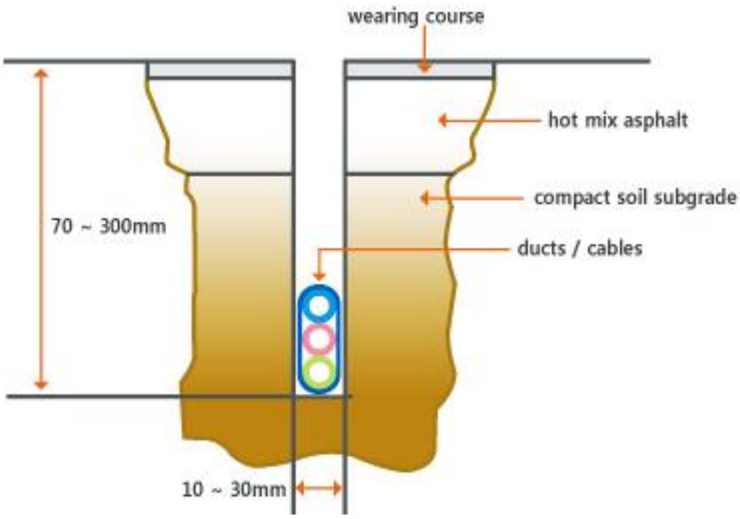


Figure 4 Micro trench (K-net)

Advantages of the microtrenching method include:

- Minimal cutting width boosts installation production and reduces cost in the amount of backfill grout needed.
- Shallow depth placement helps avoid encounters with existing utilities.
- Jobsite cleanliness with vacuum spoil removal makes microtrenching a viable alternative for urban fiber deployment projects. (Microtrenching system, Vermeer)

Problems are caused by different wells, electricity, telecommunications and sensor cables as well as district heating, which are located in the street structure of the surface layers. The fine-grained material resulting from the sawing is not used for filling the groove, but it is collected during the sawing or subsequently recovered. Side effects are caused mainly by the sound of the hardware section and the mud from the cooling water. The advantage of the micro-trenching is the small workspace need. It is possible to keep the traffic route in a passable condition during the work, for example, light traffic, so special traffic arrangements are mainly needed when transverse installations are to be done.

2.5.2 Horizontal directional drilling

Horizontal directional drilling can be used for installing all pipe construction such as gas, district heating and drinking water supply, the installation of pressure lines for sewers as well as cable protection pipe for electrical, telephone or television cables. The method is very protective towards the environment and it does not cause any ecological damage. The method is advantageous because surfaces worth conserving are neither broken up nor damaged, also restoration and repair are usually not required, which leads to high economic advantages. There are several reasons for drilling in town areas, the mainly concern the construction costs, construction periods, permission procedures, soil displacement surface restoration and the traffic, compared to the open trenching methods. The normal way for the drilling operation includes planning, preliminary survey, selecting the drilling units and drilling tools, pilot bore and detection, back reaming or upsizing bore and pulling in the pipe. To overcome the mechanical soil resistance, a high thrust and tension force is required. The application of bentonite relieves the pilot bore and the pipe traction and it provides the ability to steer in difficult soil qualities. (KRITA Engineering Pvt. Ltd.)

3 HORIZONTAL DIRECTIONAL DRILLING

Horizontal directional drilling is a nearly 40 years old method and its main principle is presented in figure 5. During this time it has become the most effective method of laying pipes under rivers and other obstacles. There exist technological and organizational boundaries for using this method, because the availability of multiple business objectives and social sustainability is not so obvious. The development strategy focuses on improving the predictability and shortening the work time. This technology should be effective and also a cheaper alternative for building the pipeline, compared to open trenching methods. Reliability and professional wisdom is the key to success. The website "Albretha engineering services" says: *"Starting from the design of the construction and the right choice of materials, through the organization of work or the selection of measures and resources suitable for the technological programs and ending with modern monitoring of the implementation of the investment."* (Albretha Engineering Services)

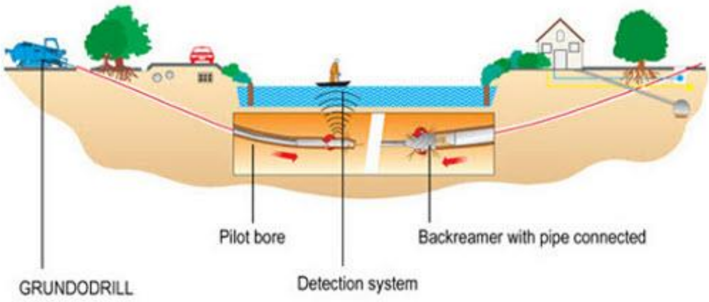


Figure 5 The main principle how horizontal directional drilling works. (KRITA Engineering Pvt. Ltd.)

3.1 Terminology for Horizontal Directional Drilling

There is a lot of terminology that is connected with the horizontal directional drilling. In this chapter the most important terms are explained in outline.

Backreamer: a cutting/mixing tool that is attached to the end of the drill string that is pulled and rotate through the pilot bore to enlarge the drill path.
Bentonite: a form of powdered clay that is used to contain fluid in the drill path.
Drill bit: the cutting tool that attaches to the front of the drill head. It mounts to the head at an angle. This angle is what provides steering capability when pushing the drill string.
Drill head: tooling that is connected between the drill stem and drill bit. The drill head houses the locator transmitter.
Gel strength: the ability of the fluid to suspend drill path cuttings.
Locator: Unit that reads the signal from the transmitter. The unit provides location, pitch, roll and depth information.
Pilot bore: the initial path created in the ground during the process of directional drilling.
Pitch: a measurement identifying the drill head's angle of ascent or descent.

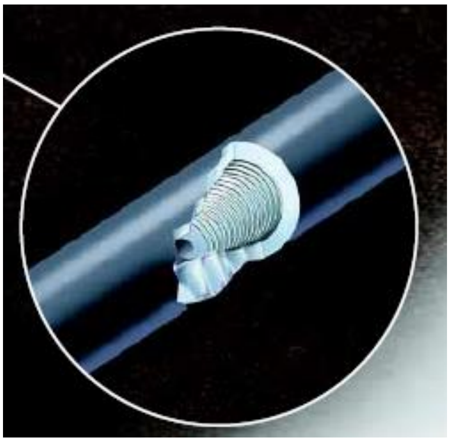
Polymer: a compound that enhances gel strength, lowers filtration rate and increases lubricity.
Pullback: the process of installing product in the drill path.
Sonde/Probe/Transmitter: an electronic device that fits inside the drill head and sends out a signal used to locate and determine the depth, pitch and position of the head. (Vermeer. The NAVIGATOR Horizontal Directional Drilling Process)

3.2 Technical framework

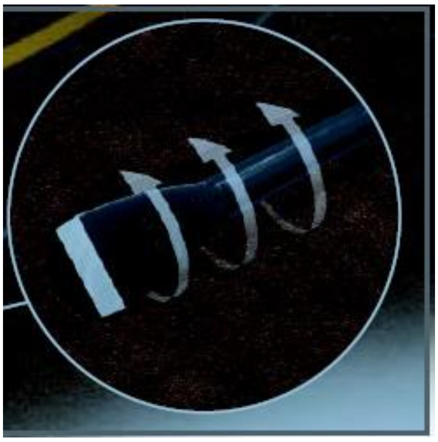
The horizontal directional drilling method is a three stage process. On stage 1 a pilot hole and entrance pit are received. After locating the existing underground obstacles and planning the intended drill path, the horizontal directional drilling unit pilot bores a path underground. Existing underground obstacles are located with the help of site maps, cable radar and well´s water level. The pilot bore is performed with minimal disruption to surface structures and above-ground activity. There is a transmitter (picture 4) in the drill head that provides depth, position and pitch information to an aboveground receiver (locator). The locating device displays this information to the user for determine if any changes are needed in the direction of the drill path.

Picture 4 The transmitter shows the depth (1, 04 m), distance (5, 04 m) and the rotation angle of the drill head in relation to the transmitter. (Miettinen, 07.04.2015)

The horizontal directional drill pushes stems into the ground. The drill head is flat and by rotating the direction of the drill head the pilot bore hole is usually reached as desired. If the ground has a lot of rocks or stuff clay, the pilot bore hole is not reached as wanted so easily. In this situation the stem has to be pulled back a bit and by rotating the drill head it finds an easier way to go further. It can be seen in picture 5 that when inserting the stem into the ground, another stem is connected to it at the machine forms the drill string. The drill string bends in response to commands of the operator, allowing the drill head to move in any direction within the drill stem's bending ability. Changes in direction during the pilot bore are allowed. The angled drill bit and flexible stem can be steered to avoid the obstacles underground. The steering happens so that the stem is pushed without rotation. When no direction change is needed, the stem is rotated and pushed simultaneously. In picture 6 there is the drill head.



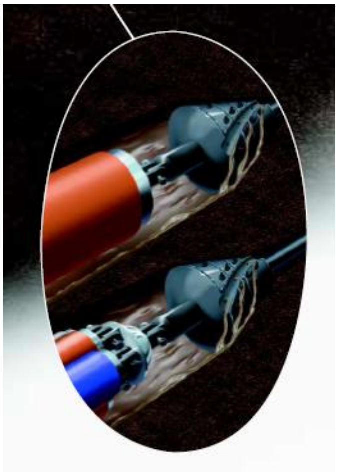
Picture 5 When inserting stem, another stem is connected to it. (Vermeer. The NAVIGATOR Horizontal Directional Drilling Process)



Picture 6. The drill head. It is flat and by rotating the direction of the drill head the pilot bore hole is usually reached as desired. (Vermeer. The NAVIGATOR Horizontal Directional Drilling Process)

To avoid overheating of the stems and the drill head, lubricate and seal the drill path, special drilling fluids are pumped through the drill system. This drilling fluid consists usually water, bentonite and baking soda. Bentonite mixes better with water with the help of baking soda. This drilling fluid also cools the transmitter and suspends the drill path cuttings, creating a flow able slurry.

On stage 2 the target hole along the axis of the pilot hole is reamed and created. When the pilot bore is completed, the drill head is removed and a backreamer is attached. The size of a backreamer is selected by the basis of the size/sizes of the pipe being installed. A backreamer is pulled and rotated to enlarge the drill path. On stage 3 the pipe is then pulled into place behind the backreamer, seen in picture 7 and 8. Drilling fluid is introduced through the backreamer and mixed with the drill path cuttings to create a flow able slurry, which is displaced by the pipe being installed in the drill path. The backreamer is sized slightly larger than the pipe being installed. This allows the slurry to flow freely around in the drill path. It is usual that stage 2 and 3 are combined. If the soil is clayey or has a lot of rocks, the reaming diameter is large or there are many pipes, stage 2 and 3 are done separately. (Albertha Engineering services. Horizontal Directional Drilling.)



Picture 7 Drilling fluids are pumped through the drill system and the pipe/pipes are pulled into place behind the backreamer. (Vermeer. The NAVIGATOR Horizontal Directional Drilling Process)

Picture 8 The pipe is pulled into behind the back reamer. (Miettinen, 07.04.2015)

After boring, the environment must bring in such a condition it was before drilling. Also all the technical parts of the drill are washed and maintained.

3.3 Drilling Project

The drilling is presented in full scale in figure 6. The drilling projects in Finland are usually quite small. From picture 9 it can be seen that horizontal directional drilling is suitable method in various cases.

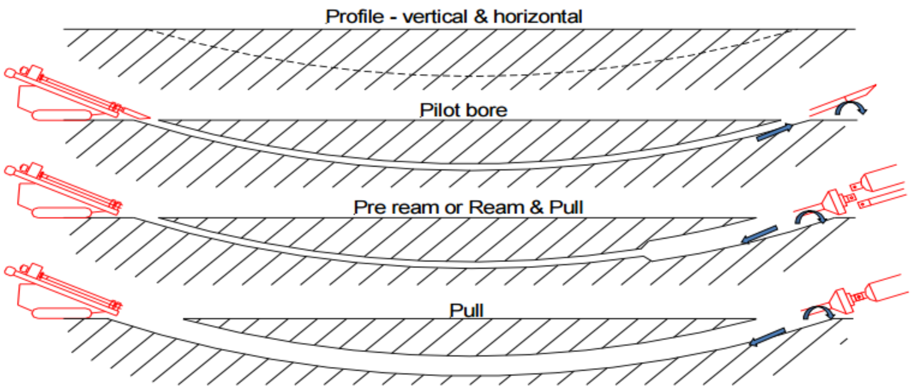
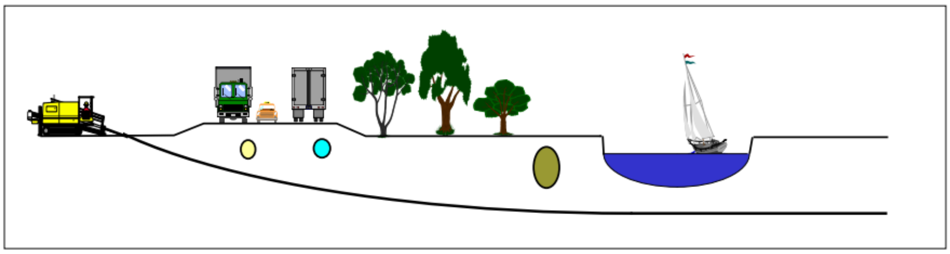


Figure 6 The drilling project in full scale. (VERMEER. Principles of HDD)



Picture 9 Pipes can be installed under roads, rivers, railways, building, trees etc. (VERMEER. General principles of HDD)

3.3.1 Preparation

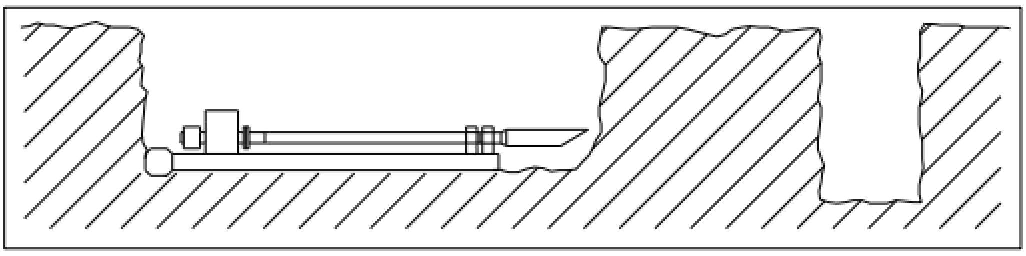
Preparation counts for 40-50% from the entire project. When the project is prepared properly, the drilling should progress smoothly. In chapter 2.3. the investing progress is already introduced. Before boring, wishes from the client must be taken into account. What does the client want and where? Also the timing is very important. Also the project conditions, such as topography, obstacles, soil conditions and stratigraphy must be taken into account. Feasible study from the drilling site, especially in bigger scale projects, makes the work more efficient and therefore it is the most important phase of the whole drilling project. (UEA. Trenchless Technology.)

3.3.2 Pilot bore

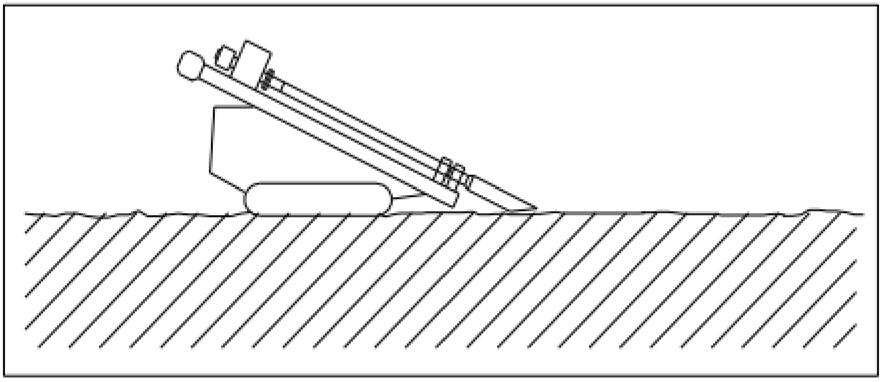
A pilot bore is done with a drill rig connected to steel rods and a drill head that has a locatable beacon at the front. The pilot bore is normally surface launched through an entry pit and is completed at the exit pit. The drill head is guided from surface and monitored for the extent of the prescribed line and depth with respect to the design specifications. The location transmitter is shown in picture 10. (UEA. Pilot bore.)

Picture 10 Transmitter receives information from the position, distance and angle of the drill head. (Miettinen, 22.3.2015)

A pilot hole is drilled due to the required path with the help of steering information. Depending on the ground conditions and project requirements, the bore is reamed in a single or multi-stage operation to a larger diameter to accommodate the product pipe. The horizontal boring machines use drilling fluids, which lubricates, cools and stabilises the bore. When starting a pilot bore, it is important to evaluate the wanted launch type. Launch can be either pit launch, shown in picture 11 or surface launch, as picture 12 shows. If the start point is cramped or the pilot bore needs to go deep relevantly early, a pit launch is a better option. With pit launch it is possible to make the pilot bore go deeper at early stage and it is also good at cramped areas. The pit is made with a small excavator. When there is space to make the pilot bore in the wanted depth, a surface pit launch is chosen. Time is spared when the excavator is only needed to make a stabile surface for the bore. (UEA. Horizontal Directional Drilling)



Picture 11 Pit launch (VERMEER. General Principles of HDD)



Picture 12 Surface launch. (VERMEER. General Principles of HDD)

3.3.3 Pre-reaming

Pre-reaming is a stage that is done only in hard, clayey or rocky soils. Picture 13 shows a cutting head, known as a reamer. It is attached to the end of the steel rods, after the pilot bore is done. The required reamer dimension is used to accommodate the final pipeline product. A general rule of thumb for the final bore diameter is 1.5 times the outside diameter of the pipe to be installed. When the reamer is attached on the exit side, the reamer is pulled back whilst rotating through the existing pilot to enlarge the bore hole. If the soil is rocky, a special reamer is attached to the drill rods on the entry side and rotated to the rock face. For larger diameters, the hole is increased in size in stages, which vary in size depending on the ground conditions. (UEA. Reaming.)

Picture 13 A reamer attached to the exit side. (Miettinen, 22.3.2015)

3.3.4 Product installation

During the final pullback stage, the product pipe is attached to the reamer by means of a swivel connector, and is pulled into the enlarged bore hole as the drill string is withdrawn. The pullback stage can be done either straight after the pilot boring with the reamer, or after pre-reaming. The bore hole is either way swabbed with the reamer to remove soil that remains in the bore hole. The product pipe is strung out on the exit side of the bore. The product pipe is attached to the rear end of the reamer via pulling head and a swivel, seen in picture 14. The pipe can be attached to the swivel either by mechanically or it is welded onto the pulling head. When the pullback starts, the drill head and drill string rotates and is pulled towards the rig. To avoid the rotation of the new product pipe inside the bore hole, only the swivel assembly rotates and the pipe slides inside the lubricated borehole without interference. To prevent a frac out, it is important that the fluid returns are running either in direction of the entry or exit pits. When the production pipe is installed, the environment is fixed to match the original condition. (UEA. Pullback)

Picture 14 The product pipe is attached to the reamer via pulling head (left) and a swivel (right). (Miettinen, 22.3.2015)

3.4 Drilling fluid

There are municipal drilling fluids that are used in directional drilling by many manufacturers. Bentonite based drilling fluids are used to control fluid losses, reduce torque, and control down hole conditions of countless horizontal directional drills.

The drilling mud lubricates and cools the drill bit, suspends and carries cuttings out of the borehole, seen in figure 7. In order to keep returns flowing, returns must be fluid. To keep returns as fluid, it can only carry a limited amount of cuttings out of the borehole. As a basic rule of the relation of borefluid and soil that keeps the returns as fluid is;

$$RETURNS\ (100\ \%) = BOREFLUID\ (75\ \%) + SOIL\ (25\ \%). \qquad 1.$$

This means that for every 1 m^3 soil we need 3 m^3 borefluid as a basic rule.

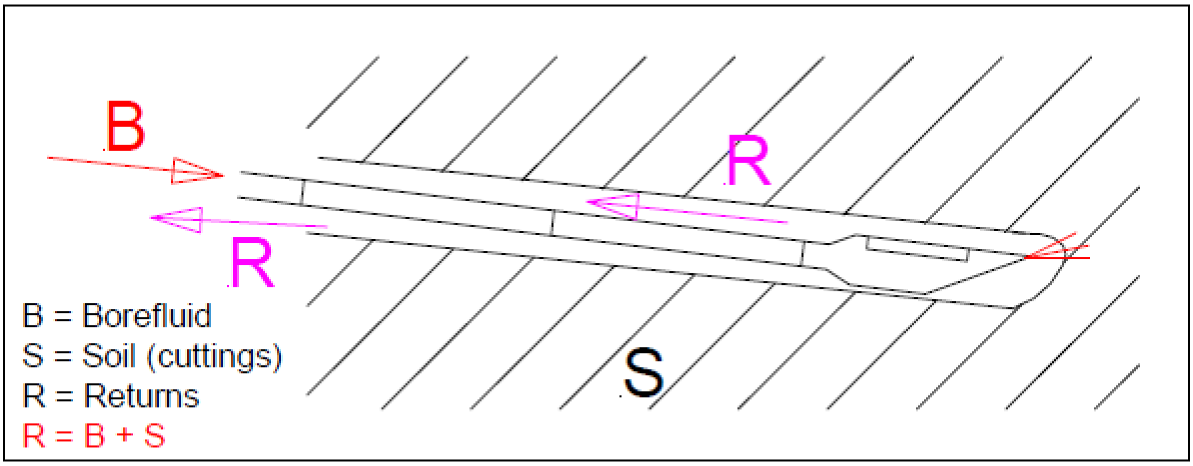


Figure 7 The drilling mud suspends and carries cuttings out of the borehole. (Vermeer, Priciples on HDD)

Drilling fluid also plasters the face of the borehole with a thin layer of solid material to prevent flow of fluids into or out of the formation and applies a hydrostatic pressure to the formation to balance the pressure and fulfils other requirements.

In order for the drilling fluid to perform needed functions it must have certain physical properties. The fluid must have a viscosity of such a magnitude that it is conveniently pumpable without undue pressure differentials. It must form a thin filter cake on the borehole face to prevent the loss of the liquid medium that is present in the drilling mud by filtration into the formations through which the borehole passes. Such a filter cake seals the face of the borehole and inhibits any tendencies toward sloughing, heaving or cave-in of rock into the borehole. The fluid must be capable of suspending weighting agents such as inorganic compounds. The fluid should also be in such a constitution that the presence of granular material, such as cuttings formed in drilling the borehole and which may be assimilated or dissolved by the drilling mud, has substantially no effect on the physical properties of the drilling fluid. (Fischer and Cook, 1951)

To calculate the volume of needed drilling fluid, first the soil volume has to be calculated, shown in formula 2, with the help of the information of the drill hole (figure 8);

$$Soil\ volume\ (m^3) = Hole\ diameter\ (m)^2 * 0{,}785 * (length\ (m) + Depth\ (m)). \qquad 2.$$

After the soil volume is calculated, the fluid volume can be calculated by multiplying the soil volume by 3, as the following formula 3 shows;

$$Fluid\ volume\ (m^3) = 3 * Soil\ volume\ (m^3). \qquad 3.$$

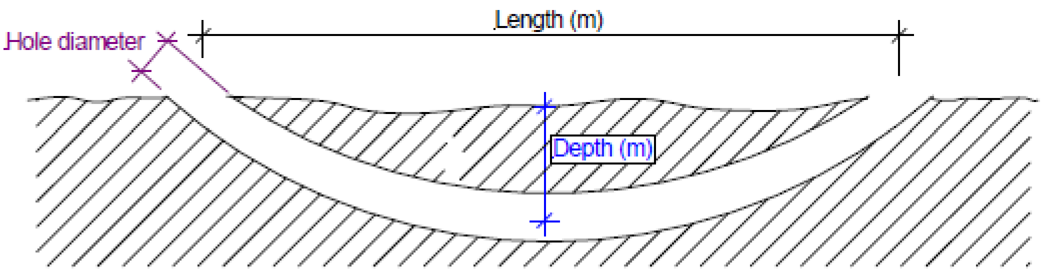


Figure 8 For calculating the soil volume and fluid pumping time, you need to know the hole diameter, length and depth of a drill hole. (Vermeer, Principles on HDD)

In some cases also the fluid pumping time is good to calculate, in order to improve efficiency. The pumping time is calculated according the information shown in figure 8. It can be seen from the following formula 4 how the fluid pumping time can be calculated;

$$Pumping\ time\ (minutes) = \frac{\text{Fluid volume (liters)}}{\text{Pump capacity }(\frac{\text{liters}}{\text{minute}})} \qquad 4.$$

The pump should provide 1 litre water per mm in hole diameter. For example if the hole diameter is 500 mm, the pump should provide 500 litres/min drilling fluid. (Vermeer, Principles on HDD)

4 SELECTION OF THE SUITABLE DRILLING METHOD

When selecting the suitable drilling method multiple factors must be taken into account. At first, the site maps are evaluated. From the site maps can be seen, if the road has been raised and approximately, how much. Also in bigger scale bore sites, a geology investigation is always carried out. There are three different specifications that can be determined from the bore sample and geotechnical report;

- SPT (Standard Penetration Test) – for unconsolidated geology
- UCS (Unconfined Compressive Strength) – rock samples
- Mohs hardness determined for the different rock samples encountered (UEA. Geology investigation.)

The rock formation hardness of different geological ground conditions is identified in figure 9 below. In larger scale bore sites this information is important to reach the maximum benefit for boring. The bore sites Oy Epuro Ab has, do not have this scale boring projects.

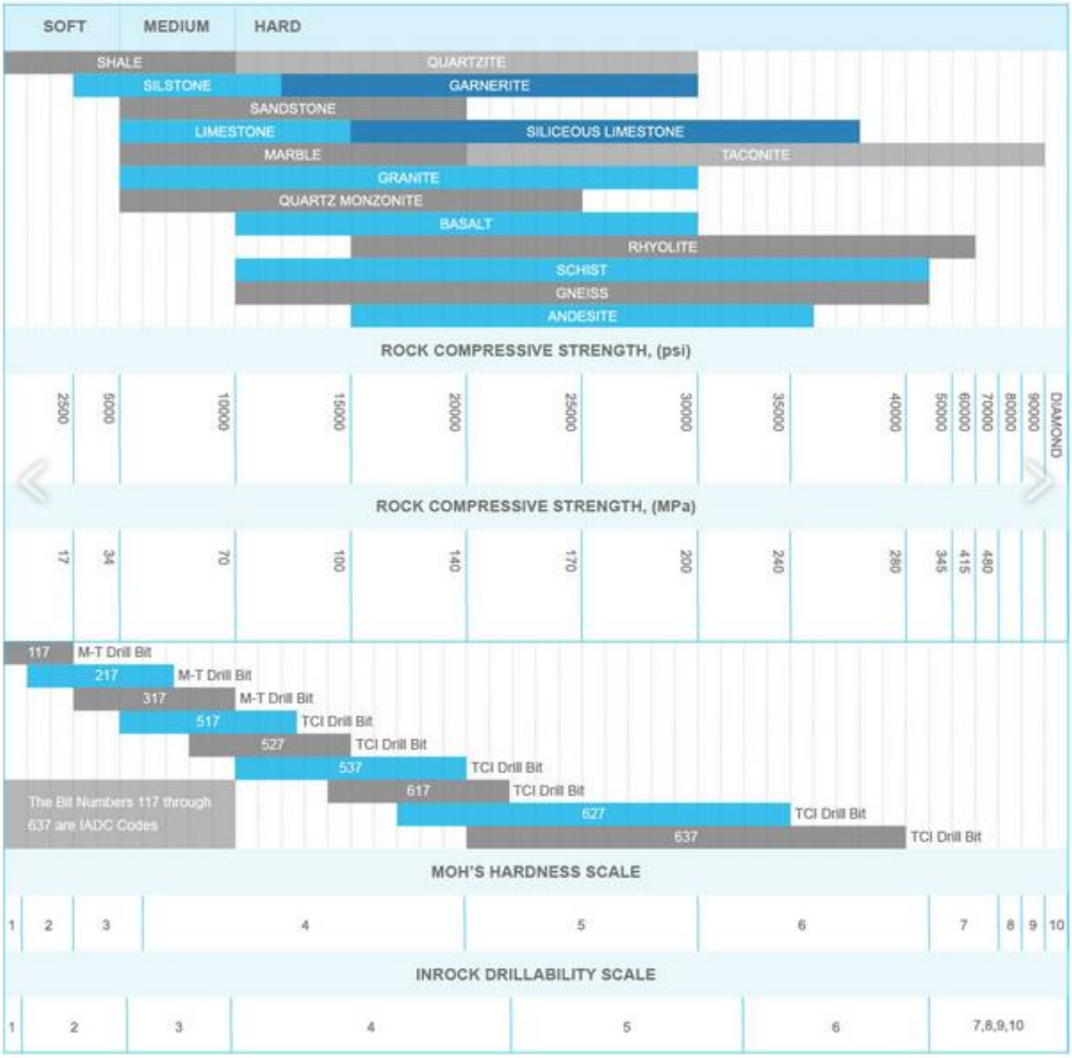
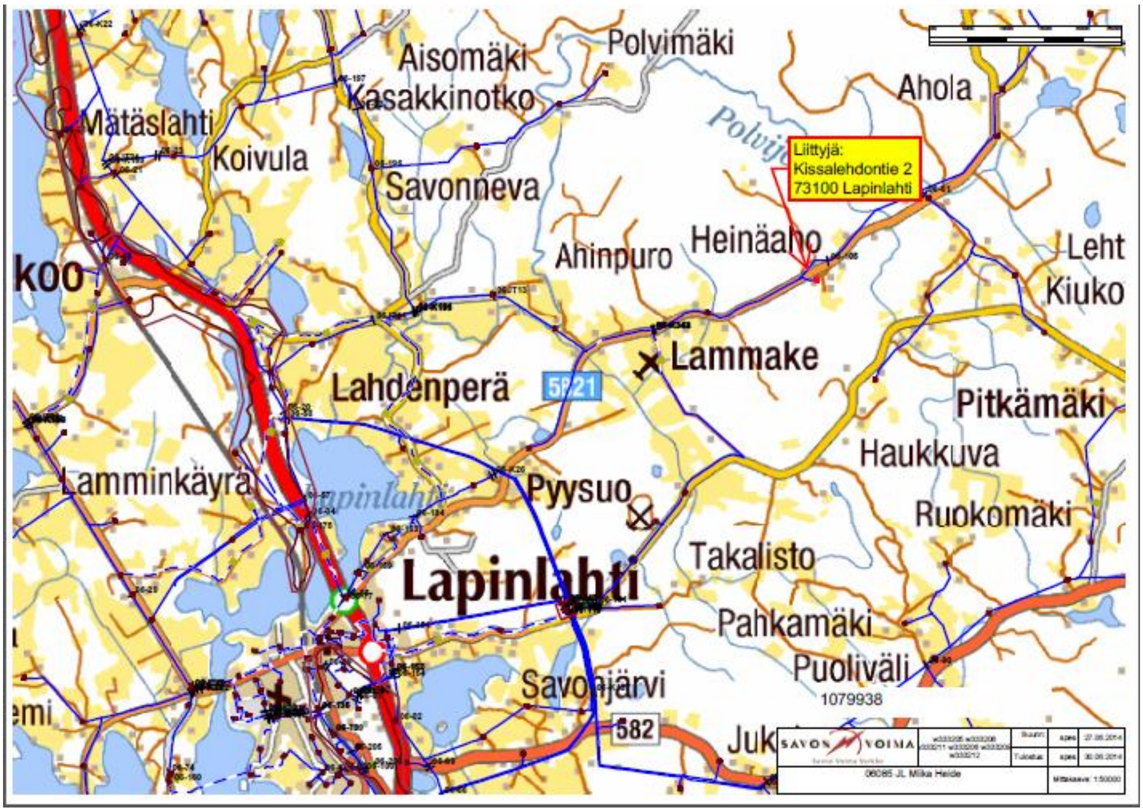
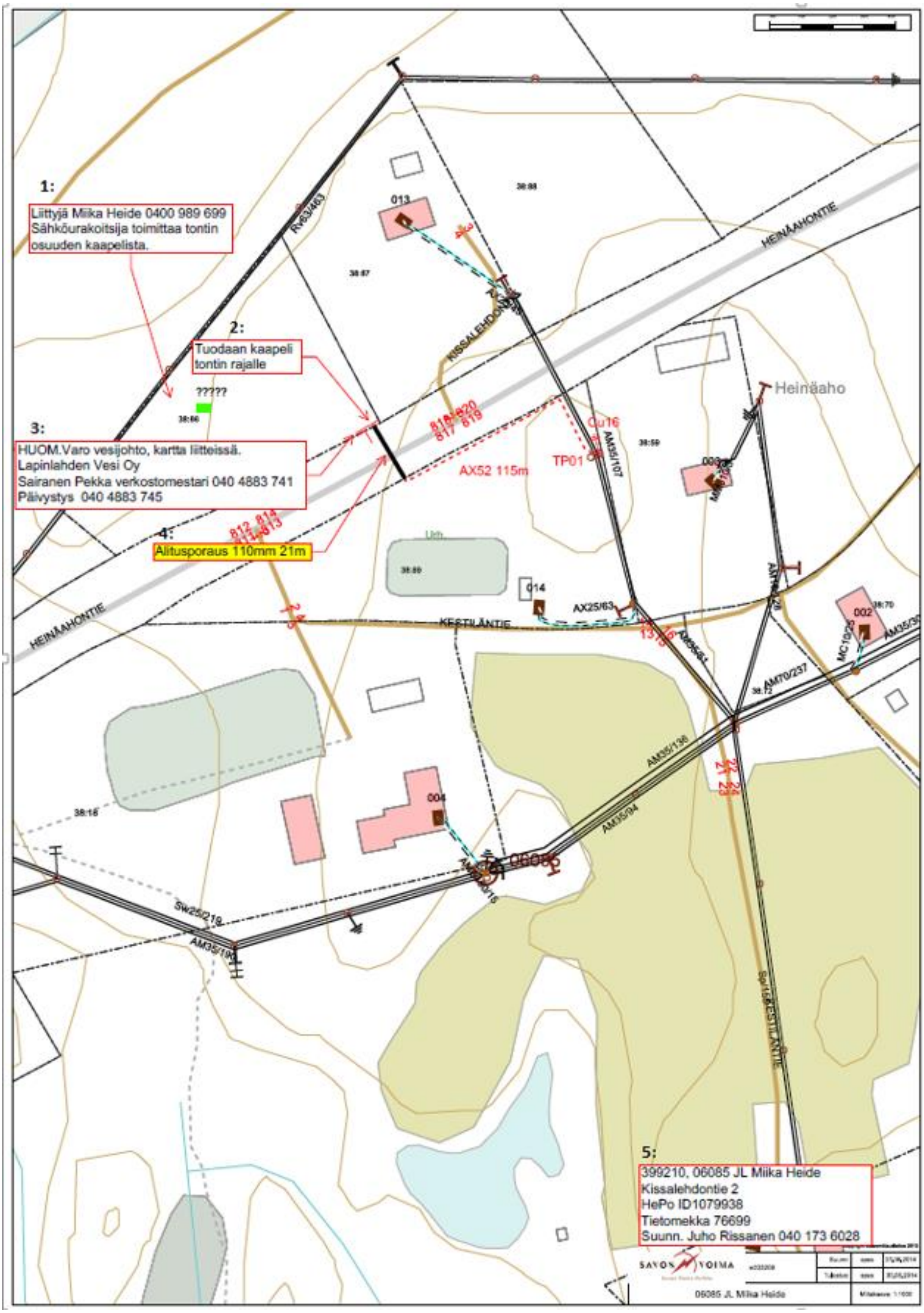


Figure 9 Rock formation hardness categories. (UEA. Geology Investigation.)

Usually Oy Epuro Ab gets the needed information by only examining the site maps. From the site map the depth scales and the type of the soil can be seen. If the terrain for example has a lot of swamps, it is most likely that the roads have been supported and filled with a rock bed. Approaching map shows the place and main lines of the site (picture 15).



Picture 15 Approaching map (Savon Voima, Juho Rissanen)



Picture 16 Land use plan. (Savon Voima, Juho Rissanen)

In picture 16 there is an example of a land use plan. Below

1: The customer: Miika Heide 0400 989699. The electrical contractor supplies the cable to the plot.

2: The cable is supplied here.

3: CAUTION! Watch out for water pipe, the map as attachment; Lapinlahden Vesi Oy, Sairanen Pekka, The master of water network, 0404883741, on-call duty, 0404883745.
4: The bore hole: 110 mm, 21 m.
5: The worknumber, work ID and initial information of the planner.

The boring liquid is selected on the basis of the evaluation of the soil type. When making the pilot bore, the type of soil can be evaluated. The making the pilot bore can be relatively light or the soil can be rocky or clayey, when the pilot bore is narrow. After the pilot bore, the workers decide the amount of boring liquid that is to be pumped on the next stage, either pre-reaming or pullback. If the pilot bore is very narrow, pre-reaming is considered, depending from the diameter of pullback and the number of pipes to be installed. In some cases, the soil can be so rocky or the pullback diameter is so large, it is recommended to make two borings instead of one.

5 WORK SAFETY ON DRILLING SITE

According to Occupational Safety and Health Act (738/2002) the 14 section (instruction and guidance to be provided for employees) tells that *"Employers shall give their employees necessary information on the hazards and risk factors of the workplace and ensure, taking the employees' occupational skills and work experience into consideration, that:*

> *(1) the employees receive an adequate orientation to the work, working conditions at the workplace, working and production methods, work equipment used in the work and the correct method of using it, as well as to safe working practices, especially before the beginning of a new job or task or a change in the work tasks, and before the introduction of new work equipment and new working or production methods;*
>
> *(2) the employees are given instruction and guidance in order to eliminate the hazards and risks of the work and to avoid any hazard or risk from the work jeopardising safety and health;*
>
> *(3) the employees are given instruction and guidance for adjustment, cleaning, maintenance and repair work as well as for disturbances and exceptional situations; and*
>
> *(4) the instruction and guidance given to the employees is complemented, when necessary.".*

By the basis of this law, for each drilling site, a specific "security screening and risk assessment for construction site" is done (Attachment 2). The contractor has prepared this document to ensure the work safety on drilling site. For each drilling site this kind of document addresses all the risks linked to the working on drilling site.

6 CONCLUSIONS

In particular, the digging causes large footprints to the environment. Filling trenches and surfaces make a large part of the total cost. Horizontal directional drilling can be cost affected (depending a lot on the surface material). Horizontal directional drilling lowers costs of the fills and the amount of excavation required is reduced. New methods can not completely replace traditional methods. Traditional methods are good and functional proven methods and the use should not stop. Problems related to methods are known and regard to the operation. New methods need to be developed and user experiences, so that they can act in the best possible way in Finnish conditions. Horizontal directional drilling offers many advantages like efficiency, speed, cost-savings and causes less disruption to the environment and traffic flow. Although it does not eliminate the need for open-cut utility construction, it is another tool in the contractor's arsenal of machines and methods. By supplementing traditional and new methods the network building costs and impacts to the environment can be reduced.

Horizontal directional drilling is quite a new method used in Finland and therefore it is not so familiar among land building companies. In Finland alternative methods are used when installing underground structures, but these methods disrupts land surface. One of the aim of this thesis was to find the benefits when using a method where land surface stays at the original condition. It became clear that from the methods used for installing underground structures horizontal directional drilling is the only one where surface does not disrupt. This leads to the fact that when installing underground structures where the planned excavation hybridize with roads, lakes or rivers, the horizontal directional drilling is only feasible method.

Finnish Road Administration requires for the most cost-effective solution when planning a telecommunications network, which is in flavour of using horizontal directional drilling as an installing method. These installation operations where cables are being installed underground, need a legislative permission and this is why all needed documents and licences must be in order before starting the work. For example all the roads administered by ELY-centre are not allowed to dig open, when horizontal directional drilling is again the only alternative method for situations where the cable line and road or street intersects.

When examining the differences between the aerial lines and underground telecommunication and electrical network it is clear that aerial lines cause more disadvantages. The maintenance of the aerial lines as well as costs of repairs, cause a number of costs yearly which affects directly to the costs paid by customers. The costs from underground structures consists mainly just from installation. The cables are also safe when placed underground.

At next I will compare the benefits of horizontal directional drilling and traditional methods when installing underground cables. Horizontal directional drilling is relatively new method in Finland and not so much known among land construction industry. The installation method for the ground-mounted cables is usually either conventional or cable ploughing. Traditional construction methods bring challenges for the contractor, such as frozen soil (work can only be done when the soil is unfrozen) and slow working speed, which causes disadvantages to the third parties. These disadvantages are for example traffic and road network harm, noise harm and changes to the landscape. Horizontal directional drilling does not cause these kind of disadvantages. Also damages to the already existing structures are low when using horizontal directional drilling as an installation method compared to the traditional installation methods.

Horizontal directional drilling has become the most effective way of laying pipes under rivers and other obstacles. The constructors aim to develop a strategy that focuses on improving the predictability and shortening the work time when installing underground cables. Horizontal directional drilling stands up its' benefits with this.

The horizontal directional drilling is very efficient process. Each stage has benefits, the other methods do not have. On stage 1 damages are minimized by locating the existing underground obstacles and by planning the intended drill path. When the drilling is guided from the surface with the locating device, all obstacles can be dodged. On stage 2 damages to the pipe being installed are minimized by using a backreamer. The backreamer enlargers the drill path to the wanted size. This is how pressure does not get too high in the drill path and make damage to the pipe being installed. Drilling fluid lubricates and cools the drill bit, suspends and carries cuttings out of the borehole. The drilling fluid makes the drilling faster and easier and it is 100% environmentally friendly.

By the basis of this thesis it can be said that horizontal directional drilling is the best installation method when installing underground structures, especially if there are already installed underground structures, roads or water obstacles at the site. It can be used for installing gas, district heating and water supply as well as the installation of pressure lines for sewers as well as cable protection pipe for electrical, telephone or television cables. It is a protective method towards the environment and does not cause ecological damage. Surfaces worth conserving are neither broken up nor damaged, which leads to high economic advantages.

My aim was to find the benefits of using horizontal directional drilling when installing underground structures in Finland and by assembling these facts in this thesis I believe that by advertising these facts horizontal directional drilling could become the most popular method when installing underground structures in Finland. The constructors should also question the traditional methods, because by the basis of this thesis it can be seen that they are not as cost-efficient as horizontal directional drilling.

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ATTACMENT 1: SECURITY SCREENING AND RISK ASSESMENT FOR CONSTRUCTION SITE

Voimatel

Security screening and risk assessment for construction site.

Order information		
Client Savon Voima Verkko Oy	Contractors work- /contract number 1009433	Work number 3R1402-2096
Project / contract 12281 cabeling	Contractor Voimatel Oy	Team 450
Corresponding supervisor Aarne Juutinen	Subcontractor Epuro Oy	

Organisa-tion	Task	Name	Telephone
	Security co-ordinator	Juutinen Aarne	017 223 465
	corresponding supervisor of electrical safety		
	Contractor:		
	Project manager	Kukkonen Ilkka	0447938500
	Head of health and safety	Heinonen Mikko	0447939836
	Foreman of electrical work	Heiskanen Jukka	0447938608
	Subcontractor: Project manager	Markus Parviainen	
Occupational safety regulations	In this project the instructions of security screening and risk assessment for construction site, the law of work safety and other instructions and regulations by authorities must be obeyed.		
Special instructions	**THE CONSTRUCTION SITE IS LOCATED AT THE MAIN AREA OF ROAD CONSTRUCTION SITE OF SAVON KULJETUS. THE WORKERS HAVE DUTY TO REPORT THE PROJECT MANAGER, JUHO HYNYNEN, BEFORE WORK. HYNYNEN 044 727 2571.**		
Safety instructions of site -Required documents -Special instructions and qualifications	Document		
	advance notification for work safety authority	If less than 10 workers, advance notification is not to be drawn	
		by the half of building contract	
	Regional plan	To be drawn up before work on site	
	Precheck for working machines	At the beginning of work	
	Maintenance check	Once a week	
-In case of accident	- Save immediately victims of the accident.		
	- Alarm, call 112 (ambulance, fire brigade)		
	- Limit the emergence of further damage		
	- Guide the assistance to the crash		
	- Notify your supervisor		

	- In case of a serious accident at work, make the declaration also to occupational health and safety, and the police
	400/110/20 kV connection with the injury, not the injury site must go before the part of the cable / drive is disconnected from the network and grounded. Contact the network to take center area.
	Phone. 0800 307 400 24 h
Orientation of employees	For every employee is either given construction site induction or is otherwise ensured that everyone knows safety regulations and instructions. Every employee has a statutory responsibility for safety and is obliged to report from defects. - Work site - Environmental factors - Protective clothing, helmet, safety shoes The main contractor keeps record from the persons that have been given familiarization training.

Risks and other matters to be considered relating to the working site		Connected	Disconnected	Other things to be considered
	Traffic arrangements	☑	☐	
	Traffic guiding and suspension arrangements	☑	☐	
	Access routes	☑	☐	
	Excavations, ramps, landslide risks.	☑	☐	
	Stands	☑	☐	
	Machinery and equipment	☑	☐	
	Warehouses, cargo loading and unloading places.	☑	☐	
	General cleanliness and waste management.	☑	☐	
	Prevention of noise, vibration and dust.	☑	☐	
	Lifting equipment, including hydra ladder	☑	☐	
	Action in special situations	☑	☐	
	Emergency standby	☑	☐	
	Firefighting equipment	☑	☐	
	Use of personal safety equipment	☑	☐	
	Electrocution, hazardous work	☑	☐	
	Fire work	☑	☐	
	Location of underground structures	☑	☐	BEHIND MEASUREMENTS
	Rear voltage	☐	☑	
	Grounding	☑	☐	
	Communication with the customer	☑	☐	
	DISCHARGED POLES	☑	☐	
		☐	☐	
		☐	☐	

Detailed descriptions of the risks and things associated with the working site.		
Traffic arrangements		The work in road, street or other traffic area or in the vicnity of it, must be performed in such a way, that they don't present any risk for workers or traffic. Work must not cause unnecessary inconvenience to traffic.
Checked		
Traffic guiding and suspension arrangements		Traffic arrangements must be agreed with the road manager. Foreman is responsible for this. The contractor is responsible for implementation of needed traffic arrangements. When working on site that may endanger traffic, must the road or section of the road where the work is performed be equipped with appropriate signs. As basis of rules and regulations, the road must be closed when circumstances require it. If the road must be closed, regional alarm centre must be informed to control the passage of emergency vehicles.
Checked		

Access routes		When special traffic arrangements are done, they must be dimensioned for pedestrians, cyclists and vehicle traffic. It must be insured the routes are safe and free from additional supplies. Routes are marked with clear and adequate signs. The walkways, floors, stairs, corridors and such a places must be kept in such a condition that the risk of slipping, tripping or falling are minimized.
Checked		
Excavations, ramps, landslide risks.		Protection and marking of excavations. Excavation must be done safely, taking into account soil type, trench depth, the slope gradient and the lad as well as the dangers caused by water and traffic vibration. The trench wall must be supported in case a collapse could cause an accident. When submitting the trench without occupation, there must be trench barriers or other mechanical barriers to prevent accidents. Warning tape can be used for warning of trench when it is placed far enough from the trench edge.
Checked		
Stands		If possible, stands (height approximately 3 m) are to be used. Before work begins, it is necessary to check structures of scaffolding and needed groundings. Stands and scaffoldings as well as the falling protection must be implemented in compliance with safety regulations.
Checked		
Machinery and equipment		Machinery and equipment must meet work and traffic safety standards. They must be safe and fit for use. On public traffic areas as well as other traffic areas the machines must stand out from the rest of the traffic. Machines must have warning lamps and other warning equipment in accordance with the regulations. Contractors and self-employed workers are responsible to make weekly checks for machinery and equipment that are given by the main contractor. Also the detectability of the machines must be checked. Daily operational trials must be implemented each day.
Checked		
Warehouses, cargo loading and unloading places.		Unloading, loading and storage sites must withstand loads due to traffic and cranes. Driveways must be organized in such a way that they do not intersect unnecessarily with other driveways on site. When working in public traffic areas, working site must be detectable with traffic control, traffic signs, safety devices and lightning.
Checked		
General cleanliness and waste management.		Good order and cleanliness as well as waste management must be maintained on working site. Waste is removed from the construction site and disposed of in accordance with laws and regulations. Materials are recycled or reused when possible. The construction site must be handed over in good order and tidied up. If necessary, the customer representatives inspect the condition of the construction site before it is released.
Checked		
Prevention of noise, vibration and dust.		Working methods causing noise and vibration should be avoided whenever possible. In urgent situations, working stages causing noise and vibration are carried out in stages to minimize the danger for workers on construction site. Preventing site dust needs special attention. The amount of dust can be reduced with dust suppression.
Checked		
Lifting equipment, including hydra ladder		The contractor makes a separate work plan for difficult and dangerous lifting work, scaffolding and other lifting work. Before starting the lifting work the contractor has a responsibility to confirm the stability and safety of the soil bearing capacity and safety of the working area. Distances from energized parts will be continuously monitored and, if necessary, set a voltage-sitter. For scaffolding special equipment for personal lifting is used and checked before use.
Checked		
Action in special situations		Occurrence report or notify must be done for the supervisor in special situations. Reasons for deviation are reported and needed actions are evaluated, how the deviation is to be fixed and prevented in the future.
Checked		
Emergency standby		RESCUE. Assess the situation and rescue, if possible. Is the victim breathing, is his/her heart beating? In case of an electric shock can you turn off the electricity? CALL 112, if necessary. Do not close your phone until you have been given permission to do so. HELP. Administer first aid if you know how. If necessary, ask for help from someone who knows how. GUIDE rescuers to the site. Do not leave the patient alone.
Checked		
Firefighting equipment		Fire extinguishing equipment and their locations should be clearly labelled and must always be easily accessible. In case of fire the fire brigade shall be alerted and initial extinguishing shall be done.
Checked		
Use of personal safety equipment		If the risk of an accident or illness can not be avoided or adequately restrict with technical precautions or with organization of work, must the employer obtain personal safety equipment for employees. The employer must also ensure, that the protective equipment is used.
Checked		

Elecrtocution, hazard-ous work		When working in the vicinity of electrical equipment, safety instructions and regulations issued by the system operator are used, as well as the regulations given in the SFS 6000 series. When working in the vicinity of uninsulated wires and devices, the danger must be prevented with protective structures or by any other means. The contractor must also ensure that safety distances must be followed when lifting machines or other machinery and vehicles are on the move. A qualified electrician should not fall below distances defined in SFS 6002. If the distances have to be undercut, a distance meter must be used when working. Safety distances have to be followed also from SFS 6002, in case the workers are qualified with other profession than electrician or portable machines are used on site.
Checked		
Fire work		Special attention must be payed to fire safety so that the risk of fire does not arise. General instructions, work site instructions and instructions given by authorities must be followed. Employee who is doing fire work is responsible for carrying out fire protection, portable fire extinguishers and if necessary, post-guarding. Employees doing fire work must have a valid firework education.
Checked		
Location of under-ground structures		Instructions for the safety of the work determine that before starting an excavation work, locations of underground structures must be determined. If there are water or sewer pipes as well as telecommunication or electrical cables, the exact location must be determined with radar. The exact location and clearance can be ensured by digging out the cables with sufficient extent. This has to be done carefully so that the cables will not damage. If necessary, the cables are protected or moved away when working. The contractor ensures that the work his doing, does not cause any danger to the buildings, structures, vegetation, appliances and equipment's.
Checked		
Dead electrical cables		Always make sure and verificate that the electrical equipment is dead before touching it/them. In case the work is suspended and there has not been any supervision by the workers, the verification must be done again. Appropriate instruments must be used for the verification. Before the verification make sure that the device definitely works.
Checked		
Grounding		With grounding the emergence of a dangerous voltage on work site is prevented. Parts of electric circuit are attached to each other and to the ground when grounding. The equipment to be grounded must be ensured to be dead before the grounding.
Checked		
Communication		To ensure smooth information flow between the customer and the supplier, responsible persons are named and their contact information is distributed to necessary extent. Informing the customer is carried out in accordance with agreed procedures. The customer is kept informed of all matters necessary during the work.
Checked		
ATTENTION		Old piles without support; do not climb !
Checked		
Checked		
Checked		

The author	Ilkka Kukkonen	Date	26.5.2014

Add persons for the project

Persons taking part for the project	
Name	Signature
Kari Kauhanen	
Pasi Jaronen	

Project leader	Signature	Date
Ilkka Kukkonen	Ilkka Kukkonen	26.5.2014