Water supply in Denmark

For many years the water works in Denmark experienced only few challenges. However, in the 1970s several constraints began to emerge. The very dry summers in 1975 and 1976 caused many watercourses around big cities to run dry (except for waste water).

Since the 1970s one of the big challenges for water resource planning and administration has been to regulate the abstraction of surface and groundwater to an acceptable level. Gradually, direct abstraction from surface water was prohibited and groundwater abstraction was regulated to secure a certain minimum flow in all rivers, mainly through moving the abstraction wells away from riverbanks and wetlands. Furthermore, drinking water suppliers have carried out comprehensive water saving campaigns.

Over the past 35 years another big challenge for the water supply has been pollution of well fields with nitrate from farming, chemicals from old waste dumps and oil tanks, toxic materials from enterprises, and pesticides from urban areas and farmland.
Background: Setting the scene of Danish water supply

Denmark has a total area of 43,000 km², with 5.5 million inhabitants, and has been continuously populated since the latest glaciation and cultivated for more than 5,000 years.

Most of the country consists of Quaternary deposits overlying Cretaceous chalk, limestone and Tertiary sand and clay. The topography is low-lying, rising to a maximum of 172 m above sea level. The combination of low topography and widespread consolidated and unconsolidated aquifers ensures a plentiful and easily accessible groundwater resource.

Danish farmers have highly developed agriculture with intensive use of fertilizers, manure and pesticides. Two-thirds of the Danish area is managed by farms with a high pig meat production of 25 million pigs per year as well as half a million cows producing 5 million m³ milk per year. Pollution from farming is a challenge to water supply.

The Danish drinking water supply is based entirely on groundwater and the government’s official position is that drinking water should be based on pure groundwater which only needs simple treatment with aeration, pH adjustment and filtration before it is distributed to the consumers. Approximately 800 million m³ of water are abstracted annually. Groundwater recharge averages 100 mm per year, varying between 50–350 mm.

Groundwater quality in deeper aquifers in Denmark is generally good, thus obviating the need for complex and expensive water purification. Except for Copenhagen, with long transmission networks, the drinking water is not chlorinated and the quality of tap water is even better than bottle water.

However, many shallow aquifers suffer from groundwater pollution, especially from nitrate and pesticides, and over recent decades many waterworks, have been closed, forced to drill deeper or forced to buy their water from neighbouring water supplies.

![Groundwater abstraction in Denmark 1989-2005](image-url)
Action Plan for the aquatic environment: reducing nitrate and phosphate

During the 20th century, increasing industrialisation of farming, increasing development of waste water discharge to surface waters and the sea, and increasing use of water by households, industry and irrigation led to depletion of the water resource in Denmark. In the 1970s there was an increasing public understanding of the reasons behind the surface water depletion; and in 1987 the Danish parliament approved the **Action Plan for the Aquatic Environment** with the objective to reduce nitrate leaching to the aquatic environment by 50% and phosphate leaching by 80% within five years. While the phosphate goal was accomplished relatively soon after the five-year period through substantial public investment in wastewater treatment plants, the nitrate goal has never been fully achieved.

In 1986 the first **Pesticide Action Plan** was introduced, this has been followed by two further action plans. The latest is from 2003 and this covers 2004-2009. The main goal has been to reduce the use of pesticides and the negative effects on health and the environment, including protection of the groundwater. There has been a shift in the type of pesticides used and a number of substances that have previously polluted the groundwater have been withdrawn from the market. Even though there has been progress, the goal in the latest plan has still not been achieved. An evaluation of the plan is ongoing.

Water resources are still over-exploited

In 1988 the Ministry of Environment approved a Statutory Order on Water Quality and Supervision of Water Supply Plants introducing quality monitoring of abstracted groundwater. The most important parameters are now analysed in all groundwater abstraction.

In order to reduce pressure on the surface water, the use of surface water for any purpose has gradually been transferred to groundwater. Abstraction of groundwater needs a permit, to be renewed at specific times, and the annual abstraction measured must be reported to
the authorities once a year. Waterworks are granted a permit for a maximum of 30 years, while irrigation permits are only for up to 15 years.

During the past 20 years, water taxes and water saving campaigns have reduced groundwater abstraction by more than a third. However, models conclude that the water balance is still over-exploited, especially in the eastern part of Denmark, with the highest population density.

Nitrate pollution of groundwater has led to closure of many minor water works based on relatively shallow aquifers. Pesticide pollution, especially in suburban areas, has led to closure of several major well fields. Leaching from waste disposals and other point sources has closed several water supply wells and finally some water works suffer from nickel pollution, mainly due to over exploitation of aquifers.

In the period 1991-2005, 1,306 wells were closed as water supply abstraction wells, solely due to content of pesticides or degradation products (metabolites) and approximately 100 wells are still closed every year due to pesticide content.

The challenge to comply with EU directives
The present challenges to Danish groundwater quality are stated in the five EU directives:

- Nitrates Directive
- Water Framework Directive
- Groundwater Directive
- Drinking Water Directive
- Pesticide Directive
The Nitrates Directive states that groundwater quality, generally speaking, should not exceed 50 mg/l nitrate.

According to the Water Framework Directive and the Groundwater Directive good groundwater status must be achieved in all groundwater bodies. This means that, initially, all the following must be fulfilled:

- Nitrates < 50 mg/l.
- Pesticides and metabolites < 0.1 μg/l.
- Pesticides and metabolites (total sum) < 0.5 μg/l.
- Concentration must not exceed quality standards applicable under other relevant EU Community legislation.
- Groundwater quality may not cause that associated waters (surface water) fail to achieve environmental objectives, any diminution of the ecological or chemical quality of such bodies, or any significant damage to terrestrial ecosystems which depend directly on the groundwater bodies.
- Changes in conductivity must not be indicative of saline or other intrusion into the groundwater body.

Furthermore, the amount of groundwater must always assure a certain minimum river flow.

There are 385 groundwater bodies, distributed within four River Basin Districts.

Implementation of the Drinking Water Directive states a series of Maximum Admissible Concentration (MAC) values for many chemical elements occurring in drinking water, and as groundwater is used for drinking water with only simple treatment, many of these MAC values are highly relevant for groundwater protection.

**Hydrogeological mapping as a basis for establishing site-specific groundwater protection zones in Denmark**

In 1994 the Danish Government presented the ten points for protection of groundwater and drinking water, including classification of groundwater abstraction areas, to improve groundwater protection of particularly valuable areas for drinking water interests.

### Danish Government’s 10-point programme from 1994

1. Pesticides injurious to health and dangerous for the environment shall be removed from the market
2. Pesticide tax - the consumption of pesticides shall be halved
3. Nitrate pollution shall be halved before 2000
4. Organic farming shall be encouraged
5. Protection of areas of special interest for drinking water
6. New Soil Contamination Act - waste deposits shall be cleaned up
7. Increased afforestation and restoration of nature to protect groundwater
8. Strengthening of the EU achievements
9. Increased control of groundwater and drinking water quality
10. Dialogue with the farmers and their organisations.
By the end of 1997, Denmark was classified according to the degree of drinking water interest:

Particularly valuable areas for drinking water interests, valuable areas for drinking water interests and less valuable areas for drinking water interests.

This classification is based on an evaluation of the size and quality of all groundwater resources. In 1998 this was followed by a decision to instigate a spatial dense hydrogeological mapping of the groundwater resource within the 40% of Denmark (17,000 km²) designated as areas with particularly valuable for drinking water interests and catchment areas for public waterworks. The consumers have to pay € 0.07 per m³ surcharge for the mapping. A family of four will pay about €12 per year.

The maps are used to establish site-specific groundwater protection zones and associated regulation of land use to prevent groundwater pollution.

The fundamental concept of site-specific groundwater protection zones is that some areas are more vulnerable to groundwater pollution than others. The goal is thus the subdivision of a given area according to the different potential of the various sub-areas as regards specific purposes and uses.
The Danish site-specific groundwater protection strategy is based on three steps:

1. Spatially dense hydrogeological mapping based on new geophysical surveys, survey drilling, water sampling, hydrological modelling, etc., aimed at facilitating the establishment of site-specific protection zones. These zones are directed at both point sources and diffuse sources of pollution within the entire groundwater recharge area, and are to supplement the traditional protection zones around wells. Vulnerability is interpreted in relation to the local hydrological and chemical conditions.

2. Mapping and assessment of all past, present and possible future sources of pollution – both point sources, and diffuse.

3. Preparation of an action plan stipulating politically determined regulations for future land use and remediation of polluted sites. The plan is to be evaluated through a public planning process with a high degree of transparency and public participation. Moreover, the plan must include a timetable for implementation, and a description of who is responsible for implementing the plan.

In Denmark, water-supply wells have been successfully protected at point sources, such as leaching of wastewater, using two-level protection zones. The protection zones encompass a 10m-diameter protection zone around the well indicated by a fence, and a 300m protection zone. Site-specific protection zones can encompass the whole recharge area, with particular
emphasis on protection of the capture zones. The protection zones will be established on the basis of model calculations of groundwater flow, and calculations of the degradation of the pollution from point sources and diffuse sources, taking into account knowledge of the local geological and geochemical conditions.

The establishment of protection zones of this type imposes demanding requirements on mapping of the water resources, because the restrictions associated with the zones have to be set at property level. The Quaternary geology of Denmark is very complex, and the existing geological maps are largely based on geological information from wells. As a consequence, the traditional maps are not sufficiently detailed and precise to enable delineation of the new protection zones. The new mapping initiative includes setting up conceptual geological models and hydrological models for use in analysing the geological information and determining the capture zone of water supply wells and the pollution risk. Particle path calculations in particular have been used to delineate the capture zone. Model resolution is normally 250m (corresponding to the average distance between the geophysical measurement lines). For the past 15 years, the MIKE-SHE model programme package, developed by DHI has been used to model major areas.

The cooperation between the HydroGeophysics Group at Aarhus University, the Danish Ministry of the Environment and GEUS is very important for ensuring high quality in the collection and interpretation of geophysical data. The HydroGeophysics Group is working intensively to continually improve measurement methods and data interpretation. The extensive measurement campaign has shown that geophysics is presently a cheap and effective method to fill in the geological picture between boreholes. The practical work of undertaking the geophysical measurements and interpreting the results has been carried out by consultancy firms. The quality assurance procedures for the geophysical measurements and the programming of interpretation programmes are carried out by the HydroGeophysics Group. All measurement data have to be submitted to the national geophysics database GERDA, located at GEUS.

Development of effective hydrogeological mapping methods at Aarhus University, especially within the geophysical area, has led to international pioneer development in 3-D mapping of groundwater bodies. The helicopter-supported SKYTEM method is especially important for mapping the groundwater occurrence, as the method can scan the geological conditions to a depth of 300m at an airspeed of 30 km per hour.
Water quality monitoring programme

The NOVANA programme covers monitoring of:

- Air quality and atmospheric deposition
- Point sources (waste water outlets)
- Groundwater
- Agricultural catchments (including groundwater)
- Lakes
- Streams
- Coastal and Marine waters
- Species and terrestrial nature types

Part of the Action Plan for the Aquatic Environment was the establishment of a water quality monitoring programme in 1988, now called the Nationwide Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment (NOVANA).

For each theme, technical guidelines have been developed and for groundwater, guidelines has been developed for well drilling and design, pumping and sampling, filtering, field measurements, analyses, data reporting, etc.

The water quality monitoring programme has been running since 1988 with adjustments every 5 - 6 years. The present NOVANA runs in the period 2004 – 2009. However a revision has been undertaken to adjust the programme to agree with the requirements of the EU Water Framework Directive and Groundwater Directive.

As the drinking water supply in Denmark is entirely based on groundwater, monitoring groundwater quality is extremely important for Danish society. With more than 62% of the total land area under agricultural use the Danish government has determined that the entire area is vulnerable to nitrate pollution, and therefore the groundwater monitoring programme should cover the entire country.

The Danish groundwater monitoring programme comprises water supply well monitoring, the groundwater monitoring network, and agricultural watershed monitoring.

Groundwater quality monitoring is carried out in a detailed analytical programme of 1415 well screens from the monitoring network comprising 70 catchment areas, and on 100 shallow screens from five agricultural watersheds. The detailed quality monitoring includes analyses for 97 chemical elements, comprising 26 main elements, 14 heavy metals, 23 organic micro-pollutants and 34 pesticides and metabolites. Furthermore the water quality control on the basis of data from approximately 6200 public water supply wells is a part of the groundwater monitoring.
The challenge with nitrate

The water supply wells generally have long screens and are intended to provide representative information on the distribution of the nitrate content in primary groundwater reservoirs. Data from water extraction wells are, however, biased since the wells are intended to ensure production of drinking water with nitrate concentrations below the maximum admissible concentration (MAC) of 50 mg nitrate per litre.

The groundwater monitoring wells give a more accurate picture of the general nitrate pollution in the Danish groundwater. In 1998–2004, mean nitrate concentrations were above the MAC limit for drinking water in 16.9% of the wells, whereas about 60% had no nitrate (< 1 mg nitrate per litre).

Over the past half century the use of fertilisers in farming has intensified dramatically. Groundwater from the monitoring screens has been dated using the CFC (chlorofluorocarbon) content, and demonstrates that the highest nitrate values reflect the increase in the use of fertilisers. Preliminary data suggest, however, that since 1979 farmers have changed their spreading practice for fertilisers and manure such that nitrate pollution is now following a declining trend.

The challenge with saline groundwater

In Denmark groundwater has a high chloride content in coastal areas and in areas where water is abstracted from aquifers affected by old seawater. The sea level in the waters surrounding Denmark has varied considerably through the ages and many deep aquifers contain trapped old seawater, for example from the early Stone Age and interglacial periods.

The challenge with nickel and arsenic

The most widespread impact from inorganic trace elements is due to nickel derived from oxidation of pyrite, bravoite and other heavy metals bearing sulphides. Implementation in 2001 of the EU Drinking Water Directive in Danish legislation has led to increased concerns with respect to arsenic, for which the MAC value was decreased from 50 to 5 μg/l. Nine percent of the monitoring well screens in the groundwater monitoring programme currently exceed 5 μg/l in all samples. Fortunately a great part of nickel, arsenic and other trace elements precipitate together with iron and remain in the sand filters.
The challenge with pesticides and metabolites

Pesticides and their metabolites are found in more than 25% of all water supply wells and monitoring wells.

The most frequently found pesticide group consists of triazines and their metabolites. These compounds are commonly found in both farming and urban areas. In the agricultural watersheds the triazines and their metabolites make up about half of all recorded pesticides and metabolites.

In water supply wells the analytical data indicate a very high frequency of 2,6-dichlorobenzamide (BAM) findings, a metabolite mainly from the pesticide dichlobenil that was used in the period 1969 – 1996 as a total herbicide on uncultivated soils, e.g. in urban areas, along roads, on farmyards, in private entrances, on fallow and set-aside fields before re-cultivation, and under fruit plantations. From 1996 dichlobenil was prohibited in Denmark. Twenty-five per cent of the wells contain BAM, and 10% have concentrations above the MAC value for drinking water of 0.1 μg/L.

The monitoring network demonstrates high detection rates for pesticides in the upper 40–50m of wells tested, and a lower number of findings with increasing depth.

It is expected that restrictive rules for using pesticides may have effectively reduced the risk for future pesticide pollution of groundwater.

Groundwater modelling

Evaluation of the water balance and groundwater infiltration through hydrological modelling is a part of the NOVANA monitoring programme.

The main objective is to increase knowledge of the water balance and the sustainable groundwater resource at catchment area, river basin and water district levels. The NOVANA modelling is expected to give quality assurance on data, integration of data and feed back to inconsistencies in conceptual models and data for the water balance.
The NOVANA model provides superior knowledge on groundwater resources and exploitation, taking climate, landuse and abstraction strategy into account. The model will further serve models on minor scale with frame conditions. The NOVANA model which today covers the entire country uses a horizontal discretisation of 500 x 500 m.

**Best practice to reduce agricultural impacts on groundwater quality**

Drastrup waterworks is one of two major well fields in the city of Aalborg, located in the northern part of Jutland. The municipal water supply supplies water to about 100,000 persons, and Drastrup accounts for about 30% or 3 million m³ per year.

The limestone aquifers around Aalborg are highly permeable and productive. However, the aquifers are mostly un-confined, without protective clay layers. Agriculture has caused extensive non-point nitrate contamination of the upper parts of the un-confined aquifers around Aalborg in the rural areas. The young groundwater has increased from 100-130 mg nitrate per litre. The EU nitrate limit of 50 mg/l can still be satisfied by mixing with the deeper groundwater.

The leakage of agricultural nitrate from the root zone must be reduced to protect the investments in the waterworks.

In 1992 the city council adopted a unified plan for future land use that has the following objectives:

- **Sustainable land use in terms of forest, permanent grassland, and environmentally friendly farming**
- **Areas of recreational countryside**
- **Ban on new sources of pollution**
- **Elimination of causes of pollution**

The changes of land use are based on a voluntary principle. Between 1997 and 2001 the city council implemented a program to redistribute the land. Farmers who wished to continue conventional farming activities were offered land outside the project area and the local authority offered to buy up the land that the farmers wished to sell. In conjunction with the redistribution of land, voluntary agreements were concluded with farmers on the use of nitrogen, pesticides and other chemicals. In collaboration with the Danish Forest and Landscape Research Institute, three different afforestation projects have been developed that result in as low level of leaching to groundwater as possible.

About 450 ha farmland has been converted to forest or permanent grass. The new forest, permanent grass areas and post-treated gravel pits have become attractive recreational areas with picnic sites.

Monitoring of the quality of the groundwater has been carried out throughout the entire project area since 1986. Total nitrate contamination under the converted forest area and grassing areas has been reduced significantly, together with the overall vulnerability of the reservoir. Also, the pesticide contamination risk has been reduced substantially.
A new action plan for the Drastrup catchment is now under implementation. This plan will provide additional resources to continue the protection efforts.

The establishment of site-specific protection zones, with regulation of land use within them, has proven successful to restore contaminated groundwater at a waterworks on the island of Tunø. About 12 years ago, the only aquifer on the island was highly contaminated with nitrate, and measures were needed to rectify the situation. It was calculated that the establishment of protection zones and associated regulation of land use would be cheaper than the introduction of water treatment. The effect of the site-specific protection zones has been monitored since 1990, and the nitrate content of the water in the upper layers of the aquifer has declined to a level below the EU limit value. In a few years time, water quality is expected to be acceptable in the whole aquifer. The land-use regulations imposed were specific to these protection zones and were accepted by the landowners because of comprehensive documentation.
Water supply is closely surveyed

Public water supply administration in Denmark

Planning and public administration in Denmark is carried out at three governmental levels: state, regional and municipal. Legislation is passed by the State and the seven state environment centres are responsible for the planning of water under the Water Framework Directive. The regional administration is responsible for remediation of pollution from old waste dumps and other polluted sites. The municipalities are responsible for the administration of water-abstraction permits and protection of water resources against pollution. The Water Plan, in accordance with the Water Framework Directive, requires the use of groundwater and surface water to be regulated through integrated planning and comprehensive assessment and protection of water resources while concomitantly ensuring water-supply needs and protection of nature and the environment. The administration of water-abstraction permits is regulated by the Water Resource Plan drawn up by regional state environmental centres. The Water Resource Plan is the framework for the Water Supply and Protection Plan drawn up by each of the 98 Municipal Councils.

Water supply is continuously adjusted in order to live up to quality and efficiency according to EU regulation. From 1980 to 2005 on average 52 water supplies were closed each year, due to pollution or outdated production possibilities. In 2005, 158 publicly owned water supplies and 2,464 common partnership-owned water supplies were registered in Denmark. The water suppliers account for by far greatest abstraction of groundwater for drinking water purposes; only around 50,000 households have their own direct supply from dug wells or shallow drilled wells.
A great challenge over time has been to change well field locations so that their influence on river flows is stabilized or re-established. But the greatest challenge was to find new well fields or deep-lying aquifers in order to comply with the drinking water quality standards. Where possible the well fields were moved to the open landscape, far away from the many urban pollution sources. To accomplish this the water suppliers used the thorough hydrogeological mapping initiated in 1998. The municipal implementation of the planning for protection of the groundwater is a condition to avoid groundwater pollution.

**Water data management**

According to the Danish Water Supply Act, all water supply data collected must be reported to the national groundwater database managed by the Geological Survey of Denmark and Greenland (GEUS).

Data on abstraction and level measurements are reported electronically, directly from the water supply to the groundwater database, while groundwater and drinking water quality data are reported via the analysis laboratory to the national databases on groundwater quality and drinking water quality respectively.
Making the water supply sector more effective

Recently the larger water suppliers have been focusing on making the water supply sector more effective through introducing a benchmarking system focusing on quality, environment, security of supply and efficiency based in user demands.

For several years the consumer has focussed on water saving initiatives. A modern toilet uses 2-4 litres water per flush compared with the former 8-10 litre per flush. All installations in the household now run with water saving mechanisms, e.g. washing machines. Waterworks have been focussing on leakages from the distribution network, because losses of less than 10% are tax-free. From 1997 to 2006 the loss from the distribution networks has been reduced from 9% to 6%. A condition for optimization of the distribution network and for finding the leakages has been a comprehensive registration of the networks and not least the development, e.g. by the Danish DHI, of advanced programmes for network calculations.

Total drinking water consumption from the water suppliers decreased from 605 million m³ in 1980 to 400 million m³ in 2005.

The latest efficiency activities within the water sector are energy efficiency and saving. Grundfos has developed new pumps that are 10% more energy efficient, and it is expected that within the supply sector considerable energy savings will be seen in the years to come. Thus the water suppliers are supporting climate change by decreasing the CO₂ emissions.

Seventy-eight water suppliers participated in the benchmarking in 2007, covering 45% of Danish consumers, with the result that, on average, over the past six years water suppliers have reduced expenses on water production by 20% per m³ of drinking water sold.

Through infiltration through soil and sediments, water is naturally cleaned and filtered, and the dissolved natural salts and lime give groundwater its taste and character. It is still possible to find groundwater with very high quality and drinking water is normally produced through simple treatment with aeration and filtering. Water analyses from drinking water comply with the drinking water standards in 97.2% of the analyses. Quality assurance and water treatment are continuously being developed, not least after the change of the compliance level for arsenic in drinking water from 50 to 5 μg per litre.

Since 1980s water saving in the water supply sector has been an important issue. Introduction of individual water meters for all consumers has given an immediate saving of up to 40% in some water supplies. Drinking water and waste water services are paid according to measured supply.

Introduction of water taxes and VAT on drinking water has increased the water price and made the price visible. The permitted and the abstracted amount of water is subject to a water tax. The tax on the permitted amount has the aim to reduce the amount applied for to get better management of the water resource. The tax on abstracted water has a triple purpose; one is purely fiscal; second is to save groundwater; third is to encourage the water suppliers to reduce leaks in the distribution network so that no more than 10% of the abstracted amount of water is accepted waste and therefore 10% is tax-free. Irrigation is looked upon as a part of the production facilities and is covered with no tax on the abstracted amount of groundwater.
**Taxes and levies**

Price of water 2008 – Municipality of Aarhus:

- The total price € 5.40 per m³
- A per m³ charge drinking water € 1.22 per m³
- A drinking water State levy € 0.83 per m³
- Groundwater mapping and protection € 0.07 per m³
- A wastewater disposal levy € 3.24 per m³
- A State wastewater levy € 0.04 per m³
- An annual drinking water meter rental € 54.00 per year
- Price include 25% VAT

For an average household consuming 170 m³ per year, the total charge for water supply and wastewater services was around € 900 per year in 2008 prices – approximately 1.6 % of the average family income.

Compared to the price of a bottle of mineral water, tap water is still very cheap. Fresh and pure drinking water can be delivered to the tap for a total price of half a European Cent per litre.

**Lessons learned**

**Water supply**

- Implementation of benchmarking focuses on efficiency and water supply quality, and good results have been achieved. The drinking water quality has improved and the production cost has decreased by 20% in just a few years.
- Introducing water meters can give an immediate reduction of up to 40%.
- The water price is important to save water – total drinking water supply has been reduced by 40% nationwide in 20 years. The water price motivates consumers to use water-saving measures in households, e.g. less water consuming toilets. Water taxes may further support water saving.
- There is a great potential for energy saving, e.g. 10% by changing to new energy-optimized pumps from Grundfos.
- Optimization of the distribution network through network registration and leakage searching may reduce water loss to 6%.
- Decentralized abstraction of groundwater reduces the size of influence on surface water. However, it is important that minor water suppliers cooperate in order to fulfil demands from implementation of EU legislation.

**Groundwater protection**

- Detailed hydrogeological mapping is an important tool to be able to efficiently protect the capture zones for the well fields. Comprehensive mapping makes it more acceptable for landowners to accept restrictions on land use.
- Public participation is very important for implementing the action plan for groundwater protection.
- Groundwater monitoring is important to document positive and negative development in groundwater quality.
- Groundwater modelling is an important tool to calculate scenarios for water balance, abstraction, capture zones and climate change.
• It is possible to restore contaminated groundwater with protection zones;
• The nation-wide regulation of agricultural nutrient use has shown measurable effects on the groundwater from nitrate pressure.
• Remediation and preventive pumping at old waste disposals and at polluted urban sites has reduced the number of point sources. Agreements with farmers have reduced pollution from pesticide spraying equipment cleaning sites.
• Regulation of pesticides has reduced pollution from farmland and urban areas.
• Afforestation is an effective way to achieve lasting protection of catchment areas. It is a Danish policy to double the Danish forest area within the coming 80 years.

Groundwater monitoring
• In order to interpret the analyses results, an understanding of the reservoir geology and of the well construction is absolutely necessary.
• Short well screens give better assurance of the origin of the sample.
• Excessive abstraction will mix water from different levels in the aquifer.
• Grundfos MP1 Submersible Sampling Pump has revolutionized Danish groundwater monitoring.
• Samples must be treated adequately, especially stored cold for short time and even frozen if stored for a longer period.
• Laboratory quality depends on human resources, laboratory technician education and on equipment maintenance.
• Water supply and monitoring data should be quality assured by the responsible authority and afterwards accessible to public use.

Contact:
Jens Stockmarr, Senior advisor
Geological Survey of Denmark and Greenland (GEUS)
sto@geus.dk

Richard Thomsen, Head of department
Geological Survey of Denmark and Greenland (GEUS)
rth@geus.dk

Read more: www.ecoinnovation.dk/english
– choose Danish Lessons