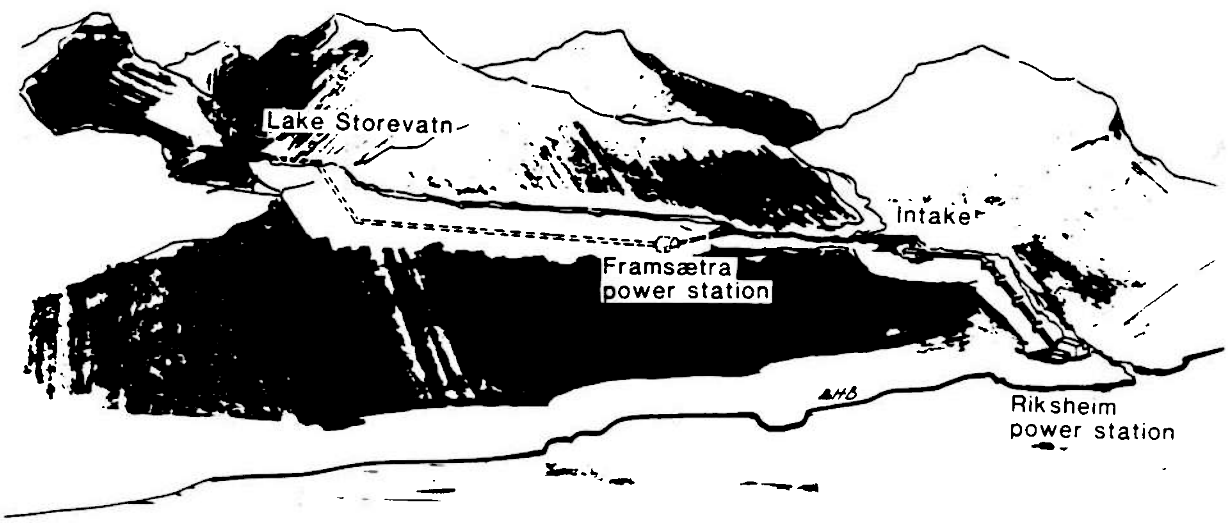
WATER RESOURCES DIRECTORATE

# HYDROPOWER IN THE RIKSHEIM RIVER




## 2 SMALL HYDROELECTRIC POWER PLANTS IN NORWAY

# FOREWORD

This paper is prepared for presentation at Hydro -88 in corporating Third International Conference on Small Hydro, to be held in Cancun, Mexico, from April 25th to 29th, 1988.

It is based on experience gained from the development of a small Norwegian water system over a period of 70 years, the Riksheim river in Sykkylven municipality.

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# HYDRO-POWER IN THE RIKSHEIM RIVER

Presenting author:

Torodd Jensen
Norwegian Water Resources and Energy Administration (NVE)
P.O. Box 5091, Majorstua, 0301 Oslo 3, Norway.

Written in collaboration with:

Bård Aspen
State Power Borad (Statkraft)
P.O. Box 5091, Majorstua, 0301 Oslo 3, Norway.

ABSTRACT

This paper describes the hydro-power development of the Riksheim water system over a period of 70 years. It also describes the beneficial effects hydro-power had upon a remote Norwegian community and the technology used over the years to develop these water resources.

Over the 70 years, Riksheim power plant has been upgraded from 450 kW to a total of 3500 kW. Present plans includes a further upgrading of Riksheim power plant to 4200 kW and the construction of a new power station that will utilize the river´s remaining hydro-power resources.

# 1. HYDRO-POWER RESOURCES IN NORWAY

The four million inhabitants of Norway have access to enormous hydro-power resources. The gross potential is estimated to be 550 TWh. Compared to the cheapest coal-fired thermal power plant, the economic potential is estimated to be approximately 200 TWh. Of the economic potential 104 TWh are developed, 4 TWh is under construction, 55 TWh are conserved and 12 TWh of the remaining 37 TWh can be developed causing only minor environmental damage.

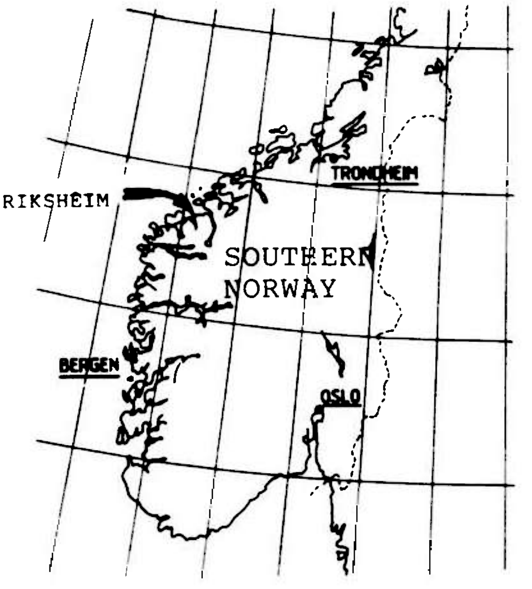
The utilization of water courses for hydro-electric power production started 102 years ago. Today 99% of the electricity produced in Norway is based on hydro-power. With the exception of grids in a few remote parts of the country, local transmission networks are now connected to the main grid. Even small hydro-power plants can therefore be built to utilize most of the water in a waterfall, since energy from run-of-river plants is mixed with the energy from hydro-power plants with large reservoirs.

The continuously growing energy demand, new and less expensive technology and possibilities for mixing low quality energy with high quality energy, have led to the idea of upgrading a lot of the older hydro-power plants in Norway. A country-wide programme to examine the resources is now underway. The Riksheim water course is an example of small water-courses in this study which includes schemes from 1 MW to 2000 MW.

# 2. RIKSHEIM POWER PLANT - HISTORICAL BACKGROUND

## 2.1 The power plant and the community

Riksheim power plant is a small hydro-power plant in Sykkylven municipality on the western coast of Norway. This part of the country is characterized by high and steep mountains and deep fjords. On the flatlands between the fjords and the mountains, people centuries ago started to cultivate the land. Their daily income was earned by combining agriculture and fishing.




The community in Sykkylven derived export revenue from the exploitation of the local timber resources. These resources were rapidly depleted, but the community accumulated both mercantile knowledge as well as experience in the exploitation of hydro power resources during this period. A large number of water power operated sawmills were in use.

In the beginning of this century, the growing population made it necessary to find other sources of income if the people were to continue living and working there. In 1915 there were a total of 2800 inhabitants in Sykkylven and 20 people were employed in the industry.

The experience gained in the timber industry, in the saw-mills and in the various small workshops, led to the idea of utilizing the rich hydro-power resources for the development of brick production, textile mills and furniture factories. In 1910, a few workshops located near river rapids already had electricity from micro hydro-power plants.

The demand for electricity, not only for industrial purposes but also for domestic lighting, increased.

At this new technology was brought to the community and high voltage transmission lines had become possible. In 1912 local people carried out pre-feasibility studies for seven small rivers in the neighbourhood, including the rivers Aura (150 kW) and Riksheim (2000 kW). The municipal council elected a group of men to investigate the possibility of purchasing one or more waterfalls, how to construct power stations and how to run them. The group decided to work on more detailed plans for the Aura and Riksheim rivers.

This committee had to find the answer to three major questions:

- The electricity demand current and in 10 years;
- Output and investment costs of the two alternatives;
- The income possibilities.

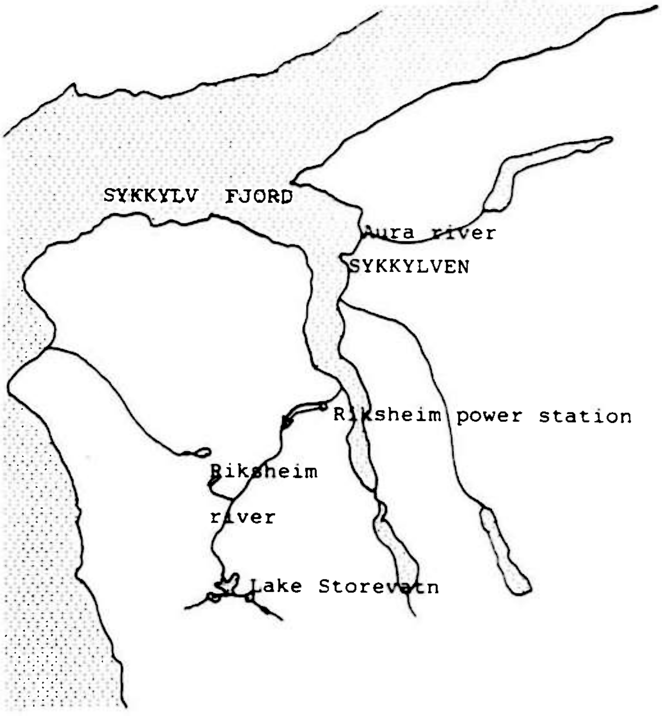
Investigations of public electricity demand and discussions with representatives of the small but growing industry, especially the furniture industry, concluded that the demand 10 years ahead, would be 600 kW.

The current demand was found to be 120 kW.

The committee found that the Aura river could scarcely cover the present demand and that this solution would not lead to increased industrial development. The output and investment cost was half the size of phase one of the Riksheim river. To find the possible income the committee had a yearly fixed price per Watt on lamps and a fixed price per horsepower (hp) for motors and heating. A slogan urged everybody to join, and they worked hard to persuade people to order electricity. From the local tradesmen they got the yearly consumption of oil and spare parts for oil-lamps and this was compared to the calculated price of electricity.

The results of the investigations were discussed for three years. Some people, especially those living close to the Aura river, thought that the Riksheim power plant was too big. They expected problems with transmission lines and argued that the loan was too risky. However, the arguments in favour of a power station serving the whole community and leading to industrial growth finally won.

In October 1915 the community municipal decided to utilize the power resources of the 254 m high Riksheim waterfall by constructing a power station, pipeline, intake pond and a reservoir, sufficient to produce 450 kW.




## 2.2 Construction and operation of the first power plant

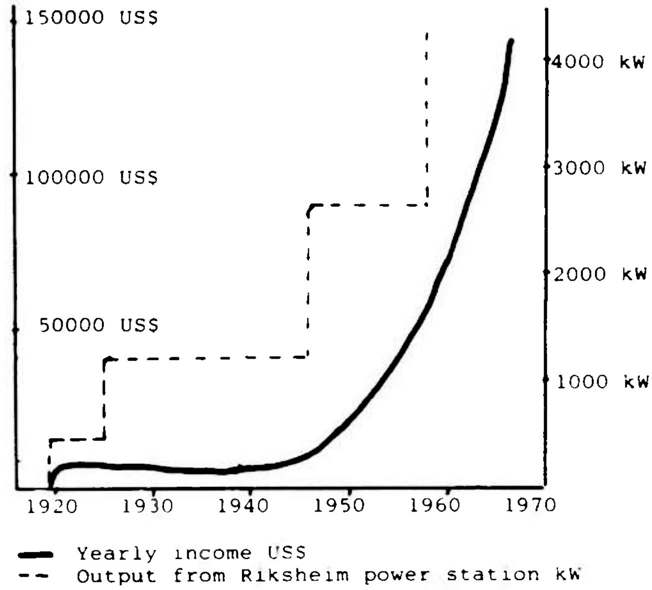
The total catchment area of the Riksheim river is 17.3 $km^2$ with an average runoff of 1.4 $m^3/s$. In the upper region of the catchment area there are three lakes. From the largest lake, Storevatn, 730 m above sea level, the river flows down the Riksheim valley to Sykkylvsfjord, a distance of 7 km.

The construction of the powerhouse, the 1100 m-long pipeline with diameter 400 mm and the intake pond lasted two years. During the time of construction the local interest was high and there was never any problem to find willing hands when the heavy equipment arrived. One hundred men pulled the turbine and generator on snow from the harbour to the power station at the hillside, and the pipes were rolled up the steep hill by means of ropes. They also had to find local solutions for the transmission lines. Due to the First World War the price of copper increased by 500% and they were forced to use mostly iron wires purchased for agricultural purposes.

Towards Christmas 1917 excitement in the community filled the air. Many people still could not believe that the Riksheim waterfall could bring light to their homes, especially to the farms high up on the steep hillside. In January 1918 the first houses got their electricity and the iron wire worked as hoped because the power production from Riksheim far exceeded the actual demand.

The investment cost had increased by 350%, and although the consumption of electricity increased rapidly, the income could not cover repayment of the loans. The deficit had to be payed by the community. After three years of operation, increased consumption made it necessary to replace the iron wires by copper ones in order to reduce the losses. Three years after that a second turbine of 750 kW had to be ordered. The rates were increased and a lot of people had problems paying for the power they used. The municipality also wanted to develop industrially, and this new growing industry could not survive without access to enough power at reasonable prices. Finally the problems were solved by cheap loans obtained from the national bank.

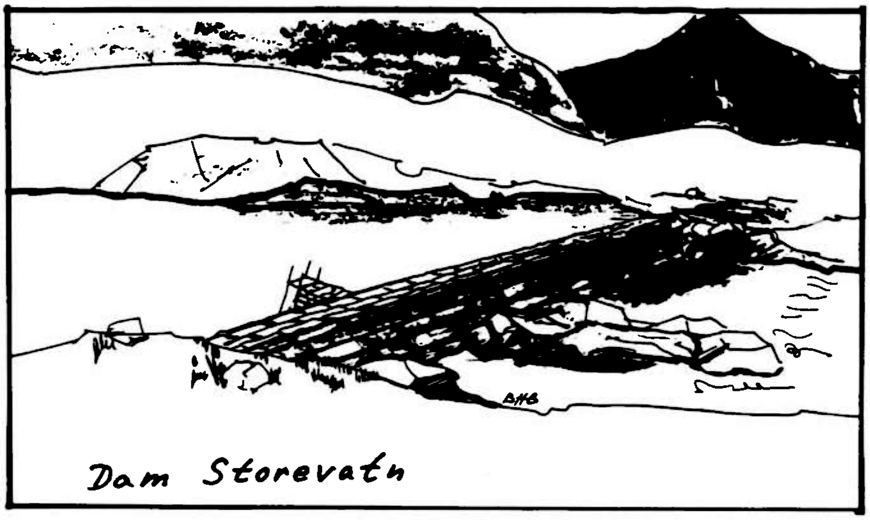
By having low energy prices and by introducing quantity discounts, the consumption increased much more than the income figures show. Ten years after installation of the second turbine the energy demand could not be satisfied during low flow periods, which in Norway are during the cold winter. The only solution was to store more water.




Cooperation with neighbouring municipalities started in 1955

## 2.3 Construction of the Storevatn reservoir

The dam at lake Storevatn, 3 m high and 43 m long, completed in 1921 and still in use has a storage capacity of 1 mill $m^3$. It is made of hand- cut stones with a frontal sealing of peat. To enlarge the reservoir a 350 m-long lake tap tunnel was planned to utilize the storage volume in the lake by tapping it 30 m.




After 16 years of discussions, planning and working on the financing, construction started in 1937. The financial solution included a combination of government loans, and loans from consumers plus reduced municipal activities in other sectors.

Experienced entrepreneurs were not available locally so an outside contractor was chosen. The construction equipment was carried from the harbour to the construction site by men and horses. After some months it became clear that the equipment used by the contractor was not adequate and it was decided that the municipality itself should purchase the necessary equipment and train local operators. This idea proved to be successful, and by the summer of 1940 the tunnel was close to the lake.

Few geological investigations had been undertaken before the position of tunnel was chosen, and now, with 30 m water-pressure close to the men working in the tunnel, uncertainties appeared. How was the quality of the rock, and how thick was the deposit of soil on top of it?

In September 1940 the piercing was made ready and hundreds of people walked to the construction site to watch. They could hear the explosion, but nothing happened in the tunnel for a long time. Suddenly they heard thunder from water, air and gravel which came through the tunnel. The work appeared to be a success, and everyone celebrated that night. Unfortunately, the layer of moraine on top of the bed rock was several metres thick at the tunnel intake, and after some weeks the sediments plugged the tunnel. Volunteers had to go in several times to blast the tunnel open again, risking their lives. These problems continued until 1985 when the deposits around the intake were removed by an excavator, which was dis-assembled and transported by helicopter to the site, and re-assembled there.

When the lake was tapped, it could be seen that the worst possible area had been chosen for the break-through point of the tunnel. Knowledge of this could have been obtained by better geological investigations, which were considered too expensive to carry out before the project started. All the problems with the tunneling work had doubled the investment cost. Again there were hard discussions in the municipal council.

## 2.4 The third and fourth upgrading of the power plant

The access to more water very soon showed that the existing pipeline was too small (it was the original steel pipe with a diameter of 400 mm). Because of the great head loss the expected power production was not reached and the demand for energy exceeded production, causing problems for the industry since rationing had to be introduced.

During the same period, both units in the power station had breakdowns. New pipes, turbine and generator were ordered. Because of the Second World War the upgrading took four years; late in 1947 the new unit of 1800 kW was installed and more power was available to the community.

During the next decade the transmission network was developed further. Cooperation with neighbouring municipalities started, including participation in other hydro power projects.

The last upgrading of Riksheim power plant took place in 1958 when a unit of 2500 kW was installed. This came in addition to the two other units of 1800 kW and 750 kW. The work also included a new wood stave pipeline from the intake pond, which replaced 350 m of the two steel penstocks. The wood stave pipe has a diameter of 1100 mm.

# 3. RIKSHEIM AND FRAMSETRA POWER PLANTS

## 3.1 Situation today

The stone dam at Storevatn with frontal sealing of peat has large leakages so the storage effect is reduced. The intake dam for Riksheim power station has recently been repaired with an upstream concrete wall.

The 750 kW unit from 1927 is out of order. A major breakdown can be expected any time for the 1800 kW unit from 1947, while the 2500 kW unit from 1958 has reduced efficiency.

In 1982 the oldest steel pipe, diameter 400 mm, was replaced by a steel pipe of diameter 600 mm. The head loss in the two 700 m-long steel pipes is nevertheless so great that the maximum output from the power station is only 3500 kW.

New underground technology and an energy demand which far exceeds the power production at Riksheim power plant make it interesting to evaluate the possibilities of utilizing the head between the main reservoir and the intake pond.

A main disadvantage with the old power station is the penstock which requires regular maintenance and also entails the operation of the power station almost continously during winter. Otherwise the water in the penstocks might freeze and the pipes will crack.

It has therefore been decided to carry out studies on:

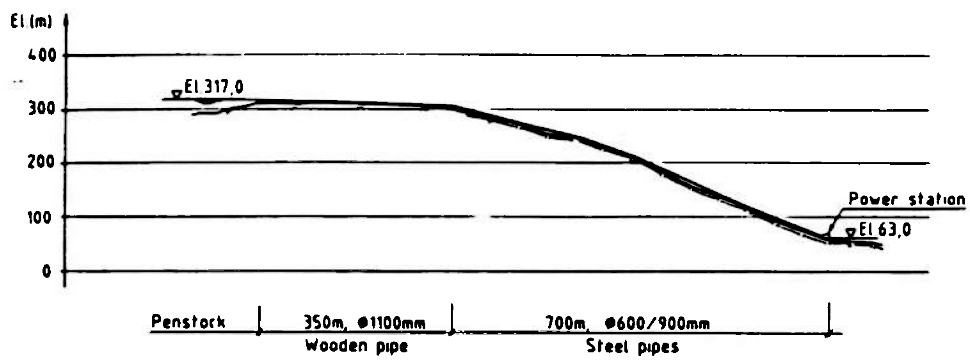
1. The upgrading of Riksheim power plant;
2. The harnessing of the hydro-power energy between Storevatn and the intake for Riksheim power plant in a new power station called Framsetra.

## 3.2 Upgrading of the Riksheim power plant

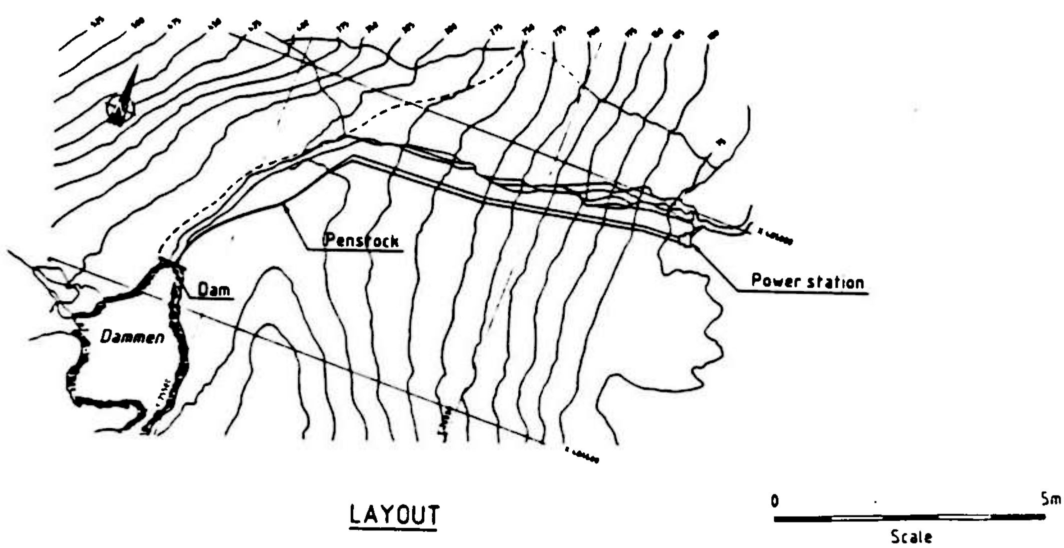
Riksheim power station

| | |
|---|---|
| Installation/increase (kW) | 4200/700 |
| Production/increase (GWh/year) | 21.0/5.2 |
| Cost (mill US$) | 3.8 |

Costestimate Appendix 1




LONGITUDINAL SECTION




LAYOUT

No major changes regarding civil works in the power station will be necessary, but revisions and replacement of machinary and electromechanical equipment will be carried out. The unit installed in 1958 will be kept.

The other two units will be removed and substituted by one new unit with an output of 2100 kW. The transformer will be substituted by two new ones with a total capacity of 5000 kVA. Switch gear and high voltage equipment will also be replaced and the power station will be equipped for remote control.

The new turbine will be a horizontal Francis with capacity of 1.1 $m^3$/s and the speed will be 1500 r.p.m.

The generator will be watercooled and have a capacity of 2750 kVA. The cooling water will be pumped from the tail-race channel.

To reduce the head loss in the waterway the old steel pipe from 1948 with diameter 600 mm will be replaced by a new one with diameter 900 mm.

The wood stave pipe with diameter 1100 mm has sufficient capacity and is supposed to function at least another 15 years and will not be replaced.

A new underground power plant was evaluated as against up-grading the old power plant. The underground solution was, however, found to be about 2.5 mill US$ more expensive and the advantage of getting a waterway free of maintenance and no operating restrictions was not found to be worth the price.

The need for operating Riksheim power plant throughout the whole winter then becomes the governing design criteria for Framsetra power station.

## 3.3 Framsetra power plant

| | |
|---|---|
| Installation (kW) | 4150 |
| Average production (GWh/year) | 15.0 |
| Cost (mill US$) | 8.2 |

Costestimate Appendix 1
Layout Appendix 2

The power plant will be constructed underground on the east side of the Riksheim valley. The gross head will be 397 m. Average yearly runoff is 17.8 mill $m^3$. Access to the station will be a 470 m long unlined tunnel with cross section 20 $m^2$. The cables from the power station are placed in a concrete culvert in the access tunnel.

The tailwater from the turbine will run in an covered channel in the bottom of the access tunnel.

From the power station a 7 $m^2$ unlined headrace tunnel, 2380 m-long with inclination of 1:10, will be blasted. The first 30 m will have steel lining. From the top of the existing tunnel for lake tapping a shaft with diameter 800 mm will be drilled down to the headrace tunnel. The shaft will be unlined. The existing pipe in the lake tap tunnel is to be coupled to the shaft by a bend and a new valve.

Because of the low velocity in the headrace tunnel (<0.2 m/s) a surge shaft is not needed.

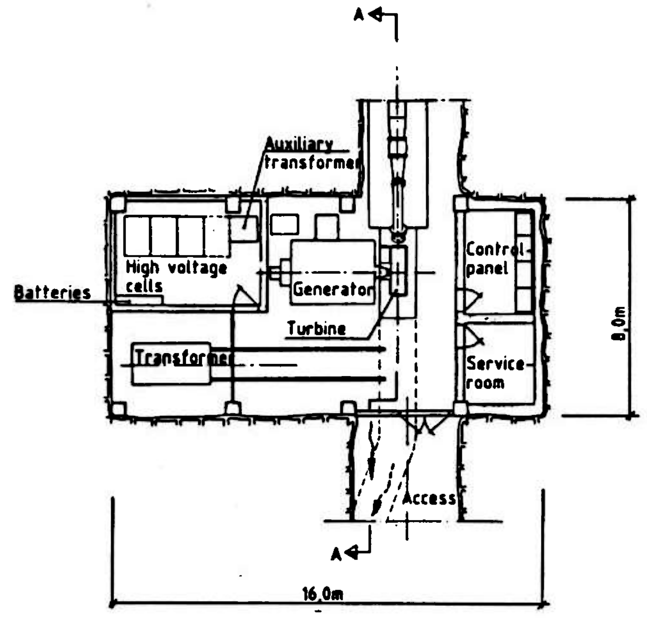
The installation is estimated to be 4100 kW and a two-jet Pelton turbine with direct connection to the generator is proposed. The turbine will have a maximum capacity of 1.3 $m^3$/s and a speed of 750 r.p.m.

The generator will be 5180 kVA and watercooled. The station will be operated by remote control from the centre in Sykkylven.

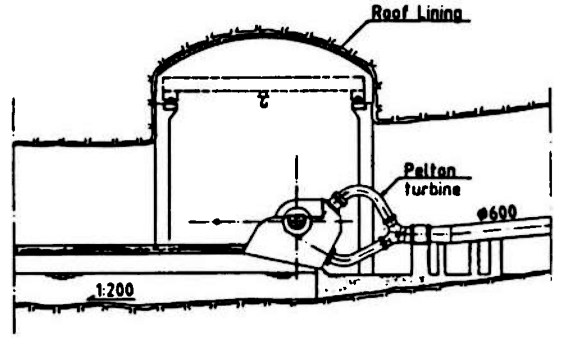
The existing road to the intake pond has to be repaired to permit transportation of the heavy equipment to the new power station.

A new road of 1.2 km has to be constructed along the west side of the intake pond for Riksheim power station, crossing the river close to the access tunnel for the new power station. Some of the rubble from the tunneling work will be used for road construction. The rest has to be deposited in the area.

A 2 km-long 22 kV transmission line has to be constructed from Riksheim power station to Framsetra along the east side of the river.




PLAN




CROSS SECTION A - A

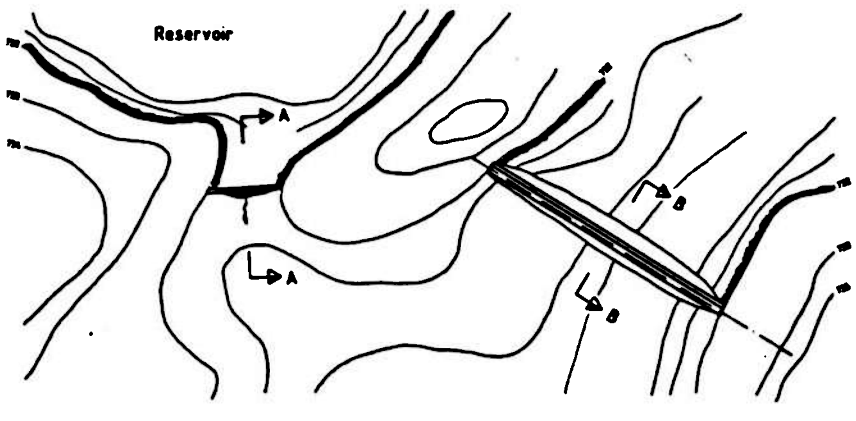
0 5m
Scale

## 3.4 Reservoir in Storevatn

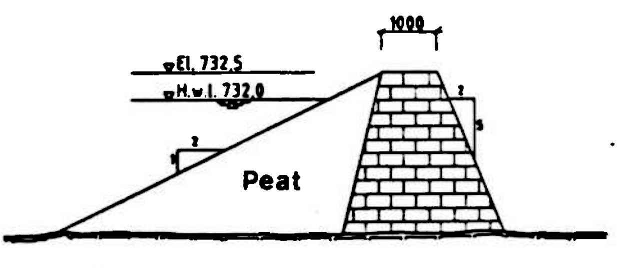
Storevatn will be the reservoir for the two power stations, with a storage capacity of 7.5 mill $m^3$.

The power stations have to be operated in such a way that the reservoir is not emptied before the end of the winter season. By choosing a capacity of 1.3 $m^3/s$ in Framsetra power station this can be done. The reservoir of 7.5 mill $m^3$ then has the capacity to retain the floods which occur in the spring. It is also necessary to have storage capacity in the autumn for floods usually occuring at that time of year.

A new concrete dam will be constructed connected to the old stone dam on the upstream side. Before construction the old peat sealing has to be removed to expose the bedrock. The rock is of good quality with few fissures and no injection work in the dam foundation is expected. If leakages do occur, injection can easily be performed after the construction of the dam. The volume of the dam is calculated to be 160 $m^3$ of concrete.

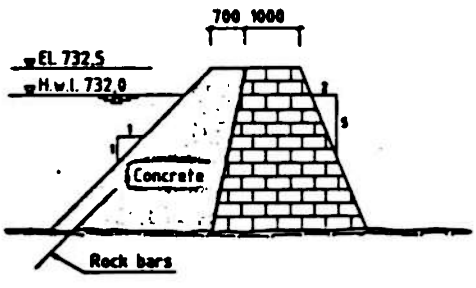



PLAN




CROSS SECTION B - B
PRESENT DAM SECTION

0 5m




CROSS SECTION B - B
DAM AFTER REHABILITATION

0 5m

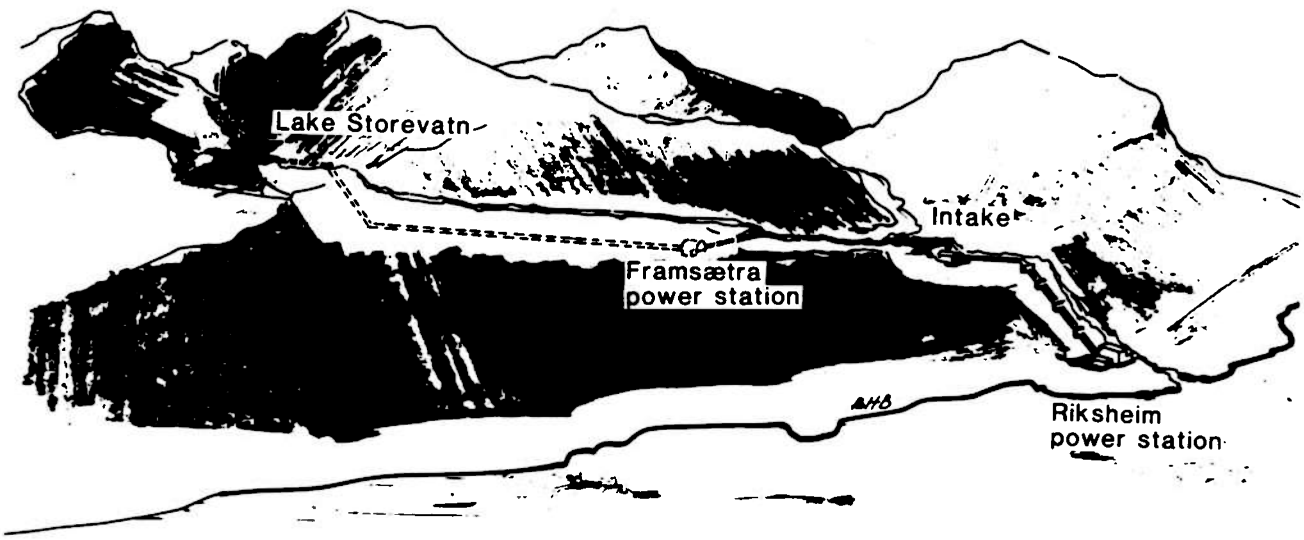
The overflow is planned as a massive retaining wall with a volume of only 15 $m^3$.

An alternative to the described concrete dam is a concrete wall with prestressed bolts in the rock on the upstream side of the old dam. The cost of such a solution will be the same but the uncertainty in the calculations will be somewhat larger.

Increasing the height of the dam by 2 m, has also been considered but this was found uneconomical.

Workers, equipment and building materials will be transported to the dam site by helicopter.

## 4. FINAL REMARKS




During the first 30 years of electricity production Riksheim power plant was looked upon as the heart of the community, providing light for people and creating industrial growth. From 1930 to 1987 the number of employees in the industry increased from 140 to more than 1600 which is 1/4 of the total population in Sykkylven. The furniture industry has been the most expansive, and today it exports to several countries in Europe as well as the USA, Australia and the Middle East.

The history of industrial development in Sykkylven, based on exploitation of water resources, may give inspiration to others. Much of the technology applied and experience gained here is highly appropriate for small-scale hydropower development in developing countries.

When the Framsetra power station is in operation and the Riksheim power plant is upgraded, Sykkylven municipality will be able to meet about half of their own electricity demand.

All experience indicates that this will be a valuable investment for the future.

Costestimate 01.01.87 1 US$ ≈ 6,5 NOK

Riksheim power plant:

| | |
|---|---|
| Reservoir (part of dam Storevatn) | 0,30 mill US$ |
| New steelpipe | 0,8 " |
| Power station civil works | 0,3 " |
| Power station mec/el. | 1,6 " |
| Administration, contingencies | 0,5 " |
| Taxes, financing | 0,3 " |
| Σ | 3,8 mill US$ |

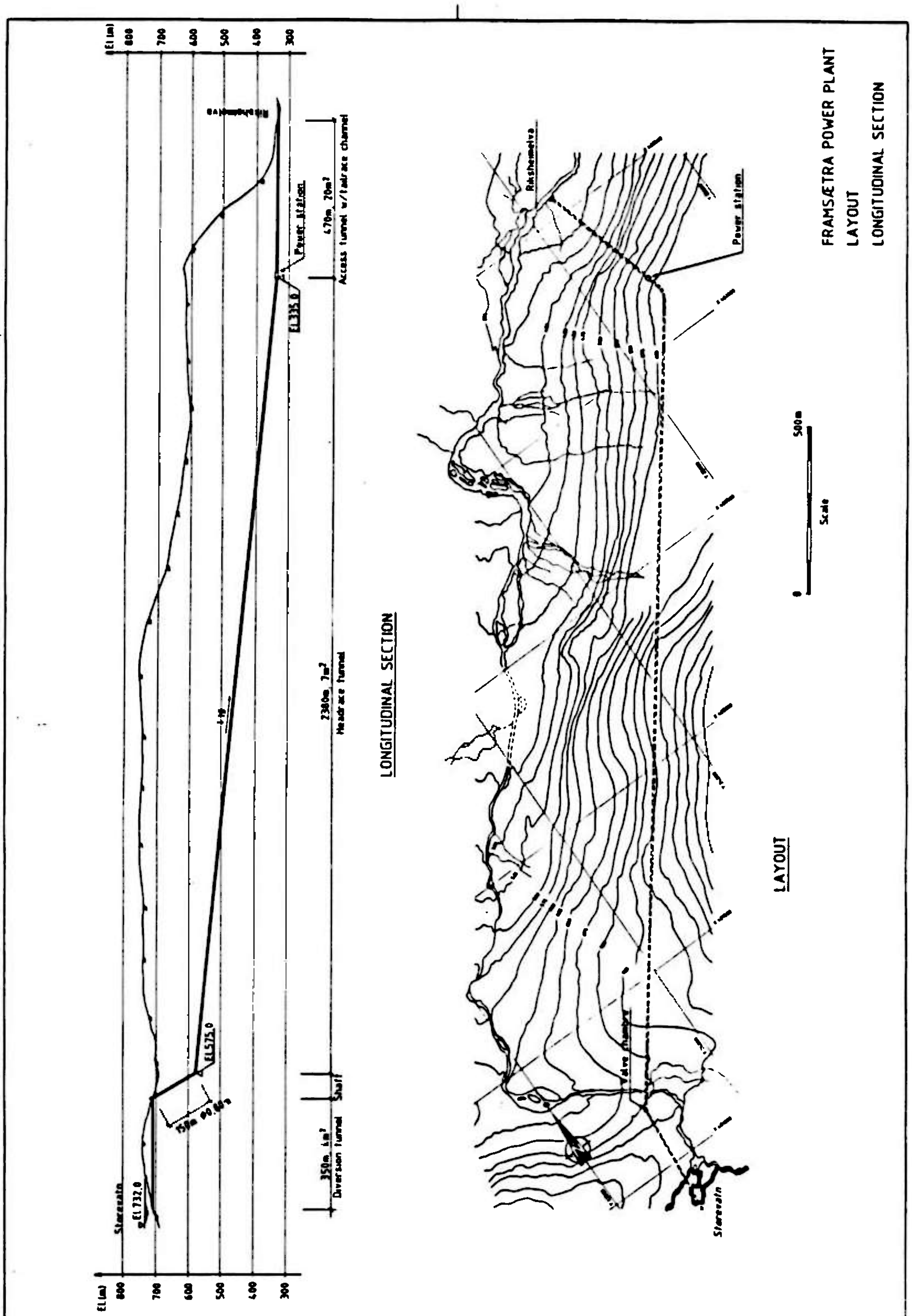
Construction time 1 year.

Framsetra power plant:

| | |
|---|---|
| Reservoir (part of dam Storevatn) | 0,2 mill US$ |
| Headrace tunnel/shaft | 2,4 " |
| Power station (incl. accesstunnel) civil works | 1,1 " |
| Power station mech/el. | 2,1 " |
| Transportation, roads, environmental works | 0,4 " |
| Administration, contingencies | 0,9 " |
| Taxes, financing | 1,1 " |
| Σ | 8,2 mill US$ |

Construction time 2 years.

APPENDIX 2


FRAMSÆTRA POWER PLANT
LAYOUT
LONGITUDINAL SECTION
LONGITUDINAL SECTION
LAYOUT
El (m)
Power station
EL 335.0
670m 20m²
Access tunnel w/tailrace channel
2380m 7m²
Headrace tunnel
EL 575.0
Shaft
350m 6m²
Diversion tunnel
EL 732.0
Storevatn
Valve chamber
Scale
500m