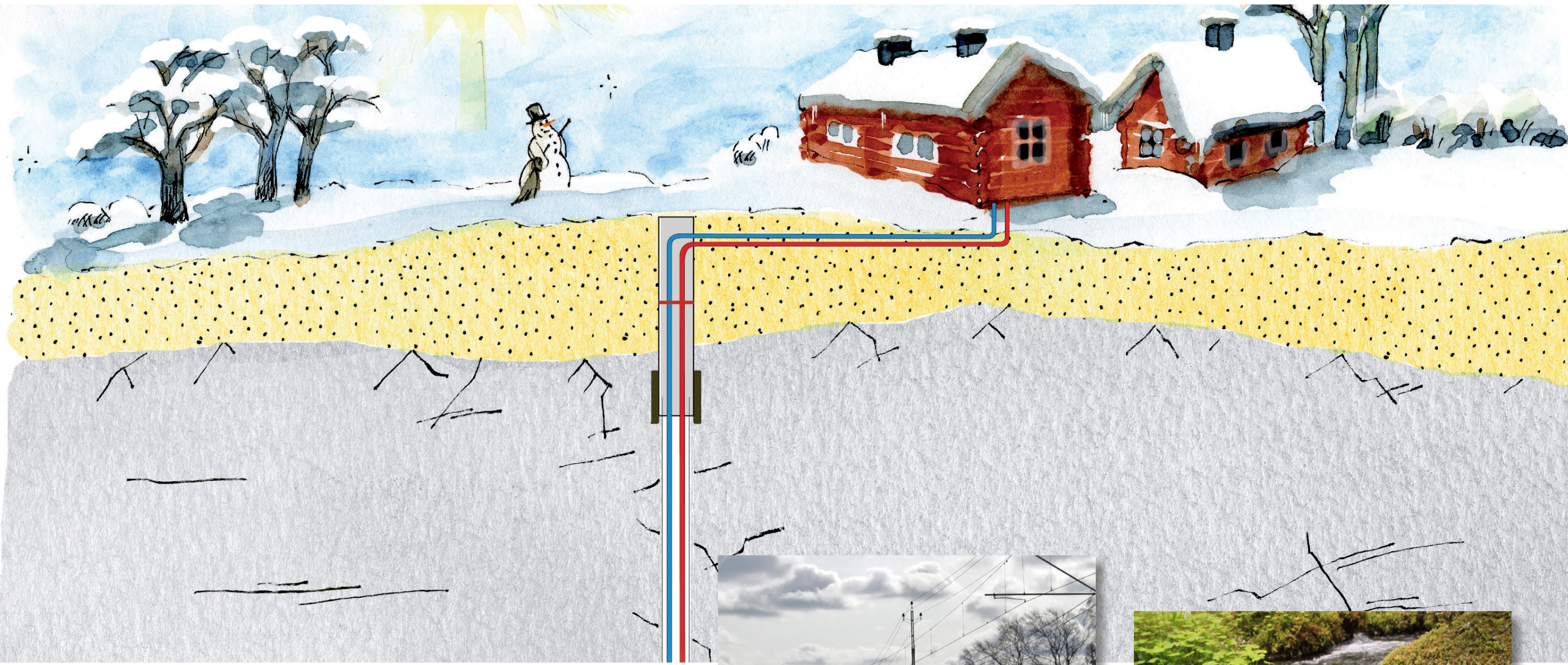
WELL STANDARD –16

GUIDELINES FOR WELL DRILLING

April 2023



SGU Geological Survey of Sweden

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PREFACE

The first Swedish publication providing guidelines for well drilling was issued in 1997. This was later expanded into *Normbrunn -07*. Since then, requests have been made for clarification and expansion, for example regarding drilling within contaminated ground and within water protection areas, and regarding the drilling of more extensive well systems.

The Geological Survey of Sweden (SGU) therefore made the decision to update the 2007 edition. The result is this 2016 issue: The structure and most of the content of the 2007 guidelines are the same; partly to make reading easier, and also because most of the conditions and requirements remain the same.

In 1999 the Swedish parliament established the national Environmental Objectives System to provide a framework for the work towards environmental sustainability in Sweden. SGU is the responsible government authority for one of the 16 Environmental Quality Objectives, *Good-Quality Groundwater*. This responsibility includes coordinating, monitoring and reporting to the government, and forms the basis of SGU's ongoing engagement regarding the publication of guidelines relating to groundwater issues.

The guidelines are mainly intended for drilling contractors. They are also included in the educational material provided by SGU as part of the certification courses for well drillers. However, the guidelines are also intended for the municipal and regional officials responsible for assessing environmental permit requirements and for following up the required environmental registrations of water and energy wells.

The guidelines are also aimed at property owners who wish to install water and energy wells. The aim is to reduce the risk of environmental impacts and thereby the risk of compensation demands. Such compensation may be demanded if drilling works lead to damages to adjacent properties or the environment. Following these guidelines will contribute to secure water supply facilities and environmentally safe energy wells. The guidelines concern the installation of wells into bedrock, mainly intended for private water supply and for heating or cooling.

The guidelines comprise how to undertake site investigations, technical installation and operation in a way that will ensure safe well installation in relation to impacts on groundwater, adjacent properties or other environmental effects.

Major municipal water supplies are not covered; for such facilities a comprehensive geotechnical investigation is generally undertaken, followed by a detailed specification for the well installation.

For the digging of wells, please refer to the guidelines issued by SGU and the Swedish Food Agency (Livsmedelsverket); *Att anlägga egen brunn för bra dricksvatten* (not published in English). Aspects relating to health and safety at work are covered in the leaflet on *Borrningssäkerhet* (not published in English) (may be ordered at www.fab.w.se).

PLEASE NOTE: This is a translation into English of the Swedish original, "Normbrunn -16, Vägledning för att borra brunn" (Well Standard 2016 – Guidelines for Well Drilling), published in December 2016. Because it is a translation, any changes in legislation or other aspects that have occurred after Normbrunn -16 was published are not included. In the event of any discrepancy between this English version and the Swedish original, the latter will take precedence.

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PRIVATE WATER SUPPLY AND ENERGY WELLS

Every year, tens of thousands of wells are drilled in Sweden. The utilisation of professional, certified contractors who know the regulations will reduce the risk of negative groundwater impact and ensure good quality drinking water.

In Sweden today, 1.2 million people obtain their drinking water from non-municipal water supplies, usually from their own private (domestic) well or a private well which is shared between several properties. According to SGU estimates, there are more than 400 000 domestic wells in Sweden used by permanent residents and a similar number for holiday residents. In the last ten years, between 5 000 and 10 000 domestic drinking water wells have been drilled every year. There is no information on the annual number of *dug wells;* however, these are estimated to be significantly fewer than the annual number of drilled wells. In the long term, dug wells are generally replaced by drilled wells, for example when holiday homes are modernised or turned into permanent homes.

The annual number of energy wells drilled for shallow geothermal heating has stabilised at a high level. In total it is estimated that 25 000 to 30 000 energy wells have been installed every year during the last five-year period. A large majority of these are based on closed heat pump systems containing a liquid refrigerant, usually ethanol-based, which circulates in a closed loop system within the well. Historically, most energy wells were utilised for the heating of detached or semi-detached properties. However, during the last ten-year period the annual number of installations of larger heat pump and cooling systems has significantly increased and has stabilised at a high level. These now comprise a large proportion of the number of newly installed wells. Recent years have also seen an increase in aquifer thermal energy storage systems, utilising groundwater resources for the use and storage of energy. However, at present such systems make up only a small part of the total number of energy wells drilled every year.

The increasing number of wells constitutes a potential threat to the groundwater and therefore a risk to both municipal and private water supplies. Safety measures must therefore be undertaken in connection with well installations. The risks can in most cases be eliminated by correct installation.

Defective well installation may lead to difficulties for the individual owner. The drinking water may be affected, or the heat pump system may not function properly. One reason could be collector tube leakage, another could be incorrect well depth or other dimensional errors. Incorrect well dimensions could also have long-term negative effects after the well installation, for example ground damage due to persistent freezing of the soil.

High levels of chloride, and effects on water quality due to surface water intrusion, are common problems for private water wells in areas at risk of saline intrusion, for example in large parts of southern Sweden. Energy wells are normally drilled to great depths. If this is done without sufficient sealing between borehole casing and bedrock in areas at risk of saline intrusion, the risk of drinking water quality problems increases.

In the case of defective installation of private drinking water wells, the first effects on water quality normally occur in the well itself. Because water from the well is used by the household, the effects are usually noticed at an early stage, and measures can be taken. The risk of negative effects on adjacent wells is therefore less for drinking water wells than for energy wells. However, the abstraction of water may cause problems in surrounding areas if it leads to shortages in the supply of fresh groundwater.

Duty to provide information

According to the *Act on the duty to provide information in connection with water supply installations* (SFS 1975:424) and *energy well drilling* (SFS 1985:245), the drilling contractor is required to provide detailed documentation of the drilling, and to report this to the SGU Well Record Archive (see Appendix 3). The information is subsequently made available at the SGU website. Well data from the Well Record Archive are a very important source of information for the characterisation and mapping of Swedish groundwater resources and hydrogeology, which is carried out by SGU and provided to the property owners, public officials, contractors, consultants, and others.

The Well Record Archive is of great interest to the general public, including property owners planning to install domestic wells and owners who are encountering problems, who may need infor-

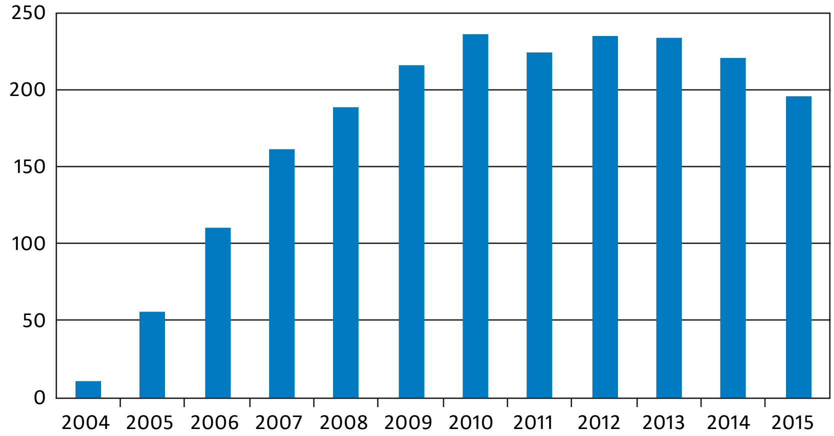


Figure 1. The number of certified well drillers in Sweden, 2004–2015.

mation both on their own and on neighbouring wells. In order to provide easy access to the general public, the information in the Well Record Archive is available on the SGU website.

Despite the above legislation on the duty to provide information, newly installed wells are not always reported to the Well Record Archive. It is therefore important that clients and customers, and licensing authorities, make sure that drilling contractors comply with the legislation by checking that the well record has been made available to the SGU Well Record Archive.

Certification of drillers and drilling contractors

It is not enough to specify standards for the drilling of wells. In order to reach the Environmental Objective of *Good-Quality Groundwater,* it is also necessary to make sure that the drilling profession has sufficient knowledge and expertise. In SGU's opinion, these guidelines, together with the work carried out by SGU to promote the education and certification of drilling contractors, are vital steps which are necessary to reach the Environmental Objective. The drilling profession has a direct involvement in almost all installations for municipal and private groundwater supplies, and in the drilling carried out for civil engineering works and energy facilities, which may also have an impact on groundwater. Therefore, the aim is that all practising contractors within water supply and energy drilling works shall be educated and certified.

However, to reach these aims it is necessary to inform the general public, and that municipal and regional officers have sufficient knowledge. It is also vital that the licensing authorities stipulate that drilling operations must be undertaken solely by contractors with documented professional experience.

A national indicator has been created to monitor the number of certified drillers and contractors, and their annual number of drilling operations.

This indicator has been developed by SGU as part of the work on the Environmental Objective *Good-Quality Groundwater.* At the beginning of 2014 there were more than 230 certified drillers in Sweden (Figure 1). Another approximately 300 drillers had completed the certification course but not yet applied for the certificate.

The proportion of wells installed by certified drillers has been rising since 2006. During the same period the number of certified drillers has also increased. However, the increase halted in 2013 and the number subsequently decreased slightly. The reason for this is not clear but one of the reasons may be that not all municipal authorities require drilling to be undertaken by certified contractors. To reach the Environmental Objective *Good-Quality Groundwater* one requirement is that 95 percent of all Swedish wells shall be drilled by certified contractors.

Certified drilling contractors
Certified drilling contractors must employ a management system adapted to the drilling trade. Annual revisions ensure that the requirements are met.

Certified drillers
As from 2004, certified drilling contractors are required to employ certified drillers. The skills required are listed at www.sitac.se. The certification requirements have been drawn up by SGU and Sitac in consultation with Avanti, Geotec and others.

GROUNDWATER

Groundwater is stored in both subsoil and bedrock. Finding out about site conditions before drilling will increase the chances of avoiding problems and of finding groundwater of good quality.

Some 80 percent of the water within Swedish lakes and water courses originates from groundwater. Groundwater performs vital hydrological and ecological functions. It is found in all types of geological formations – in the bedrock as well as within glaciofluvial eskers, but available groundwater yields vary, as does the chemical composition.

The flow pattern and chemical composition of groundwater depend on the composition of the subsoil and bedrock, and on conductivity, porosity and fracture properties. Large groundwater yields are mainly available within courser sediment formations and in porous or highly fractured bedrock (for example glaciofluvial eskers and some types of sedimentary bedrock).

Groundwater levels vary

Groundwater is created when rainwater or meltwater infiltrates through the ground, filling pore spaces and fractures within the soil and bedrock (Figure 2).

Before infiltration some of the water evaporates to the atmosphere. Part of the remaining water is taken up by the vegetation and returned to the atmosphere by transpiration. This is the natural way plants use to regulate their water balance. The remaining water continues downwards towards the groundwater table, and eventually becomes groundwater.

The upper boundary of the saturated zone – the groundwater zone – within which all pores and fractures are water-filled, is known as the groundwater table. The extent of the groundwater zone varies throughout the year, for example depending on levels of precipitation and groundwater abstraction. Normally groundwater levels are at their lowest during late summer and early autumn, when the majority of rainfall is absorbed by vegetation. Groundwater levels are at their lowest when the depth from the ground surface to the groundwater table is at its greatest. Groundwater levels may also be low during late winter before the onset of snow melt (Figure 3).

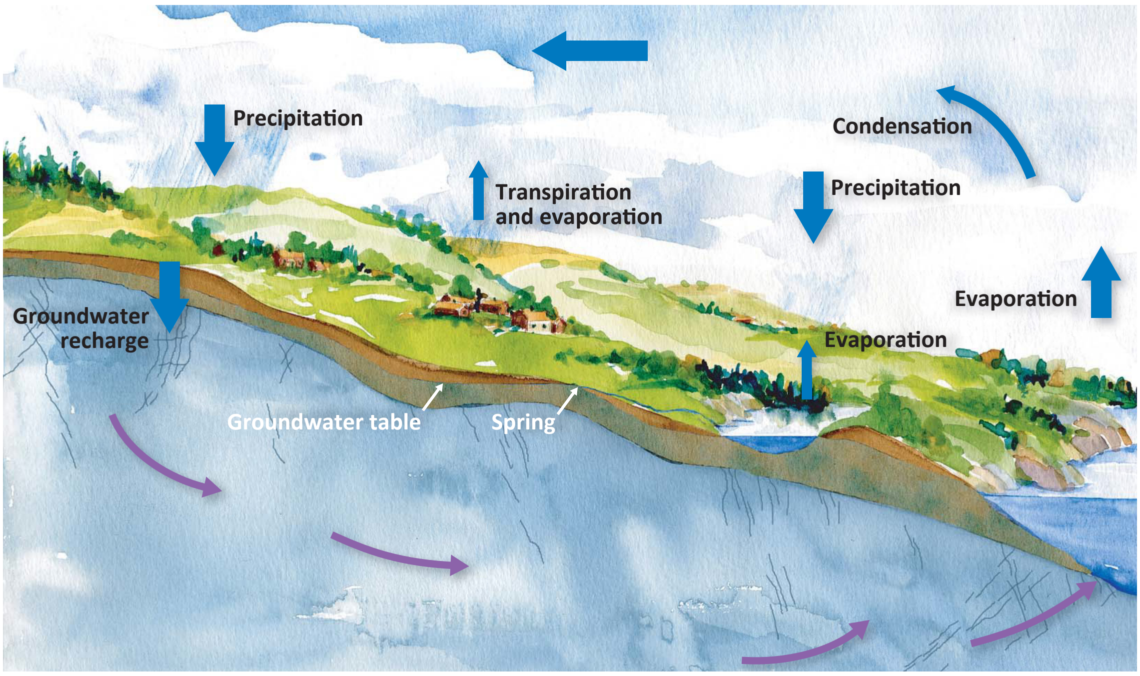


Figure 2. Almost all fresh groundwater consists of rainwater which has infiltrated into the ground. The water continues downwards towards lower levels and eventually ends up in streams, lakes or the sea, where it will evaporate into the atmosphere. This process is known as the water cycle.

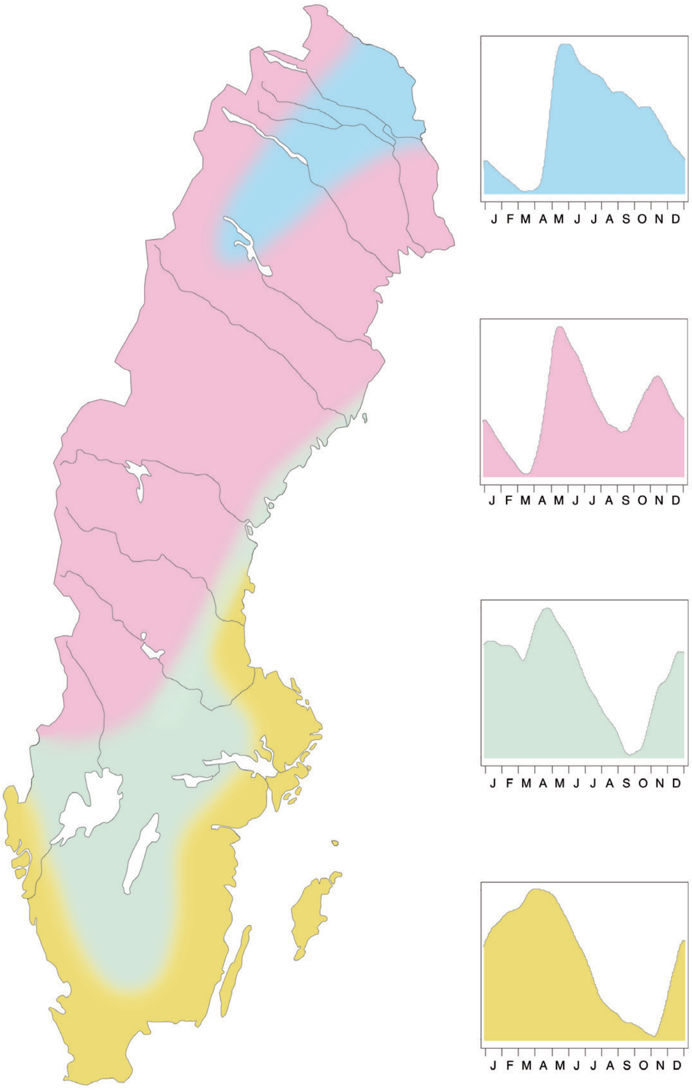


Figure 3. Groundwater levels, average variation patterns throughout the year (groundwater regime) in different parts of Sweden during 1981–2010. The variation patterns shown pertains to fast-reacting (small) groundwater reservoirs, common in moraine (till) subsoils and within the Swedish crystalline bedrock.

Subsoil groundwater

Good conditions for obtaining substantial groundwater yields can generally be found in large subsoil deposits of course-grained soils, consisting of sand and gravel with large pore sizes. Fine-grained soils, e.g. silt and clay, contain large amounts of water but the pore sizes are small. This means that the available volume of water for abstraction is limited.

The most common soil type in Sweden is glacial till. Pore volumes, conductivities and soil depths of this soil type vary, leading to large differences in available groundwater yields. Yields enabling large-scale abstraction are rare, but amounts are usually sufficient for private supplies. Wells installed in glacial till or in other shallow subsoils are often more sensitive to changes in groundwater levels than wells drilled within bedrock. They therefore risk running dry during prolonged dry spells. However, subsoil wells may provide a good alternative to wells drilled in bedrock within areas at risk of saltwater (saline) intrusion.

The subsoil layers also provide important recharge capacity for groundwater resources in the bedrock. Rainwater is infiltrated and stored as groundwater in the soil layers and gradually filters down to recharge the bedrock fractures. If subsoil layers are thin there is an increased risk of wells running dry during prolonged dry spells.

Groundwater within bedrock

Different types of bedrock will exhibit different groundwater storage properties (reservoir properties). The bedrock of Sweden consists mainly of crystalline rocks, e.g. gneisses and granites. Within such dense bedrock the groundwater occurs in large or small fractures. Available yields will therefore depend on the size and frequency of fractures, and also on the extent and interconnectivity of the fracture systems.

Sedimentary bedrock – sandstone in particular but also limestone – is generally porous compared with the crystalline bedrock. In a similar way to subsoil storage, groundwater is stored within the pore spaces. This type of bedrock will generally hold more groundwater than the crystalline bedrock, especially when fractured. In Sweden, sandstone ranks among the highest-yielding types of bedrock. Different types of sedimentary bedrock – sandstones, limestones and slates – often occur in adjacent layers (Figure 4). Slates not containing vertical fissures may constitute sealing layers between porous water-bearing layers. It is important to note that drilling through a sealing layer, e.g. slate, may lead to hydraulic short-circuiting of different aquifers. This means that water from the different water-bearing layers may be mixed in the well.

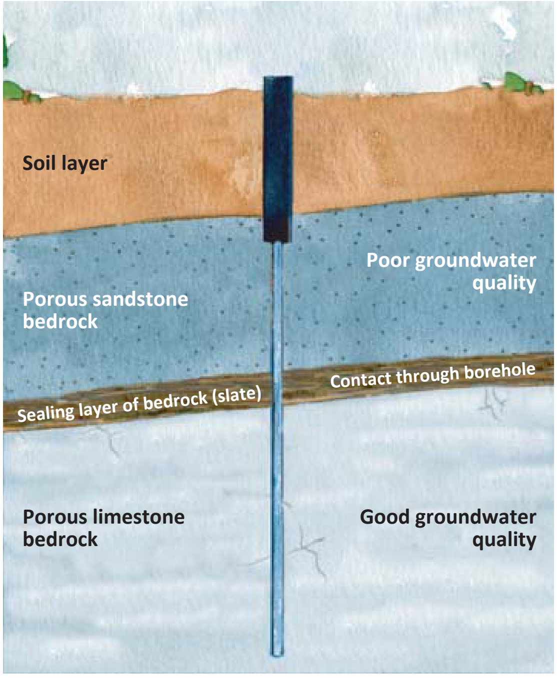


Figure 4. Different types of sedimentary bedrock often occur in successive layers. Slates may constitute sealing layers between water-bearing layers, preventing water of good quality from mixing with water of poorer quality.

Groundwater quality

Groundwater quality generally varies between bedrock and subsoil. In general, groundwater at greater depths will be of more consistent and usually higher quality than groundwater closer to the surface. This is due to its longer infiltration period through the subsoil layers, leading to increased purification. In order to protect the deep-seated groundwater it is therefore vital to prevent shallow water from entering the well during drilling.

However, the long retention time and the chemical composition of the bedrock could adversely affect water quality. In some areas, elevated levels of e.g. arsenic, uranium, radon and fluoride have been observed in wells within bedrock that naturally contains these chemical substances. This is due to the substances dissolving into the groundwater as the water makes its way through the bedrock.

The risk of encountering saline water increases with depth. This means that there are limits to how deeply a well may be drilled in order to provide groundwater of good quality. This is especially the case in low-lying areas, for example coastal regions.

The presence of saline water in wells within bedrock may be due to several causes. Normally the reason is that the well has been influenced by naturally saline groundwater at greater or lesser depths. However in some cases it is due to human activities at the ground surface, e.g. road salts, landfill facilities and similar. These kinds of impacts usually occur relatively close to the source of the contamination and are therefore easier to prevent, trace and remediate.

The most common problem, naturally saline groundwater infiltrating into the well, originates from fossil saltwater. This originates from the time when parts of Sweden were covered in saline or brackish water. The concept HK – highest coastline level – is used to identify those areas which were once situated below sea level.

When assessing the risk of fossil saltwater in terms of well drilling, the HK level can, however, be misleading. The seas covering parts of Sweden during certain periods sometimes consisted of freshwater from the melting of the glaciation ice sheets. The marine boundary, MG, therefore constitutes a more useful concept for the identification of saltwater risk areas. The marine boundary identifies the areas once covered by saltwater seas (Figure 5). However, even in areas below the marine boundary the risk may vary of encountering saline water during well drilling. The risk of encountering saline water in shallower wells is greatest within areas which are low-lying and below the marine boundary. This is illustrated by the saltwater risk map of the region of Blekinge in Figure 6.

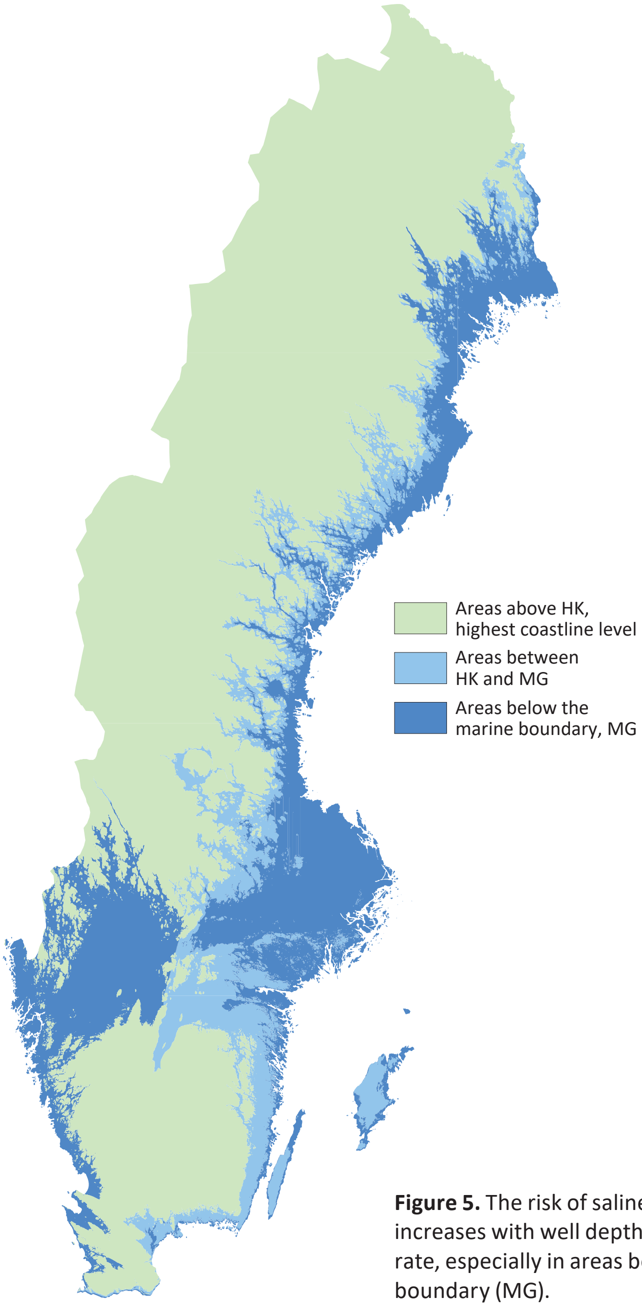


Figure 5. The risk of saline intrusion increases with well depth and abstraction rate, especially in areas below the marine boundary (MG).

There are also cases where saline intrusion from current seawater occurs. This will occur in coastal areas and seldom at distances of more than 200 metres from the shoreline.

Experience shows that saline groundwater occurs everywhere, not only near the coastline, nor only in areas covered by saltwater seas after the last glaciation. Even in low-lying areas above the marine boundary, risks of elevated salt levels occur, especially within areas of sedimentary bedrock. However, in comparison to areas below the MG level, the risks of saline intrusion is generally lower. In such areas, the main threat to groundwater supplies from saline intrusion is posed by shallow sources, e.g. road salts.

How to avoid saline intrusion

The intrusion of saltwater into a well mainly occurs when the rate of abstraction exceeds the groundwater recharge rate. This may occur if the groundwater abstraction is increased. It may also occur in periods of low groundwater recharge due to low precipitation or high evaporation, and when groundwater levels are low. This means that the salt concentration of the groundwater will vary with time.

Because the risk of saline intrusion increases with greater borehole depths, it is important to carefully record chloride concentrations during drilling – or conductivity levels; these also reflect the salt content. This information must be registered on the well record.

When drilling for water, the aim should be to stop drilling when enough water is encountered. It is important to avoid drilling deeper if it is unnecessary – saline groundwater could be present at depth. By finding out about the geological conditions at the proposed well site, for example if the site lies below the marine boundary (MG) level, an indication can be obtained of expected drilling conditions. Finding out about the depths and saline concentrations of energy and water wells in the surrounding area will also be of value. This type of information can be obtained from the SGU Well Record Archive and other sources.

In some cases, for example in areas where the risks of saline intrusion or other water quality problems are high, a well dug or drilled within the subsoil may provide a better option than a well drilled into the bedrock.

Major groundwater resources

Groundwater of good quality is an important natural resource. The availability to society of such resources is of significant interest, both locally and regionally and in some cases nationally. Groundwater resources are abundant in Sweden; however they are often limited on a local or regional level. In Sweden, major groundwater supplies are often located in large sand and gravel deposits (eskers and other glaciofluvial deposits). Such deposits constitute natural groundwater reservoirs and may also be utilised for artificial infiltration if natural groundwater recharge rates are insufficient.

In some regions, particularly in Skåne, the sedimentary bedrock provides major groundwater reservoirs. The crystalline bedrock of Sweden also provides reasonable opportunities for groundwater abstraction, mainly for private water supply. However, with a favourably chosen well site, groundwater from the crystalline bedrock can at times provide drinking water for a small community, village or hamlet. Drinking water supply in an area containing many, but relatively small, groundwater sources may involve both advantages and disadvantages. If one of the groundwater sources is contaminated, the impact will be limited. However the distance to another supply source of sufficient good-quality yields may be significant. General information on the locations of major groundwater sources in Sweden is available from the SGU website, www.sgu.se. More detailed local and regional groundwater mapping information can be obtained by contacting SGU Customer Services or from the SGU website.

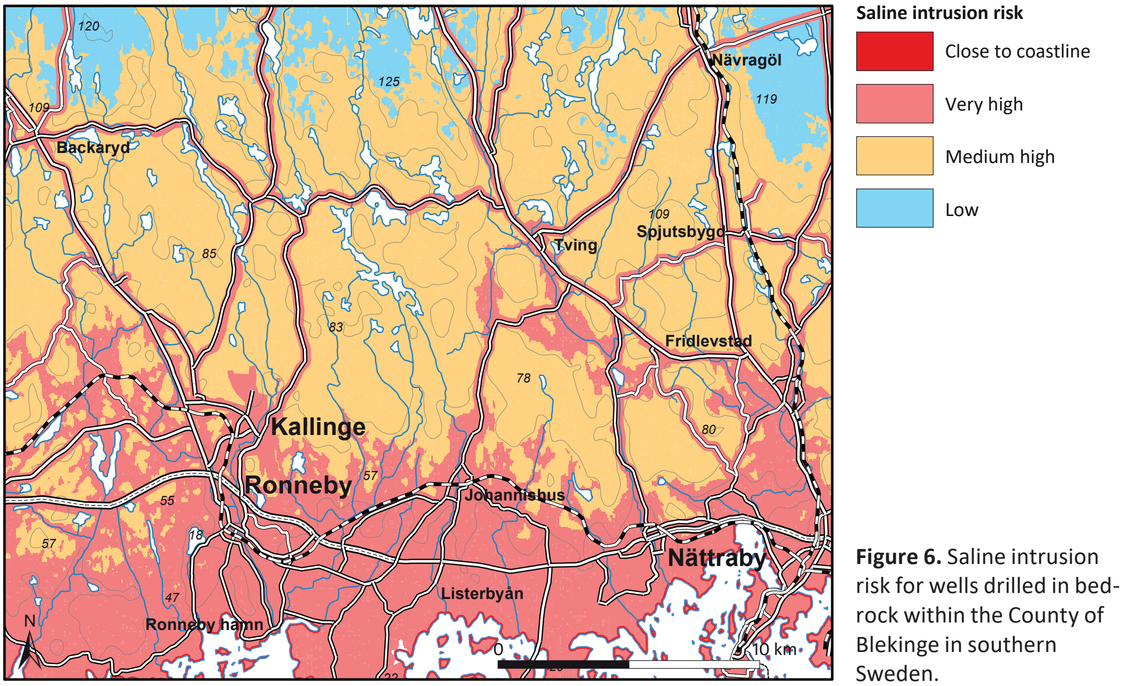


Figure 6. Saline intrusion risk for wells drilled in bedrock within the County of Blekinge in southern Sweden.

LEGISLATION

Well installation is regulated through legislation in various ways. The regulations also govern the relationship between the customer, the drilling contractor and the regulatory authorities. In this chapter the main aspects of the relevant legislation are summarised.

The planning and building act

Regulation of land and water use

The Planning and Building Act is the main municipal instrument for the management of proposed and built development. The municipality will detail (on maps) where different kinds of built development may take place, e.g. housing, industry or recreational facilities. The developments shown in the planning documents are normally implemented by other agents than the municipality.

Within the planning documents, municipalities can set out requirements for development design and layouts, and for building permits. A building permit may, for example, be required for well installations in areas of drinking water shortages, or where new well installations may cause adverse impacts, e.g. by saline intrusion. Municipalities may also stipulate the installation of water conservation measures.

The municipal planning documents show the client and the drilling contractor the requirements for well installation. The driller may be required to answer such questions as:

- Is there sufficient capacity for a new well, in relation to possible water shortages?
- How great is the risk of saline intrusion?
- Could the new well lead to damage on foundations of adjacent buildings?

Decision instruments

There are several different planning and decision instruments:

- The Structure Plan covers the entire municipality. This plan gives an overview of the state and municipality strategy for the use of land and water. More detailed information may be provided for some areas about their general characteristics, any development interests and other demands and interests involved.
- A Local Plan describes and regulates where and how different types of built development is permissible. Local Plans also show if well installations require a building permit.
- A Building Permit from the municipality may be necessary for the establishment of a building or an installation (e.g. a well) in a specific location.
- A Building Consultation with the municipality may be necessary. This can involve technical design issues and any required controls and monitoring.

Facts and information

The planning documents provide information on permits and licensing – but they also provide useful general knowledge about sites and localities within the municipality. Information on site conditions and about risks is presented, e.g. about sensitive areas and about areas of cultural or natural value. Such areas must be presented on the map and any threats to the identified interests must be described; – in what ways could the values identified be damaged? For works within such interest areas the drilling contractor can expect demands on additional preventative measures, both with regard to the Environmental Code and to consumer legislation. This may mean that particular care must be taken when driving vehicles and machinery, or when choosing suitable well locations.

Water bodies and the interests associated with these may be shown on the planning map. Areas of conflicting interests will be presented. Specific interests may lead to permit requirements (e.g. a water operations permit in accordance with the Environmental Code). In addition, the requirements for preventative measures will be stricter in cases of conflicting interests.

The planning documents are a useful source of information and may show:

- existing general interests in the vicinity (natural, cultural etc). Could the proposed well negatively affect these interests – or might it be possible to enhance them by taking appropriate measures?
- existing and proposed water-related operations and interests which may affect, or be affected by, the proposed well.

- any building rights and permits detailed on local plans in the vicinity. Could there be future competition or conflicts of interest in relation to water use?
- whether the contractor should advise the consumer on potentially useful collaborative solutions.
- any sensitive areas regarding water or sewerage congestion, water shortages or saline intrusion problems.
- if the chosen well location is suitable or not.
- if a building permit is required from the municipality for well installation or for changes to existing wells. Has a building permit been granted?
- any equipment recommendations set by the municipality. Could this influence the well design or its location?

The environmental code

Long-term sustainability

The Environmental Code is one of several tools for the implementation of the political aims of sustainable development. The Environmental Code applies to the external environment, and its purpose is to protect human health and the environment. The environment comprises both natural and cultural aspects, including water, air, landscape and cultural heritage.

Focus lies on the public environmental interest (state and municipality). The environmental legislation is not aimed towards the protection of private interests, e.g. a well-maintained garden. Such interests are regulated in agreements between the client and the contractor, and by the Swedish Land Code regarding interests between neighbours.

The main instruments of the Environmental Code are:

- the requirement for everyone to show consideration in daily life and during all operations to prevent impact on human health and the environment,
- restrictions on the use of areas of natural and cultural value,
- requirements on prior registration and/or permits for certain operations, for example the diversion of water, shoreline installations, the use of chemicals within water protection areas.
- the right of authorities to intervene against operations counteracting the aims of the Code, using various forms of fees and penalties as sanctions.

Personal responsibility for environmental consideration

Environmental responsibility within a company is directly linked to the individual and his work duties. Not only company directors and managers but also each employee is responsible for taking the environment into consideration. Each individual is responsible for considering the environment in relation to his or her work tasks. Unlike the health and safety legislation, a written assignation of responsibility is not required; environmental responsibility is directly linked to the work tasks involved in each individual´s work duties.

An individual deeming himself to lack the knowledge which is necessary to exercise the required environmental consideration in relation to his work duties should request education and training.

Environmental consideration involves undertaking the work duties in such a way that adverse effects on human health and the environment are avoided. The directions of the supervisory authority must be followed.

A driver or operator of vehicles or machinery in a sensitive area or next to an ancient artefact may be held individually responsible for any damage that occurs. A person who contributes to the dispersion of contaminants present in the soil could be held responsible for remediation measures.

The company may also be held economically and judicially responsible for any negative environmental effects, e.g. from well installation works, as well as for any impact on neighbours.

The Environmental Code places considerable environmental responsibility on each individual. Everyone shall contribute to creating the right conditions for taking adequate care, remediate any damage caused and obtain sufficient knowledge before undertaking any operations.

Thinking before acting costs less

Regardless of formal requirements there is good reason to think before acting. Taking existing site conditions into consideration is more effective than working against them. Avoiding impact is better than remediating damage.

This means that the requirements of the Environmental Code encourage routines which promote high-quality installations and cost-effective operations. This will also contribute to fulfilling the requirements of the consumer legislation.

Consumer sales act and consumer services act

Professional conduct

The consumer legislation is intended to promote professional behaviour towards consumers, and to fulfil consumer expectations regarding products and services. The legislation also regulates pricing, payments and reparations.

The legal requirement of professional conduct does not only refer to professional, skilful execution, but also requires the operations as a whole to be conducted in a professional manner.

In order to fulfil these requirements, and to avoid unnecessary reparation costs, the company needs to establish routines, for example ensuring the documentation of site conditions and all required interaction and contacts to be made.

Support to consumers

The main focus of the legislation is on commercial responsibility. This is because the company is considered to be the stronger party. However, the consumer also has responsibilities, e.g. to act within a certain time period in order to invoke the protection afforded by law.

Institutions consisting of representatives from both trade and consumers are responsible for trying complaints brought forward by consumers, and for providing recommendations to businesses regarding any corrective action – e.g. the National Board for Consumer Disputes and the Consumer Board of the Heat Pump Trade.

Consumer contracts act, tort liability act, Swedish Land Code

Right and wrong

The Consumer Contracts Act covers the steps involved when entering into a contractual agreement (tender quotation and acceptance) and the consequences of agreements not based on correct premises (e.g. fraud, ineligible parties). Normally, company operations will be covered by standardised agreements – but it could still be useful to drilling contractors to have an awareness of the steps of the Consumer Contracts Act, and of the interpretation of contracts.

For consumer agreements, the main rule regarding contract freedom has been largely replaced by compulsory regulations.

Non-contractual damages

The Tort Liability Act is applicable to damages which are not regulated by contract agreements. In most cases, drilling contractor commissions are regulated by direct oral or written contract agreements with the consumer, or indirectly by a contract agreement with another company as "middle-man". In such cases, any reparation demands are governed by the contract and by consumer legislation.

Damage not covered by such agreements is mainly applicable to impact on neighbours. In such cases the provisions of the Environmental Code apply, provided that the damage is the result of environmentally hazardous activities. If not, the Swedish Land Code regulations on damages and reparations apply.

Between neighbours

The Swedish Land Code stipulates the exercise of due care and attention, and of responsibility for works which may harm adjacent property, such as excavation or blasting. These rules mainly apply to the relationship between the property owner (the client) and his or her neighbour. However, the liability may be shared by the contractor; he, too, is bound by the requirement for due care and attention. There are also situations and matters to which the "reputable professional" should show particular attention and skill.

Figure 7. All drillers carry a personal responsibility for the environment. Relevant education and training for drillers is important to ensure professional skills which are compatible with the work tasks.
Photo: Marcus Gidekull.

WELL DESIGN

A well which is correctly located, designed and installed is more likely to provide sufficient water of good quality and less likely to negatively impact surrounding properties and environment. The works should be tailored to suit the site conditions.

Four main well designs are common in Sweden: bedrock wells, filter screen wells, dug wells and driven wells (well-points). The choice of well design depends on the geological and hydrogeological conditions. The design should be chosen mainly for its ability to provide sufficient water quantity and good water quality.

These guidelines are only applicable to bedrock wells for the abstraction of water or energy. Currently, bedrock wells are by far the most common well type. For information on other wells, reference should be made to the leaflets *Att anlägga egen brunn för bra dricksvatten* och *Sköt om din brunn för bra dricksvatten* (not published in English) issued by the National Board of Health and Welfare.

Bedrock wells

Wells drilled into bedrock use the bedrock as a source of water or energy. This type of drilling normally requires the use of pneumatic down-the-hole hammer equipment combining rotation and percussion.

The well is installed in two stages

A bedrock well is installed in two stages. In *Stage 1,* drilling is undertaken by utilising casing which is driven through the subsoil layers down into at least two metres of solid bedrock. The most commonly used drill bits are ring bits or eccentric bits.

The space between the casing and the surrounding bedrock is subsequently sealed, normally using a cement sealant which casts the casing into the surrounding bedrock. This will prevent soil and rock material, and shallow groundwater, from entering the borehole (Figure 8).

Because the subsoil usually acts as a cleansing filter, the risk of negative effects on the groundwater is lower when the subsoil is deep. If the subsoil depth is shallow, it is important to ensure that the casing is drilled deeply into the bedrock, or to seal the well in other ways. At the SGU website, the Subsoil Depth Map (jorddjupskartan) can be found. This can provide support regarding the general risk of shallow subsoil depths.

Today, steel casing is used in almost all situations. However, in the future steel may be replaced by other materials less susceptible to corrosion. Plastic casing is one of the materials which have been under development for some time.

Stage 2 involves drilling through bedrock until sufficient water can be abstracted, or until the design depth of the energy well has been reached. This borehole constitutes the actual well. The chosen diameter of the borehole may vary, however the most common are 115 mm, 140 mm and 165 mm. Larger diameters may also occur. An example of a bedrock well is shown in Figure 8.

In crystalline bedrock, a newly drilled well would normally yield 100-1000 litres/hour. If, however, a large-scale fracture zone is encountered, the available yield may be significantly greater. Within sedimentary bedrock it is not unusual to encounter water yields in excess of 10 000 litres/hour. For a normal household, 100 l/h will generally be sufficient.

If the flow rate is insufficient, it is possible to increase the water yield by enlarging the fractures; methods include high pressure flushing or blasting using dynamite. Such measures may, however, lead to negative effects on both groundwater supply, water quality and well stability. These should therefore be performed with care.

High pressure flushing

High pressure flushing is a common method of increasing the water yields of newly drilled wells. In general the flushing is undertaken by the drilling contractor or a sub-contractor.

This is carried out by placing a well packer at a suitable depth within the well. The purpose of the packer is to prevent contact between the shallower part of the borehole (above the packer) with the deeper part below the packer. From a tanker vehicle (with a pressure capacity of between 100 and 120 bar) water is then flushed into the well below the packer at a pressure of between 50 and 100 bar. There is some risk that the groundwater within the drilled well may come into contact with shallow groundwater during flushing. This is one of the reasons why the well packer must not be installed at a shallow level.

High pressure flushing sometimes leads to increased levels of mud particles in the well, i.e. water which is less clear and more turbid. Other known negative effects include dramatically increased water pressure in neighbouring wells, with water cascading up from the neighbouring well, leading to flooding and pump damage. Contact with owners of other wells in the vicinity should therefore be considered by the drilling contractor.

However extensive experience of high pressure flushing shows that such damage is rare and that good water yields are achieved, as long as the flushing is undertaken by skilled professionals.

Blasting

Dynamite blasting at the bottom of the well used to be a common method; today, however, high pressure flushing is normally used. Existing fractures are cleaned and enlarged by the pressure wave and vacuum effect generated when water is pushed upwards by the blast. Risks include borehole collapse and effects on water quality as the dynamite may give an unpleasant taste to the water. It is also difficult to predict in advance where the blast will have the greatest effect. Shallow water may, for example, enter into the well. Today the method is only used by a few contractors, and generally only as a last resort when satisfactory results have not been obtained by high pressure flushing.

Well drilling hazards

All underground works including drilling works are associated with a number of risks. Most of these can be eliminated or significantly reduced if the risks are carefully considered before and during the contract works (Figure 9).

A summary of the risks to be considered by client and contractor before drilling works begin is provided below.

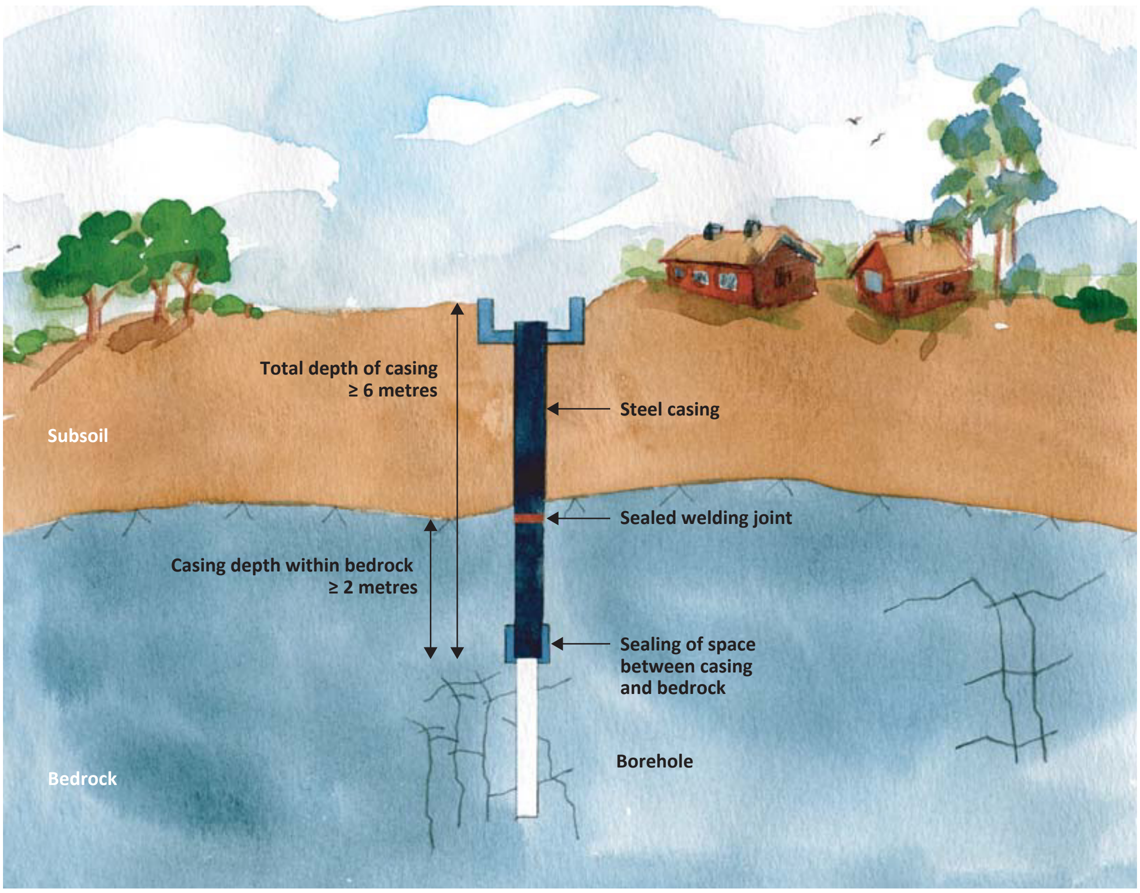


Figure 8. The normal procedure is to drive the casing down to solid bedrock and to seal the space between casing and bedrock with cement. Drilling is then undertaken until sufficient groundwater is encountered.

Well location

The well location shall be chosen to prevent pollution from sewerage, manure and fertilizer storage, and farmland – see Figure 10. The well should always be placed upstream of any contamination sources. The direction of groundwater flow will generally follow the inclination of the ground surface. The well should therefore be situated at a higher ground level than any contamination sources. The recommended distance to the contamination source is between 30 and 50 metres.

The distance is dependent on the type of contaminant, the subsoil rate of infiltration, and the depth to and inclination of the groundwater table. Water wells should generally be located at a greater distance from contamination sources than energy wells, but always upstream of the contamination source. In the case of energy wells there is no water abstraction, which reduces the risk of contaminant transport towards the well.

Well casing

In order to prevent soil and shallow groundwater from entering the well, the casing must always be driven down through the subsoil and cast at least two metres into the bedrock. The use of high-quality casing is important. Any welding must be carried out by professionals to prevent leakage through welding joints by polluting particles, surface water and shallow groundwater. It is important to ensure that the well is sealed and cast at least two metres into the bedrock to prevent shallow groundwater from penetrating into the well from the external side of the casing, see Figure 11A. It is particularly important to ensure that the sealant penetrates deeply into the bedrock when subsoil depths are limited (due to the increased risk of negative effects on water quality when the filtering subsoil layer is shallow), and within areas affected by contamination. Welding joints and sealant must be drip-proof to be defined as non-leaking. This means that visible leakage into the well is not accepted.

There are, however, exceptions. Water may in some cases be abstracted from both an upper and a lower aquifer. In such cases drilling is carried out without sealing the space between casing and bedrock. This must be documented in the well record.

There are, however, exceptions. In certain cases, water wells may be drilled to abstract water

Figure 9. The drilling rig used for the drilling of wells is large and heavy. It is important for the contractor to take care in order to minimise any damage, especially on sensitive ground. It is also important to keep the equipment in good condition in order to prevent diesel or oil leakage.
Photo: Elisabeth Magnusson.

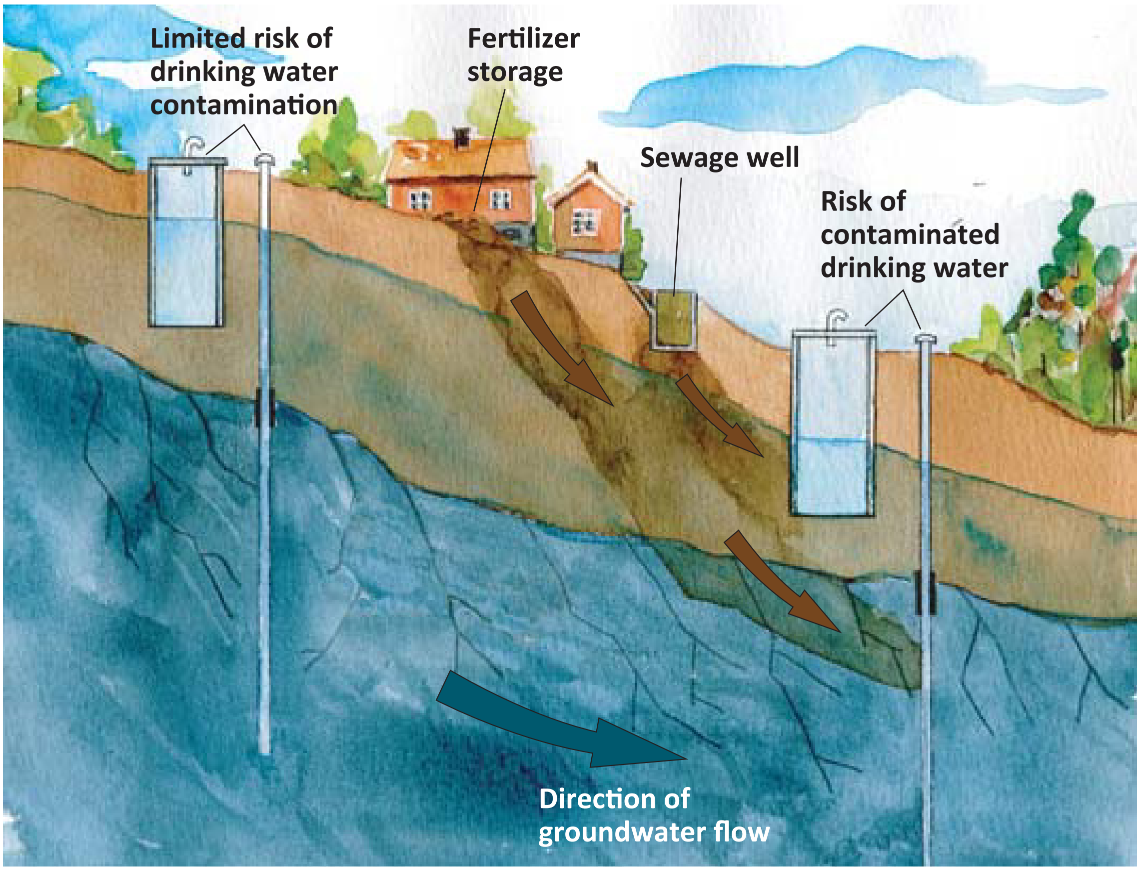


Figure 10. The well should be placed upstream of any potential contamination sources such as sewerage and fertilizer storage.

both from the subsoil layers (upper aquifer) and from the bedrock (lower aquifer), without sealing the space between well casing and bedrock. In such cases, this deviation shall be noted on the well record, and advantages and drawbacks discussed with the client.

When installing energy wells, there are cases when the entire borehole should be backfilled with a sealant, for example in water protection areas and in contaminated areas. In such cases, separate sealing between casing and bedrock is not necessary since the backfilling sealant will be sufficient.

Filter screen wells

Filter screen wells (Figure 11B) are mainly used within course-grained, porous subsoils e.g. sand or gravel. In some cases this type of well may also be used within fractured bedrock or sedimentary bedrock with good water yields.

The water intake takes place through a screen or filter – perforated plastic piping or slotted stainless steel casing – hence the name. The size of the slots is adapted to the grain size of the subsoil in order to filter through as much water as possible, but still preventing soil material from entering the well. In order to dimension the filter correctly, it is in many cases necessary to analyse the grain sizes of a soil sample which is representative of the soil of the filter intake. There are significantly fewer drilling contractors who are experienced in the installation of filter wells compared with the number of experienced drillers of wells into bedrock.

Saline intrusion

The risk of saline intrusion increases with higher water yields and deeper drilling. For this reason, the concentration of chloride, or the conductivity (a measure of salt levels), must be documented during drilling, both for water wells and energy wells. The drilling contractor is responsible for providing information in advance to both himself and his customer regarding any risk of saline intrusion. This is especially true in cases of significant depths or high abstraction rates.

A B

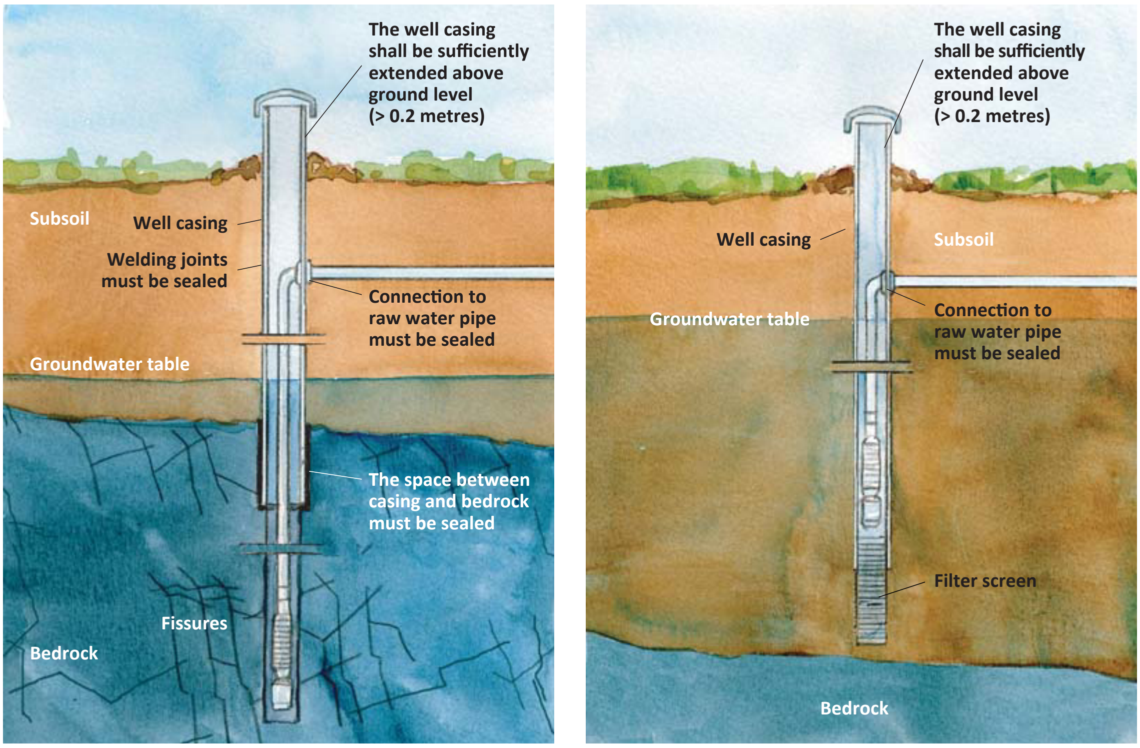


Figure 11. Principle sketches of (**A**) Water well drilled into bedrock (**B**) Water well within subsoil.

Energy well refrigerant

In order to absorb the heat from the bedrock, a refrigerant liquid circulates within the energy well in a closed loop, the collector tube, which connects the heat exchanger to the borehole. The plastic collector tube usually reaches down to the bottom of the well. In Sweden, the most common refrigerant is a mixture of water and bioethanol at a concentration of approximately 25 % ethanol. Other refrigerants include propylene glycol, saline solutions and vegetable oils. SGU recommends the use of water-bioethanol refrigerants. Advantages include ease of handling and the relatively harmless and well-known properties of ethanol. A disadvantage is that the legally required addition to the ethanol liquid of a denaturant, e.g. 2-propanol or n-butanol, has been shown to extend the degradation time in cases of leakage. The denaturant also has a greater effect on the taste of water than ethanol does.

The refrigerant is relatively harmless; nevertheless even small spillages can lead to negative effects on the water quality of adjacent wells, mainly due to the odour and taste of the denaturants. In addition, biological degradation of the refrigerant may cause the oxygen in the groundwater to be used up, leading to reducing conditions. An indication of reducing conditions is the smell of "rotten eggs" (hydrogen sulphide). This may also lead to the precipitation of iron and manganese. If the water contains nitrogen (usually nitrate) this may be converted into nitrite and ammonium. Because the refrigerant contains organic substances, the chemical oxygen demand, COD, may increase, in particular in cases where the refrigerant proportion is large. Previous experience indicates that the problems tend to disappear relatively quickly in cases of limited leakage, because of degradation and attenuation of the refrigerant. However for large-scale leakages, in excess of 50 litres of refrigerant-water mixture, negative effects of hydrogen sulphide and denaturants have been known to remain for longer periods, even up to a year. It is therefore vital that drilling contractors install high-quality collector systems and implement measures for the minimisation of refrigerant leakages.

Hydraulic contact between boreholes

If two wells are connected – through so-called hydraulic contact between different water-bearing layers or fissures – they may influence each other both qualitatively and quantitatively. Hydraulic contact is, however, unusual between subsoil wells and bedrock wells. The risk of hydraulic contact also decreases with increasing distance between wells. Release of particles into adjacent wells, clouding, may occur during drilling. This may happen because of the use of high pressure air and the drilling vibrations leading to the material contained within fractures being released. Such effects are normally temporary and usually disappear within a fortnight; however in a worst-case scenario the well may collapse. Care must therefore be exercised during drilling and high pressure flushing in the vicinity of other wells. Lower air pressures should be used and adjacent wells should be monitored, especially when large water yields are available, since this is an indication of highly fissured bedrock. Hydraulic contact between wells is more common in aquifer thermal energy storage systems, where many wells are drilled in close proximity to one another. This means that specific health & safety measures are necessary in order to minimise the risk to the people working on site.

Artesian water

Artesian groundwater, i.e. groundwater where the pressure level lies above the ground surface, is unusual. This usually occurs in low-lying areas where the upper soil layers consist of fine-grained, confining layers, e.g. clay. If the theoretical level of the water table, and therefore the groundwater pressure, is greater than ground level (Figure 12), the drilling of a well will cause water to discharge above ground level. If this is undesirable, or if the water cannot be drained off, the well should be sealed off. The sealing should be placed below the casing, below the sealed space between casing and bedrock to prevent the sealant from disintegrating, which will cause the artesian water to escape upwards on the outside of the casing. Thus, drilling in artesian conditions involve technical difficulties and may lead to increased costs.

Impact on buildings

Drilling adjacent to properties involves the risk of damage to drainage or the building itself. The nature of the risk involved depends on the foundation type, whether the building rests on fine-grained subsoils, e.g. clay, and if there is a basement. Drilling into clay and other fine-grained soils may lead to vibrations affecting adjacent properties. The main risk involves air being pressed into subsoil layers beneath the building if the casing or diversion tubing is blocked up. The high air pressures involved when drilling means that the air cushion which is created may be big enough to lift or rupture building foundations. In addition, settlement created may damage adjacent buildings. In some cases, vibrations caused by drilling can affect adjacent buildings. Drilling in the vicinity of a building is also a health and safety hazard; the risk of crushing injuries between building wall and drilling rig is one such hazard. Drilling closer to a building than 4 metres should therefore be avoided, and drilling in the vicinity of buildings must be undertaken with great care, utilising low air pressures and plenty of water flushing. In particularly sensitive locations drilling should be advised against, unless alternative drilling methods can be considered to be feasible, e.g. utilising water instead of compressed air.

Before any drilling in the vicinity of a building, the facade, foundation and basement should be inspected, and the results documented in consultation with both client and property owner.

Thermal impact

Shallow geothermal energy involves the abstraction of heat from the bedrock surrounding the energy well and may therefore lead to thermal impact. Close spacing between two or more heat pump facilities, or if the borehole is too shallow in relation to the energy need and the size of the heat pump, may lead to lower bedrock temperatures than estimated. This will lead to reduced efficiency of the facility. In addition, if lowered temperatures around the borehole cause freezing, and the borehole is under-dimensioned, ice formation may lead to compression and damage to the tubing. In a worst-case scenario, this may lead to refrigerant leakage and contamination of the groundwater, and to malfunction of the heat pump installation. If the energy well has been drilled in frost sensitive soils (clay or silt), freezing of the surrounding soil may lead to ground damage which, in some cases, could become relatively extensive.

In order to minimise the above risks, energy wells should always be located as centrally as possible on the property plot, and the depth of drilling should be dimensioned to allow any neighbours to install energy wells in the future – even if there are no such plans at the time of drilling. This will minimise the temperature impact on surrounding properties and enable continued expansion of energy well facilities in the surrounding area.

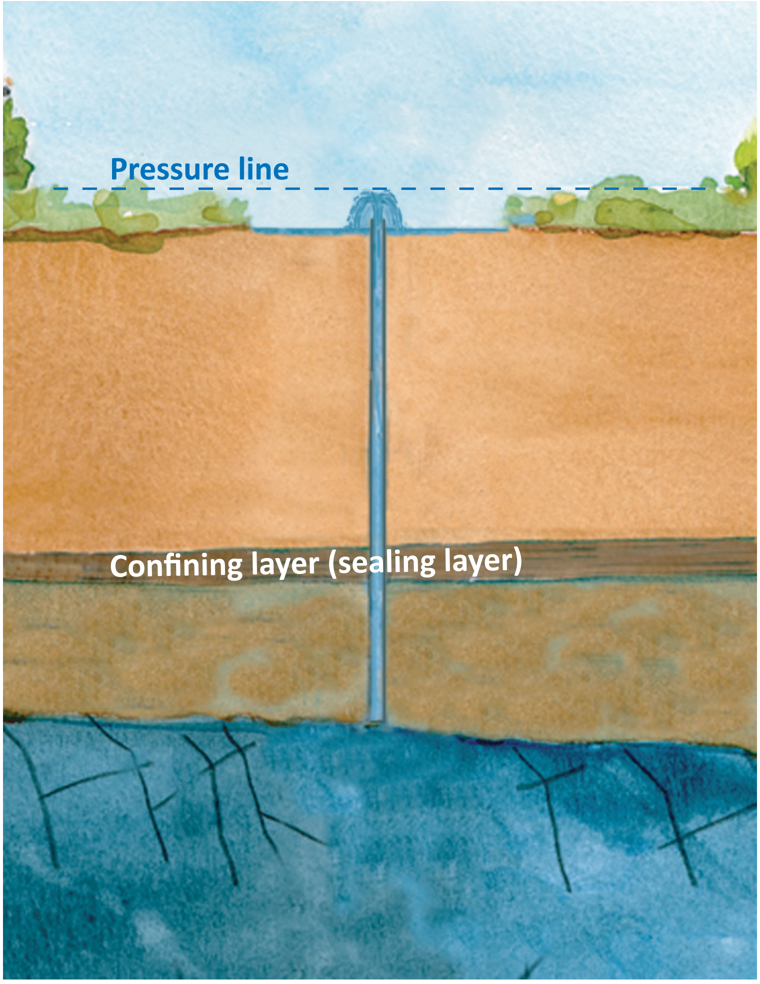


Figure 12. Artesian water. The drilling of a well through a confining layer into a water-bearing layer where the water pressure level is higher than the ground surface will cause the water to rise above ground level. In such cases drainage will be required, or the well must be sealed off.

If for practical reasons a central location cannot be achieved, the borehole should be inclined towards the centre of the property, and, in some cases, also compensated by increasing the well depth. Other measures, such as thermal recharge utilising solar energy, may be an alternative to increasing the borehole depth.

Leakage risks

During drilling there is always a risk of oil or diesel leakage from the drilling rig, support vehicle or compressor. The drilling contractor has a legal duty to carry out regular equipment checks with respect to leakage. Suitable oil absorbents (e.g. absol) must always be available during the drilling works, regardless of location. Where rapid infiltration can be expected, for example in sands or gravels, the rig vehicle and compressor should be placed on a sealed surface. This could be a tarpaulin sheet with upturned edges to prevent any leakages infiltrating into the soil.

Well standard procedure

In order to minimise risks and protect the groundwater, SGU has drawn up a series of recommendations for the undertaking of drilling works, the Well Standard Procedure (see Appendix 1). The intention is to enable licensing authorities to direct clients and contractors to using the appendix as a checklist for drilling works.

In the certification course for drillers the well standard procedure is included in the course material. All certified drillers possess the expertise and experience required to undertake the drilling of water and energy wells in accordance with the well standard procedure.

BACKFILLING AND SEALING OF BOREHOLES

In some locations drilling may cause negative impact on, or a potential threat to, the groundwater. One way of protecting the groundwater aquifer may be to backfill or seal the borehole. Energy wells pose greater risks as the water is not used as drinking water and therefore not monitored.

For boreholes which present a risk of negatively impacting a groundwater reservoir, backfilling or other additional sealing measures may be necessary. This may be the case within areas at risk of saline intrusion, within contaminated sites, in areas where sedimentary bedrock presents a risk of hydraulic short-circuiting, or in areas at risk of other negative impacts, for example due to the presence of alum shale. Backfilling is also recommended when boreholes are abandoned or replaced by new boreholes, and normally within water protection areas. Energy wells usually present greater risks: because the water is not used for consumption it is not regularly monitored. It is not necessary to abandon the energy well should problems occur; it is fully feasible to backfill the well with the collector tubes still in place and in use. Before backfilling the following should be considered:

- The sealing material must not negatively impact the groundwater.
- The material must have sufficient sealing properties for the prevailing geological conditions.
- Injection must be undertaken from the bottom of the well upwards in order to ensure that the entire void space is filled.
- The sealing material must withstand freezing without damaging the tubing and without losing its sealing properties.
- The collector tubes within the borehole must be dimensioned to withstand the increased pressure created by the backfill material.
- It is important to compensate backfilling with increased borehole depths because of the reduced heat exchange; 25–30 % depending on the type of backfill material.

If another method than injection from the bottom of the well is used, it must be possible to verify the alternative method, and reference objects must be provided. In addition, it must be verified that the amount of sealing material used is in correct proportion to the void space to be filled.

If the well is suffering from saline intrusion – within areas at general risk of saline intrusion or in areas of fresh groundwater shortage – it is recommended that the entire saltwater-bearing horizon, and a part of the freshwater-bearing horizon, is backfilled. For energy wells an alternative method is to seal off the borehole in the transition zone between saline and fresh groundwater. However, the sealing must be of sufficient length (more than 10 metres) to ensure that saline water cannot escape past the sealant through fracture zones. Drillers must therefore always ensure careful logging of any changes in chloride or conductivity levels during drilling. SGU recommends that if such documentation is missing, the entire borehole should be backfilled with a sealant.

DRILLING WITHIN WATER PROTECTION AREAS

Particular care must be taken when drilling energy wells within water protection areas. Oil leakage from the equipment, short-circuiting between water-bearing layers, or saltwater intrusion may affect the entire water supply. If negative effects cannot be ruled out, the borehole should be backfilled or drilling completely avoided.

A water protection area will generally comprise a source zone, primary and secondary protection zones, and, if required, a tertiary protection zone. According to the *Ordinance 2003:16* issued by the Swedish Environmental Protection Agency, drilling works are prohibited within the primary zone and require a permit within the secondary zone. It is important to undertake additional preventative measures if permission for drilling is granted within such areas. Before the installation of energy wells within a water protection area it is important to consider both the geological conditions and the characteristics of the water source and water supply.

Careful consideration should also always be given to the risk of increased contact between different water-bearing layers. In areas of sedimentary bedrock in particular, the water supply may be affected by water from geological strata of different chemical and physical composition, which may cause a deterioration in water quality. In general the risk of impact is greater in the uncased part of the borehole, i.e. within the bedrock. This means that the risk of negative impacts to the water source due to water and energy drilling is greater for water wells with the abstraction point in bedrock than for wells where abstraction occurs in the subsoil. A confining clay layer may become disturbed by the installation of casing, thus increasing the risk of pollutants from the ground surface entering the groundwater reservoir.

Licensing authorities should consider the following risks before granting a permit:

1 – Risks during installation

Risks during installation include risks during drilling, excavation or digging. These risks mainly involve the risk of contamination of the ground and water from the machinery and plant utilised. In order to reduce these risks, it is necessary to stipulate that the contractor must use sealing membranes during drilling. In addition, clean-up equipment must always be available during the installation works.

2 – Geological impact

The installation may affect the geological site conditions in several ways. One example is the installation of ground source heat pump systems within the subsoil, which can lead to altered ground infiltration properties due to the mixing of soil layers of different permeabilities. Another is that a well installation may provide a contamination pathway down to the groundwater, or that the well causes hydraulic short-circuiting of previously separate groundwater aquifers. This may affect the quality and quantity of the groundwater yields. The risks of negative consequences due to the mixing of water from different aquifer layers are particularly high in areas containing different types of sedimentary bedrock and in areas at risk of saline intrusion. Such changes may be permanent and will largely depend on how the installations have been carried out.

3 – Risks during operation

During operation, there is a risk of contaminant leakage from the installation. For energy installations the risk is mainly refrigerant leakage. The operating risk of wells used for the abstraction (or recharge) of water is that the available yield may change because of the abstraction, or that the water quality changes due to the water flow generated.

In SGU's opinion, there is considerable variation in the risk of an energy well, or other type of shallow geothermal energy installation, causing negative impacts on the groundwater. The final decision on whether an energy installation may be permitted must be made on a case-by-case basis, and all the above types of risk (1)–(3) must be considered.

If a municipality grants permission for an energy well at a particular property, risks (1)–(3) can be reduced by setting requirements for how the work is carried out and how the installation is designed and built, e.g: drilling rig and compressor must be placed on an impermeable surface during drilling; the energy well must be backfilled with sealing material, drilling must be undertaken in accordance with these guidelines, the driller must have a well standard procedure certificate.

DRILLING WITHIN CONTAMINATED AREAS

Drilling through contaminated soil or bedrock may involve several risks depending on the geological conditions, the extent of the contamination and its characteristics. There are more than 80 000 documented contaminated sites in Sweden, many in the vicinity of built-up areas where the installation of shallow geothermal energy may be considered. The installation of water wells is more unusual, partly because municipal water supplies are commonly provided, and partly due to the risk involved in abstracting water within contaminated areas.

Risk assessments are vital

In recent years there has been an increase in questions regarding how the municipality should act when an application for a shallow geothermal energy installation in a contaminated area is received. In many cases there is insufficient knowledge about the extent, distribution and propagation of the contaminants. With more people wishing to utilise shallow geothermal energy in both residential areas and industrial sites, SGU recommends that municipalities and regional councils should aim for the inclusion of a risk assessment of drilling and excavation works before any inventories or clean-up works are undertaken within a contaminated site. This risk assessment can subsequently be used as a basis for decisions regarding appropriate stipulations to be made in connection with the drilling and installation of shallow geothermal energy.

A well which is installed in a contaminated area can in some cases increase the spreading of contaminants by opening up a pathway along the borehole. The risk is greater if the contaminants have high solubility and high density.

There are several uncertainties associated with carrying out a single water sampling immediately after drilling in order to investigate whether there is contamination in the groundwater, e.g:

- Groundwater conditions may have been disturbed during the drilling works, making the water sample non-representative
- Even if a clean water sample is obtained immediately after drilling there may still be groundwater contamination in the future

In most cases it is therefore necessary to establish a monitoring programme, enabling several water samples to be taken over a longer period. This may be both time-consuming and costly, especially if the energy well is operational.

Backfilling the borehole immediately after drilling is a much easier way of preventing contaminants from spreading – see the previous chapter *Backfilling and sealing of boreholes*.

If the contamination is mainly confined to the subsoil layers with the presence of sealing layers (clay layers) beneath the contamination it may be appropriate to stipulate the that the entire drilling through the oil layers is backfilled. In such cases the subsoil casing must be removed after drilling and backfilling undertaken all the way to the ground surface.

Drilling within contaminated areas should, however, always be avoided if

- risks to the health and safety of the drilling contractor cannot be ruled out, or
- the installation of a shallow geothermal energy facility could make future remediation efforts more difficult.

APPENDIX 1. WELL STANDARD PROCEDURE

1. Before drilling

1.1 Siting of wells – general

The same basic principles apply for the siting of both water wells and energy wells. The location should be chosen in order to achieve maximum water quality whilst minimising the risk of negative impact, including the spreading of pollutants.

Before the drilling of a new well, information should therefore be sought on past and present land use in order to optimise the well location.

1.2 Distance between well and sewage outlet or similar contamination source

If possible, wells should be sited at higher levels in the terrain, as far away as possible from the pollution source. The risk of negative impact depends on the nature of the contamination source and on the extent, depth and permeability of the subsoil layers. The recommended minimum distance between the well and the sewage outlet is 30 metres. The risk of negative impact is normally greater for a drinking water well than for an energy well. For water wells in particular it is therefore important to keep to the recommended distances and ensuring well siting at higher terrain levels.

For energy wells where the recommended distances cannot be achieved, or if negative impact cannot be ruled out, it is recommended that the well should be backfilled or sealed to considerable depths in order to prevent the spreading of contaminants.

1.3 Well siting in relation to other wells

Drillers must take considerable care if well installation is undertaken in the vicinity of another well. The purpose of the recommended distances is to provide an indication of reasonable consideration in connection with drilling works. To achieve appropriate distancing of wells within the same property, the well siting should be carried out jointly by the contractor and property owner. Applying the distances indicated below will however not guarantee that negative impacts are avoided. If there are no wells on adjacent properties, a distance of at least 10 metres (for energy wells) or 15 metres (for water wells) from the property boundary should be achieved in order not to prevent adjacent property owners to instal new wells.

Type of well	Recommended distance
Water (bedrock)/Water (bedrock)	30 m
Water (bedrock)/Energy (bedrock)	30 m
Energy (bedrock)/Energy (bedrock)	20 m
Water (bedrock)/Water (subsoil)	20 m
Energy (bedrock)/Water (subsoil)	20 m

If a replacement well is to be installed, any problems with the existing well must first be clarified. If the problems are due to sewage, saline intrusion or similar, the existing well should be backfilled with a sealing material to minimise the risk of impact on the new well or other existing wells. Wells not intended for future use should always be backfilled in order to avoid future problems.

If the recommended distances cannot be achieved between two energy wells the following measures can be considered in order to avoid thermal interaction:

- inclination of the borehole away from the existing well
- increased drilling depth
- dissuading the client from energy drilling

Local geological anomalies may also be a reason to depart from the recommended distances, e.g. large subsoil depths or the presence of water-bearing fissures which may increase the risk of hydraulic communication.

1.4 Well siting in relation to buildings

Drilling in the vicinity of buildings involves the risk of damage to the building or its drainage system. The well should be located at least 4 metres from the external wall of the building if there is any uncertainty regarding the risk of damage. Additional safety distances may be required depending on foundation type, or if the property has a basement, or if it is founded on vibration-sensitive soil. In some cases drilling should be avoided. Before drilling, the facade, foundation and basement should be inspected, and the results documented in consultation with the client and the property owner. Drilling in the vicinity of buildings should always be undertaken utilising the lowest possible air pressure, with careful control of the discharge of drill cuttings from the borehole.

1.5 Restrictions, permits and duty to register

The supervisory authority, usually the municipality, is authorised to place restrictions on drilling according to both the Planning and Building Act (PBL) and the Environmental Code. It is the responsibility of the property owner to comply with any restrictions. Drillers must ensure compliance with the following rules before beginning any drilling works:

- As a minimum, the drilling of energy wells requires registration with the supervisory authority.
- Normally, drilling is either prohibited or requires an environmental permit within water protection areas.
- In areas of fresh groundwater shortage, municipalities can prescribe environmental permits to be required for drilling works.
- The municipality may decide that a building permit is required for the drilling of water and energy wells in certain areas.
- Within areas of confirmed or presumed contaminated land, municipalities can prescribe either that drilling is prohibited, or that it requires an environmental permit.

Initial consultation with the municipality is always recommended before beginning any drilling works.

2. During drilling works

The purpose of the guidelines provided below is to minimise the risk of shallow groundwater and soil material entering the well. In areas of shallow subsoils and within contaminated or otherwise impacted sites, it is particularly important to seal the well to sufficient depths into the bedrock. The risk of negative effects generally increases with decreasing subsoil depths.

- The well must be sealed at least 2 metres into solid bedrock and down to a depth of at least 6 metres from the ground surface. This means that at least 6 metres of casing will always be required.
- Casing shall always be employed when drilling through subsoil down to the bedrock, see *2.1 Casing materials* below.
- The welding joints between casing units must be able to withstand working pressures in order to ensure the integrity of the casing against leakage.
- Sealing between casing and bedrock shall always be undertaken.
- Water well casing shall if possible be extended at least 0.2 metres above ground level.

Exceptions from the above guidelines may be made if:

- it is desirable to allow contact with water from the subsoils above. Such cases shall always be agreed in advance with the client and documented in the well record.
- backfilling of the borehole is carried out up to the ground level (see the previous chapter *Backfilling and sealing of boreholes*). In such cases it is sufficient to ensure that the casing is anchored into the bedrock.

2.1 Casing materials

Recommended steel casing dimensions:

139.7 mm × ≥ 5.0 mm
168.3 mm × ≥ 5.0 mm
193.7 mm × ≥ 5.0 mm

For all the above dimensions, steel quality shall be in accordance with ST 37.0 and tolerances in accordance with EN 102 or equivalent. Among other things this will ensure a certain resistance against corrosion. If other casing materials are used, e.g. plastic casing, the durability of the material must comply with that required for steel casing. This must include sufficient resistance against the pressure exerted by the subsoil at the depths employed.

2.2 Drilling within crystalline bedrock

Continuous monitoring of chloride or conductivity levels shall always be undertaken during drilling in areas at risk of saline intrusion. Chloride or conductivity shall be measured every twenty metres or when changes in water yields occur. The results shall be registered in the well record together with the depth at which the measurement was made.

Elevated chloride (> 50 mg/l) or conductivity levels (> 50 mS/m) within energy wells may result in saltwater impact in adjacent wells. If impacts on surrounding wells cannot be ruled out, it is recommended that the well is sealed off.

2.3 Drilling within sedimentary bedrock
The risks and potential environmental impacts involved when drilling into sedimentary bedrock are complex. Different water-bearing strata may be separated by confining layers. If there a risk of short-circuiting two or more groundwater aquifers, sealing or backfilling should be undertaken to minimise the potential impact. Chloride or conductivity levels shall be measured regularly and documented.

2.4 Drilling equipment
- Compressors shall be inspected and tested to current drilling industry standards.
- The compressed air tubing shall be compatible with the maximum working pressure of the compressor.
- Bio-degradable oils should be used.

2.5 Sealing of boreholes
If there is a risk of saline intrusion (see 2.2) or short-circuiting of aquifers (see 2.3), the borehole should be backfilled.

3. Collector installation
The following specifications for materials and installations are required in order to minimise the risk of refrigerant leakage and of pressure dips within the collector system.

3.1 Materials
Borehole and ground collectors
Fully welded plastic collector tubing shall be utilised in accordance with the relevant chapters within SS-EN-12201 (refer to the guidelines *Anvisningar av förläggning av kollektorer i geoenergisystem,* issued by the Swedish Center of Geoenergy (not available in English)).

It must be possible to inspect any mechanical couplings used (inspection well or equivalent). Mechanical couplings may not be installed in direct vicinity of the borehole.

Borehole cover
The cover must be secured to the casing in such a way to prevent collector uplift due to ice formation on the tubing. Tight-fitting covers are required in order to prevent surface water or soil from entering the well.

3.2 Pressure testing
Before the collector tube is inserted into the borehole it must be inspected for any transportation damage. Pressure testing must also be carried out:

- Fill the collector system with the refrigerant. Air bleed the system. Pressurise the system by closing the valve on the return pipe to the pump. Build up an excess pressure of at least 3 bar.
- Allow at least 30 minutes to pass after pressurisation, then inspect the system visually. Throughout the waiting period, the excess pressure must be kept constant by pumping. Particular care shall be taken to inspect all joints in order to detect any small leakages.
- Pressure testing shall be undertaken on a sealed surface.
- The results of the test shall be documented on a pressure test protocol.

Ground installation of collector systems shall comply with the guidelines *Anvisningar av förläggning av kollektorer i geoenergisystem* issued by the Swedish Center of Geoenergy. Welding of plastic joints shall be undertaken utilising approved materials and welding equipment.

Pressure testing shall be undertaken on completion of the installation in connection with the trial run of the heat pump. If the energy well is not visible at ground level, its position shall be clearly noted within the property grounds with a small metal plate on the outer wall of the building or at another clearly visible location. The position of the well shall be recorded to the nearest ±0.1 m.

Any refrigerant spill or leakage during or after installation shall be immediately remediated. If required, all refrigerant fluid shall be pumped out of the collector loop and all tubing removed to enable repair or replacement. The pump shall subsequently be installed and the well pumped out until the water is free of any refrigerant taste or smell.

4 . Pump installation within a water or engergy well

Installation of pumps for water or energy wells shall be undertaken using components which are adapted for water abstraction. All components employed shall be detailed and the documentation made available to the client and the supervisory authority on request.

- Connections through the borehole casing shall be sealed against leakage.
- The well head shall be provided with a sealed well cap.
- Electricity cabling within the borehole shall be approved for drinking water installations.

4.1 Water quality analysis

Chemical analysis of water quality shall always be included in the drilling contract if the well is to be used for drinking water purposes. As a minimum, the analysis should correspond to the standard analysis in accordance with Appendix 2 of the publication *Råd om enskild vattenförsörjning* by the National Board of Health and Welfare.

5. Duty to provide information

In Sweden, there is a legal duty to provide information on well installations (Acts SFS 1975:424 and SFS 1985:245. As well as providing the customer with the original, it is a legal requirement to send a copy of the well record to the SGU Well Record Archive. The well installed does not conform to this Well Standard if the well record has not been forwarded to the Well Record Archive at SGU.

APPENDIX 2. CONSUMER CHECK-LIST

1. Study the leaflets on well installation and maintenance issued by SGU and the National Board of Health and Welfare *Att anlägga egen brunn för bra dricksvatten* and *Sköt om din brunn för bra dricksvatten*.

2. Ask the municipality about rules and regulations regarding well drilling in your area. Are any permits, e.g. a building permit, required? What requirements must be met to comply with the permit?

3. Find out the obligations and rights which apply regarding your neighbours before well drilling.

4. Find out which obligations apply to you as a customer/client and which obligations apply to the drilling contractor.

5. Find out if there are any certified drilling contractors in your municipality or in a neighbouring municipality, www.sp.se

6. When it is time to ask for quotations, direct your request to several drilling contractors. Your request for tenders should contain information on the extent of the works, how the works should be executed, time for start and completion, required warranties, price including Swedish VAT (moms) (it is important that the well driller represents a company), and that the tender quotation provides for any costs which may occur in an area at risk of saline intrusion, leakage into the well from contaminated surface water, additional sealing and backfilling of the borehole.

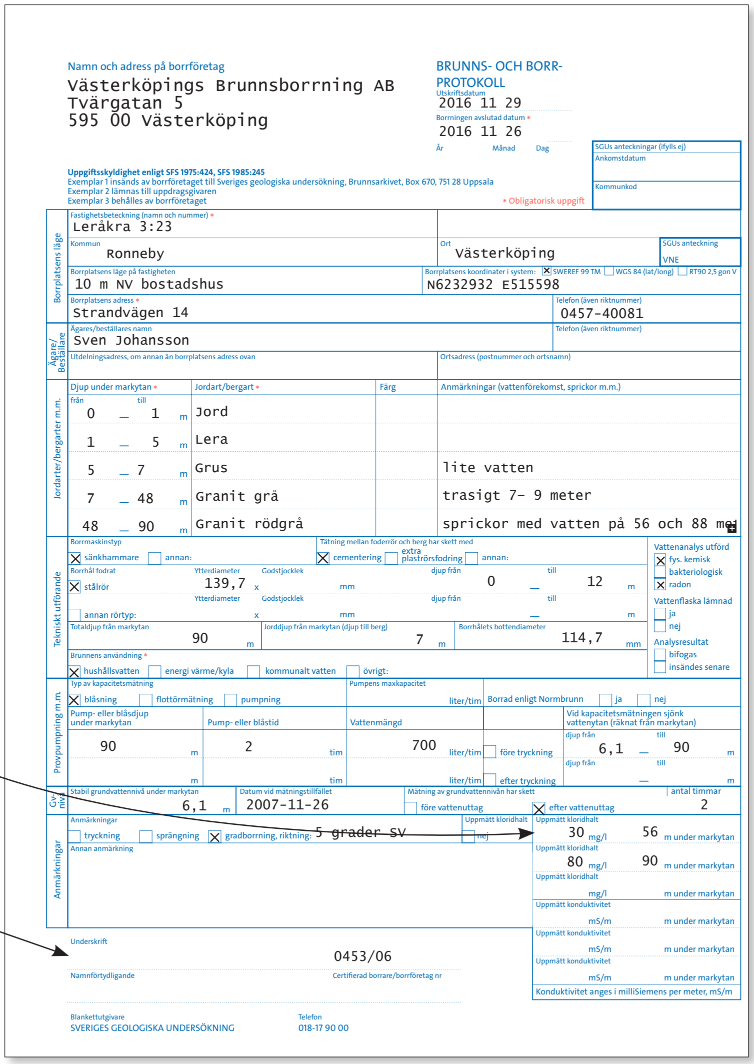
APPENDIX 3. WELL RECORD

In most cases the well record constitutes the only documentation of the well, an investment of several thousand Euros. It is therefore vital, and should be standard procedure, that the information logged is as detailed as possible. Well records containing detailed and correct information will significantly aid any future refurbishments or investigations into well damage.

The information regarding owner/client mainly relates to the contract between customer and contractor. In cases of frequent changes of property ownership it may prove useful to know who ordered the drilling works.

The contractor's measurements of chloride or conductivity levels shall be recorded. These will provide the basis for determining suitable measures in case of any problems.

The signature is important for liability reasons. The name of the person signing the well record shall always be legible, as shall the name of the company which carried out the works.


Namn och adress på borrföretag
Västerköpings Brunnsborrning AB
Tvärgatan 5
595 00 Västerköping

BRUNNS- OCH BORR-PROTOKOLL
Utskriftsdatum 2016 11 29
Borringen avslutad datum * 2016 11 26
År Månad Dag

SGUs anteckningar (fylls ej)
Ankomstdatum
Kommunkod

Uppgiftsskyldighet enligt SFS 1975:424, SFS 1985:245
Exemplar 1 insänds av borrföretaget till Sveriges geologiska undersökning, Brunnsarkivet, Box 670, 751 28 Uppsala
Exemplar 2 lämnas till uppdragsgivaren
Exemplar 3 behålles av borrföretaget
* Obligatorisk uppgift

Borrplatsens läge
Fastighetsbeteckning (namn och nummer) * Leråkra 3:23
Kommun Ronneby
Ort Västerköping
SGUs anteckning VNE
Borrplatsens läge på fastigheten 10 m NV bostadshus
Borrplatsens koordinater i system: [X] SWEREF 99 TM [ ] WGS 84 (lat/long) [ ] RT90 2,5 gon V
N6232932 E515598
Borrplatsens adress * Strandvägen 14
Telefon (även riktnummer) 0457-40081

Ägare/Beställare
Ägares/beställares namn Sven Johansson
Telefon (även riktnummer)
Utdelningsadress, om annan än borrplatsens adress ovan
Ortsadress (postnummer och ortsnamn)

Jordarter/bergarter m.m.

Djup under markytan * från	till	Jordart/bergart *	Färg	Anmärkningar (vattenförekomst, sprickor m.m.)
0	1 m	Jord		
1	5 m	Lera		
5	7 m	Grus		lite vatten
7	48 m	Granit grå		trasigt 7- 9 meter
48	90 m	Granit rödgrå		sprickor med vatten på 56 och 88 meter

Tekniskt utförande
Borrmaskinstyp [X] sänkhammare [ ] annan:
Tätning mellan foderrör och berg har skett med [X] cementering [ ] extra plaströrsfodring [ ] annan:
Borrhål fodrat [X] stålrör Ytterdiameter 139,7 x Godstjocklek mm djup från 0 – till 12 m
[ ] annan rörtyp: Ytterdiameter x Godstjocklek mm djup från – till m
Totaldjup från markytan 90 m
Jorddjup från markytan (djup till berg) 7 m
Borrhålets bottendiameter 114,7 mm
Brunnens användning * [X] hushållsvatten [ ] energi värme/kyla [ ] kommunalt vatten [ ] övrigt:
Vattenanalys utförd [X] fys. kemisk [ ] bakteriologisk [X] radon
Vattenflaska lämnad [ ] ja [ ] nej
Analysresultat [ ] bifogas [ ] insändes senare

Provpumpning m.m.
Typ av kapacitetsmätning [X] blåsning [ ] flottörmätning [ ] pumpning
Pumpens maxkapacitet liter/tim
Borrad enligt Normbrunn [ ] ja [ ] nej
Pump- eller blåsdjup under markytan 90 m
Pump- eller blåstid 2 tim
Vattenmängd 700 liter/tim [ ] före tryckning
liter/tim [ ] efter tryckning
Vid kapacitetsmätningen sjönk vattenytan (räknat från markytan) djup från 6,1 – till 90 m

Gv-nivå
Stabil grundvattennivå under markytan 6,1 m
Datum vid mätningstillfället 2007-11-26
Mätning av grundvattennivån har skett [ ] före vattenuttag [X] efter vattenuttag
antal timmar 2

Anmärkningar
[ ] tryckning [ ] sprängning [X] gradborrning, riktning: 5 grader SV
Uppmätt kloridhalt [ ] nej
Annan anmärkning

Uppmätt kloridhalt 30 mg/l 56 m under markytan
Uppmätt kloridhalt 80 mg/l 90 m under markytan
Uppmätt kloridhalt mg/l m under markytan
Uppmätt konduktivitet mS/m m under markytan
Uppmätt konduktivitet mS/m m under markytan
Uppmätt konduktivitet mS/m m under markytan
Konduktivitet anges i milliSiemens per meter, mS/m

Underskrift
Namnförtydligande
0453/06
Certifierad borrare/borrföretag nr

Blankettutgivare SVERIGES GEOLOGISKA UNDERSÖKNING
Telefon 018-17 90 00

Borrplatsens läge			
Fastighetsbeteckning (namn och nummer) * Leråkra 3:23			
Kommun Ronneby	Ort Västerköping		SGUs anteckning VNE
Borrplatsens läge på fastigheten 10 m NV bostadshus	Borrplatsens koordinater i system: [X] SWEREF 99 TM [ ] WGS 84 (lat/long) [ ] RT90 2,5 gon V N6232932 E515598		
Borrplatsens adress * Strandvägen 14		Telefon (även riktnummer) 0457-40081	

Well position

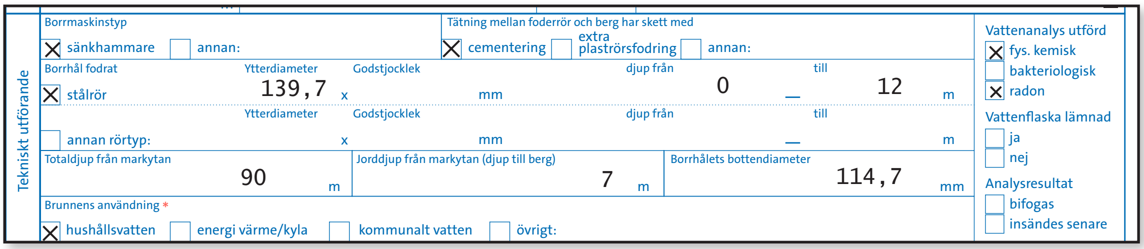
Recording the *well position* is important for well identification. The plot registration name, and normally the address too, is unique for each municipality. If correctly recorded there is no risk of conflicting information. Using this information SGU will register the well coordinates.

Wells which were drilled a long time ago are often difficult to locate; therefore it is important to correctly record the well position. A sign on the outer wall of the building describing the location of the well can also be very helpful.

Djup under markytan * (från – till)	Jordart/bergart *	Färg	Anmärkningar (vattenförekomst, sprickor m.m.)
0 – 1 m	Jord		
1 – 5 m	Lera		
5 – 7 m	Grus		lite vatten
7 – 48 m	Granit grå		trasigt 7- 9 meter
48 – 90 m	Granit rödgrå		sprickor med vatten på 56 och 88 me

Subsoil/bedrock type

Subsoil/bedrock type etc. provides factual information regarding the site conditions of the well location. Here, the sequence of subsoil and bedrock layers should be recorded, the levels of any water-bearing fractures etc. Should any problems regarding water quality or quantity occur, these details will frequently provide the answer to where sealing measures should be undertaken, or the level at which high pressure flushing should be carried out.



Tekniskt utförande

Borrmaskinstyp: [X] sänkhammare [ ] annan:

Tätning mellan foderrör och berg har skett med: [X] cementering [ ] extra plaströrsfodring [ ] annan:

Borrhål fodrat: [X] stålrör — Ytterdiameter 139,7 x Godstjocklek mm — djup från 0 till 12 m

[ ] annan rörtyp: Ytterdiameter x Godstjocklek mm — djup från till m

Totaldjup från markytan: 90 m — Jorddjup från markytan (djup till berg): 7 m — Borrhålets bottendiameter: 114,7 mm

Brunnens användning *: [X] hushållsvatten [ ] energi värme/kyla [ ] kommunalt vatten [ ] övrigt:

Vattenanalys utförd: [X] fys. kemisk [ ] bakteriologisk [X] radon

Vattenflaska lämnad: [ ] ja [ ] nej

Analysresultat: [ ] bifogas [ ] insändes senare

Technical details

By studying the information regarding *technical details* it is often possible to determine whether the well works have been undertaken in a professional manner.

It is of particular importance to record how the well has been sealed off between the casing and the bedrock, how many metres of casing have been used and the dimensions of the casing.

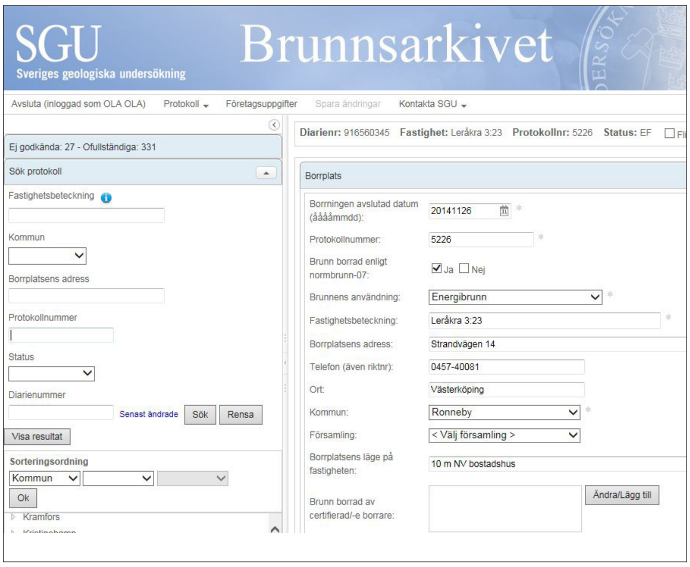
The information on total well depth and on subsoil depths should always concur with the information on subsoil and bedrock layers.

The bottom diameter of the well shall be recorded as the diameter of the drill bit used to drill the deepest part of the well. This information is important when choosing the size of the drill bit for any future deepening of the well – to avoid the drill becoming stuck in the well.

The information on well use, normally household drinking water or energy use, is of importance in the case of any adjacent construction works.

Recording well information using the web form

Today, drilling contractors can feed drilling information directly into the SGU Well Record Archive using a *web form*. This will generate the well record as a pdf-document which can be printed and undersigned. The web application enables the contractor to add his company logotype and any certification logos. Please contact SGU to receive a username and password, 018-17 90 00.



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