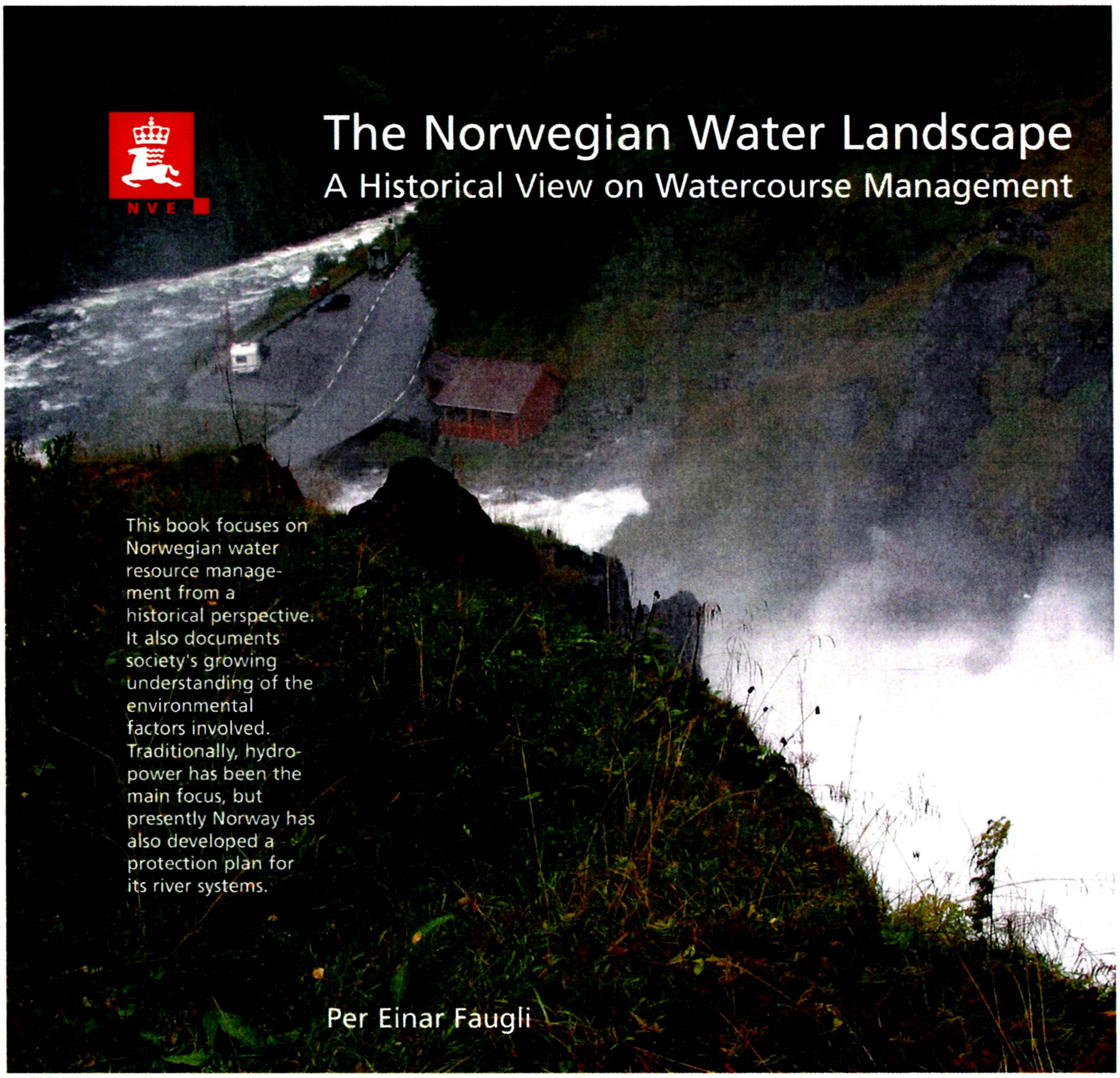

Per Einar Faugli:
THE NORWEGIAN WATER LANDSCAPE
- a historical view on watercourse management
(V 1.0•)

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Front: Låtefoss waterfall in the protected river Opo, Odda.
Back: Drammensmarka, outside Drammen.

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INTRODUCTION

Norway has a very large number of waterfalls and watercourses. These are of great value to society, financially and to the public. The Norwegian water resource administration was established in 1804, however the country's legislation had concerned itself with the use of water and watercourses long before this. The watercourses are a renewable resource the administration of which requires high level competence.

In this book Per Einar Faugli puts focus on Norwegian water resource administration as seen from a historic perspective and from society's increasing understanding of environmental factors. Having worked for more than 30 years in the watercourse sector and having had the University of Oslo, The Ministry of the Environment and now the water resource department at NVE as employer, he has followed the development from different perspectives in the public sector. Since the union with Sweden was dissolved in 1905 the use and protection of our watercourses has been a central element in the political debate.

The text is the author's responsibility. He has emphasized adapting the material for use in education, which is natural as the author has much experience teaching at college and university. Another of the book's goals is to give the readers, especially foreign readers, insight into the country's water resource administration. The country's administration is distinctive internationally because of the dominant role of hydropower and the establishment of watercourse protection.

I hope that the book will lead to a greater understanding and interest in Norway's water administration, and thank the author for his initiative and hard work. Tone Hesjedal, Norwegian Museum of Hydropower and industry, has been in charge of final translation, and Kjell Arne Olufsen has had the main responsibility for layout and design. Both are thanked for their effort. All who have contributed pictures as well as other assistance are also thanked. The photographer's name is mentioned for all pictures not taken by the author.

Oslo, March 2005

Are Mobæk
Director of departement
Water Resource Department

The latest version of this publication can be downloaded from www.faugli.no

THE WATER LANDSCAPE

WATER AND TOPOGRAPHY

In Norway water exists in wide variety: rivers, ice and glaciers, mountain brooks, streams with dramatic rapids and waterfalls, slow moving rivers, tiny ponds and large lakes, deltas and fjords.

Mountains, valleys and water are the main elements of Norway's landscape. Over millions of years geologic forces have caused great changes and developed large fissure systems which have led to the creation of valleys. A few million years ago we have an oblique, unsymmetrical uplift of the present landmass with the highest elevation in the west. Later ice and running water further modelled the surface. This has resulted in different watercourse patterns.

Norway has highly varied nature and landscape, with high and low lands, rural and urban population. Huge mountainous massifs loom over the coastland, and the deeply incised fjords link with deep valleys. Here are green, flat and fertile lands, supporting agriculture in the southeast and opening up toward the ocean in the southwest.

Small lake in Drammensmarka, outside Drammen.

The Norwegian watercourse landscape is characterised by great variety: ice and glacier, small mountain brooks, rivers with waterfalls and rapids, calm and slow flowing rivers, small ponds and great lakes, deltas and fjords. It contains so much magnificence and surprising detail. Here are fertile forest valleys, barren mountain plateaus. Here are rivers that float wide and quiet along the banks of primeval forests in wide valleys before being hurled down high waterfalls or pushed through narrow gorges.

Water connects towns, regions, and even countries. Water is a pantry as well as a place for recreation, it provides for energy and transportation. Man has had an impact on the landscape directly and indirectly- in various ways and degrees. The watercourses are the lifenerve in our valleys and in the surrounding forest and mountain regions. All processes depend on each other in the hydrological circle, like pieces in a jigsaw puzzle.

Norway's geographic location far to the north means that we have a particular responsibility to take care of watercourse nature in artic regions. Our mountain areas with glaciers, the

Nærøydalen valley, view from Stalheim.

fact that we have clean water and large virtually uninhabited areas, means that the conservation value is high on an international scale. It is also significant that we have much precipitation all year round.

In the more untouched areas it is nature's own processes that shape the watercourse landscape. The natural processes can also lead to fast changes and the glacial landscape of today is not the same as the glacial landscape of tomorrow. The effect of climatic changes seems to accelerate this. In lower regions there are particular watercourse elements like meanders, anastomosis, deltas, ravines and riparian vegetation. Several of these elements are disappearing. The natural processes develop the shape and change it through floods, but the everyday influence of water, erosion, transport and accumulated material is also a factor.

It is this dynamic that brings the watercourse landscape to life. Biological life is conditioned by the physical surroundings. In a world where biodiversity is a priority, the Norwegian river systems have an important function. The purity of the water and the silence of nature furthermore create perfect conditions for recreation and outdoor activities.

Norway has around 4000 rivers draining to the fjords and the ocean. There are 240 000 lakes and ponds. Eighteen lakes are larger than 50 km^2. Such a landscape with a multitude of lakes normally exists only where the land has been glaciated. Norway's fresh-water lakes cover five per cent of the country's land surface. Some of the Norwegian waterfalls are among the highest in the world. Vettisfossen in West Norway has a free fall of 275 meters, and is the highest non-developed waterfall. The non-developed Kjelsfossen, however, has a total fall of 840 meters. Norway even boasts four of the deepest lakes in Europe, ranging from 452 to 514 meters in depth.

GEOLOGY AND CLIMATE

Combined with low temperatures and glacial activity, the Caledonian mountain chain from which most of Norway originates has produced conditions that are particularly favourable for hydropower production. The steep topography of western Norway translates into large volumes of precipitation and short distances from reservoirs to power stations close to population centres, cutting the cost of power transmission.

The glaciers shaped the landscape into wide u-shaped valleys which are far better suited for reservoirs than the steep v-shaped valleys formed by river erosion. Some 0.8 percent of continental Norway is covered by glaciers, numbering about 1600. Their number and size are changing with the climate. Norway has repeatedly been covered by ice. The last Ice Age culminated some 20 000 years ago, and the inland ice melted less than 10 000 years ago.

The glaciers have also caused the formation of numerous lakes in the mountain regions, in part with moraine deposits as natural dams. In terms of hydropower, the volume of water is of great interest. Relatively small dams on our large mountain lakes can create reservoirs for large volumes of water. This is a contrast to the situation in the Alps, for instance, where much larger, more towering dams are needed to obtain a corresponding volume of water.

The glaciers scraped the mountains down to the harder layers of rock. This makes it easier to build facilities in the mountains. The geology of the rock masses is dominated by hard types of rock which are easy to handle. The Norwegian mainland is located in a relatively stable area, geologically speaking. There is little earthquake activity and no active volcanoes, which represent a threat to hydropower installations in other parts of the world.

The parts of Norway that have the largest deposits of sedimentary rock and which are therefore best suited for agriculture are least suited for large power plants. This helps reduce the dilemma many countries face in giving priority to hydropower at the expense of agriculture.

Precipitation levels vary from one part of the country to another, from season to season and from year to year. The large amounts of precipitation in Norway, particularly on the west coast, come from the vast Atlantic low-pressure areas that move from south-west to north-east where temperate and arctic air masses meet. Average annual precipitation along the coast varies from 3000 mm in the south-west to 1000 mm in the north. In the eastern parts of Norway that are sheltered by the mountains, the annual precipitation can

be as low as 300 mm. There is also a clear tendency for precipitation to increase with elevation above sea level. In some mountainous areas in the west, annual precipitation can be as great as 6000 mm

Owing to the relatively low air temperatures in Norway, evaporation is moderate throughout the year and slightest in the areas with the heaviest precipitation. More than half of the precipitation in the southern parts of eastern Norway evaporates, whereas only one-tenth of the precipitation evaporates in highland areas on the west coast.

Seasonal variations in runoff make it possible to divide the country into distinct hydrological regions. The coastal areas have the least rate of flow in summer and highest rate in autumn and winter. The inland areas have their peak season in spring (April-June) due to melt-off, a low rate of flow in winter, and then a higher rate of flow again in autumn (September-November). The mountainous regions peak during spring thaw (May-June) and have a low rate of flow in winter, while melt-off in glacial areas peaks in summer (July-August), and there is little runoff in winter.

Due to snow melting, the rate of flow is high during periods characterised by lighter demand for electric power than in the winter, when the inflow is limited. When watercourses are regulated for hydropower production, this sporadic inflow is exploited by storing the water in reservoirs in order to generate a steady supply of electricity.

As Norway is sparsely inhabited, receives plenty of precipitation, and has rather moderate pollution problems, we enjoy good water quality. Less than half of one per thousand of available water resources is used for domestic water supply.

A HYDRO POWERED NATION

HYDROPOWER - TYPE OF POWER PLANTS

Nature endowed Norway with favourable conditions for hydropower generation. Norway's climate, topography and geology all comprise very special advantages. Norway shares these conditions with a number of nations that have not yet taken advantage of their water resources in the same way.

All hydroelectric production is dependent on two basic conditions: water supply and fall. Like many other countries, Norway has been generously endowed with both of these, but there are a number of other explanations why the country has attained its prominent international position within the hydropower sector. Generally speaking, Norway's extensive production of hydropower can be ascribed to four conditions; topography, geology, climate and social considerations.

Initially, we must look for historical and social explanations to identify the most decisive factors for hydropower development in Norway.

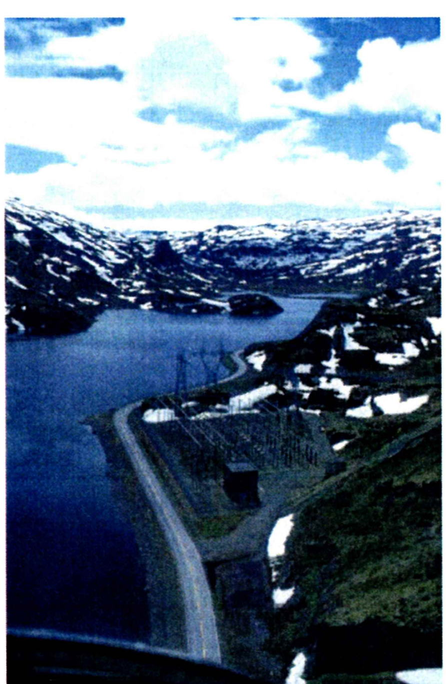
For more than 100 years, Norway has had the world's highest per capita production of hydropower. Even in absolute terms, the country ranks number six in the world after Canada, the US, Russia, Brazil and China.

The first dam of hydropower reservoir in Europe, Senja, Norway.

Technologically speaking, Norway is a world leader and no other nation has comparable expertise and experience in building power plants inside mountains.

It has been necessary to use water and water-courses as energy source throughout Norway's short industrial history. Even today hydropower constitutes 99 % of our electricity production. No other country has as many hydropower plants covering as much of the electricity consumption as Norway.

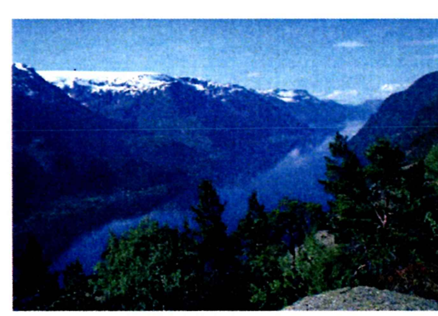
Unlike certain other countries, Norway has not had to re-locate large numbers of inhabitants to develop its hydropower resources. Most



From Steinbergdalen valley, Aurland. Photo: Jon Arne Eie, NVE

Norwegian hydropower development has taken place in highland areas with little or no population.

Norway is also in a special situation with respect to power transmission. Already early on in the history of electricity, transmission



The fjord Sørfjorden in Hardanger.

technology was lagging fairly far behind production technology. The result was that power-intensive industry was located near the sources of power rather than near its markets in established urban areas.

No other single factor has been as important for Norway's economic growth and material welfare as hydropower. In 1920, 64 per cent of the population lived in housing supplied with electricity. This was highest in the world, followed by Canada with 38%. No other country experienced more rapid growth in this area.

The water volume and head of water determine the potential energy of a waterfall. The head of water is the height difference between the reservoir intake and the outlet from the

The dam Mysevatn, Sogn og Fjordane County. Photo: Statkraft.

power plant. Water is directed into pressure shafts leading down to a power plant, where it strikes the turbine runner at high pressure. The kinetic energy of the water is transmitted via the propeller shaft to a generator, which converts it into electric energy.

Low-head power plants often make use of a large water volume, but have a small head of water, as in a run-of-river power plant. It is difficult to regulate the water flow, so that the water is generally used as and when it is available. The amount of electricity generated

therefore rises considerably when the river is carrying more water, for example during the thaw or when precipitation is very high. Most run-of-river power plants are situated in lowland areas, particularly in Eastern Norway and in Trøndelag. There are several run-of-river power plants along the river Glomma (the catchment area is 41 200 km^2 and covers 13 % of Norway's total land area). Vamma power plant in the river Glomma, which has a maximum output capacity of 215 MW and an average annual production of 1275 GWh, is the largest run-of-river power plant in Norway.

High-head power plants are generally constructed to utilize a large head of water but a smaller water volume than run-of-river power plants. Such power plants are dependent on water storage in reservoirs, and are also called power plants with reservoirs. They usually have a larger installed capacity than run-of-river power plants, but a shorter utilization period. A high-head power plant is often excavated near the reservoirs that are used to regulate the volume of water supplied to the power plant. The power plant and the reservoirs are connected by tunnels through the mountain or pipes down the mountainside. Kvilldal power plant is the largest in Norway with a capacity of 1240 MW and a mean annual production of 3517 GWh.

INFLOW AND RESERVOIRS

Water inflow is the volume of water flowing from the entire catchment area of a river system into the reservoirs. A catchment area is the geographical area that collects the precipitation which runs into a particular river system. Useful inflow is the amount of water that can be used for hydropower generation.

Dams are required because inflow varies according to geographic and climatic conditions. During periods of abundant inflow, such as during melt-off or periods of heavy precipitation, the water must be collected in order to be released through the turbines during periods of little or no inflow. Such variations in inflow are not limited to seasonal fluctuations, but are equally the result of fluctuations from year to year. In general, hydroelectric production fluctuates by 20 per cent from one year to the next, depending on the amount of precipitation and reservoir levels. By way of illustration, 20 per cent of the total production corresponds to five times the annual consumption of electricity in Oslo (the capital of Norway). Total reservoir capacity in Norway is 84.3 TWh.

The dam Styggevass in the Jostedøla water catchment.
Photo: Finn Loftesnes, Naturfoto.

Generally speaking, the volume of inflow is inversely proportional to the demand for electric power. During warm periods with heavy melt-off inflow, there is usually little demand for power. During cold spells, the demand for electricity is higher, but the inflow is light.

The potential energy of water can be stored in regulation reservoirs constructed either in natural lakes or in artificial basins made by building dams across a river. Water is collected in the regulation reservoirs in Norway when inflow is high and consumption is low. When inflow is low and consumption is high, stored water can be drawn from the reservoirs and used to generate electricity. Regulation reservoirs are generally situated in sparsely populated areas, and usually at high altitudes in the mountains in order to make the fullest possible use of the head of water. The difference between the highest and lowest permitted water levels in a reservoir is stipulated in a watercourse regulation licence (rules for reservoir drawdown), which among other things takes into account topographical conditions and environmental considerations.

Storage of water in summer for use in winter when the demand for power is highest is called seasonal regulation. Dry-year or multi-year regulation is made possible by large reservoirs that can store water in wet years for use in years when precipitation is low. Short term regulation involves a daily or weekly filling and emptying cycle. The energy capability of a reservoir is the amount of power that can be generated from a full reservoir. Since 1980, the energy capability of Norway's reservoirs has risen by 26, 5 TWh.

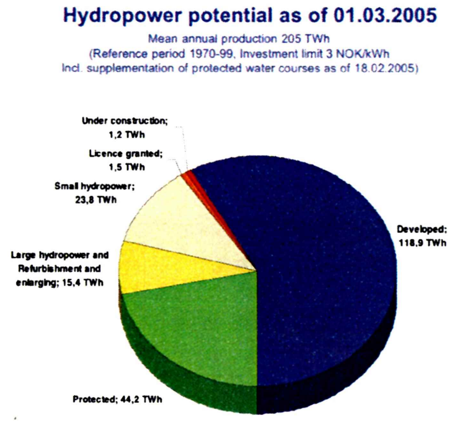
The degree of filling of the reservoirs is a measure of how much water (potential energy) they contain at any given time. Normally water is drawn off during autumn and winter when electricity demand is highest. In spring and summer, electricity demand is at its lowest and the reservoirs fill. Changes in the degree of filling of the reservoirs reflect changes in electricity generation and water inflow during the year. An economic gain can be obtained by pumping water uphill to a reservoir with a greater head of water, because the potential energy of the water increases in proportion with the head of water. If electricity prices are low, it may be profitable for the producers to use power to move water to a reservoir located at a higher altitude, so that the water can be used for production when prices rise again.

POWER PRODUCTION

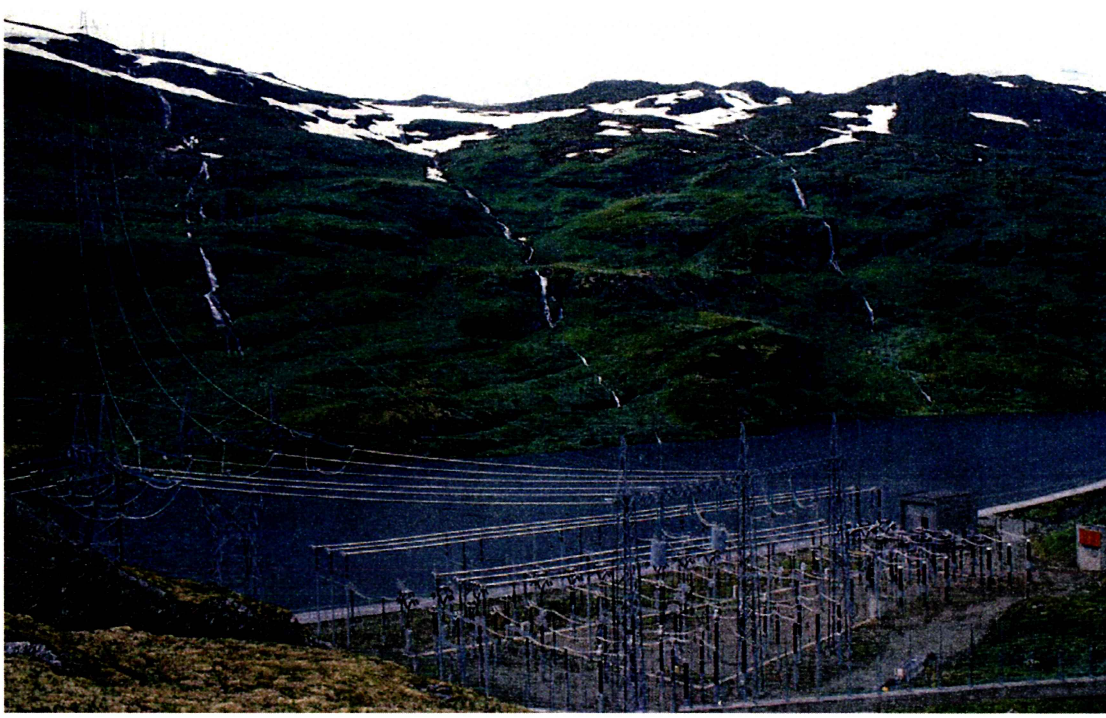
Because inflow and the demand for energy vary throughout the year, a power station never runs at constant maximum capacity. The ratio between reported annual production and highest installed capacity is called the load factor. The average load factor of most Norwegian power plants ranges from 3500 to 5000 hours of the 8760 hours in a year.

Norway's total reported production capacity of January 2004 is 27 3000 MW, distributed among 581 power plants. The greatest growth in capacity evolved from 1970 to 1985, when capacity increased by 10 730 MW, or an average of 715 MW annually. By way of comparison, production has increased by an average of 100 to 150 MW per year in recent years. This will probably decline in the years ahead as Norway approaches the limit of what is economically feasible or in other ways acceptable to develop of its water power potential.

The limit for the exploitation of Norwegian yearly average hydropower potential is estimated to be 205 TWh (reference period of runoff 1970-1999). The percentage of this potential that should be developed depends on environmental factors and profitability. Based on average annual inflow until 2005, 118.9 TWh of the total potential has been developed and 44.2 TWh is protected.



The scope of Norwegian hydropower production is politically determined, based on such considerations as the authorities' views on environmental requirements. Thus there is reason to believe that future analyses will generate estimates of hydropower potential which differ from the ones on which the present "limit" of 186.5 TWh is based. The possibility to choose energy sources other than hydropower, such as natural gas, bio energy or wind power complicates decision-making processes related to future hydropower



From the Aurland hydropower scheme.

projects. The potential savings represented by energy conservation measures must also be considered in this context. In terms of prices and production levels, Norway's future energy situation will also be more dependent on power exchange systems with other countries. I addition there is a potential of 15 TWh from new small hydro (less than 10 MW), but it is only realistic to develop 5 TWh before 2010.

In 1929, Norway had 1452 hydropower stations, 1315, or more than 90 per cent of which had a generating capacity of less than 1 MW. Megawatts (MW) are used to measure output or generating capacity. Impressive, large-scale projects like at Rjukan (for instance Vemork and Såheim) had been completed under the supervision of Norsk Hydro. Nonetheless, hydroelectric development did not gather momentum in earnest until somewhat later. In 1938, less than a decade later, more than 4000 hydropower stations were in operation in Norway. In 1946 it was about 1800 hydropower stations of which had a capacity of less than 1MW.

By way of comparison, 581 of Norway's 753 power stations in 2000 have an installed capacity of more than 1 MW. In 2004

THE AURLAND HYDRO POWER SYSTEM AND CONSEQUENCES - AN EXAMPLE

The Aurland watercourse is situated in the western part of Norway. The rivers outlet is at the end of one of the Sogne Fjord's southern arms (Aurlandsfjorden), in a confined fjord system characterized by tremendous contrasts.

The Aurland project is a result of a study of various schemes for utilizing the power resources of the river basin. When the actual plan was introduced by a formal application for concession in 1965 and subsequent public hearings, it became extremely controversial right away. The Aurland valley, with a cascading river in the midst of dramatic mountain scenery had for long been one of the most popular areas for mountain hiking. The roads required for the projects were also controversial.

A new plan was created and the runoff from the north-eastern area is collected unregulated at the 1000 m level. Tunnelling could be carried out using just 4 adits discreetly located in valleys along the route, and consequently the need for roads into virgin terrain was considerably reduced.

The average annual output of the five power plants is 2600 GWh. The effect is 1128 MW. 112.7 km of tunnel were constructed to channel the water. The power station relies on 10 stream intakes and 10 dams and 14 reservoirs had to be constructed. The tailings from the tunnels have been placed in eight tips. 22.5 km of road tunnels had to be blasted through the mountains. Discharge is severely curtailed for nearly 100 km, but 28 weirs have been built to help alleviate the problem.

After completion of the Aurland hydropower plant, NVE initiated a follow-up R&D programme to document the impact of hydropower development on the basis of science.

From the Aurland valley, upstreams Østerbø.

A marked change in the water-flow regime alerted the system's annual rhythm. The summer discharge was reduced by an average of 20-50 %. A number of mountain lakes were impacted by primary encroachments to a greater or lesser degree. Low and medium-altitude alpine heaths were converted to regulation zones in connection with the reservoirs. The establishment of some rather large highland reservoirs altered the landscape, making surroundings less attractive for outdoor activities.

The capacity of the rivers has been reduced. In places this has disturbed the equilibrium of confluence areas. New vegetation has begun colonising the riverbeds, reducing their capacity. Regulation encroachments and manoeuvring practices have led to a marked reduction in summer temperatures in a watercourse that was "cold" to begin with. The effects on botanical conditions are being seen on benthic invertebrates.

The sea trout stock was reduced considerably following the regulations. The average age And length of migrating sea trout smolt did not change from 1911 until after regulation, apart from when the smolt stocks have experienced reductions when stocked in spring due to fish-eating birds. It appears that the percentage of smolt recaught is far lower than might be expected on the basis of previous tagging experiments performed in Norway.

The stock of water birds that spend the winter in the lower reaches of the watercourse are not different after regulation than is otherwise found in comparable watercourses. Regulation activities in the highlands have not greatly affected the composition of alpine bird stock, although local stocks were not doubt lost when the reservoir was built.

The constructed highland reservoirs have influenced and changed the wild reindeer's migration pattern.

The roads through the highlands have changed the way the Aurland Mountains and the Aurland Valley are used by tourists. The area is still popular for hikers, but the way they use it has changed.

This watercourse has had a central position as regards watercourse management. Many were of the opinion that the watercourse ought to have been protected, but it was decided that the river should be regulated. However, strict guidelines were drawn up for the project. These guidelines were clearly the result of the discussion regarding the protection of watercourses, and the protection of untouched mountain wilderness for recreational purposes.

HYDROPOWER - A HISTORICAL REVIEW

RIVERS - A SOURCE OF ENERGY

The Norwegian landscape is a water landscape. Not just as an arena for the Norwegians' outdoor activities but as something without which the development of Norwegian society cannot be understood.

The fact that there is a great difference in altitude between the source and the mouth of most Norwegian rivers has been the single most important factor in the development of modern Norway. A consequence of this is that the energy extracted from precipitation is far greater in Norway than in other countries. Anyone who has travelled in Norway has seen this; -from the accumulation of snow and rain in the mountain regions the rivers do not run straight into the sea. They run in ledges, in twists and turns, from a number of small lakes, and further into an even larger number of rivers and brooks, day out and day in, year after year. The precipitation has another and truly rare characteristic: It runs from our own mountains into our own fjords. In Norway the rivers are a national resource.

Compared with other countries in the world Norway has been and is an Eldorado of national running water. More than half the world's population live by watercourses that are shared between two or more countries. The watercourses in Norway are spread all over the country, and the watercourses run in all directions. There are no entirely dominating collection rivers. A watercourse belongs to the person or persons who own the land where the river runs.

When the mill technology started to spread around Europe, Norway was in quite a unique situation. Thousands of small rivers and brooks made it possible for farmers to build their own mills. In the 1830s there were between 20 000 and 30 000 mills.

Water and watercourses have been decisive for the development of Norwegian society. Since so much activity was based on the exploitation of, and connected to rivers for several hundred years, it had consequences for business structure and the relationship between urban and rural areas. Many of the settlements of the early hunters and fishermen were located along watercourses providing ample food. Rivers have also always been important for travel and transport.

Already before 1350, rivers were used for floating timber. Large quantities of plank and board were exported. The Norwegian sawmill

The regulated river, Ekso.

industry was regulated by public authorities from 1587 until 1860. From the 1850s canals were constructed in the lower parts of the country to facilitate floating and other forms of transport. The canalisation period was important in the history of Norwegian communication. Obviously railways and cars have gradually covered most of the transport needs, and since the 1960-1970s timber floating has completely disappeared.

In the 1980s the rivers got a brand new function. The small, short and clean rivers on the west coast are central and, compared with other countries, easily accessible. Consequently they have become a cheap resource for the fish-farming industry (the farming of salmon and trout), also called the blue revolution.

The recognition of rivers as a source of energy came early. Already in the Viking Age flour was milled using small water wheels. Around 1530 larger water wheels were taken into use in the mining industry, and the first pulp mill was established in 1868. Gradually, water power was utilised in the new paper mills as well.

From the very beginning of Norway's brief history as an industrial country it has been imperative to exploit water as a source of energy. There are no major deposits of coal on the Mainland, and mills and water-driven sawmills had to be built along the watercourses to process raw materials from agriculture and forestry. The need for transport and energy fostered the development of industry along the rivers. The first industrial activity of any magnitude in Norway was linked to the exploitation of domestic forest resources. Most of the forests on the British Isles, the cradle of modern industry, had been cleared by the mid-1880s. Norway was favourably situated in terms of resources and transportation to be a major exporter of pulp and paper.

Actually, it was the pulp and paper industry that initially spurred power production in Norway. Foreign investors were aware of Norway's potential for hydropower production and furnished capital for the first project.

Borregaard, owned by the Kellner Partington group of the UK, acquired the rights to the west side of the Sarpsfossen waterfall on the Glomma River and started building two power plants in 1898, each of them producing 800 kW. At the same time German investors acquired the rights to the east side of the waterfall.

Without the foreign investors, who later included Swiss, Danes, French, Swedes and Americans, it is unlikely that Norwegian capital would have managed to construct these power plants at the beginning of the century, regardless of their eagerness to do so.

Norway's economic policy, especially its system of taxes, particularly favoured foreign investors' access to the Norwegian market at a time when technological expertise and available capital were at a low. From the early 1800s, Norway had pursued a liberal trade policy, and even when Sweden became noticeably more protectionist at the end of the century, Norway maintained its free trade policy. Incidentally, this also brought the customs union between Norway and Sweden to an end in 1897.

HYDROPOWER AND INDUSTRIALISATION

From the mid 1800s Norwegian industrialisation went through different evolutionary steps and stages. The first wave of industrialisation commenced with the construction of the textile industry and the mechanical workshop industry around 1850. Towards the end of the century the food and beverage industry and the pulp and paper industry went through a period of great expansion. From around 1905 the development of the electrometallurgical and electro chemical industry marked a new step in the industrialisation of Norway.

The two plants in Glomma at Sarpsborg were the first of any great size in Norway, but electricity as a source of power for industry had been introduced in 1885 when the first electrical power plant was built near Skien. The first electric lights in Norway were lit in 1877. The pioneer behind the Skien project was Gunnar Knudsen, engineer and later Prime Minister. In 1891, Norway's first electric streetlights were installed in Hammerfest in the north of Norway, and the following year the first incandescent lamps were lit on the streets of Oslo.

From the protected hydropower plant Tysso I.
Photo: Harald Hognerud, NVIM.

The Hardangerfjord.

This illustrates how quickly Norwegian business and industry adopted new technology, a trend that has continued up to present time in other sectors as well.

However, the production of electricity and hydropower developments has also affected our environmental values. From 1960 until today Norway's conservation plans for water resources have been formulated and put into action.

The turn of the 19th century was a period of great transition for Norwegian industry. The timber trade, which had been the country's largest production sector by far, was losing ground to the pulp and paper industry. In terms of employment, the percentage of workers employed in the pulp and paper industry increased from 1 to 15 per cent of the work force from 1870 to 1910, and dropped from 30 to 15 percent in the timber trade during the same period. Pulp and paper manufacturing became Norway's first modern large-scale industry. There are many reasons for this. There was a rapidly increasing demand for pulp in the European market, and Norway had relatively short transportation routes easily accessible by sea.

Most significant in the present context, however, was the fact that the pulp and paper industry is considerably more energy-intensive than the saw-mill industry. Newly developed water turbines revitalised manufacturing; the new technology was first applied in Norway in 1844. By adopting new production techniques, during the course of the 1880s, Norwegian manufacturers managed to lower the costs of wood pulp to a third of its original cost.

Thus hydropower became an incentive for introducing new types of production and, later, for promoting innovation in the engineering industry. Even so, the country lagged far behind in terms of exploiting hydropower for electricity. There were no electrical engineering courses in Norway before 1900. Consequently, it was to a great extent foreign capital and expertise that led to the establishment of an electrical engineering environment in Norway.

In 1905 Norway's union with Sweden was dissolved and Norway became a fully independent monarchy. The following years saw the briskest boom so far in industrial development and in hydro power in particular.

Yet there was one key industrial area which helped give Norwegians technological self-confidence: the introduction of electrochemical mineral fertiliser production by Norsk Hydro in 1905. Norway dominated the world market in this field for several decades. Norsk Hydro's first development completed in 1907 (Svelgfoss power plant - 34 MW), demonstrated dramatically the capability of Norwegian hydro power engineers at this time. Next Norsk Hydro built the high head plants Vemork (42 MW) and Såheim 108 MW), further up in the same river.

Photo: Arne T. Hamarsland, NVE.

Industry now looked for sites in the western fjords, near steep rivers, and with deep water for docks. Important sites developed from 1906 to 1920 were Sauda, Tyssedal, Bjølve, Høyanger and Svelgen.

Major foreign companies such as ASEA, Brown Bovery, AEG, Siemens and Telefunken soon discovered the value of access to cheap hydropower in Norway, launching joint ventures with Norwegian industry. One of the reasons why the access to electric power was so cheap in Norway was that there were many high and medium high waterfalls, and that the ground was usually solid rock. The regulations of the watercourses could take place in unpopulated areas where there was no agriculture so that the question of compensation was avoided. Especially the developments in the years 1905 -1915 were inexpensive.

The electro-metallurgical industry in the UK, Canada and France introduced new technology for smelting steel, aluminium and nickel using Norwegian hydropower. Historians have pointed out the remarkable way in which this foreign influence enriched the Norwegian technological community rather than suppressing it. In the 1920s, Norwegian engineers were at the forefront of international development in several fields.

As early as 1922 the British host of the first world energy conference (arranged in London 1924) invited the newly established NVE, and encouraged the organisation of a national committee for technology, science and industry. The small, but hydropower rich Norway took the matter seriously and submitted 18 lectures to the conference, which gather 2000 delegates from 40 countries. The width and extent of the conference was a telling expression of the distribution and significance of electricity in the world.

In 1906 757 power plants were registered in Norway. This was impressive for a country outside Europe's industrial core area. Much suggests that Norway already at the beginning of the 20th century was becoming one of the leading electricity countries in the world.
As early as 1882 the first hydro power dam in the country, and the second in the world was completed (Hamn in Senja), 1 1/2 months after the world's first hydropower dam was completed in Fox River, Wisconsin, USA. Until around 1900 the technology dictated that the water rich watercourses on the east-coast were most suited for regulation. Few years later high pressure plants that were able to exploit the height differences on the west-coast were developed.

There is a direct link between the use of hydropower as a source of energy and the founding of the Norwegian College of Technology in Trondheim in 1910 and the National Institute of Technology in 1917. Hydropower, combined with Norway's natural abundance of raw materials (ore, forests and fish) opened the world market for Norwegian products. Norway tripled its production of goods from 1895 to 1914, and the export share of industrial output increased from 30 per cent in 1909 to nearly 50 per cent in 1916.

NATIONAL AND INTERNATIONAL CONTEXT

The reason for the hydropower development in for instance Tyssedal, was the construction of the world's largest carbide factory in Odda (3 km south of Tyssedal) The factory was erected in the period 1906-08, parallel with the first stage of construction of the Tysso I power station. In 1909 the factory was expanded with

From the protected hydropower plant Tysso I. Photo: Harald Hognerud, NVIM.

a cyanamide factory, the world needed fertiliser. The factories in Odda and Tyssedal became together with similar industrial communities in Norway and abroad important instruments. Because of the available technology the power intensive industry had to be placed close to the power source instead of close to the markets.

Hydropower had been a so-called comparative advantage in all Norwegian industrialisation so far. One example is the textile industry. In Norway this industry could be based on hydropower and not steam power as in the country of origin, England. The industry that developed after 1905 demanded energy to a far greater extent than before. The second industrial revolution was based on the growth of new science and technology, with the invention and development of new industrial processes, where electricity refined various raw materials and made new production methods possible. This gave rise to great hydropower developments.

All stages of industrialisation in Norway must be seen in context with central international development features. An important prerequisite for the industrial development from around 1850 was a liberalisation of international trade. Towards the turn of the century international competition became fiercer. This competition played out in an international market, but it was the individual countries that set the superior political framework. The competition was part of a greater rivalry between the western countries.

The first hydropower developments in Norway were privately orchestrated by various small companies or joint ventures. As time passed the municipalities came to play a key role, and in the period towards 1920 the municipalities took point guard when it came to making hydropower available for private households, small businesses and agriculture. In Norway there were no capital holders wealthy enough to take on the burden of hydro power development to the extent the new industry required. Consequently the main challenge for Norwegian politicians after 1905 was to welcome international investors while at the same time maintaining political control over the hydropower development.

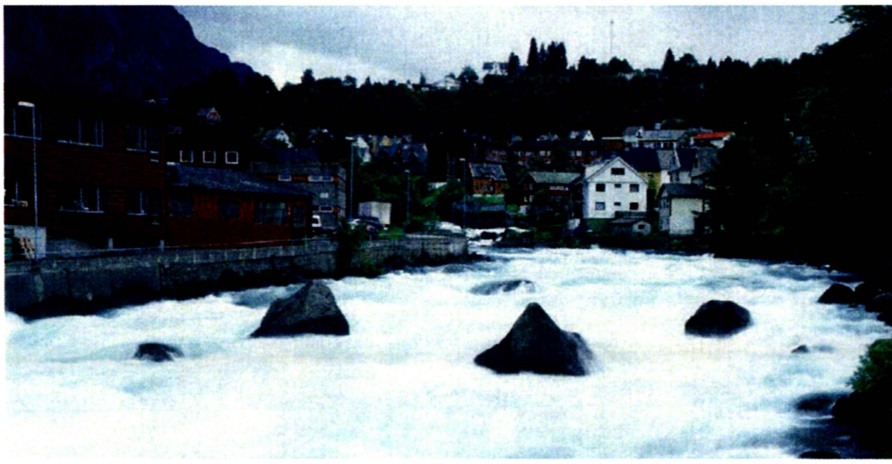
Concession legislation became key: -it put in place a strict political framework for the hydropower development. One aspect of the new legislation was the return policy which stated that the developed hydro power plants were to be returned to the state after a period of 60-80 years. This represented a new interpretation of the private property laws.

Today the structure of the industrial towns is changing. More and more factories are shutting down. Electricity is sold to other consumers in the Nordic market.

FROM INDUSTRIAL ENERGY TO HOUSEHOLD ELECTRICITY

The period of Norwegian hydropower development from 1906-1920 was characterised by a tremendous rate of construction that declined during the years leading up to WWII due to the Depression and a glut of cheap coal. During a deflationary period in the 1930s, moreover, it became difficult for some of the electric utilities to bear the costs of the capital-intensive development projects from the first two decades of the century. The products manufactured by energy-intensive industries were also difficult to sell during the years between the wars. The time was definitely not ripe for large investments in new hydropower projects.

Fuel shortages during the war years, from 1940-45, resulted in a shift in electricity



The protected river Opo through Odda city. Photo: Arne T. Hamarsland, NVE.

consumption patterns towards household consumption. When the war was over, and the need for increased industrial production re-emerged, there was an urgent need to intensify hydroelectric development. Whereas earlier hydropower epochs had been characterised by small or medium-size projects, this marked the advent of the age of large-scale installations.

Several of the largest projects were directly related to industrial restoration in the wake of the war. In 1946, the decision was made to build Norsk Jernverk (the Norwegian iron-works) at Mo i Rana and aluminium factories at Årdal and in Sunndalsøra. The Marshall Plan gave Norwegian industry a tremendous boost during the years immediately following the war.

As a result, the consumption of electricity by energy-intensive industry sharply increased during the first decades after WWII, and the trend was sustained until the mid-1960s. Since then it has levelled off, and now represents a

steadily decreasing share of the total consumption of electricity in relative terms.

Today, households and services dominate the domestic market for electricity. The industrial argument for new developments has been weakened accordingly. The environmental protests since the mid-1960s can be understood in this context. The history of hydropower from 1973 and until present time is characterised by comprehensive, wide-ranging plans that restricted further development.

THE 1990s

The Energy Act of 1990 entered into force on January 1 1991. The law was aimed to ensure that electricity prices were a result of a balance between supply and demand, rather than based on political assessments of future consumption. Such political processes had a dual negative effect:

Firstly, new development projects were assessed on the basis of more or less arbitrary expectations regarding the need for energy. Energy prices were used as a basis for developing watercourses only to a limited extent. As a result, costs were automatically passed on to consumers when unprofitable projects were developed.

Secondly, as environmentalists pointed out, politically based assessments of future consumption could easily be confused with targets for energy consumption, and thus the pricing system in itself served to increase energy consumption. In other words, Norway risked developing hydropower in excess of the actual demand.

One of the objectives of deregulating the electricity market was that power companies would evaluate future projects more on the basis of economic criteria. Given the fact that consumers have been given the opportunity to purchase electricity from the cheapest supplier since 1990, power companies must place more emphasis on streamlining and on efficiency measures, as well as on assessments of the profitability of new projects. It used to be virtually impossible for a power company to go bankrupt. Today there is significant economic risk involved in operating an energy enterprise.

THE SITUATION OF 2004/2005

Through a strong focus on hydropower and the development of a national transmission grid, hydropower has for a long time been the corner stone of Norway's energy supply. It laid the foundation for a large power intensive industry, and the abundance of hydropower in earlier times has led to electricity being extensively used for heating. Today consumption has increased to such an extent that we are dependent on import. In order to get more stable energy access Norwegian power supply must be made less dependant on hydropower as power source and on electricity as energy carrier. This is made clear when we consider that the hydropower production for an average year is 118.4 TWh while the consumption for each year is around 125 TWh.

Consequently the government has for the past few years been developing a long term plan for rerouting the energy production and the energy consumption. However, hydropower will be the dominant energy source for many years to come.

The uncertainty about how much hydropower can be produced each year, and the fact that for several years the growth in production and transmission capacity has been stagnant compared with the increase in consumption, is cause for worry. The power supply has become more vulnerable. The market's price mechanism has had a stabilising effect, while high prices in periods of scarcity has caused both private and business consumers to limit their electricity consumption.

To meet this challenge, Norway has embarked on new development strategies:

- Harnessing the wind power potential, with a target of at least 3 TWh wind power by 2010
- Focus on research and development project to enhance gas thermal generation plants with no emissions of CO_2 and NO_x
- Support district heating system to reduce dependence on oil and electricity for heating
- Continued support on energy conservation technologies and schemes
- Map of resources for small hydro without re reservoirs, and develop financing systems to enhance the implementation of these plants
- Upgrade existing hydropower stations, which include reservoir capacity for benefit of adopting unregulated small hydro in large number and wind power

In 2003, value added by the electricity supply sector was NOK 37, 2 billion, or about 3 per cent of the gross domestic product in mainland-Norway. The real capital was NOK 170 billion, which corresponds to 5, 3 per cent of all fixed capital in mainland-Norway. In more recent years, there has been a drop in the number of people employed. In 2004, about 15 000 people were employed in the electricity supply sector.

ENVIRONMENTAL AWARENESS

ENVIRONMENTAL CONSEQUENCES

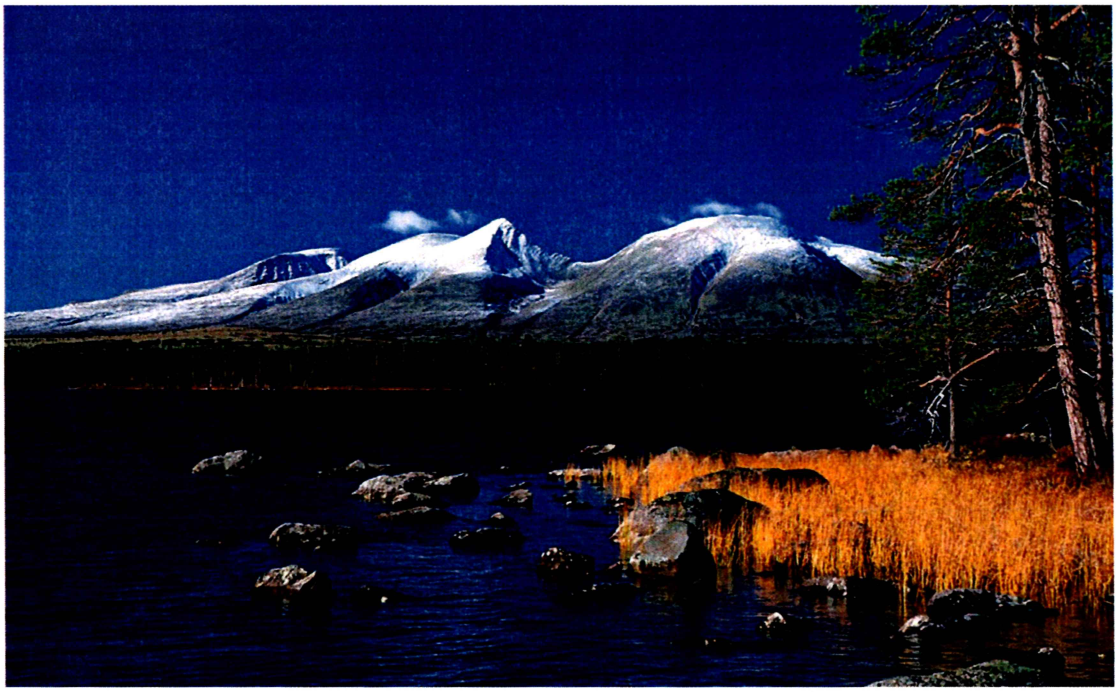
In the beginning it was particularly the lack of water in the large waterfalls that people reacted against when the consequences of hydropower development were discussed. At a later stage there were reactions against the drawdown zone of reservoirs where water had been tapped, the ugly looking pipe-lines, tips that had not been well located in relation to the terrain and the construction of numerous roads and dams which completely dominated the landscape.

There is growing awareness of the environmental consequences of watercourse regulation. Norway possesses world-class expertise in this field.

The goal is that no species will disappear from Norwegian nature as a result of human activities. The species' natural distribution and the genetic variation and special characteristics of local stocks must be protected. Flora and fauna communities must be managed in a manner that allows them to flourish and grow under natural conditions.

The landscape

The regulation of river systems has environmental impact, directly in the form of land use, and more indirectly in the fragmentation of areas of natural environment and the regulation of lakes. In addition to the actual production installations, developments such as access roads, quarries for the extraction of deposits and stone tips are generally needed. Access roads tend to increase traffic and may result in changes in land use. Such developments can reduce the aesthetic value of the landscape and come into conflict with protection of cultural heritage. At the same time, however, a number of the older hydropower installations are considered to be important cultural and industrial monuments. It is not possible to harness the energy in a watercourse without having considerable impact on the natural landscape. Old water mills are considered to be quite picturesque and today they would be deemed worthy of conservation as part of our cultural heritage. However, the industrial exploitation of watercourses for the production of electrical energy necessitates constructions of a completely different dimension. Even before the turn of the last century this led to the initiation of discussions concerning conservation of the natural landscape.



Poto: Arne T. Hamarsland, NVE.

The River Systems

Hydropower developments and production can have various impacts on the flora and fauna in and around river systems. The effect of hydropower development on fish is a rather complex relationship between a number of physical and biological factors. Several user interests are involved with the use of various species of fish, making this an issue about which many people appear to hold a wide variety of opinions, sometimes very strong opinions.

Rapid changes in production, and therefore in discharge volume, are characteristic of hydropower. Changes in discharge volume may have an impact on fish stocks and other freshwater organisms. The anticipated environmental impact is the main reason why many rivers are protected against hydropower development. Applications for licences for hydropower developments in other river systems go through extensive procedures, including a thorough review of the environmental impact. An application may be refused on environmental grounds. The authorities may also require measures to mitigate the impact of a development project. One example is the requirement to establish a fund for stock enhancement if regulation damages fish stocks in a river, or rules on the minimum permitted rate of flow or discharge volumes that are to be maintained at different times of year.

Reservoirs

The reservoirs in Norway's hydropower system have generally been located in mountainous regions with little human activity, that is, in areas with no significant extraneous sources of pollution. This means there is little change in water quality as a result of hydropower regulation projects. In those cases in which there have been appreciable changes in water quality, the changes have occurred in stretches of river in which the flow rate has been altered significantly, and in which the following conditions may apply:

When reservoirs are established certain areas will be frequently flooded. It is often difficult to predict how such a flooding will affect a particular plant or animal stock. The shore zone is the most important. Such areas are not only of local significance. They may determine survival of animals which otherwise occupy neighbouring areas during difficult periods such as winter.

As well as reducing the area of dry land, reservoirs may be an obstacle to animal migrations, such as those undertaken by wild reindeer.

The shallow areas of lakes are usually the most productive, but in reservoirs those are the areas which are exposed and the fine material is eroded by changes in water level, consequently the production of plants, benthos and fish will be affected.

The regulation zone is unstable. Few plants and animals are able to adapt to such an environment. As the regulation zone becomes "washed out" production will decline. This means that regulation especially affects animals and plants adapted to the shore zone and animals that live off such organisms.

When a land area is flooded there will be a short-term effect. This usually gives an increase in fish production, often larger and in better shape than previously, on account of increased nutrient supply from the flooded areas. However, in the long-term, when the fine material has been eroded down to deeper waters, production will stabilize at a lower level than before. In some reservoirs the initial flooding effect lasts for 5-10 years. Depending on geological conditions, the initial raising of the lake level can lead to cave ins and erosion of fine deposits.

All the vegetation which is flooded dies. Depending on the regulation regime, the regulation zone may become fertile again. However, the environment is very unstable and the species frequently change. In general, it will be a poorer environment than the more stable, natural shore zones.

All this leads to considerable variation in plant and animal communities during the first few years. Some species may disappear, will others will vary greatly in number and distribution.

Regulated rivers
Active processes are most susceptible to alteration in technical exploitation. Glacial watercourses are particularly at risk because both the intensity and the development of the fluvial processes become disturbed. These forms and processes connected to running water are very closely linked to the drainage regime, the gradient, the intensity and particle composition of the transport of material along with material at the bottom and sides of the river channel.

The water flow is reduced below reservoirs and stream intakes. The effect will vary with the degree of change. If the production area for plants and animals is reduced this will normally lead to a reduction in the fish stock. A shift over to brown trout at the expense of Atlantic salmon often takes place when these two species are present.

Water temperature is of paramount importance for the speed of egg development in fish. Lower temperatures which cause lower growth rates in sea trout and salmon will mean that a number of juveniles have to spend an extra year in the river before they smoltify and migrate out to sea. This can reduce smolt production. However, the unregulated Jostedøla had even lower temperatures, so regulation may be positive for smolt production. Discharge and river temperature are also important parameters determining the timing of the salmon and sea trout run.

The regulated river Årøy, Sogn og Fjordane County.

A more even discharge usually increases the amount of rooted plants. The competitive relationships between members of the plant community may be changed leading to the mass occurrence of certain species. In some rivers this has had a positive effect. A change in the pattern of nutrient supply in relation to discharge, together with different temperatures, also leads to a change in production. This may be either advantageous or disadvantageous. These changes may also influence the pollution status of the river.

In regulated rivers the magnitude and frequency of floods is often reduced. There can be less washing out of nutrients, but at the same time the rivers productive area is diminished. Extensive long-term studies have shown that the effects of reduced discharge are not unambiguous and far from negative in all cases. It has also been shown that with relatively simple measures the deleterious effects may be considerably reduced. In certain documented cases the conditions for water birds and certain species of fish were improved.

The ability of the river to transport material is usually strongly reduced after regulation. New sedimentation sites arise and the river channel has a totally different character. The material carried by the unregulated tributaries will not change, but when water flow is reduced in the main river the material will build up there. If a major flood occurs in the main river new areas will be susceptible to flooding as the river channel has been elevated. The river channel also often becomes congested by vegetation which encroaches from the sides. This intensifies the sedimentation and the system becomes imbalanced.

RESEARCH AND DEVELOPMENT (R & D)

During the 1960s focus was put on the environmental consequences of watercourse development. This meant that the watercourse administration required more knowledge related to environmental concerns. Furthermore measures had to be developed limiting the harm of watercourse development.

NVE initiated and carried out a number of management directed R&D programs. They were carried out in close cooperation with the power industry, environmental management, R&D institutions and the universities. The program was a supplement to the activities of The Research Council of Norway.

The first major project to be carried out was the Weir project, which commenced in the early 1970s and was completed in 1983. The goal was to map out ecological changes which take place in running water after regulation and threshold construction, so that suitable measures could be developed in relation to watercourse alterations. The project was replaced by "The Biotope Adjustment Programme", which took place in the period 1985 -1995. Biotope adjustment means focused measures that aim to develop and expedite the establishment of desired biotopes, first and foremost after various forms of alterations. Practical measures were developed that are

virtually maintenance free and which promote natural processes.

"The Watercourse Program" took place in the period 1988-1993, and its purpose was to give swift responses to questions relating to the management and running of watercourses as well as improve the management's competence level.

"The Follow-up Program" took place in the period 1988-1996 in developed watercourses in order to gather information about the effects of development, and thereby improve the environment of the watercourse after development.

In 2005 the 5 year program "Environmental flows" is completed. Its background is that environmental flows are a strategic element in the management of hydropower development. Norwegian licensing procedures require the setting of specific flows in the reaches affected by dams, as well as water diversions and transfers. Licensing authorities require an objective system that takes account of the needs of the developer, the environment and other present and future users, also with respect to remedial measures. The new Water Resources Act opens for a more flexible treatment of instream flows. The programme will involve both practical trials and the development of new, user-friendly models.

The program "Environmental friendly water resource management in a changing climate and energy regime ("VAKLE") is implemented by The Research Council of Norway. This is a program about how physical processes and ecosystems in running waters, lakes and reservoirs will be altered. It studies and quantifies changes in abiotic conditions due to a changing climate and changes in hydropower production. The impact on invertebrates and fish is one of the physical factors studied, and mitigation efforts are proposed to decrease negative environmental impact combined with an optimal use of the hydropower system.

THE NATIONAL PLAN FOR PROTECTING RIVER BASINS

A dominant feature in the history of nature conservation in Norway has been the struggle to protect some of the most scenic and scientifically valuable river watersheds from being exploited for hydropower development. The strong increase in the development of hydropower in the 1950's and 1960's made it necessary to take the environmental impacts into closer consideration. This early Norwegian plan for protection of whole river systems, and the theoretical and practical framework around it, seems to be unique.

The waterfall Låtefoss in the protected river Opo, Odda. Photo: Arne T. Hamarsland. NVE.

However, as early as 1892 it was proposed in parliament that the government ought to purchase waterfalls of particular value as tourist attractions, in order to protect them from hydropower development. Nothing came of this proposal. The waterfalls have always been central to our appreciation of nature.

In 1960, parliament raised the question of a national plan for the conservation of watercourses from hydroelectric development. The discussion was motivated by the desire for a comprehensive evaluation of the watercourses that were partially or wholly untouched by hydropower projects. The first recommendation was submitted in 1963, but further progress was not made until 1969 when the government gave a committee a mandate to prepare a conservation plan for watercourses.

Until 2005 the national plan is adopted by parliament in four successive stages between 1973 and 1993. The governmental guidelines for the protection plan were:

- The selected river systems with adjacent areas should provide a variety of uses and riverscapes. Some of the areas should be extensive in size.
- The conservation plan should ensure a fair distribution throughout the country, i.e. give priority to centrally located river areas of recreational value.
- The plan must not be so comprehensive that it puts too heavy a burden on Norway's electricity supply
- Other inroads into protected areas that may impair their value for nature conservation, sports recreation and science should be avoided.

In the spring of 2001 Parliament decided that the protection plan should be expanded and 18th February 2005 they made their decision. Up for consideration are the watercourses that under the Master Plan are categorised as “great disadvantages” or “negative consequences” to develop, and watercourses that are important to conserve because of the wild-salmon consideration (national salmon watercourses). It is also possible to bring up watercourses on the basis of previously established guidelines.

Through parliamentary consideration of the protection plan for watercourses in the period 1973-2005 390 watercourses have been protected from hydropower development. The power potential in these watercourses is around 43.5 TWh.

The demand for more scientific knowledge about the river systems increased gradually, through the process from the first to the third stage, from fragmentary knowledge through personal communications to more elaborate field studies. Unfortunately, however, the demand for documentation was again reduced. Totally the natural values and conditions of the whole catchment were assessed. In addition to the natural value, the agricultural and forestry potentials were evaluated, together with the value for fish and game activities. The recreational value and occurrence of cultural relics were also assessed.

It is important to emphasize that what is central when evaluating a river system is the catchment and not only the river. Rivers flowing undisturbed from source areas to the sea were judged to be of special value. In parts of Norway, it is still possible to find relatively undisturbed catchments, but in most of the country the river systems are more or less affected by human activities. It therefore became necessary to include also second order and even third order rivers.

At that point, the work on the conservation plans had uncovered a need to view future hydropower development in a larger context than that of weighing up the demand for power against environmental interests. This method of planning was a useful new tool for working on the conservation plan.

No other impact on nature is as regulated by laws as regulation for hydropower production. Normally, it is necessary to undertake environmental impact assessment studies of most of the affected areas, and no other factor has contributed more to our knowledge of Norwegian nature. Almost the same assessment programme is used daily in new projects, and thus the new material is comparable to the old. The information gathered during the protection plan period, and earlier and later assessments, have given us a reasonable overview of natural variation, and biodiversity and natural processes, and that is perhaps one of the major results of the protection plan. The second important output is a better general understanding of nature conservation and an increased awareness of the impact on the environment.

Special provisions relating to works in protected watercourses

The purpose of including watercourses in the protection plans for water resources has been to prevent any reduction of their conservation value through hydropower developments. However, even if a watercourse is protected against hydropower development, other kinds of developments may also reduce its conservation value.

To prevent this from happening, the Water Resources Act includes several special provisions relating to the management of protected watercourses. The most important of these is the statutory principle that whenever a decision is made pursuant to the Water Resources Act that is of importance to protected watercourses the conservation value of the watercourse is to be given considerable weight. This will, for example, result in stricter treatment of applications for licences in protected watercourses than in other watercourses.

THE MASTER PLAN FOR WATER RESOURCES

The Master Plan is a recommendation from the government to parliament. The process of The Master Plan for Water Resources started around 1980 as a result of the conflicts between environmental interests, hydropower developers and the authorities. The aim was to set out an order of priority for the consideration of individual hydropower projects, dividing the projects into two categories. Those in category I may be considered for licensing now, as may certain projects that are exempted from the Master Plan. Projects in category II and projects that are not treated in the Master Plan may not be considered for licensing at present, but may be used for hydropower development or other purposes at a later date.

The order of priority for the consideration of individual hydropower projects is based on economic considerations and the degree of conflict with other interests. In other words, it is intended to ensure that those rivers which can provide the cheapest power, and where the environmental impact of development is smallest, are developed first. However, the fact that a project has been approved in the Master Plan does not mean that the authorities have made an advance commitment to grant a licence.

Photo: Arne T. Hamarsland, NVE.

Since parliament considered the Master Plan in 1993, the framework for hydropower development has altered in number of ways. Environmental policy principles have changed, and most projects that are planned today are different in technological, environmental and economic terms from those described in the Master Plan. The government proposed considerable modification and simplification of the Master Plan. The current categorisation of watercourse projects will be replaced by a watercourse based division.

In connection with the last decision of the national plan for protected river basins of 18th February 2005, Parliament also resolved that that hydro power plant with effect up to 10 MW or with annual yield up to 50 GWh is exempted the procedure of the Master Plan.

ON THE AGENDA: HYDROPOWER DEVELOPMENT - ENVIRONMENTAL PROTECTION

The protest against the development of the Aurland River in the scenic Aurland Valley (which was decided in 1969), was among the first national confrontations between environmental and national interests (see also p. 17). The environmentalists were mainly city dwellers, while local residents and the municipality sided with the developers.

In 1970, the decision to harness the potential of the Mardal Falls (in the northwest), one of Europe's largest, most beautiful waterfalls, resulted in one of the most large-scale environmental protests of the time. A new feature of opposition to hydropower was that locals joined the struggle. The protestors received widespread coverage in the newspapers and broadcasting when they chained themselves together and refused to give way for the heavy construction machinery. The police had to intervene and carry the demonstrators away. and Headed by the famous philosopher and professor Arne Næss, this was the first environmental protest of its kind in Norway. It was inspired by Gandhi's ideology of non-violence This form of environmental activism has since characterised opposition to hydropower development in Norway, even during periods when more militant means have gained a foothold among environmental activists in the international arena.

The conflict regarding the construction of a dam on the Alta-Kautokeino watercourse (in the north) became politicised from the mid-1970s in an entirely different manner than the Mardøla conflict, when the rights of an ethnic minority, the Sami (previously known as Lapps), were brought into the struggle. The opponents sowed doubt as to whether Norway needed the electricity from the Alta River. This question had attracted little attention during the Mardøla conflict, but now had much greater effect because it questioned the individual household's consumption of electricity just as much as that of industry.

Thus, the opponents of the Alta hydropower project came from much broader political circles than those involved in the Mardøla protests.

The idea that virgin wilderness should be conserved was linked to a wave of national romanticism from the mid-1800s. The US created its first national park in 1872, and there were movements in both Sweden and Denmark to preserve large areas from construction, roads and railroads. In Norway, as in other countries, the pressure group representing environmental interests consisted from the outset mostly of well-educated people who used the mountain regions for recreational purposes. Their views were initially voiced by the Norwegian Mountain Touring Association, which from the time it was founded in 1868 had taken the initiative to preserve old roads across the mountains, build cairns and conserve waterfalls through provisos that certain watercourses could not be diverted through pipelines.

Photo: Per Kr. Lofsberg, NVE.

The 1920s marked the advent of the most heated environmental debate that had ever occurred in Norway up to that time. It was sparked by plans to develop vast areas in the Jotunheimen mountain range (area that had become part of the national heritage, particularly because of Henrik Ibsen's Peer Gynt).

The increasing awareness of environmental protection was a necessary, useful corrective to the deeply-rooted belief that hydropower represented progress, a belief which pervaded the largest political parties from the very beginning of the last century.

Toward the end of the 1960s considerable focus was put on environmental protection. Especially ecological and biological issues were discussed. An overview of the ecosystem's function in varying types of landscape was needed. Ecological insight and competence had to be the foundation for the development of rational administration strategies.

It was not just in Norway that more and more people became aware that the expansion of industrial society was a dangerous path leading to the destruction of nature and its resources. This was part of the reason why 1970 was declared as European Year of Environmental Protection. This also came to have great significance for the management of watercourses, where the work to protect watercourses against hydropower development had started, and legislation were updated in relation to environmental issues.

In the political arena the increase in environmental awareness led to the establishment of the Ministry of the Environment in 1972. The main task of the ministry was to work for the best possible exploitation of our resources, for economic growth and for the protection of environmental resources to the advantage of human comfort and health.

FROM CONFLICT TO CONSENSUS

In the 1960s, the prevailing ideology among the establishment was to build up the Scandinavian welfare model. Economic growth took precedence over environmental concerns. From the early 1970s, environmental awareness was increasingly in focus both as a political issue and within the government. After mandatory prior notification was introduced, the scientific studies accompanying licensing application were given much stricter guidelines from the administration. To improve the scientific assessments, conscious effort was made to strengthen natural science expertise. Through the university system, the National Contact Committee for Watercourse Regulation was established. Funding was provided by the Hydropower Licensing Fee Fund. The relevant university institutes took part in the studies and assessments, reporting. As a result, research expertise within the natural sciences had seminal influence on the work preparing licence applications and the Conservation Plans for Watercourses.

The Laboratory for Freshwater Ecology and Inland Fisheries (LFI) was created at the Universities in Bergen, Oslo and Trondheim in 1969. In addition, the then Directorate for Game and Freshwater Fisheries had its own research group in connection with the Regulation Impact Studies. Norwegian Institute for Nature Research was established 1988, while Norwegian Institute of Water Research was established in 1958.

As the licensing authorities set more stringent requirements for licensing applications, to some extent in response to pressure from active "counter-expertise" in environmental protection organisations, the power sector recognised the logic of allocating resources for comprehensive consequence analyses of environmental impact and potential environmental improvement measures in advance of development, instead of passively accepting orders from the authorities.

Since the power producers' organisation and the major power enterprises saw the significance of taking environmental questions into account and actively contributing to research in this field, they began hiring personnel with environmental expertise.

From the early 1980s, the Ministry of the Environment took a greater interest in resource management and the research system within the hydropower sector, and instituted a number of organisational changes. The Directorate for Game and Freshwater Fisheries was expanded and renamed the Directorate for Nature Management, and environmental divisions were established at the county governors' offices. As a result of the desire for increased local autonomy, environmental adviser positions were created in some municipalities. The Norwegian Pollution Control Authority (SFT) was established in 1974. Meanwhile the university system was deemphasized.

In 1987 the UN report "Our Common Future" was published by the "World Commission of Environment and Development. The work was led by the then Prime Minister of Norway, Gro Harlem Brundtland. The report put focus on shared problems, shared challenges and shared effort. Cooperation was the key to achieving practical results. The core message was "sustainable development"

2003 was declared as Water Year by the UN, which increased the focus on the world's water problems. The year was given much attention in Norway. Put simply Norway's water problems are:

- Conflicts connected with the use and protection of watercourses with a focus on environmental protection, watercourse landscape, untouched nature and wild salmon.
- Pollution is a much smaller problem than in many other countries.
- Power production is the dominant user interest.

- The mountain reservoirs have led to other conflicts than in most other development countries. Relocation of population has not been necessary and consequently the social ramifications have been fewer and there have been no water related illnesses.
- No problems have arisen in relation to the supply of drinking water, and there is ample water.

THE CULTURAL HERITAGE

There is varied cultural heritage associated with the utilization of water resources, and buildings and other installations are to be found in the immediate vicinity of watercourses - for example installations used for timber floating, watermills, hydropower installations and canals.

Responsibility to the sector's history

In Norway the sectors / ministries have a responsibility to preserve their own history and their own cultural heritage. The Ministry of Petroleum and Energy maintains its sector's cultural responsibility through the museum cooperation, which was established in 2003, and which is managed by NVE. The goal is:

- To document and promote the historical perspectives of Norwegian watercourses and Norwegian energy supply.
- Create greater awareness about NVE's history.
- Raise the competency level so that the department can consider and commence measures to secure cultural heritage interests within the watercourse and energy sector.
- Contribute to critical reflection and creative insight into the relationship between culture and nature.

The museum cooperation is taking place without a museum building per se, but in close cooperation with two main museums and several project oriented museums. The Norwegian Museum of Forestry in Elverum and The Norwegian Museum of Hydropower and Industry in Tyssedal are NVE's two main partner museums.

The two main museums have a responsibility to learn about, keep track of, document and promote subjects that are of great significance to Norway as a water kingdom. Special focus is put on reaching children and youth through educational measures.

Recently, collaboration with the hydro power industry has also commenced. The project, called "Cultural heritage within Norwegian hydro power production", supposed to be finished in 2005, will give a cultural and historical evaluation of hydro power plants worth preserving from a national perspective.

The power plant Tysso I by the fjord Sørfjorden, Hardanger. Photo: Harald Hognerud, NVIM.

Hydropower and UNESCO's world heritage list:
Early on man seems to have had a diverse and eternal perspective when it comes to the use of this resource. In countries with an apparent great surplus of water resources, like Norway, it is natural to neglect studies of antrogen water landscapes and also hydropower use as cultural phenomena.

Hydropower and electricity has an important place in the global community, and it seems proper that the sector be represented on UNESCO's world heritage list. Consequently Norway, as one of the world's leading hydropower nations, has put focus on this.

Norway is now working to get the hydropower plant Tysso I, as a highly professional candidate, included on UNESCO's world heritage list. This site is an especially worthy representative of water, watercourses, hydropower, industry and community development, not just in Norway, but also globally.

Tysso I, along with the hydropower and waterfall landscape, and the industrial community which surrounds it, is a unique technical and industrial cultural heritage site. Tysso I is authentic and has great significance historically and aesthetically. Tysso I has been

declared protected on a national level. In connection with the extensive renovations a professional community dedicated to conservation has developed. Regional and national contributors have invested large sums into the renovation and the presentation of the heritage site. The most important force behind this work is the Norwegian Museum of Hydropower and Industry. (NVIM)

In august 2003 UNESCO's website informs that there are 754 world heritage sites on the List. Of these 582 are cultural sites, 149 natural sites and 23 "mixed properties". 33 is characterised as technological industrial cultural heritage sites. Hydropower plants combined with protected water courses is as far as we know not represented on the list. As far as is known nowhere else in the world is found a power plant from the childhood of electricity, with power consumer intact. Here the connection between power station, electricity grid, and smelting work is intact cultural heritage, an example of the large plants that are found around the world, and the industrialisation from 1906 on. In combination with the surrounding protected watercourses it is also unique in an international context.

The following points are emphasized:

- The Norwegian hydropower landscape is unique globally and Norway is the water country.
- Norway is also the hydropower nation. The power station Tysso I was the first power station in Northern Europe built in accordance with modern principles with a water reservoir and pipelines with a high fall.
- The Tysso I plant got a lot of international professional attention.
- The development was a milestone in Norwegian hydropower legislation.
- Large foreign companies established cooperation with Norwegian industry when they early on understood the value of cheap power supply.
- Tysso I is an impressive monument to the attempt at building a political instrument to control the industrial development.
- Tysso I is today located in a vibrant industrial community.
- The Tysso watercourse was central in the early protection of waterfalls, and the "place of birth" for the protection of watercourses. The Norwegian "Plan for the protection of watercourses" is unique internationally.
- The buffer zone around Tysso I includes protected watercourses and national parks that have qualities such as mountain plateaus, glaciers, waterfalls and fjords.

• The administration of watercourses (protected, developed and others) and other protected nature sites is subject to special Norwegian legislation.

To the east lies Hardangervidda National Park, representing Europe's largest mountain plateau, the habitat of Europe's largest stock of wild reindeer and several other rare and endangered birds and animals. Sections of this area fall within the mentioned protected watercourses creating the boundaries of a buffer zone to the east.

To the west lies Folgefonna national park, which is to be opened in spring 2005. The biological value is great nationally and regionally, and this will also secure the last remaining mountain wilderness in the county. The glacial area (Folgefonna) with its melting-water rivers contributes to maintain Norway's responsibility for protecting areas of glaciological and artic significance.

LEGISLATION AND MANAGEMENT

ALTERING LEGISLATION

Legislation developed as early as year 1000 discussed private and public interests in watercourses. Norway's 12th century provincial laws were also based on the concept of private rights of ownership, but also included restrictions on the types of changes owners were permitted to make, particularly if they might affect fisheries. Most of these rules were retained in the Norwegian legislation passed by King Christian V in 1687. This was the first Act which may be regarded as a direct precursor of current legislation in this field. Later legislation, from the 1700s, was influenced by the development taking place within the forestry, agriculture and communication sectors. The first Watercourse Act dates from 1887. The Act relating to river systems and ground water (the Water Resources Act) entered into force on January 1st 2001.

Early on, the Norwegian authorities recognised the importance of being able to control the use of water, rivers and waterfalls. This was significant both for environmental reasons and for keeping foreign investors from seizing control of the resources of this young nation that had just acquired its independence. Moreover, hydropower became an important source of revenue for building the Norwegian welfare state.

The dissolution of Norway's union with Sweden in 1905 combined with national sentiments and alarming international instances of foreign capital allowed to run amuck without restrictions, caused Norwegian public opinion to strongly oppose the acquisition of Norwegian watercourses by foreigners. The "Panic Act" of 1906 was adopted as a consequence of a government report revealing that foreigners had acquired rights to waterfalls with an energy potential twice as great as what had already been developed. This legislation, which imposed a temporary ban on foreign firms setting up operation in Norway without a licence, was finally passed in 1908 following a comprehensive debate on hydropower in Norway. The Norwegian Water Resources Administration was established as early as in 1907, illustrating the strong public involvement in this new sector.

"The Concession Act" illustrates the level of national awareness of hydropower's potential. Licensing requirements were introduced for all foreigners, stating that after 80 years all waterfalls, penstocks, and even power stations would revert to the Norwegian State without remuneration. There were also strict social conditions attached to foreign investments. The sharp debate regarding the Concession Act indicated a pronounced division in Norwegian politics at the time.

A liberal policy was pursued in enforcing relevant legislation, and foreign capital continued to pour into the country, but the foreigners were forced to co-operate with Norwegians in many ways, enriching Norway's technological environments and in turn its industry.

The Watercourse Regulation Act adopted in 1917 was one of the first laws of its kind. It was to have a strong impact on the further development of hydropower in Norway, for it defined the national interests involved and the political commitment of our legislators. National sentiment put its stamp on the legislation, and national control of this important natural resource was a major concern. Concession was now required for the development of water resources. Water management was to include the electricity sector. In 1921 NVE was established. - The Norwegian Directorate of Water Resources and Electricity Board.

The focus on the environment also influenced watercourse legislation. The main legislation for the hydropower sector, the Watercourse Regulation Act, has been amended a number of

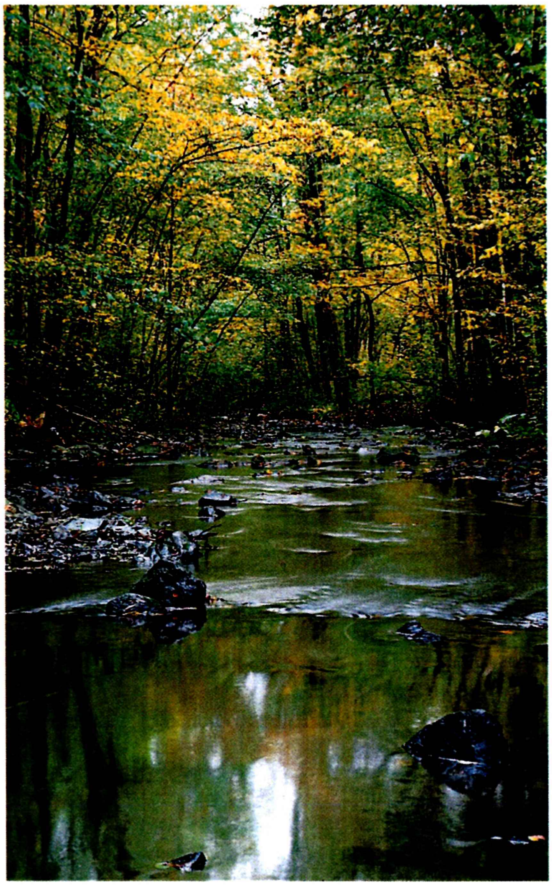


Photo: Arne T. Hamarsland, NVE.

times. In 1959, regulations were stipulated which increased revenues for the municipalities affected. In 1969, prior notification (§ 4a) provisions were introduced. This had vast ramifications for consequential analyses in general and environmental impact assessments in particular. Comprehensive demands were placed on NVE regarding the substance of applications. As a result, hydropower projects were among the first to produce environmental impact assessments.

TODAY'S LEGISLATION

The Watercourse Regulation Act of 1917

A developer must have a licence pursuant to the Watercourse Regulation Act to carry out regulatory measures or divert water in a watercourse. This Act also gives the licence-holder the authority to expropriate the necessary property and rights in order to carry out regulatory measures. The Industrial Concession Act lays down that anyone who acquires ownership or user rights to a waterfall must obtain a licence. In addition development of a waterfall and construction of a power plant usually requires a licence pursuant to the Watercourses Act. The Energy Act requires licensing of all installations for the production, transmission and distribution of electricity, from the power plant to the consumer. A licence pursuant to the Energy Act is also required to trade electricity. The legislation mentioned above is of particular importance for the energy and water resources sector.

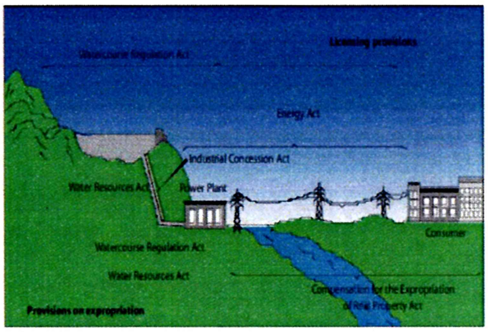
The Water Resources Act of 2001

The purpose of the Act is to ensure that river systems and ground water are used and managed in accordance with the interests of society. It gives weight both to natural resource considerations and to user interests, and is more resource-oriented than its predecessor.

Water resources themselves are renewable, but parts of the ecological system along and in watercourses are not. Nature conservation has an important place in the Water Resources Act. There are general provisions on people's conduct in watercourses, and the Act sets out general requirements and restrictions as regards the use, planning and implementation of works in watercourses. Most of the requirements follow from the general provisions, and are laid down on the basis of conditions in watercourses.

The main objectives of the Water Resources Act are to promote sustainable development and the maintenance of biodiversity and natural processes in river systems. The intrinsic value of river systems, both as landscape elements and as habitats for plants and animals, is of central importance.

Laws administered by the NVE



The principle of sustainable development underlies several of the provisions of the Act, for example the rules on conservation of waterside vegetation and on the minimum permitted flow rate in watercourses. Both of these provisions are intended to provide good conditions for biological reproduction and diversity in watercourses. In the long term, the amount of ground water abstracted may not exceed the inflow.

The provisions relating to sanctions have been substantially strengthened compared with earlier legislation. For example, there are more severe penal measures to deal with environmental crimes in watercourses.

Other important Acts

A number of other Acts are of importance for water resource management. The Planning and Building Act governs general land use, and also applies to river systems and ground water. The Act includes provisions relating to land use planning, environmental impact assessment and procedures for dealing with building applications. The Watercourse Regulation Act is now well coordinated with the Planning and Building Act.

The Neighbouring Properties Act governs the legal relationship between neighbours, and not only between neighbouring properties. This Act is only applicable insofar as not otherwise provided by special legislation. This has been interpreted as meaning that the Watercourses Act took precedence over the provisions of the Neighbouring Properties Act in matters concerning watercourses. However, under the Water Resources Act, the Neighbouring Properties Act will also apply to matters concerning watercourses.

Pollution is regulated by the Pollution Control Act. The Water Resources Act defines the key concept "works in watercourses" in a way that excludes pollution. This will ensure that pollution of river systems continues to be governed by the Pollution Control Act, whereas other impacts are regulated by the Water Resources

Act. Many of the provisions of the Cultural Heritage Act are important for works in watercourses. Licences pursuant to water resource legislation currently include conditions related to safeguarding cultural monuments that are automatically protected pursuant to the Cultural Heritage Act. Cultural heritage conservation is also taken into account in several other ways in the Water Resources Act. Cultural heritage considerations may result in a requirement to obtain a licence, in a refusal to grant a licence, or in the inclusion of conditions requiring the developer to safeguard cultural monuments. The Outdoor Recreation Act governs the public right of access to and passage through other people's property.

The actual right of passage on lakes and rivers is governed by the Water Resources Act, while other activities (bathing, landing and mooring boats) are governed by the Outdoor Recreation Act. In addition, the Nature Conservation Act, the Wildlife Act, the Act relating to salmonid and fresh-water fish, and the Aquaculture Act may all be applicable to works in watercourses.

SPECIAL LEGISLATIVE FRAMEWORK FOR HYDROPOWER DEVELOPMENT

When a watercourse is used for hydropower development, conflicts may arise between a number of user groups and environmental interests. It has therefore been necessary for the authorities to develop extensive legislation relating to hydropower, which lays down requirements to obtain licences for various purposes. The most important elements of the framework for hydropower development are now the Protection Plan for Water Resources, the Master Plan for Water Resources, the Industrial Concession Act, the Watercourse Regulation Act and the Water Resources Act. The water resource authorities, in cooperation with the environmental authorities, are responsible for managing water resources within this framework. The licensing authorities are the bodies that are responsible for processing applications for licences and for issuing licences. They include parliament, the government, the Ministry of Petroleum and Energy and the Norwegian Water Resources and Energy Directorate (NVE). In cases where a licence is required pursuant to the Industrial Concession Act or the Watercourse Regulation Act, NVE is responsible for coordinating application procedures.

Once a project has been approved in the Master Plan for Watercourses, the actual application process starts when the developer sends notification of the project to the Directorate. The notification is deposited for public inspection and circulated to local authorities and organizations for comment.

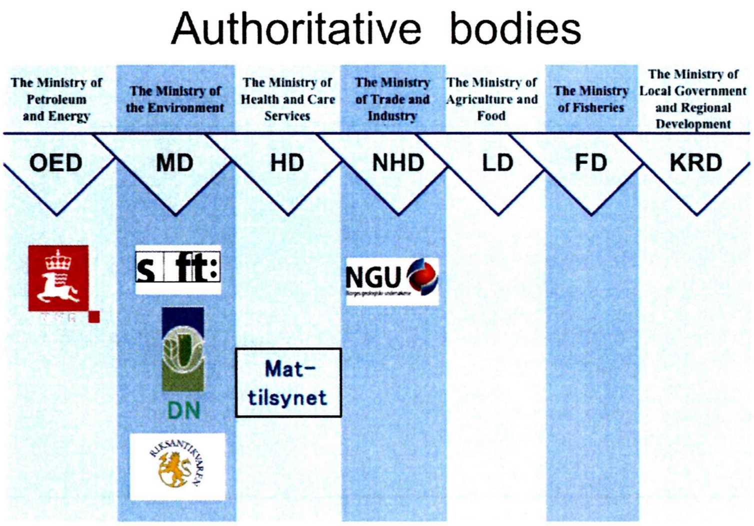
When the study programme has been completed, it is submitted along with the licence application. The application and environmental impact statement, if any, are sent for comment to authorities, organizations and landowners affected by the proposal. NVE then makes and overall evaluation of the project and sends its recommendations to the Ministry of Petroleum and Energy. Licences for micro, mini and small power plants up to 10 MW are granted by the NVE. The Ministry prepares the matter for the Government and submits its recommendation on the project. The recommendation is based on the application, the recommendations of NVE, the views of the ministries involved and of local authorities, and the Ministry of Petroleum and Energy.

TODAY'S WATER MANAGEMENT

The strong links between water and energy are unique for Norway. The main reason for is that the electricity production is almost exclusively generated by hydropower. Drinking water supply has also a very high priority, but as the water resource base is so plentiful, there are in general no problems in allocating sufficient water for all purposes.

The water management is based on a well developed legislation, and involves several Ministries with subordinated Directorates. Supplementing the central management, a wide range of cases is handled at the regional and local levels. The normal case is that decisions are made at the lowest appropriate level. Major cases of national interest and consequence are decided upon by the Government or the Parliament.

Norway is subdivided into 19 counties. The interests of the state are looked after by a County governor, providing an important link between central guidance and local operation of water management. Counties also have a politically elected body, the County municipality, with an administration of its own. Within water management it has a role to play through regional planning activities. The municipalities are involved in most water matters of local interest and will be heard in larger cases, and have decision authority in minor cases.



The Ministry of Petroleum and Energy (OED) manages the Water Resources Act and the Watercourse Regulation Act. The Ministry is also responsible for integrated water resource management and for questions like physical impact, energy development, erosion protection, river safety, and the protection plans in cooperation with the Ministry of the Environment.

Directorate:
The Norwegian Water Resources and Energy Directorate (NVE) has the same area of responsibility as the Ministry, but with additional operational responsibility for hydrological data collection and analyses, flood warnings, preparedness for river accidents, and preservation of the aquatic environment.

The Ministry of the Environment (MD) administers the environmental legislation including the Planning and Building Act, The Pollution Control Act and the Act relating to salmonid and freshwater fish etc.
- The Directorate for Nature Management (DN) (responsible for the management of natural resources, environmental protection, biodiversity, wild salmon)
- The Norwegian Pollution Control Authority (SFT)
- The Directorate for Cultural Heritage (Riksantikvaren)

The Ministry of Health and Care Services (HD) is responsible for the health aspects of water supply and alimentary aspects.
- The Norwegian Food Safety Authority (Mattilsynet), whose aim is to ensure that food and drinking water are as safe and healthy as possible for consumers.

The Ministry of Trade and Industry (NHD) – Geological Survey of Norway (NGU) is the national institution for knowledge on bedrock, mineral resources, surficial deposits and groundwater.

The Ministry of Agriculture and Food (LD) deals with illnesses in fish, technical measures in agriculture, compensation after flooding.

The Ministry of Fisheries (FD) is responsible for aquaculture and fish farming.

The Ministry of Local Government and Regional Development (KRD) deals with construction matters and water supply subsidies.

NORWEGIAN WATER RESOURCES AND ENERGY DIRECTORATE (NVE)

Established in 1921, the Norwegian Water Resources and Energy Directorate is a directorate under the Ministry of Petroleum and Energy and is responsible for the management of Norway's water and energy resources.

The vision:
Water and energy for sustainable development.

NVEs goal:
- *To ensure integrated and environmentally sound management of Norway's water resources.*
- *To promote a reliable, efficient and environmentally sound energy supply.*

It is the responsibility of NVE to ensure integrated and environmentally sound management of Norway's water resources, promoting an efficient energy market and cost-effective energy systems and take initiatives to promote efficient energy use. The Directorate has a central role in national flood contingency planning and has the overall responsibility for maintaining national power supply.

NVE is involved in Research & Development and international development co-operation and is Norway's centre of expertise in hydrology.

The Directorate monitors the country's energy systems, including generation, sales, transmission and energy use. NVE assesses economic as well as environmental factors, and is able to make an overall evaluation of future needs in the generation and transmission system by cataloguing energy resources, and carrying out power supply system planning and technological and economic analyses. NVE also regulate the grid companies to ensure that they construct and operate the grids efficiently. Since the Energy Act was adopted in 1990, there have been major developments in the energy sector, and customers can now choose their own electricity supplier. The Directorate takes measures to provide for optimal market efficiency by ensuring that all the operators have the best possible market access. The transmission of power is a monopoly area, and the Directorate protects customers' interests by setting limits on the grid companies' revenues.

Our water resources are mainly used for water supply, energy production, and fish farming as recipients for used water, industry (mainly cooling purposes), transport, fishing and recreation. Rivers also provide raw material in the form of sand and gravel, and they are objects for research and education. Several rivers are protected against alteration, mainly from hydropower development. Measures to prevent against erosion and clay and quick-clay

slides are well developed to save lives and property.

The Directorate is responsible for weighing the different interests against each other when plans for work in watercourses are presented. On the basis of legislation relating to watercourses, the Directorate safeguards and develops all the resources associated with watercourses. The Directorate aims to prevent damage and improve safety within watercourses by implementing safety measures against flooding, erosion and landslides along watercourses, and by mapping flood prone areas. By mapping flood prone areas and actively cooperating with local authorities, the Directorate encourages local authorities to take flood prone areas into account in their land-use planning. NVE is also assessing if new developments within the watercourses will have impacts that make licensing mandatory. The Directorate manages protected watercourses, proposes restoration in connection with former watercourse developments, and co-ordinate management duties in accordance with the Planning and Building Act. NVE' work follows the guidelines of EU's Water Framework Directive.

The building of power stations, dams and other installations in watercourses, or the construction of major power lines and other energy installations require a permit from the authorities. This permit, or licence, is granted under the terms of the Watercourse and Energy Acts. The Directorate puts particular focus on protection of the environment during the planning stages. The owners of dams and other hydropower installations are responsible for the safety of the installations. The Directorate monitors owners to ensure that they meet this responsibility and that they have prepared an emergency response to deal with abnormal situations in watercourses. The Directorate also supervises power companies' contingency plans against power failure, and ensures that the power industry has the necessary contingency capacity to meet various crises.

As the national centre of expertise for hydrology, the Directorate is responsible for collecting and disseminating information about surface water and ground water. This work also includes conducting studies and providing advice about glaciers, ice and snow conditions, as well as sediments in watercourses. NVE carries out research activities and undertake commissioned work to a considerable extent. The Directorate is also responsible for the national flood forecasting service. Our nationwide network of monitoring stations provides some of the information used by the service. By our emphasis on research and quality assurance, we are able to make constant improvements in our data and prognoses.

The waterfall Låtefossen.

The Directorate has five regional offices responsible for planning and carrying out work in watercourses. These offices offer a high level of expertise on water resource management, hydrology, watercourse safety and licensing conditions. Their expertise enables them to provide advice and guidance on issues related to watercourses.

Norway's long tradition in water management and hydropower has been used for the benefit of developing countries for many years. Typically, institutional co-operation between NVE and similar water and energy organisations in developing countries may include assistance in: organisational set-ups and training, water and energy legislation with regulation and licensing procedures, development of hydro-meteorological networks, preparation of national water resources management plans, development of regulatory framework and concrete hydropower projects and advisory services on other energy sources.

THE HISTORY OF NVE

NVE (and its predecessors) have for more than 200 years had, and continues to have, a central function in the country's water resource administration. The story of NVE is first and foremost the story of the public administration of Norwegian watercourses and water resources. The watercourses are a natural resource, and consequently the story of NVE is also the story of some of the first attempts at having a national natural resource administration.

NVE had its origin in a Directorate for Canals and Harbours from 1804, after 1847 being responsible for rivers, lakes and canals. Some of its main activities focused on floating, transportation, and the prevention of flood damage. From 1895, a national hydrological service was added. I 1907 the name was changed to the Watercourse Directorate. In 1912 the first regional office opened. Its designated area was the west coast. Today there are a total of five regional offices.

Major government involvement in hydropower development led to the establishment of the Norwegian Watercourses and Electricity Board, from 1921. NVE was the first public body to include and develop particular environmental competence (since 1963). In 1972, responsibility for water pollution matters was transferred to the newly established Ministry of the Environment.

The strong links between water and energy are unique for Norway. The main reason for this is that the electricity production is almost exclusively generated by hydropower. In 1986 today's Statkraft and Statnett were separated and from then on NVE functioned purely as a directorate

Drinking water supply has the highest priority, but as the water resource base is so plentiful, there are in general no problems in allocating sufficient water for all purposes.

CHALLENGES

INTEGRATED WATER RESOURCE MANAGEMENT

In Norway there are a number of user interests related to water resource management. Historically hydropower was the most important interest, but today environmental needs and conservation are given more importance.

The big challenge is to co-ordinate the different laws, governmental agencies and user interest so that the different parties in the decision-making process is clearly defined and that the procedures are effective. Time consumption, predictability, transparency and cost must be give attention. Any case related to watercourse and river systems runs into this problem.

The delta of river Jostedøla, Gaupne.

Today's watercourse management emphasises the environmental aspects in line with the government's environmental action plan. It is a goal that

- biodiversity and physical processes in the watercourse are maintained.
- the landscape and opportunity for outdoor activities, with a special focus on untouched stretches of watercourse and valuable natural and cultural landscapes, are maintained.
- the environmental qualities are to be improved where inferior.
- awareness and knowledge level are improved.

This entails that watercourse and energy plants must be constructed within environmentally acceptable frames. When the terms for concession are revaluated, environmental aspects will be given particular weight. The starting point then becomes that the measures are to have a positive effect on the environment in total, and that they do not to any extent reduce hydropower production. Consequently it is important to identify the cause of the problems that are to be solved.

THE EUROPEAN UNION'S FRAMEWORK WATER DIRECTIVE

Norway is working to institute EU's water directive. The purpose of the directive is to promote integrated and consistent water management, having as starting point the work for good ecological and chemical conditions in freshwater and marine areas up to 1 nautical mile outside the coastline. The Ministry of Environment coordinates the implementation of the water directive.
This is to be achieved by

- establishing water regions that follow the precipitation zones and coastline
- integrate the administration of water, biodiversity and pollution
- put into action environmental improvements where needed.
- integrate economic analyses in water administration.

All kinds of strains on water are according to the new directive to be seen in context. Planning, environmental knowledge, water resources and financial analyses should be part of the process. The goal of the directive is to limit the damaging effects of flood and draught.

In order to be able to assess all kinds of strains the starting point should be the total effect of the strain. The total effect is best revealed in biological parameters, and this is why the directive links the environmental goals to "ecological status". A number of parameters that can describe the ecological status (these are primarily biological, but also chemical and hydromorphological parameters will be important).

The use of water, and cost to society is to be mapped. Things that are of great benefit to society will be able to diminish the environmental goal. Covering expenses, "the polluter pays principle" and water prices will be important tools. Cost-efficiency analyses are to be used to evaluate the measures in a watercourse. Trends in the development of water consumption are to be mapped and included in the risk evaluation of water sources. The directive has deadlines for a number of important milestones in the work to carry out the directive.

A surveillance program is to be operational by 2007. This will give a clear overview of the ecological conditions of the precipitation regions. Hydrological and chemical parameters will be important support parameters in deciding the ecological condition. The water sources that are exposed to great pressure or where good water status has not been achieved will be especially closely monitored.

The water sources are to be characterised. This gives the countries the opportunity to point out water sources that are "Heavily Modified Water Bodies" (HMWBD). This includes water sources that because of physical modifications risk not meeting the demand of good status, but where the measure, because of its considerable benefit to society is desirable to maintain. Such measures, like for instance Norwegian hydropower developments can be given the opportunity to determine especially adjusted and perhaps milder environmental demands. These demands will aim at good ecological potential, the best ecological condition achievable without removal of the measure and preservation of its intention.

This ensures that water sources with physical modifications that can qualify as HMWB is part of the first characterisation which in Norway is to be conducted and reported by 2005. The criteria for HMWB is developed as strongly inclusive because the regulation altitude for lake / reservoir is put low when compared to the regulation practice in Norway, an estimated 3 metres. The waterflow criteria for the selection of HMWB will by this approach include traditional low flow sizes, regulation degree and area considerations. The preliminary selection does not mean that the watercourses will automatically be permanently classified as HMWB, but make sure they go

through a procedure which ensures that ecological as well as social aspects will be considered.

In addition to the ecological consideration of the measure there is to be, in the implementation process 2006-2009, an evaluation not only of the socioeconomic and environmental consequences of removal or reduction of the measure, but also of the environmental consequences, for instance the pollution aspect of replacing hydropower with imported coal power.

The Norwegian watercourse legislation already contains all the same environmental goals as the water directive. However, the directive does not contain any mention of the ethic aspects, or consideration of the consequences for outdoor activities when a watercourse is regulated. These are main points when treating hydropower cases.

CLIMATIC CHANGES

The climate has always been changing. The current geological period (2-3 million years) is distinguished by relatively regular intervals of glacial age and interglacial age. One of the reasons for this is periodical changes in the earth's orbit around the sun. Also over shorter periods of time the climate can undergo significant changes. Such swift climate changes are dramatic for the eco-systems, and for us humans. We are now in a period of global warming. The models show that in the coming decades we will be facing climatic changes.

Over most of Norway there will be more precipitation, and large precipitation events become more likely. An increase in temperature will somewhat increase the runoff, but still the increase in precipitation will increase the flow of rivers and brooks.

The increase will be most noticeable on the west coast. Here runoff will increase with between 400 and 1100 mm throughout the year. The changes for the east coast and Finnmark will be significantly less. There will also be seasonal changes. In autumn runoff

The Nigard valley. The picture shows the retreat of the glacier. Photo: Bjørn Wold, NVE.

will increase most places and particularly along the west coast and Trøndelag. The changes will be smaller in summer. The amount of snow will increase in the mountains in South Norway and consequently the runoff to the mountain rivers in spring. The rest of the country will mostly get less snow. The increased amount of snow in the mountain regions of the south west will more than compensate for the increased melting of the glaciers, and they will by and by become larger.

More unstable weather conditions increases the risk of ice drift in the rivers in winter. Part of the permafrost regions in the mountains will begin to thaw. Increased runoff in winter will create increased erosion and more transport of loose material to the rivers, and the nutritional substance of agricultural areas as well as the land surface in general will be washed out more.

The climatic changes will have considerable repercussions for nature and society. The hydrological changes will probably have greater and more wide reaching effects than the actual changes in temperature. Damages and problems will be linked not only to greater environmental disasters under extreme conditions but also to average conditions.

The direct danger of floods will increase as a consequence of more snow accumulating in the mountains, a greater danger of intense local rainfall and the accumulation of gravel and rocks in the riverbeds. Less glide and erosion along rivers and brooks can create increased problems with landslides in clay areas, where many of the most populated regions in Norway are located. An increase in landslides and avalanches is probable, possibly also an increased danger of large landslides.

The populated environment in Norway will get increased stress on construction from precipitation and moisture, more wind, more snow, slides, floods, and from exhausted drainage systems. Power lines and reservoir systems will be more exposed to climatic stress and energy loss. On the other hand the production potential for hydropower will increase, even though there are great differences between the different parts of the country, related to the increase in runoff and the capacity of the hydropower plants. In total it looks like there will be more water to manage in the future.

FLOODS

For people, loss of life and material damage are the most important consequences of floods. A large part of the flood damage in Norway is caused by inundation, erosion and landslides, conditions which often occur when smaller rivers overflow and find new channels. Danger to human life is greatest during floods in small rivers of this kind. In such cases, the floods come quickly, without warning and often in combination with landslides. Inundation of alluvial plains along major river basin often leads to damage to buildings, infrastructure and farmland. However, in such river basins, there is more time to implement damage-reducing measures, because the floods do not develop as quickly as in smaller rivers.

A river basin is a system that is always changing, and floods make up a natural part of the system. Although floods result in environmental changes, the environment is not damaged by them. It is only when man-made assets are destroyed by floods that it is correct to speak of damage.

The main cause of floods in Norway is rain, and of major floods a combination of rain and melting snow. Distributions of precipitation and temperature levels have the greatest influence over a flood's magnitude. The capacity that vegetation, surface features, bedrock, lakes, rivers and streams have for storing water is also important. People also influence flood conditions. We do this through the intensive development of areas near rivers and by removing forests and other vegetation.

In the future flood protection measures will be less technical than today. Land-use planning, preparedness and flood warnings will be more important tools for reducing flood damage. In some of Norway's watercourses there has been, and still is, a need for measures to reduce the effects of spring floods when the melt-off season is at its peak.

Technological measures such as regulation reservoirs, built for hydro power generation, can be important for controlling floods. Hydropower generation has significant impact on reducing spring floods. Peak flooding is considerably reduced in magnitude, and spring floods generally occur earlier. The number of years when the greatest floods occur in the autumn has increased. The dams afford us the opportunity of discharging water in advance of anticipated surges in inflow.

On the other hand, major floods can also occur in regulated watercourses. Full reservoirs combined with a terrain that offers little resistance may result in flooded watercourses in the event of heavy precipitation.

After the flood in the river Glomma 1995.

Frequent, severe flooding can have adverse effects not only because of submersion and erosion, but also because the transport of large volumes of water can wash out substrates from the riverbed, causing the river to be low in nutrients for a brief period of time and having a knock-out effect on the fish in the watercourse. Sometimes regulation helps improve conditions in watercourses for users other than hydropower developers.

Problems associated with erosion, sediment transport and deposition are also of major concern in damage mitigation along rivers with steep and short courses.

There is also risk of severe accidents caused by quick clay slides in Norway. During the past two decades mapping of areas with a potential for quick clay slides has been carried out in mid Norway and south-east Norway. Many of these areas border on watercourses, both large rivers and smaller streams. Flooding and erosion may initiate quick clay landslides with a potential for loss of lives and huge damages. A major programme mapping and classifying the risk of clay slides in populated areas was initiated in 1999.

The vast floods that struck the Glomma River in May/June 1995 were ascribable to unusually large volumes of snow, considerably delayed but intense snow melt-off and 50-70 mm of rain. The damage was extensive. This flood was the second largest in Norway's recorded history.

The total economic damage of the flood was USD 250 mill and 7000 people were evacuated. A central message after the flood is that 'planning and carrying out flood protection measures demands an integrated approach'. Floods are naturally occurring events that are difficult to foresee, and the risk of flood damage is affected by a long chain of decisions at both local and central levels of government. It is not adequate to focus on one single measure to reduce the risk of flood damage

A major research programme (HYDRA) has been carried out after this flood and the end report is called 'Living with floods'. After that flood NVE's flood forecasting service (carried out since 1967) was strengthened, a flood inundation mapping programme was initiated and guidelines on land use in flood prone areas drawn up.

FLOWS - AN EU PROJECT

NVE is an active participant in the EU project "FLOWS". To individuals and communities across Europe, flooding presents a clear danger. Climate change will mean that some areas will become warmer and sea levels will rise. Many countries are using large areas of land for housing and agriculture which years ago would have been flooded. The FLOWS (Flood-plain and Land-use Optimising Workable Sustainability)-programme is designed to look at the issues and deliver practical projects to identify how people need to adapt to live with water.

The project, bringing together partners from Germany, the Netherlands, Sweden, the United Kingdom and Norway, will result in a shared approach which in turn will provide decision makers with better information. Furthermore, the fact that local communities will be involved in finding and applying practical solutions will be of great significance.

A government agency from each country acts as lead partner in the respective participant countries. FLOWS is being funded by the European Regional Development Fund (ERDF) and Norwegian ERDF through the Interreg IIIB North Sea Region programme and the partner countries. FLOWS was approved in November 2002 and the programme has to be completed by June 2006. Practical work is well under way and the challenge of influencing decision makers in all member states is one of our measures of success.

Lead partner is Cambridgeshire County Council. The results of the project are communicated to decision makers and planners across Europe. See also: www.flows.nu.

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