Heavily Modified Waters in Europe

Case Study on the Suldalslågen River

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Information on Case Studies

	Item	Unit	Information
1.	Country	text	Norway
2.	Name of the case study (name of water body)	text	Suldalslågen river
3.	Steering Committee member(s) responsible for the case study	text	
4.	Institution funding the case study	text	Norwegian Water Resources and Energy Administration
5.	Institution carrying out the case study	text	Freshwater Ecology and Inland Fisheries Laboratory (LFI), Norwegian Institute for Water Research (NIVA), Statkraft-Grøner AS
6.	Start of the work on the case study	Date	1/4 2001
7.	Description of pressures & impacts expected by	Date	20/6 2001
8.	Estimated date for final results	Date	31/12 2001
9.	Type of Water (river, lake, AWB, freshwater)	text	River (reach)
10.	Catchment area	km^2	2139 (1463 natural)
11.	Length/Size	km/ km^2	22/135 (local catchment)
12.	Mean discharge/volume	m^3/s or m^3	101 unregulated, reduced to approx. 50 in the present situation
13.	Population in catchment	number	4100
14.	Population density	Inh./km^2	2.4
15.	Modifications: Physical Pressures / Agricultural influences	text	Hydropower development

16.	Impacts?	text	Changed runoff regime, changed temperature regime, increased siltation, increased aquatic moss cover, changed abundance of invertebrates and fish
17.	Problems?	text	reduced atlantic salmon abundance and catch
18.	Environmental Pressures?	text	acidification
19.	What actions/alterations are planned?	text	artificial large floods
20.	Additional Information	text	
21.	What information / data is available?	text	
22.	What type of sub-group would you find helpful?	text	
23.	Additional Comments	text	

3 Introduction

3.1 Choice of Case Study

The history of hydropower in Norway is very much the history of the industrialisation and development of the country over the last hundred years. Until recently Norway has been self-sufficient with respect to electricity, but is now in the situation of importing this commodity. A possible change in the water management regime through the WFD could have impact on this situation. Consequently the two Norwegian cases chosen for HMWB represent the sub-group hydropower.

Hydropower is the most important source to electricity in Norway. About 99,7 % of the production come from hydropower. Of a total economically available potential of 187 TWh, 118 TWh is developed (2001). About 36,5 TWh is within protected areas and is not developed. The rest consists of watercourses with a more limited economical potential, and attempts to develop some of these has lead to strong conflicts between regulators and environmentalists and other stakeholders.

The river Suldalslågen and the upstream watercourse is heavily regulated through several steps, involving power plants, dams and transfer of water cross catchment borders. The challenges experienced in this watercourse is common for quite a few regulations on the western coast of Norway, among other things involving the conflicts concerning salmon fisheries and minimum water release. As such it could be said to be representative for this type of regulations. The magnitude of surveys done on the watercourse and the availability of information is also an important reason for choosing this waterbody.

Suldalslågen is also appointed a pilot-case for a three-year study of the implementation of the WFD. The contractors performing the study have to a great extent been involved in earlier studies in the watercourse.

The Norwegian participation in HMWB is managed by The Norwegian Water Resources and Energy Directorate.

3.2 General Remarks

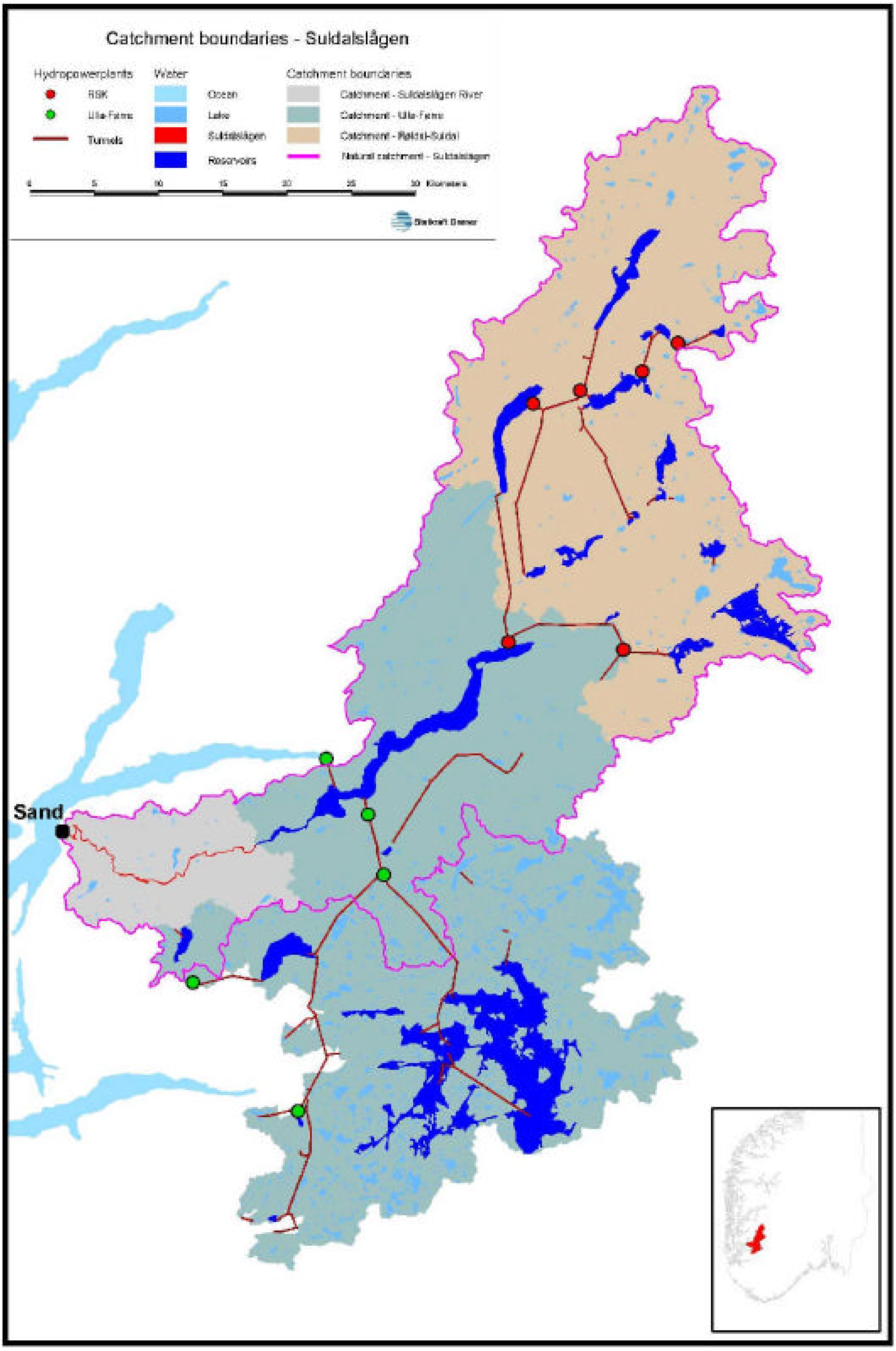
The Suldalslågen watercourse is located in Rogaland County, SW-Norway. Within the catchment one will find two large hydropower schemes, each with several reservoirs and power stations.

This case study focuses on the lowermost part of the river, from Lake Suldalsvatn to the sea, a distance of about 22 km. The case study is placed in the sub-group Hydropower in the European project on heavily modified water bodies.

4 Description of Case Study Area

4.1 Geology, Topography and Hydrology

Box 1 Map of Suldalslågen with transfers and hydropower plants



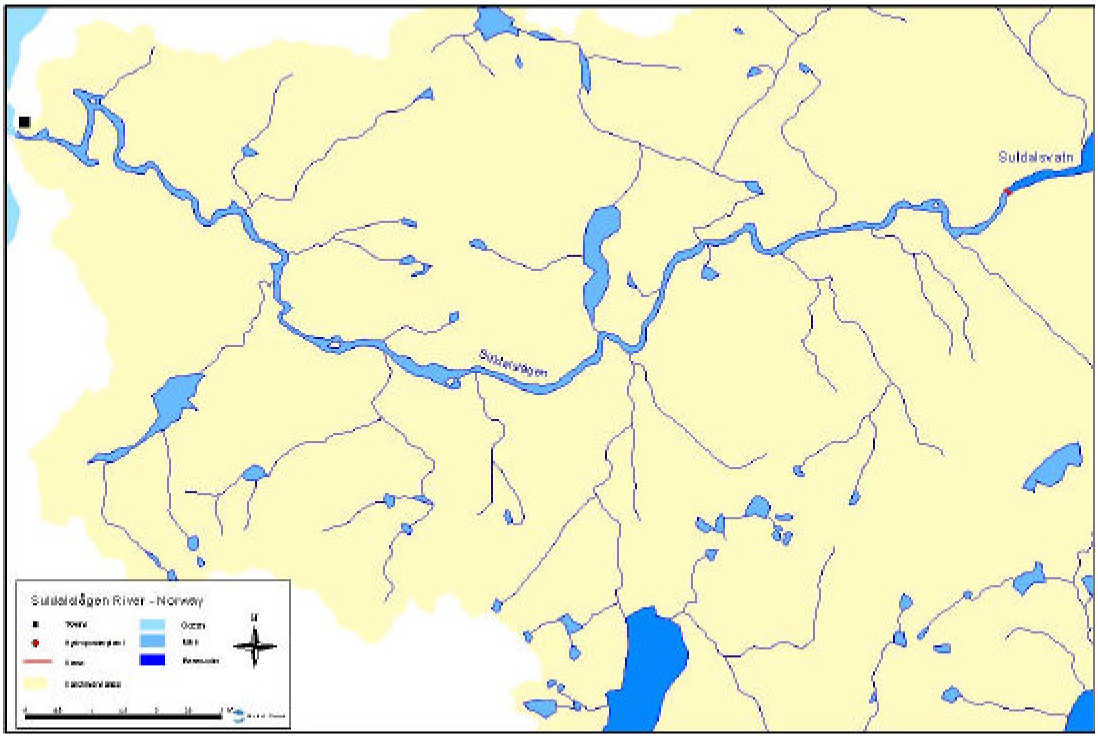
The Suldalslågen River has a natural catchment area of 1463 km², of which about 75 % is above the timberline at 6 – 700 m a.s.l and can be considered as high-mountain areas. The catchment reaches to altitudes more than 1200 m a.s.l. Today the catchment area is increased to 2139 km², about 80 % above the timberline, through the establishment of Ulla-Førre Hydropower Plant (Box 1).

The local catchment of the Case Study Area is today 135 km². Through hydropower development about 23 km² of the natural catchment has been diverted. About 25 to 30 % of the local catchment is located above the timberline.

The major part of the catchment consists of granite and gneiss, both rock types that undergo slow weathering processes.

The river section to be studied in this case study has a length of about 22 km and reaches from the reservoir Lake Suldalsvatn, at about 68 m a.s.l., to the sea (Box 2).

Box 2 Map of the water body, Suldalslågen downstream the Suldalsvatn Dam



The mean annual precipitation in the catchment varies between 1600 and 2700 mm, with maximum precipitation in the months September to December. The annual mean temperature varies with altitude from 6 to 0 ºC, with minimum temperatures below 0 ºC during the winter even at sea level. Usually the precipitation in the winter will fall as snow, but in the areas below approx. 200 m a.s.l. there are often several episodes with snowmelt and precipitation as rain each winter.

The flow distribution in the river is strongly influenced by the snow regime, with the lowest discharges in the winter months December to April and maximum during the spring snowmelt in the months May to July. Mean annual natural flow in the case study section of the river is 90 m³/s at Suldalsosen, the outlet of Lake Suldalsvatn, and 101 m³/s down at Sand, at the outlet into the sea. Through the diversion to the Hylen hydropower plant, the mean annual flow at Suldalsosen is reduced to approximately 50 m³/s.

4.2 Socio-Economic Geography and Human Activities in the Catchment

The river Suldalslågen runs through the municipality Suldal, with a population of approx. 4100, or about 2.4 inh./km². About 1200 persons live in the municipal centre Sand. Agriculture is dominant in the countryside. In addition fishing and hunting are important in the area. Tourism is of great importance to the community. Much of this activity is connected directly or indirectly to the river.

The river Suldalslågen is one of Norway's most famous Atlantic salmon rivers, known for large fish. The angling of salmon is mainly concentrated within the case study area. Different constructions have been built in and along the river to improve the angling, such as fish ladders and arrangements to improve the access to the good fishing grounds.

The river is to some extent used by farmers for irrigation and water for animals.

The river is affected by agricultural run-off. At least one gully in the valleyside was probably initiated by clear-felling. This has caused increased erosion and supply of fine sediments to the river.

Two large hydropower schemes (Røldal-Suldal and Ulla-Førre) lie within the Suldalslågen river system. They generate approx. 6 % of the total electricity production in Norway. Both are upstream the study area, but one plant, Hylen, diverts water from the Suldalsvatn reservoir directly to the sea.

The Røldal-Suldal Hydropower Plant, in the northern part of the watercourse, consists of 7 power stations and 16 reservoirs. The major part of the system was set into operation between 1965 and 1970. Mean annual electricity production is 2630 GWh. The discharge from the RSK hydropower system ends up as inflow to Lake Suldalsvatn. The Ulla-Førre Hydropower Plant consists of 7 reservoirs, located both within and outside the Suldalslågen watercourse. The largest reservoir, Blåsjø at 1050 m a.s.l., is the second largest in Norway, with a volume of 3105 mill. m³. Furthermore there are 4 power stations and 3 pumps within the Ulla-Førre power system. The power stations were set into operation between 1980 and 1986. Water is diverted from other rivers to the Suldalslågen watercourse through the Ulla-Førre system. The lowermost power station, Hylen located in the bottom of the fjord Hylsfjorden, utilises the head between Lake Suldalsvatn and the sea. Through this station a large volume of water is diverted from the river Suldalslågen. The mean annual electricity production is 4550 GWh.

In addition to the two hydropower schemes mentioned above, one small hydropower station is located within the case study area, in a tributary to the main river. In this study this power station is disregarded, as it has minimal impacts on the river flows.

4.3 Identification of Water Bodies

The case study section of the river Suldalslågen, length 22 km, is considered to be one water body in the river category. The type of water body, according to system A (WFD Annex II 1.2), is shown below.

Ecoregion: Borealic uplands

Type: Lowland (the section of the river runs from 68 m a.s.l. to the sea)

Local catchment: medium (natural 158 km², today 135 km²)

Total catchment: large (natural 1463 km², today 2139 km²)

Geology: mainly granite and gneiss rock types

The case study water body is the section of the river Suldalslågen from the reservoir Lake Suldalsvatn to the sea. The main pressures of the water body are due to hydropower, i.e. the dam in the outlet of Lake Suldalsvatn and diversion of almost 50% of the annual flow through the power station Hylen. Along the river section a lot of tributaries from the local catchment contributes to the flow in the main river. Most of these tributaries are unaffected by hydropower development.

Immediately upstream of the water body is the reservoir Lake Suldalsvatn, also modified by hydropower development. The lake is affected by the dam itself, but also because several hydropower stations upstream the lake have changed the inflow to the lake.

Downstream of the water body is the sea, the fjord Sandsfjorden. This fjord and the adjoining fjord Hylsfjorden, is affected by reduced flow in the river Suldalslågen and increased flow through Hylen hydropower station. In addition to an increased amount of inflow to the sea the seasonal distribution is also changed and differs considerably from natural conditions.

4.4 Discussion and Conclusions

The system A classification is very coarse (most of Norway is Borealic uplands), and not helpful for identifying reference water bodies.

The river regulation does strongly influence the adjacent fjord system. The changed flow regime in River Suldalslågen affects the estuarine area, but more important, the shunting Hylen power plant pours large amount of freshwater into the Hylsfjorden branch, a fjord arm that earlier was nearly without inflow. In addition to this, the transfer of the Ulla-Førre catchment displaces 1600 mill m^3/yr from the outer fjord system area to the inner, from outside an important fjord sill to the inside. The seasonal distribution of the freshwater inflow is also strongly changed. These impacts are not considered in this study, but it would be natural to consider this fjord system (Saudafjorden/Hylsfjorden/Sandsfjorden) as a separate water body, which also have the potential for being designated HMWB due to river regulation impacts.

This fjord system is thoroughly studied, the main results are reported in Lie *et al* (1992), Kaasa (1998), Hansen & Asvall (1985). The main effects of the river regulations on the fjord system considered are:

- stronger vertical mixing of the top water layer, resulting in a deeper brackish water layer;
- changed surface water temperature;
- strong surface exiting current, with compensating ingoing current below;
- increased influx of nutrients;
- risks of salmon mistracking on returning to river;
- algae blooms of the *Prymnesium* species, that has caused fish deaths in the fish farms in the fjord system.
- no ice cover in Hylsfjorden after establishment of Hylen power plant.

Generally, these impacts cause changes in the algae and plankton communities.

5 Physical Alterations

5.1 Pressures and Uses

On the case study section of river Suldalslågen the main pressure is:

- **Hydropower generation**

Other important uses of the river and the riverbed, which also may cause significant pressure, are:

- Angling – e.g. fish ladders, liming
- Recreation
- Agriculture – e.g. agricultural run-off, clear-cutting of riparian forest
- Road construction on or near the riverbed
- Establishment of areas for industrial activity at or out into the river
- Sand-pits

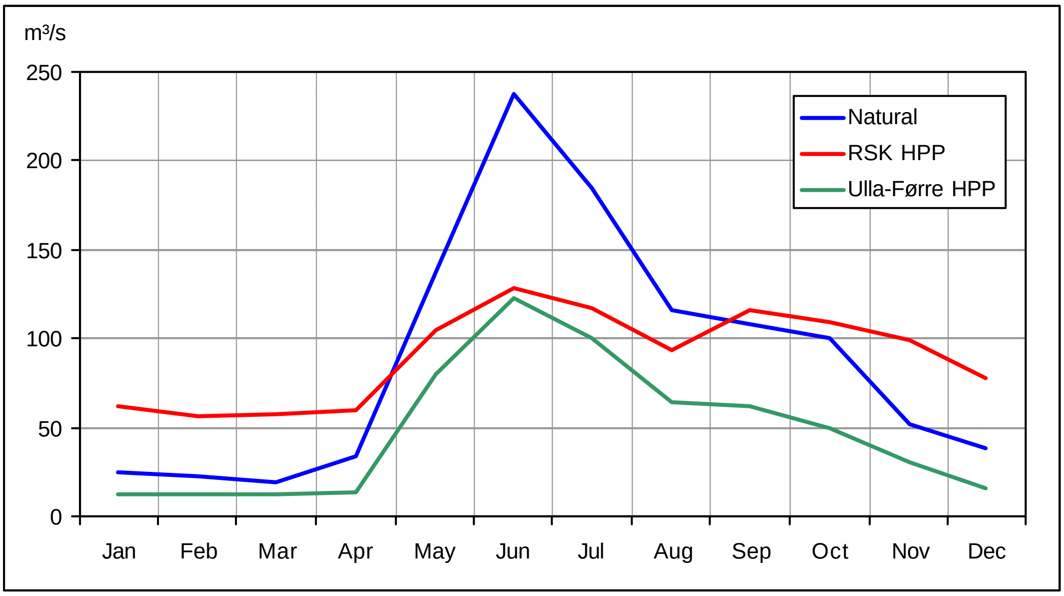
5.2 Physical Alterations

The most important physical alteration is due to the dam at Suldalsosen causing a disruption of river continuum and change of downstream flow. The dam has several large gates to provide discharge into the river Suldalslågen. The reservoir Suldalsvatn is operated between HWL at el. 68.5 and LWL at el. 67.0, and acts as reservoir for Hylen power station. The dam, and indirectly the power station, causes reduced mean flow in the river as well as reduced flood-peak values. Only a few times each year one can expect the water level in the Lake Suldalsvatn to reach above HWL and cause uncontrolled floods. And even in such situations the floods are not likely to become very large, since also the catchment upstream of the reservoir Suldalsvatn is very well regulated through both RSK and Ulla-Førre hydropower plants (ref. chapter 4).

Other physical alterations are small and not very important, but some can be mentioned:

- Two fish ladders, at each side of the river, are constructed in the Sandsfossen waterfall. The waterfall is located at Sand, just upstream the sea. The purpose is to help Atlantic salmon of small and medium size and anadromouse brown trout to pass the waterfall and enter the river for spawning.
- Four installations for liming, in the main river at the dam in the outlet of Lake Suldalsvatn and in three tributaries downstream the dam. In addition liming of one tributary catchment. The reason for the liming is the general acidification in southern Norway.
- Some removal of riparian forest.

Box 3 Seasonal flow, three hydrological regimes



5.3 Changes in the Hydromorphological Characteristics of the Water Bodies and Assessment of Resulting Impacts

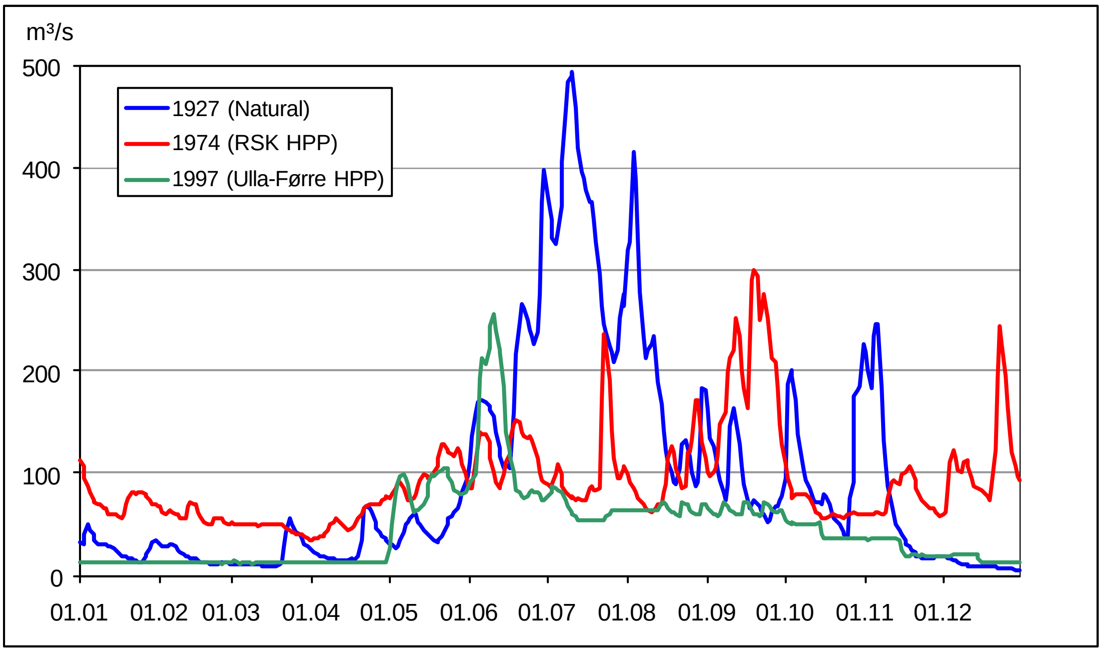
The physical alterations result in several hydromorphological changes, especially related to flow conditions, water temperature and sediment transport. Since the flow in the main river has been significantly reduced, the influence and importance of the inflow from, and the conditions in, the local catchment has been increased.

5.3.1 Flow conditions

The Hylen hydropower station is through its rules for operation instructed to release a minimum discharge to the river Suldalslågen. This discharge varies from at least 12 m^3/s in the winter to at least 150 m^3/s during the snow melt period. In the summer the release is 60 m^3/s, gradually decreasing to 12 m^3/s in late autumn. The operational rules are under revision, and a new set of rules will probably be established around 2005. The most important part to be revised is the decisions connected to release of minimum discharges into the river Suldalslågen. The main objective of the new operational rules is to improve the conditions for the Atlantic salmon.

The flow conditions today are compared to natural conditions at two locations in the river Suldalslågen, at the beginning (Suldalsosen) and at the end (Sand) of the studied section of the (Box 3). In addition the flow in the period 1967 – 80 are shown. This was the period with only the Røldal-Suldal Power Plant in operation, and the flow distribution was quite different from both natural conditions and today's conditions. Especially the

Box 4 River Suldalslågen at Suldalsosen – Three Typical "Normal" Years



winter flows were large, and the variation throughout the year was much less than today, as well as under natural conditions.

Today there are discharge gauging stations at both locations. In order to describe natural conditions one has to look at discharges from the period before 1964. At that time only the gauging station at the natural lake outlet, very close to today's dam site, was in operation. Mean monthly flows out of Lake Suldalsvatn, at Suldalsosen, for the three periods with different hydrological regimes are shown in the diagram in Box 3. Hydrographs from three typical years are shown in Box 4.

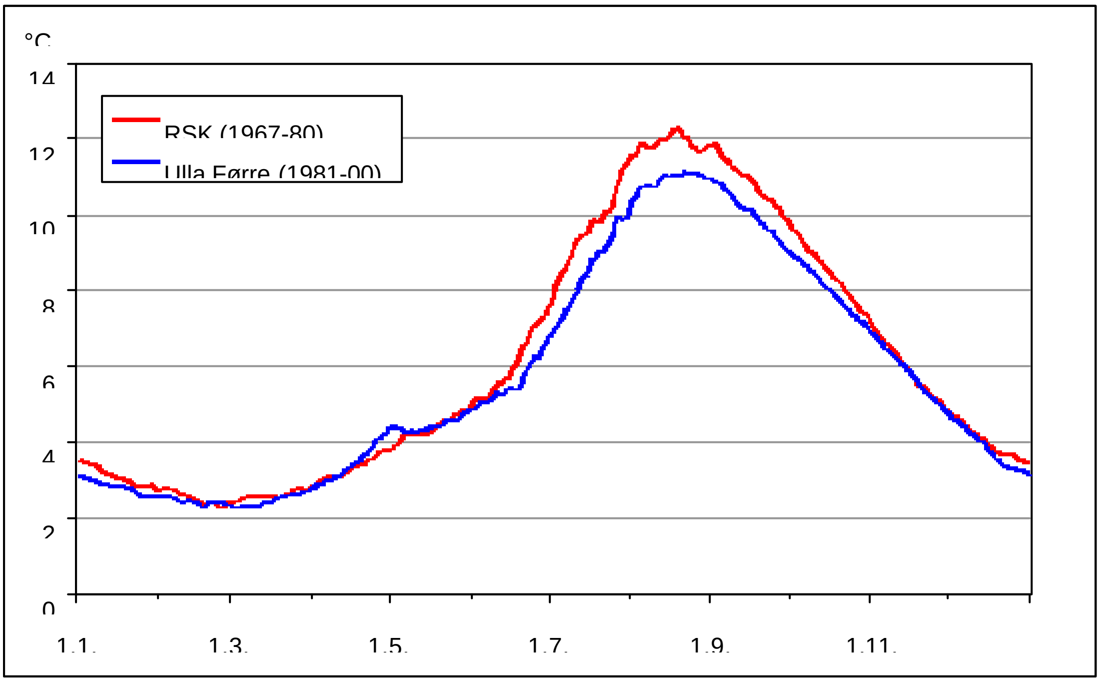
In Annex 1 monthly mean flows are shown, at both locations. Natural flows at Sand has been calculated based on observed flows at the lake outlet and observed inflow from the local catchment downstream the lake from the period 1981 – 2000. Annex 2 shows the changes from natural to today's conditions at Suldalsosen in more detail. In addition to monthly means the monthly maximum and minimum daily flow from each period are given.

The flow conditions during the winter are today quite similar to the natural situation, but with less variability. During the spring flood, summer and autumn, however, the flows are now significantly reduced. The occurrence of large floods is strongly reduced.

5.3.2 Water temperature

Water temperature is measured at two sites within the case study section of the river Suldalslågen, at Suldalsosen since 1962 and at Sand since 1972. The two periods with hydropower plants in operation, 1967 to 1980 with the Røldal-Suldal HPP and 1981 to present with both Røldal-Suldal and Ulla Førre HPP, are well covered with observations. However, this is not the situation for the period before 1964, under natural flow conditions in the river. Since 1969 additional measurements have been taken at

Box 5 Water Temperature Measurements at Suldalsosen – daily means



Stordalsvatnet, in a nearby river which is unaffected by hydropower development, in order to describe natural variations in water temperature in the region.

Winter temperatures were increased in the period 1967 to 1980 due to high winter flows, but are now back at levels almost similar to natural conditions. Summer temperatures are lower today compared with natural conditions. The diagram in Box 5 shows daily mean water temperatures for the two regulated regimes.

May to October is the period the salmon and brown trout juveniles grow. The degree-day sums have been calculated for the two sites in river Suldalslågen as well as in the nearby unaffected location (Box 6 and Annex 3). Mean values for each of the three periods are given in Table 1.

5.3.3 River ice

There has never been much river ice in Suldalslågen. Prior to hydropower development in the watercourse there could be complete ice-cover in the lowermost parts of the river and some ice on quiet sections elsewhere for some weeks in midwinter. In the period 1967 to 1980, with the RSK HPP in operation, hardly no river ice at all occurred. Since 1981, with Ulla-Førre HPP in operation, the winter flow has been reduced to a level more similar to natural conditions and river ice conditions are more or less back to natural conditions. River ice again occurs in cold periods throughout the winter, especially in the lowermost parts of the river. Ice cover often occurs upstream ice-dams formed by bottom ice, due to backwater effects creating areas with reduced flow velocity.

Box 6 Degree-day Sums in the Growth Period May to October

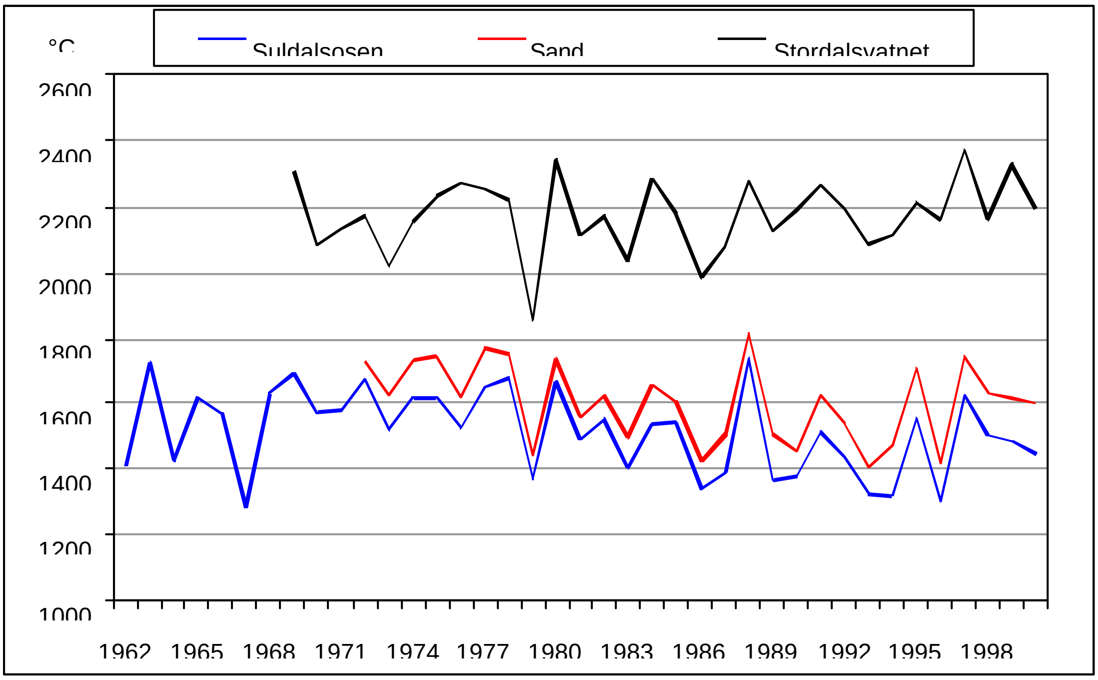


Table 1 Mean Degree-day Sums for the Months May to October

Period	Suldalsosen	Sand	Stordalsvatnet
Natural (1962 – 1964)	1519		
RSK HPP (1967 – 1980)	1576	1685	2170
Ulla Førre HPP (1981 – 2000)	1461	1571	2177

5.3.4 Sediment transport

During the nineties the transportation of sediments, both suspended and bed load, has been investigated. Between 60 and 80 % of the contribution of sediments to the river come from agricultural areas, and between 20 and 40 % from gullies in the valleyside, both natural and man-made. The total annual yield is estimated to be between 100 and 500 tons (Bogen *et al* 1997).

Naturally the sediment flow out of Lake Suldalsvatn was very low, and the establishment of the dam has probably not reduced the sediment inflow to the river. However, bed load calculations indicate that the diversion of almost 50 % of the annual flow, as well as a considerable reduction of the magnitude of the floods, probably have reduced the transport capacity of the river. This again may lead to accumulation of sediments in the river, giving siltation and increasing the level of the riverbed. The extensive accumulation of sand on the river bed has clogged the interstices between cobbles and boulders, and thus affected the fish habitat.

5.4 Discussion and Conclusions

In order to make a more proper comparison between regulated and natural flow conditions, these situations should have been calculated and for the same period of time. Such information did not exist for the River Suldalslågen.

Very little water temperature data existed from the period with natural flow conditions, i.e. before 1964.

Changes of methods for water temperature measurements make it difficult to compare data from different periods.

In general the lack of data from the period with natural conditions makes it difficult to estimate the effects caused by hydropower development. In addition a lot of changes during the last 40 years, not caused by hydropower development, have affected the natural conditions in the river systems. In order to describe the changes in the hydromorphological characteristics, and their impacts, in a best possible way one should have had data from river systems unaffected by hydropower development for comparison.

6 Ecological Status

6.1 Biological Quality Elements

6.1.1 Phytoplankton

Composition and abundance

Lake Suldalsvatn is an ultraoligotrophic lake with a poor phytoplankton community dominated by crysomonades and µ-algae (Annex 4) (Rørslett *et al* 1989). Max biomass was about 70 mm³/m³ in 1988 and annual production was estimated to 10-15 gC/m². The phytoplankton is very important for the zooplankton production in Lake Suldalsvatn, which was an important foodsource (as drift) for the juvenile Atlantic Salmon in Suldalslågen (Lillehammer 1964, Lillehammer and Saltveit 1979).

Impacts

The phytoplankton community is probably near undisturbed conditions in this type of lakes. Data on the phytoplankton community before the regulation impact do not exist.

6.1.2 Phytobentos (benthic algae)

Composition and abundance

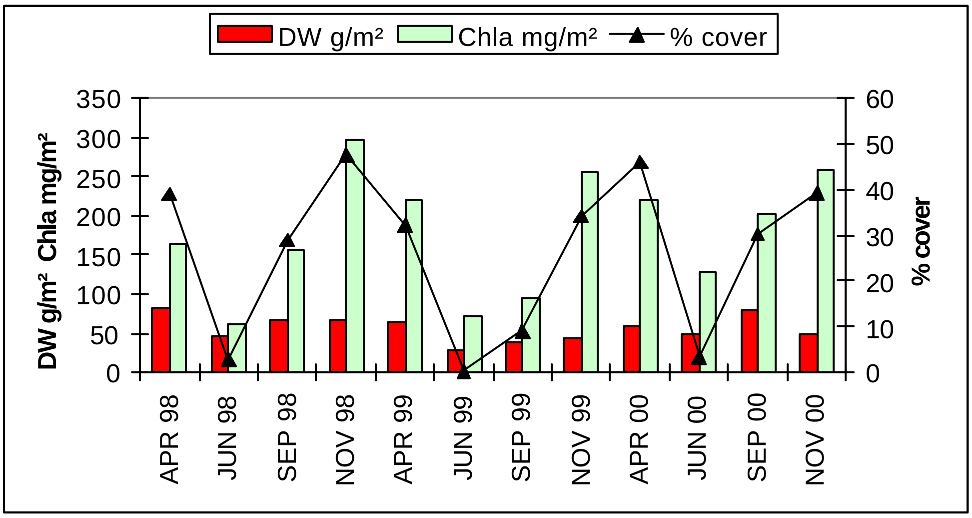
There are now registered at least 117 taxa of phytobentos based on samples taken in the period 1998-2000. These algae distribute on the following groups; Cyanophyceae (28), Chlorophyceae (32), Chrysophyceae (1), Rhodophyceae (3) and Bacillariophyceae (53). The most important taxa in these groups are the cyanobacterian *Clastidium setigerum*, *Coleodesmium sagarmathae*, Cyan*ophanon mirabile*, *Homeothrix nordstedtii*, Stigon*ema mamillosum*, the green algae *Binuclearia tectorum*, *Bulbochaete sp.*, *Hormidium rivulare*, *Microspora palustris*, *Mougeotia a*, *Penium spp.*, *Zygogonium sp3*, the red algae *Lemanea sp*, the chrysophyte *Hydrurus foetidus* og the diatomes *Achnantes minutissima*, *Eunotia curvata*, *Eunotia exigua*, *Eunotia incica*, *Eunotia naegelii*, *Peronia fibula* and *Tabellaria flocculosa*. A complete table of all taxa are present in Annex 5.

Today the quantitative dominating benthic algae is the filamentous greenalgae community. These algae establish and settle down on carpets of liverworts and can cover 100% of the riverbed where the cover of liverworts are correspondingly high. The cover of greenalgae varies in time of season. Greatest cover is recorded in spring (April) and late autumn (November). Least cover is recorded in June-July. Corresponding levels of biomass of greenalgae are measured to 29-82 g DW/m² and 61-300 mg Chla/m². The variation during the year is illustrated in Box 7.

Impacts

The community of benthic algae show a normal high species diversity in all groups dominated by species connected to clean water. A considerable amount of acidification sensitive species in the whole river, show that Suldalslågen is not strongly affected by acidification. Due to lack of old data before the RSK-regulation on species composition, time series are difficult to establish. Several species which were common in 1981 (the first published data) is still among the important and most conspicuous today. It is reason to believe that the number of species has increased a little after the regulation impact, as the flow conditions have become more stable and probably increased the niche rooms for the phytobentos.

Box 7 Percentage cover and biomass as gDW/m² and mgChla/m² of filamentous green algae in Suldalslågen in the period 1998-2000. Average of five locations at each time.



Earlier descriptions from Suldalslågen from the period 1960-1962 before the regulation impact says, "Algae-vegetation was common at several locations in the river" (Lillehammer 1964). Descriptions from 1981 indicate vigorous growth of algae with large biomass at some locations (Skulberg 1981). Dominating species in the algae community were i.a *Hydrurus foetidus*, *Microspora spp*. and cf. *Phormidium sp*.. It is rare to see both *Hydrurus* and *Phormidium* with large cover and biomass in Suldalslågen today. These algae prefer stone substrate, which has decreased as the moss vegetation has increased after the regulation impact. Biomass of green algae has not been measured before 1994. After 1994 the levels of biomass has not changed much. Cover of greenalgae has been measured since 1988. Since then the average cover has increased because of the increasing cover of liverworts. However, there can still be variations from year to year due to climatic and hydrological variations.

6.1.3 Macrophytes

Composition and abundance

In this section we have included mosses and liverworts among the macrophytes. A total of 17 mosses and liverworts are recorded in Suldalslågen (Annex 6) and the diversity is normal. The diversity would be higher if the river banks are included. Today the dominant community of permanent water covered areas due to minimum release consists of *Fontinalis spp*. and carpets of liverworts such as *Marsupella aquatica* and *Scapania undulata*. *Polytrichum commune* is also common in the carpets of liverworts in the river sections were the sedimentation is large.

Macrophytes were investigated in 1974 after the RSK-regulation was established. 14 water living species and a lot of helophytes were recorded (Rørslett and Skulberg 1975). It was established that Suldalslågen was poor in species and had sparing vegetation where *Callitriche hamulata* and *Juncus supinus* was the dominating species in the submersed vegetation. This is almost the same situation in 2000. In 1988 the two species covered 3.1% of the river bottom where *Callitriche hamulata* formed almost 3% alone. In 2000 corresponding values of total cover was 3.4% where *Callitriche* formed about 2,5% and *Juncus* 0,9%. In the period 1988-2000 *Juncus supinus* has increased a little while *Callitriche hamulata* has showed fluctuating occurrence. The full list is shown in Annex 7.

Impacts

Mosses

Before the RSK-regulation (1960-1962) both *Fontinalis dalecarlica* and *Marsupella emarginata* were common on stone substrate and several locations had dense moss vegetation (Lillehammer 1964). In 1974 the same situation was described (Rørslett 1975), but for the period 1981-1986 a total of 10 species were recorded and it was stated; “It seems to be an increased occurrence of mosses in Suldalslågen” (Skulberg 1986). In 1988 the moss community was quantified according to per cent cover of the river bottom for the first time. 64% of the river bottom was covered; 26% with *Fontinalis* and 38% with liverworts (Rørslett et al. 1989). In 2000 corresponding values are 81%; 21% with *Fontinalis* and 60% with liverworts. Quantitatively it has become more moss vegetation in Suldalslågen after the regulation impact. The reasons for this are strongly reduced frequency of large floods, increased winter low flows, less ice cover and by that no ice jam events.

Macrophytes

Different locations analyst and different purposes of the investigations probably cause a decrease in number of species from 1974 to 2000. It is no evidence that the species composition has changed after the regulation impact. Quantitatively it has probably occurred a slight increase in the amount of both *Callitriche* and *Juncus,* mainly due to formation of a better substrate for these species caused by reduced flow and increased sedimentation.

6.1.4 Benthic invertebrate fauna

Composition and abundance

Study periods

Studies of benthic invertebrate fauna have been carried out in the following periods:

Prior to regulation: 1961-1962

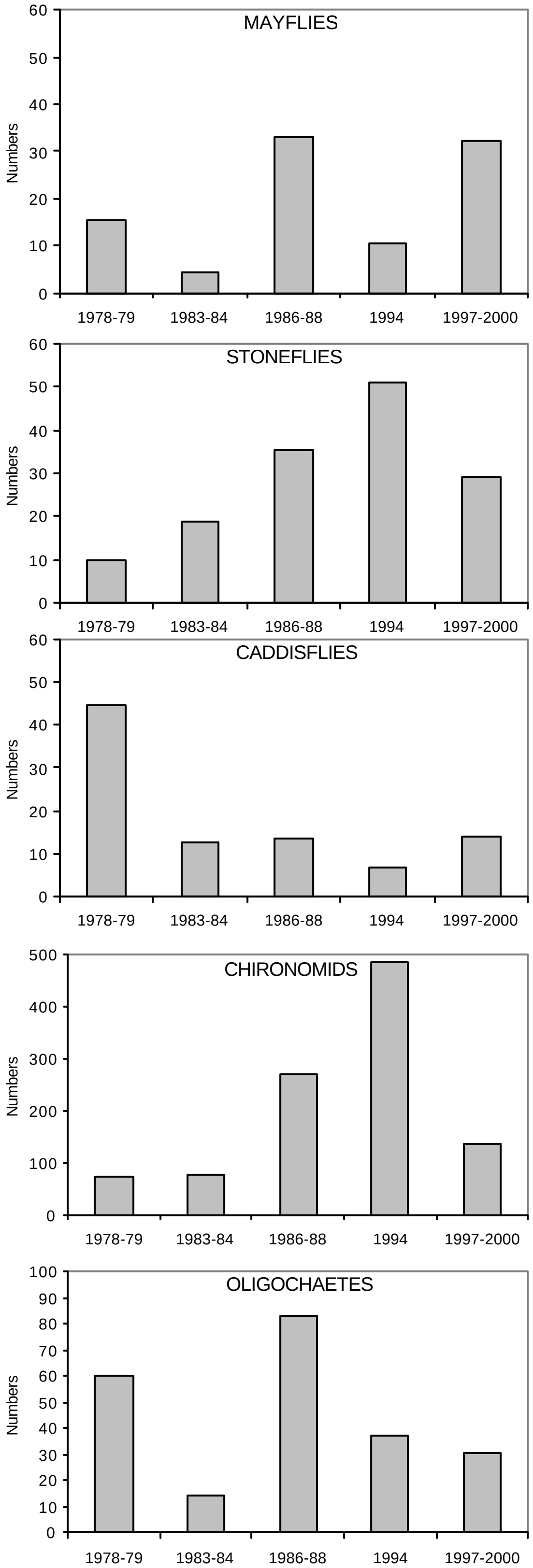
After regulation (Røldal-Suldal scheme only in operation): 1978-1979

After regulation (present system): 1983-1984; 1986-1988; 1992-1994; 1997 - 2001

General

The benthic macro invertebrate fauna is dominated by chironomids, mayflies, stoneflies, caddisflies and oligochaetes (Box 8). The most abundant group is chironomids. The density is high during autumn, winter and spring, and low during summer. Full list of species is given in Annex 8.

Box 8 Density of different invertebrate taxa during dfferent periods in Suldalslågen.



Mean density of stoneflies increased from 1978 to 1994. Fourteen species of stoneflies have been recorded from the river. The three most common species are *Amphinemura borealis*, *A. sulcicollis, Diura nanseni* and *Leuctra fusca*. Except for *Capnia atra*, recorded only in 1983-84 as rare, and *Taenipteryx nebulosa*, not found in 1978-79, all the species have been recorded during the whole study period.

Seven mayfly species have been recorded. The species *Baëtis rhodani* dominates and was abundant except for in 1983-84, when it was rare. *Ephemerella aurivilli* is common and has also been recorded throughout the study period. The other species are rare and occurs occasionally.

At least 15 species of caddisflies has been recorded from the river. However, only a few of these are abundant. The most abundant species, *Polycentropus flavomaculatus,* is only recognised as abundant in the upper part close to the outlet from the lake Suldalsvatn.

Two species of Coleoptera occurs occasionally in the river. The chironomid fauna is the most species abundant, with a total of 33 species. Only one gastropod species are present, being rare, but are found at every sampling occasion. The oligochaets consist of 10 species, of which three species are recognised as abundant.

Impacts

Regulation effects

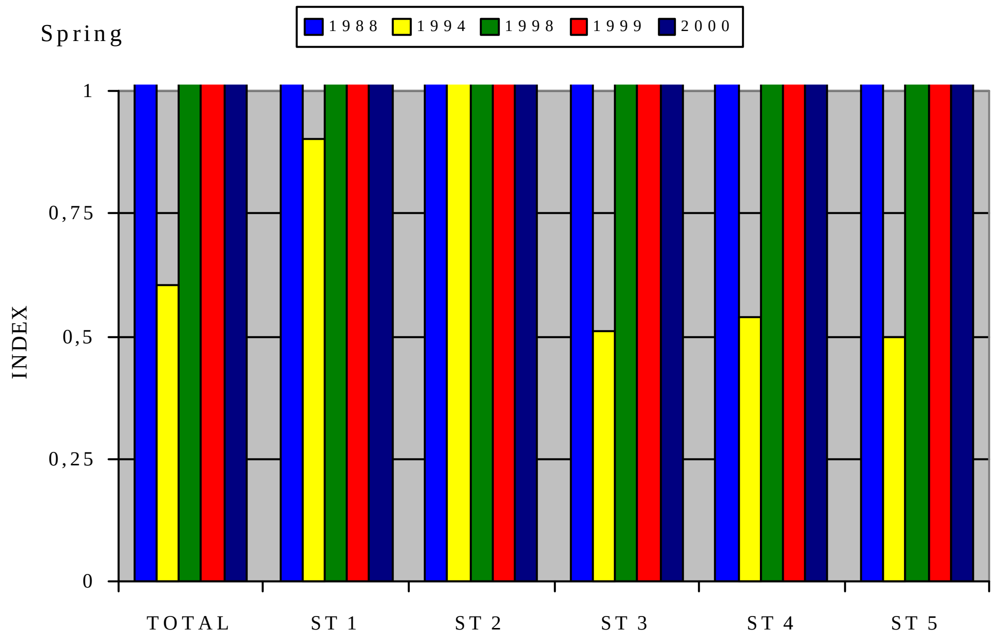
Invertebrate density declined in 1983-1984 compared to 1961-1962. This was mainly due a strong reduction in caddisflies, primarily of the filter feeding *P. flavomaculatus*. Main reason was lack of drifting food from the Lake Suldalsvatn and clogging of the drift nets due to silting.

The abundance declined until 1984, but increased again in 1986 - 1988, but was low in 1994. Main reasons are silting and episodes with acid water.

Effect of aquatic moss

Two morphologically distinct moss communities are found in the River Suldalslågen. The liverwort community consists of species, which form a dense mat on the bottom, while the river moss (*Fontinalis*) community forms long tufts. Moss growth has increased after the hydropower regulations due to reduced floods and increased winter low flows, see chpt 6.1.3. Increased moss cover affects the bottom structure, as well as intra-gravel and near-bottom hydraulics. Chironomids dominated the fauna found in moss. Simulids and stoneflies were negatively effected, while some oligochate families had a preferance to moss. This was also the case for mayflies, but only for river moss.

Box 9 Acidification index for different stations and years in Suldalslågen



Effects from acid water

The area is generally vulnerable to acidification, especially through sea salt deposition episodes. The regulation has increased the risk for acidification problems as more acidic water has been transferred to the catchment from more exposed areas to the south. In addition, the power plant shunt from Lake Suldalsvatn to the sea has reduced river flow and increased the contribution from the more acidic catchments below dam and the severity of sea salt episodes.

Level of acidification is estimated using an index described by Kroglund *et al* (1994); 0.5 + D/S. D = is number of individuals of less acid tolerant mayflies; S is number of individuals of acid tolerant stoneflies. Used mayfly indicator species are: *Baëtis rhodani* and *Ephemerella aurivillii*, while the stonefly used are: *Amphinemura borealis*, *A. sulcicollis*, *Protonemura meyeri*, *Nemoura cinerea*, *Taeniopteryx nebulosa*, *Brachyptera risi*, *Leuctra hippopus* og *L. niger*. Maximum value is 1, indicating little or no acidification. Index values for different years are given in Box 9. Stations are numbered from the dam and downstream. Low values in 1994 are due to a sea salt episode. Besides that the river is not negatively impacted due to acid water based on this index.

6.1.5 Fish fauna

Composition, abundance and age structure

Studies of fish fauna composition, abundance and age structure have been carried out in the following periods:

Prior to regulation: none

After regulation (Røldal-Suldal scheme only): 1976 - 1980

After regulation (present system): 1980 - 2000

Composition

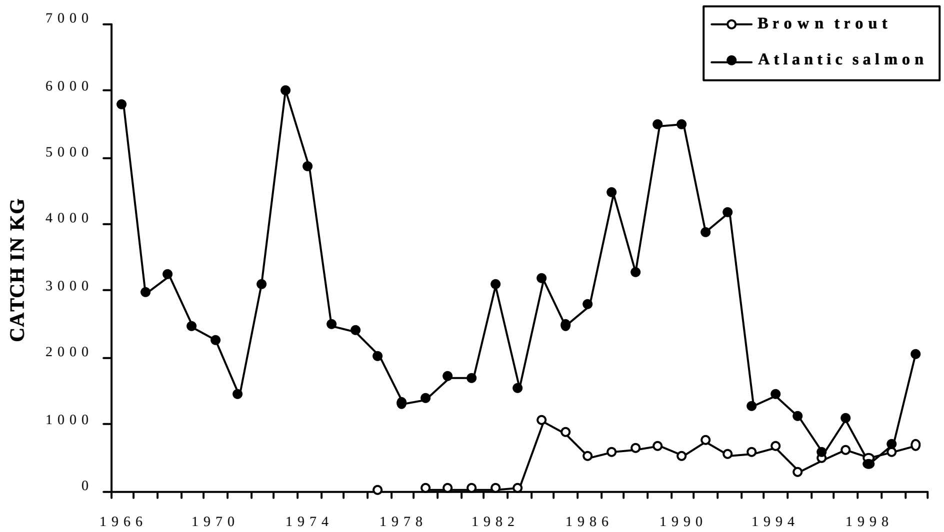
The dominant fish species are Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*). In addition occur three spined sticklebacks (*Gasterosteus aculeatus*) and eel (*Anguilla anguilla*). River Suldalslågen below the Suldalsosen dam produces anadromous fish along its entire length. In Lake Suldalsvatn brown trout and Arctic charr (*Salvelinus alpinus*) are found.

Abundance

Adult Atlantic salmon and brown trout

The Atlantic salmon is under heavy pressure in Western Norway, and as a general rule the abundance and catches in most rivers have declined dramatically over the last decades. The pressures and threats in freshwater stems mainly from river regulation and other physical alterations, acidification and *Gyrodactylus salaris* infestations. Threats in the marine environment are related to salmon lice (to a large extend with origin in fish farms) infections on migrating smolt, and fishing/predation pressure. Ocean temperature variations is another possible influencing factor. Genetic effects through interbreeding with escaped farmed salmon is another matter for concern. The relative importance of the different pressures, regionally and for the individual river (and salmon strain) is still not fully understood (NOU 1999).

Box 10 Fish catches in Suldalslågen

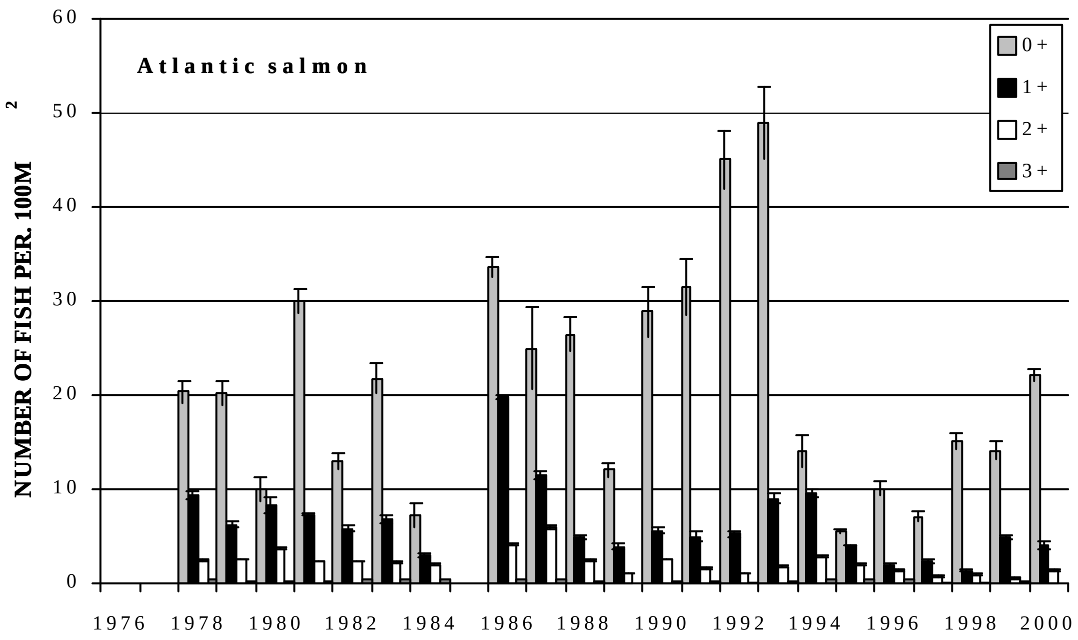


In Box 10 abundance of Atlantic salmon and sea trout is given as catches in kg since 1966. Rather large variations are seen. After the regulation in 1980 there is a gradually increase in catches of salmon. However, in 1993 the catch drops dramatically and it is still on a historically low level. Sægrov (1996) attributes the reduction of spawners primarily to factors in the marine environment. The separate reporting of brown trout (sea trout) catches was started in 1977, but evidently the reporting has not been active in the years up to 1984.

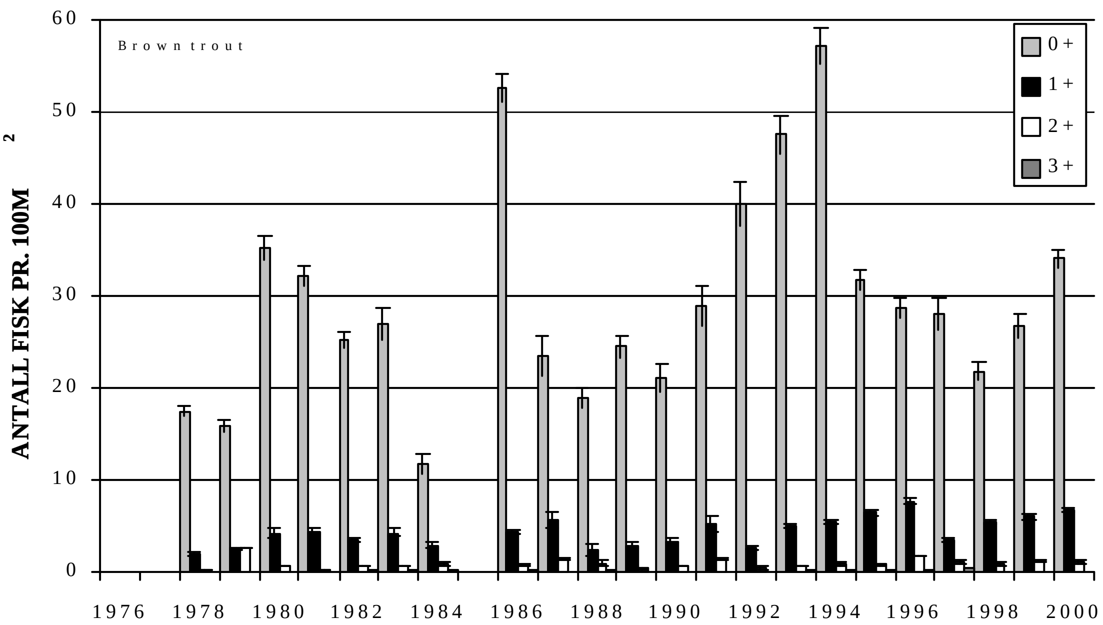
Juvenile Atlantic salmon and brown trout

Mean density (based on 16 localities) of different year classes of juvenile Atlantic salmon and brown trout given as numbers pr. 100 m^2 is shown in Boxes 11 and 12. Four year classes of salmon are found in the river (Saltveit 2000). Young of year (YoY) are the most abundant year class. Except for in 1986 and 1987, the density of 1+ parr never exceeds 10 ind. pr 100 m^2. The two other year classes show low densities. A dramatic decrease in fish density is seen from 1994, corresponding to the decline in the spawning population from 1993 (see Box 10).

Box 11 Density of juvenile Atlantic salmon in Suldalslågen

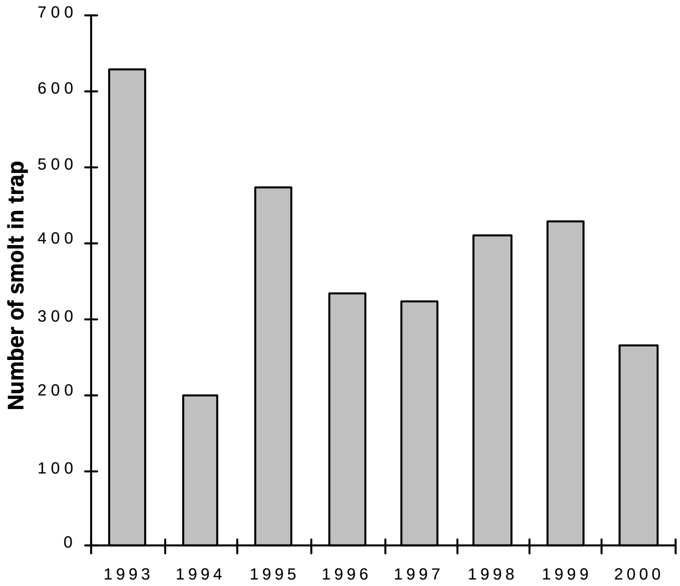


Box 12 Density of juvenile brown trout in Suldalslågen



Normally three year classes of brown trout are found in Suldalslågen (Box 12) (Saltveit 2000). This is due to faster growth. YoY is far the most abundant year class in the river.

Box 13 Number of Atlantic Salmon smolt caught in migration trap

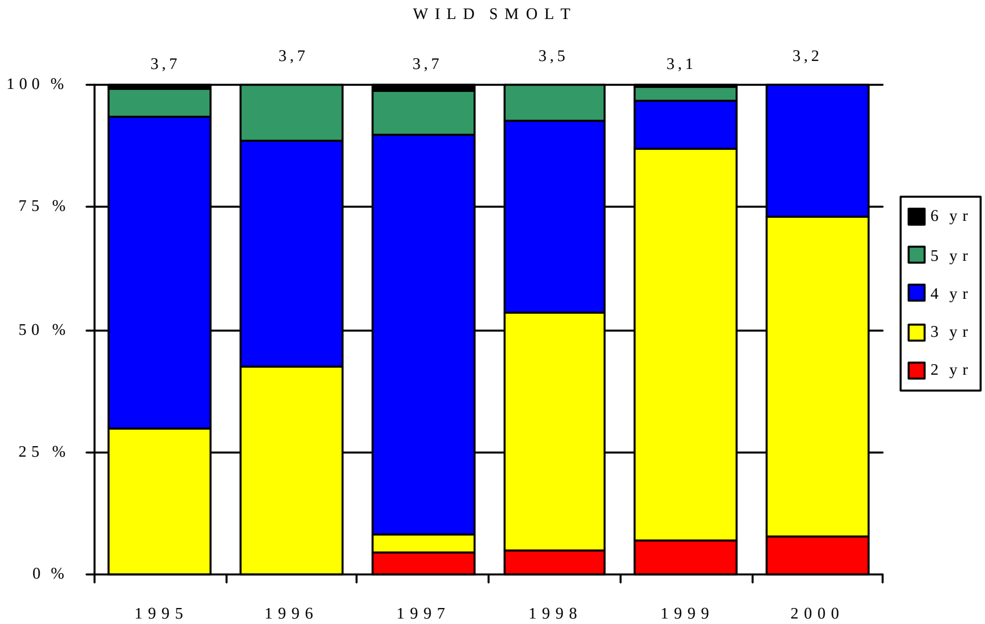


The other year classes appear in small numbers and never exceeds 10 ind pr. 100 m^2. The same strong decrease in YoY density seen in salmon after 1994 is not apparent in trout, indicating a factor specific to salmon. However, for both species there is a strong reduction in density from YoY to 1+ parr, indicating a high mortality. The reason are probably low water temperature during spring/early summer and lack of suitable habitats during winter and spring at low flow, due to sand and carpets of liverworts.

Smolt of Atlantic salmon

Data on smolt exist only from 1993 (Saltveit 1998b). Number of Atlantic salmon smolt caught in the migration trap in Suldalslågen is given in Box 13. Based on capture and recapture method, the total number of wild smolt leaving the river has for 1999 and 2000 been estimated to respectively 32700 and 31500 individuals (Saltveit unpubl. results). Normally three year classes of smolt are found, however, since 1997 there has been a reduction in older (4-6 year) smolt and an increase in two year old smolt. This has lead to a decrease in smolt age from 3.7 to 3.2 years (Box 14). This is due to a better growth in juvenile, caused by lower fish density (reduced competition).

Box 14 Smolt age distribution in Suldalslågen



Impacts

Regulation effects

Water temperature

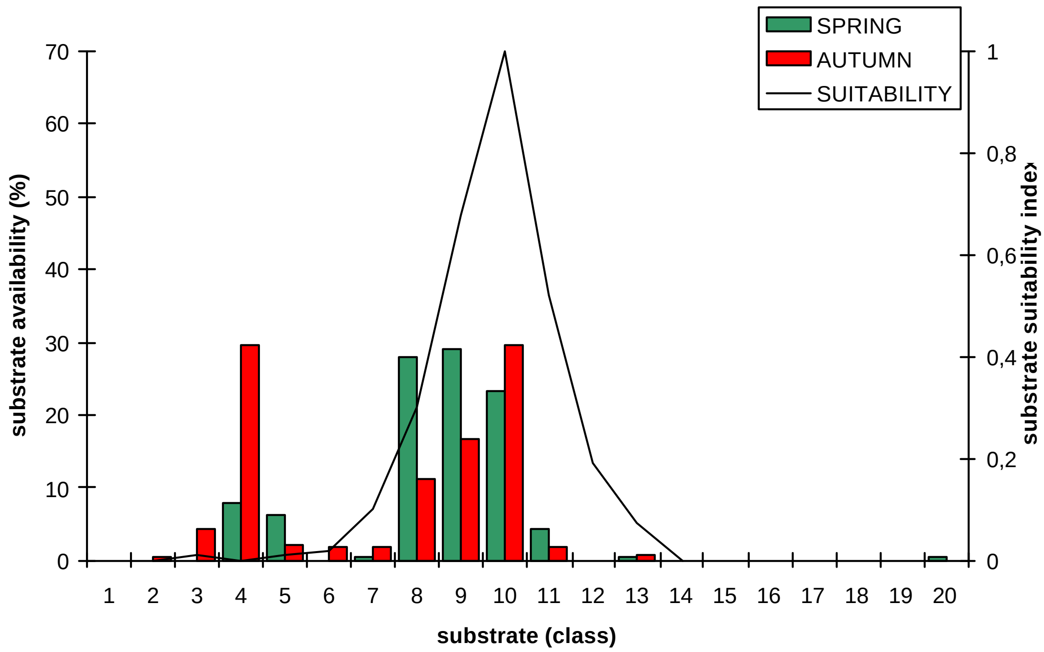
In winter temperature conditions are similar to the conditions found in the unregulated river. During summer there has been a decline in water temperature corresponding to approximately 100 day-degrees. A decline in fish growth was expected - however, due to lower fish density and reduced competition, fish growth has increased (Saltveit 2000).

Changes in flow regime

Compared to the natural conditions, river flow is reduced, especially during spring and summer. Historically high floods are never occurring. During the period 1980 to 1985 events with rapid flow reduction led to stranding of fish. A new operation strategy has eliminated this. Generally, the season flow pattern resembles the natural flow. Hylen power plant is not operated during June and July to keep summer flows up and to avoid luring returning salmon into the wrong fjord branch.

Lower flow - especially the absence of large floods - has led to increase in moss growth (see below) and probably to a higher accumulation of gravel and sand in the river, which has impaired the fish habitat (see below).

Box 15 Distribution of substrate classes and their suitability to salmon parr



Increased growth of aquatic mosses

As mentioned earlier in this chapter, moss growth has increased after the hydropower regulations, probably due to reduced floods and increased winter low flows (Rørslett *et al.*, 1989). Increased moss cover affects the bottom structure, as well as intra-gravel and near-bottom hydraulics. Moss may have both a direct and an indirect impact on fish, affecting both habitat and food quality and food availability (Bremnes and Saltveit 1997, Heggenes and Saltveit, 2002). Areas with dense mats of liverworts held lower densities of salmon parr than areas where the moss had been removed. No differences in densities of 0+ salmon were found between areas with and without *Fontinalis*. No major differences were found with regard to microhabitat selection between areas with and without river moss, suggesting that habitat quality in these areas was similar during summer. It is concluded that the increase in liverworts in the River Suldalslågen has a negative impact on fish density.

Habitat changes

Atlantic salmon prefer to stay close to the stony bottom, and seldom uses areas with substrate smaller than 1 to 2 cm (substrate class 6-7; Box 15) (Karlström 1977, Heggenes 1990). Coarse substrate creates cavities and shelter, and is especially important to smaller fish in winter (Heggenes *et al.* 1993). The figure indicates that a large amount of habitat both at high (summer) and low (winter/spring) flow in Suldalslågen consist of substrate not preferred by salmon (around 40%). As coarse substrate may be lacking, depth will be the preferred habitat during winter. However, also habitat with suitable depth is limited during winter at low flow, as approximately 50% of available depth is shallower than 50 cm, while 85% of the fish uses depth deeper than 50 cm. A limited suitable winter habitat may therefore be a main reason for high mortality during the first year of life. However, the habitat conditions during summer may also be a limiting factor to salmon production, as a large part of it consist of non preferred substrate.

Management strategies such as stocking and fish ladders

Fish stocking is practised in Suldalslågen to mitigate anthropogenic impacts on fish reproduction or to increase fish production and yield. The ecological consequences from stocking are complex, see for instance Einum & Fleming (2001). Withdrawal of hatchery fish (Norwegian legislation requires that these are taken from the local population) can negatively effect natural recruitment when spawners are in deficit (Saltveit, 1998a). Fish stocking in Suldalslågen produce the same number of smolt as natural recruitment, however, only around 5% of the catches of adult fish are from the stocking. Therefore, stocking seems to impose a negative effect on the salmon population in this river.

Acid water

Water quality has changed due to transfer of more acidic water with low alkalinity from neighbour catchments to the south. In addition to the regional acidification, this has led to a general process of acidification with steadily decline in pH and alkalinity (Blakar 1996). Reduced river flow also increase the relative importance of water from acidic tributaries below the dam, especially in the lower part. As the fish population was in the danger of being affected, the river has been limed since 1998. However, no clear negative effects from acid water are seen on the fish populations within the river (Saltveit 2000). The decline in Atlantic juvenile fish density since 1993 is probably mainly related to lack of spawners - to a large degree caused by factors in the ocean, and increased mortality caused by habitat changes, as described above.

6.2 Physico-Chemical Elements

6.2.1 Thermal conditions

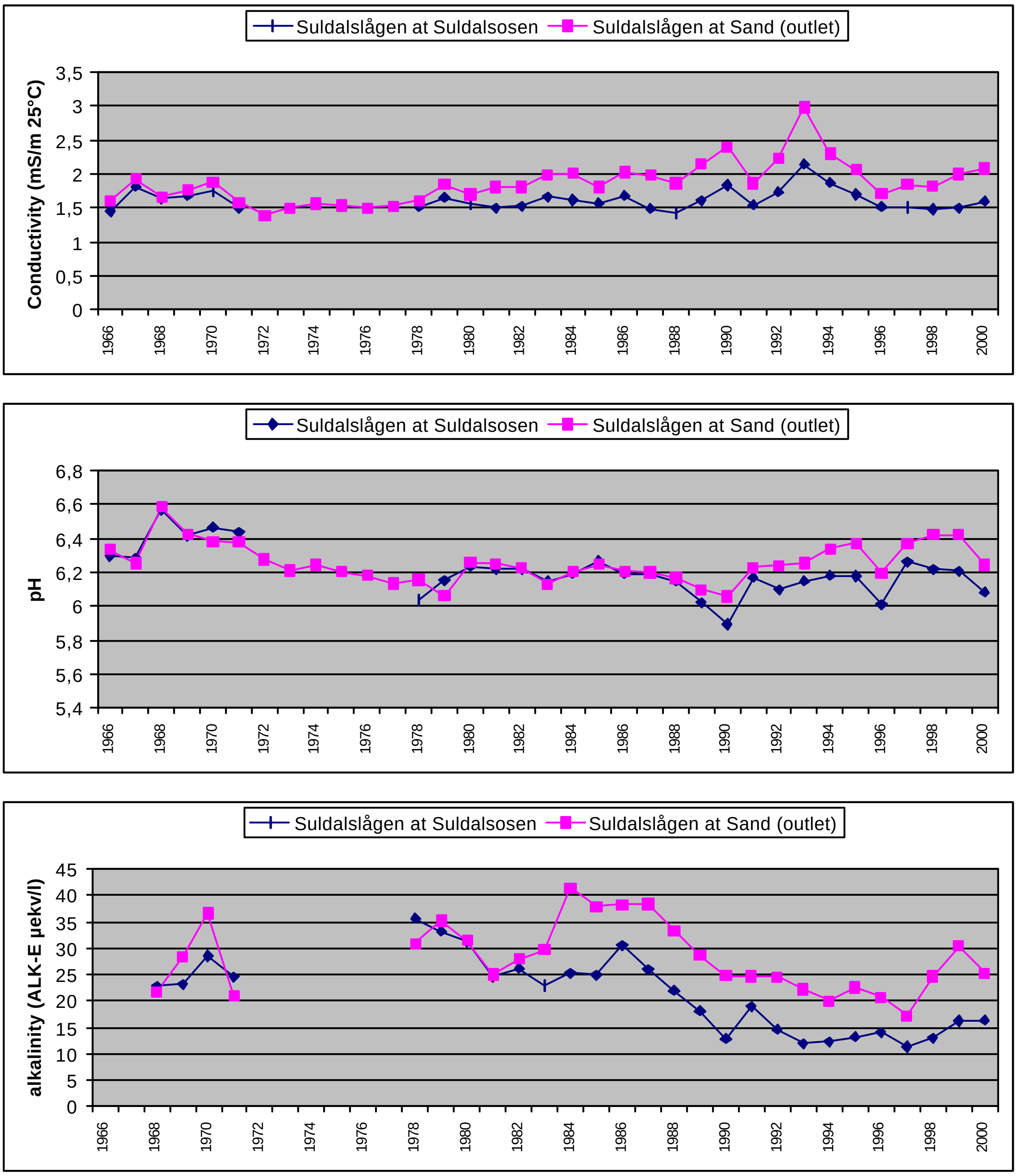
Suldalslågen is a summer-cold river with max temperature 10-12 °C in August. The temperature increased during the winter after the RSK-regulation due to increased waterflow in the winter period. The summer temperature also increased, but this was a response to climatic effects. Today, after the Ulla-Førre regulation, water temperature in winter is similar to the conditions found in the unregulated river. During summer in the growth period May – October there has been a decline in water temperature corresponding to approximately 100 day degrees.

6.2.2 Chemical Elements

The chemical water quality of Suldalslågen is summarised in Annex 9 and Box 16. Suldalslågen has generally a clear (not humified), slightly acid, ionic- and nutrient-poor water with low buffering capacity. The river has been partly limed with a doser at Suldalsosen (outlet of Suldalsvatn) since 1986 and full limed since 1998 with several dosers supplied with terrestrial and lake liming in the unregulated local catchment.

The RSK-regulation did not change the water quality in Suldalslågen, but we can see the effect of the general acidification in this region in the period 1970-1980 as a decline in pH values. After the Ulla-Førre regulation (from 1981) the water from the local catchment has become more important to the water quality in Suldalslågen. A general increase in conductivity has become a normal situation in Suldalslågen at Sand compared to outlet Suldalsvatn. After the water in the reservoir Blåsjø has been transferred to Lake Suldalsvatn (from 1986), the alkalinity has declined gradually in Suldalslågen at Suldalsosen to a level <15µekv/l. Today the most critical period for the water quality in Suldalslågen is the period in winter with low discharge from the dam. Large transfers from Lake Blåsjø and episodes with much precipitation in the local catchment in this period can cause bad conditions for the biology in the river. From 1998 liming shall compensate for this situation.

Box 16 Annual mean values of Conductivity, pH and alkalinity in Suldalslågen at Suldalsosen (the outlet of Lake Suldalsvatn) and Suldalslågen at Sand (the outlet into the sea) in the period 1966-2000.



6.2.3 Nutrients

Nutrient elements have been measured in Suldalslågen sporadically in the period 1981-1988 and more systematically since 1990. Generally low levels of both nitrogen and phosphorus has been measured in the period 1990-1999. Total phosphorus has varied between 1 and 13 µgP/l with an average of 3,2 µgP/l, the PO_4-phosphorus has varied between <0,5 and 2,4 µgP/l with an average of 0,7 µgP/l. Total nitrogen has varied between 178 and 389 µgN/l (average 241 µgN/l) while NO_3 has varied between 128 and 350 µgN/l (average 187 µgN/l). There is no evidence that Suldalslågen has become richer in nutrients since the regulation impact even if the recipient capacity has been reduced.

6.2.4 Specific synthetic pollutants

Specific synthetic pollutants have been measured in Suldalslågen since 1990. Examples of measured concentrations of Lindane and PCBs are given in Annex 10. In the whole period of measurements it has only been measured very low concentrations. The observations are from river water only, not from biota or sediments. No data exists from before the regulation impact.

6.2.5 Specific non synthetic pollutants

Specific non-synthetic pollutants have been measured in Suldalslågen since 1990. Examples of measured concentrations of heavy metals are given in Table 2. In the whole period of measurements only very low concentrations have been observed. The observations are from river water only, not from biota or sediments. No data exists from before the regulation impact.

Table 2 Measured concentrations of heavy metals in Suldalslågen in 1998

Date	Cu µg/l	Zn µg/l	Cd µg/l	Pb µg/l	Ni µg/l	Hg ng/l	As µg/l	Cr-T µg/l
980217	0,3	1,9	0,01	0,12	0,3	1,5		
980615	0,2	1,3	0,01	0,05	<0,2	<1,0		
980810	0,3	1,2	0,01	0,06	<0,2	<1,0		
981021	0,4	1,9	0,01	0,14	0,2	<1,0	<0,1	<0,5

6.3 Definition of Current Ecological status

In the following table we have summarised our definitions for current ecological status based on the different elements. All classifications are based on expert judgement.

Biological quality elements

Element	Status	Comments
Phytoplankton	High	
Phytobenthos	Moderate	Significant changes in balances between species - filamentous green algae has gained on the cost of other species, mainly due to moss cover changes. No species lost.
Macrophytes	Moderate	Main disturbance is moss cover changes. Liverwort cover seems to at least have doubled.
Benthic invertebrate fauna	Moderate	Affected by moss cover changes. Increase of Chironomids, reduction of stoneflies and caddisflies. No species loss recorded.
Fish fauna	Poor	Collapse of Atlantic salmon population in early nineties (population reduced to less than half the pre-regulation level) - habitat changes due to increase in moss cover and siltation are probably major causes on the freshwater side. Survival may be threatened in the long run.

Hydromorphological quality elements

Element	Status	Comments
Hydrological regime	Poor	Does not support good ecological status - reduction in variability, especially flood regimes has resulted in increased moss cover and adverse substrate changes.
River continuity	Poor (if dam is included in water body)	Dam acts as migration obstacle.
Morphological conditions	Moderate	Substrate changes due to siltation.

Physico-chemical quality elements

Element	Status	Comments
General conditions	Good	Affected by acidification, mitigated by liming.
Specific synthetic pollutants	Good	Lindane detected, but in low concentrations.
Specific non synthetic pollutants	High	

6.4 Discussion and Conclusions

In general the lack of data from the period with natural conditions makes it difficult to estimate the effects caused by hydropower development. In addition a lot of changes during the last 40 years, not caused by hydropower development, have affected the natural conditions in the river systems. Even in this thoroughly investigated river, data and knowledge from unregulated reference catchments are needed for the assessments. The Norwegian landscape is however very varied, both in topography, geology, and land use, and representative references sites are not easily found. One is left with a fair amount of expert judgement.

As there are no guidelines for distinction between "moderate" and "poor" classifications, it is felt that distinguishing between these classes are more difficult and the result is even more subjective than distinguishing between "good" and "moderate". The latter distinction is of course more critical operationally than the former one.

In the present case, there seems to have been no loss of species due to the influence of the physical alterations, but the abundance and balance between species have been altered. Whether this qualifies for a classification of the relevant biological quality hydromorphological elements as "moderate" or "poor" ecological status is not evident to the project group, but loss of species is certainly a more severe impact than changes in abundance. It is our choice at this stage to define "poor" as loss of key species (or threat of loss species) and to use "moderate" for large changes in abundance. Further development of the criteria might change this.

The water body is not in a stable condition, it is in a transitional state due to the changes in the hydrological regime caused by river regulation. The classification above refers to the present state of the water body, not a foreseen future stationary situation.

7 Identification and Designation of Water Bodies as Heavily Modified

The deviations from good ecological status are mainly caused by changes in the flow regime after the regulation. The strongly reduced frequency of large floods, and disappearance of ice jam events have given increased moss cover. The reduced floods has also reduced the transportation capacity for sand and fine sediments, while the local sources are at least as active as before the regulation. This has led to increased siltation in the river bed.

The increased moss cover and the changed substrate have affected the ecological status for benthic algae, invertebrates and fish. Disregarding oceanic pressures and possible effects of acidification, the changed moss cover and substrate is the main cause for reduced abundance of Atlantic salmon.

The dam at Suldalsosen is an obstacle to, but does not fully stop fish migration from the river to Lake Suldalsvatn.

7.1 Necessary Hydromorphological Changes to Achieve Good Ecological Status

The most effective mitigating action to restore good ecological status would be to reintroduce occasional large scouring floods, typically 500 m^3/s, with a frequency of approximately five years. The flood should last several (five) days to ensure that scoured material is washed out of the river. The capacity of the gate in the dam is approximately 200 m^3/s. A flood of 500 m^3/s can thus only be obtained by spilling 300 m^3/s over the dam and opening the gate. This is only viable during a heavy inflow event, especially if the flood is to last for a prolonged period. Hylen HPP probably would have to be stopped during the event.

To the extent that the dam area is part of the water body, fish migrating upstream should be improved by constructing fish passes.

7.2 Assessment of Other Environmental Options

A full restoration of the flow conditions in river reach to pre-regulation conditions would require additional releases of approximately 1350 mill m^3 per year. This would be bypassed the Hylen HPP, but also some redistribution of production in the high head hydropower plants in the system might be necessary. The lost energy production in Hylen would be approximately 220 GWh/yr (close to half the present production) with a first hand production value of approximately 4 mill EUR. The alternative environmental options will be to produce the energy production lost in other plants in the Scandinavian/North European Electricity production system, with its mixture of Hydropower, Thermal Power and Nuclear Power plants, or by new production facilities in the Norwegian system - hydropower, natural gas power plants or wind power plants. By the present situation in the system, a large part of the substitution will be through thermal power systems, or hydropower plants with larger environmental impacts than the Hylen scheme. Table 3 summaries this option.

Table 3 Mitigation: Naturalised flow

Assessing the significance of the impact on use(s)

Assessing the significance of the impact on use(s)	Actual use				Foreseen use with good ecological status				Comparison actual versus good ecological status				Assessment
	Use (quantity, quality)	Production	Turn over, income	Employment	Use (quantity, quality)	Production	Turn over, income	Employment	Use (quantity, quality)	Production	Turn over, income	Employment	
Hylen HPP	power prod.	500 GWH/yr	10 mill EUR			280 GWh/yr	6 mill EUR			- 220 GWh/yr	- 4 mill EUR		
Recreation	salmon fisheries	1500 kg/yr	0.7 mill EUR			3000 kg/yr	1.2 mill EUR			+1500 kg/yr	+ 500000 EUR/yr		Non-verified estimates
Flood reduction	Use of flood plain				Impaired use of flood plain/flood damage				Flood damages, changed use of flood plain		- 50000 EUR/yr		Non-verified guessestimates
Wider environment													
Significant impact on use(s) - Overall assessment													

Comparing existing modification with alternatives serving the same beneficial objectives

Environmental impact	Actual Use			Buy thermal			Buy wind power			Option 3			
	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	
Air	None			CO2 and NOx emissions			None						
Water	Reduced flow and floods			Naturalised flow and floods			Naturalised flow and floods						
Soil	None			None			None						
Landscape	Dam			Dam			Dam						
Environmental impact - Overall assessment													

Costs	Actual use	Buy thermal	Option 2	Option 3	
Investment costs					
Operation & Maintenance costs					
Possible foregone economic benefits					

Total annualised costs					

Table 4 Mitigation: Restored flood regime

Assessing the significance of the impact on use(s)

Assessing the significance of the impact on use(s)	**Actual use**				**Foreseen use with good ecological status**				**Comparison actual versus good ecological status**				**Assesment**
	Use (quantity, quality)	**Production**	**Turn over, income**	**Employment**	**Use (quantity, quality)**	**Production**	**Turn over, income**	**Employment**	**Use (quantity, quality)**	**Production**	**Turn over, income**	**Employment**	
Hylen HPP	power prod.	500 GWH/yr	10 mill EUR			496 GWh/yr	9.95 mill EUR/yr			- 4 GWh/yr	- 50000 EUR/yr		
Recreation	salmon fisheries	1500 kg/yr	0.7 mill EUR			3000 kg/yr	1 mill EUR				+500000 EUR/yr		Non-verified estimates
Flood reduction	Use of flood plain				Impaired use of flood plain/flood damage				Flood damages, changed use of flood plain		- 50000 EUR/yr		Non-verified guesstimates
Wider environment													
Significant impact on use(s) - Overall assessment													

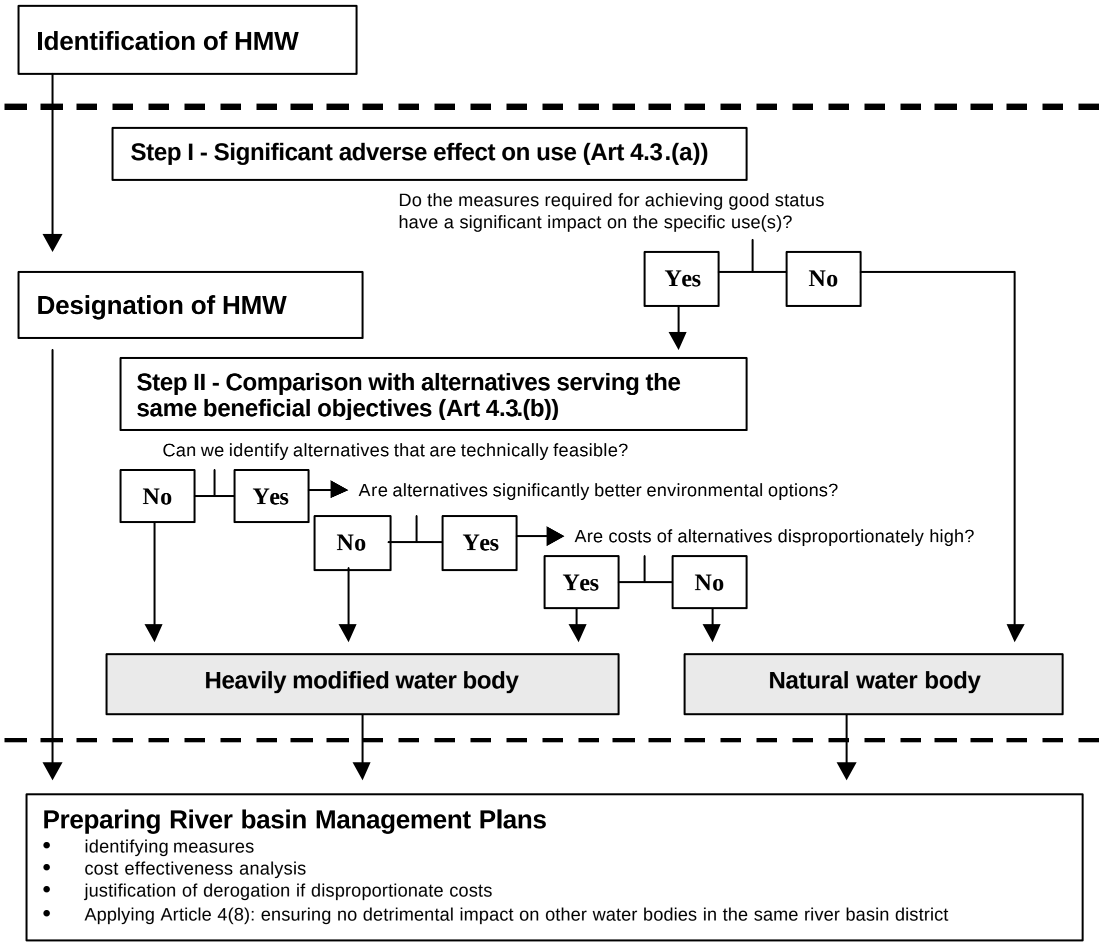
Comparing existing modification with alternatives serving the same beneficial objectives

Environmental impact	**Actual Use**			**Buy thermal**			**Buy "surplus" hydropower**			**Option 3**			
	Qualitative	**Physical**	**Monetary**	**Qualitative**	**Physical**	**Monetary**	**Qualitative**	**Physical**	**Monetary**	**Qualitative**	**Physical**	**Monetary**	
Air	None			CO2 and NOx emissions			None						
Water	Reduced flow and floods			Restored flood regime			Restored flood regime locally						
Soil	None			None			None						
Landscape	Dam			Dam			Dam						
Environmental impact - Overall assessment													

Costs	**Actual use**	**Buy thermal**	**Buy "surplus" hydropower**	**Option 3**	
Investment costs					
Operation & Maintenance costs					

Possible foregone economic benefits					
Total annualised costs					

Box 17 Flow chart of the designation process, from Strategy Paper no 8



However, as described above, the natural flow conditions are not necessarily required to give a hydrological regime consistent with good ecological status in the river reach. The establishment of a flood regime in better correspondence with the natural regime would probably suffice. The release of scouring floods every five years or so would require extra releases of in the order of 25 mill m^3/yr[1] if it is combined with high runoff events, and thus a moderate energy production loss (in the order of 4 GWh - equivalent to approximately 50 000 EUR in periods with high production in the Norwegian hydropower system). Moreover, this loss would occur in periods with high production in the west Norwegian hydropower system, and would probably be absorbed with marginal impacts in the energy system. Table 4 summarises this alternative.

Reintroduction of high floods in the river reach is not in correspondence with the present licenced operation rules for the system, and would probably not be welcomed by most riparian owners and users. The use of the flood plains have adapted to the regulated flood regime, and a new operation strategy would have impacts on the present land use. Floods higher than 300 m^3/s will result in damage in the flood plain areas. It would

[1] Calculated as an extra release of 300 m^3/s over five days every fifth year. Some water is expected to be spilled anyhow - this is set to 200 m^3/s

not be an environmentally friendly option to protect the present land use by extensive flood levee construction, so the present land use would have to change - at a cost. Another problem is that the present dam is not construced for passing large floods operationally, and may need some reconstruction.

7.3 Designation of Heavily Modified Water Bodies

The discussion above indicates that there exists mitigating action that would bring the water body back into good ecological status. We make the assumption for further discussion that this mitigating action can not be implemented due to practical (operational) constraints, and concern of other riparian user interests, and designate the reach as a Heavily Modified Water Body.

7.4 Discussion and Conclusions

A summary of the designation procedure as described in Box 17, and which is discussed in the preceding paragraphs, is given in Table 5.

The tentative conclusion of the discussion above is that option a) probably would be environmentally and economically unacceptable, and thus call for designation of the water body as heavily modified. Option b) could realistically be implemented. The open question that can not easily be answered within the present state of clarification of the concepts of the WFD is however:

- **Can a water body that has an ecosystem composition that is fairly close to the natural system be considered to have good ecological status when the flow is reduced by 50%?**

As this is a desktop study, it should not be inferred that the mitigating action proposed is necessary adequate. Practical tests would have to be carried out, including full scale test releases. This is not necessarily possible within the framework of the present operational rules, which limits the flood releases in Suldalslågen.

In this context, it should be noted that the expert's opinions on the reason for the decline in the salmon population differ. The main theories are:

1. Habitat changes in the river due to river regulation;
2. Water quality changes in the river (especially due to transfers of water with different quality from the Ulla-Førre catchments, and by transferring the less acidified headwater inflow out of the lower part of the river through Hylen power plant);
3. Salmon lice infections on migrating smolt from fish farms in the outer fjord system;
4. Ocean water temperature variations.
5. Pressure from commercial fisheries in the ocean.

Table 5 Summary of Designation process for Suldalslågen

Question	Answer	Comment
Is the waterbody artificial?	No	
Is the waterbody substantially changed due to physical alterations by humans?	Yes	The hydropower regulation has substantially modified the river flow
Characterisation of significant impacts upon hydromorphology - is the good ecological status endangered?	Yes	The changed flow, especially the flood regime has altered siltation and water moss coverage - these constitute important habitat changes. The situation is non-stationary.
Water body designated provisionally as heavily modified		
What hydromorphological changes would be necessary for achieving good ecological status?		To options considered: a) full restoration of natural flow - b) restoration of flood regime
Would making these changes have a significant adverse effect on the specified uses?	Yes	Option a) would strongly reduce hydropower production, and worsen flood conditions. Option b) would somewhat reduce hydropower production, and worsen flood conditions.
Can the objectives be achieved by other means, which are a significantly better environmental option?	Not conclusive	Energy production lost by option a) would probably be substituted by other production forms that are less environmentally friendly. Energy production lost by option b) could probably be absorbed in existing hydropower system or substituted by for instance wind power. It is not clear whether restoration of the natural flood regime would be considered acceptable by riparian users. Extensive flood levee construction would be a less environmentally friendly solution.
Final designation not conclusive		

It is not unlikely that a combination of these effects is influencing the salmon population. However, lack of similarity in the trends in Atlantic salmon and anadromous brown trout catch and the juvenile density in the river indicate that different factors are affecting the two species.

The different possible causes would have very different outcomes when it comes to classification and mitigating activities directed towards fish fauna:

Habitat changes: Considered above.

Water quality changes, transfers into the system: As the transfer is served by Norway's largest reservoir, and constitutes the main inflow to two of the major hydropower plants (Saurdal and Kvilldal), it is not realistic even to consider a return to the pre-regulation situation. The possible impacts would have to be handled by mitigation, or would release classification as HMWB.

Water quality changes, transfers out of the system: This could in principle be adjusted by manipulating the operation of Hylen power plant, but is probably difficult due to the input of acidified water from Ulla-Førre. Local mitigating activities are already in effect through operation of liming operations. If this is a dominating effect, in spite of present liming, more attention need to be focused on extreme events like sea salt deposition episodes, and mitigation activities oriented towards such episodes.

Salmon lice infections: This is an interesting case - and possibly relevant for many river/fjord systems in Norway. In this case, the physical impact/alteration (the fish farm) is in the coastal waters - but not on hydromorphological elements, and affects a parameter (fish) that is not addressed for coastal waters, but is relevant for the river system, as anadromous species is affected. The river system could in principle be classified as Heavily Modified due to a modification in the coastal waters. Mitigating activities would have to be directed towards the fish farms.

Before the start-up of the Hylen power station in 1980, Hylsfjorden was ice-covered at least part of the winter months. In cold winters the whole fjord system was ice-covered, hampering the boat traffic for months. The strong inflow of fresh water from Hylen power station has initiated a mixing process in the inner part of the fjord, bringing salt and warm fjord water up to the surface. This mixed water does not freeze easily and the effect is that the inner part of Hylsfjorden now stays ice-free (Hansen and Asvall, 1985).

During the eighties fish farming took advantage of this new situation and was established in Hylsfjorden. Thus there there may be an indirect chain of impact from the regulation to salmon lice problem, through the changed ice conditions, which have given more favourable conditions for fish farming.

Ocean water temperature: If this is the main cause, the population variations would be natural, and not cause for action.

Pressure from fisheries: If the fisheries are inside the waters covered by the WFD, the pressure should be addressed by the management plans. If they are outside, the issue would have to be lifted to another administration and management level.

It should however be noted that the deviation of the status of the river from "good ecological status" is also (at least in principle) released by the deviations in the macrophyte and benthic invertebrate fauna parameters. But it is an intriguing question whether these deviations would have been serious enough to downgrade from good ecological status if the fish fauna status was "good".

When it comes to hydropower schemes, assessment of other environmental options is always difficult. For a single water body, moderate increases of releases can often be absorbed in the hydropower production system with moderate environmental costs, especially when it comes to high flow releases as in this case. Aggregation of many such mitigating actions in the system would however release the need for new energy production facilities, if it is not compensated with reduced releases in other hydropower plants where the environmental consequences would be less. To assess the resulting overall environmental "balance account" of such adjustment is extremely complex.

8 Definition of Maximum Ecological Potential

No attempt on defining Maximum Ecological Potential (MEP) boundary values for individual quality elements has been carried out at this stage.

8.1 Actual status

Apart from the hydropower regulation, the water body is not much affected by anthropogenic activities, and does therefore not deviate much from Maximum Ecological Potential (MEP), except minor impacts from acid rain/liming. An expert judgment based assessment on the actual status is given in Table 6. No attempt on defining MEP for individual quality elements has been carried out at this stage. A tentative comparison with the Norwegian Environmental Quality Standards for Biodiversity and Nature Conservation (SFT 1997) is given in Table 7.

Table 6 Ecological potential - actual status in water body

Element	Current status
Biological quality elements	The deviations from maximum ecological status are caused by the artificial modification ➢ Maximum ecological potential[2]
Hydromorphological elements	Upstream migration past dam restricted. Reduced breeding and spawning grounds due to increased moss coverage and siltation - again a result of changed flood regime. ➢ Good ecological potential/moderate ecological potential
Physicochemical elements	
General conditions	Physiochemical elements: pH deviated from natural conditions - to a large extent compensated by liming. Other physiochemical elements in accordance with natural conditions. Nutrients in accordance with natural conditions. Temperature: some deviations from undisturbed conditions, especially summer temperature. ➢ Good ecological potential
Specific synthetic pollutants	Lindane detected, PCB below detection level. Only water investigated, not sediments or biota. ➢ Good ecological potential
Specific non synthetic pollutants	Only observations of metals. Only water investigated, not sediments or biota. Metals in accordance with natural levels.

[2] This is according to a strict interpretation of the wording in the WFD, and is under the condition that no other effect than river regulation is affecting the Atlantic Salmon in Suldalslågen. Such other impacts would reduce the classification to good or moderate.

	➢ Good ecological potential

Table 7 Suldalslågen classification, Norwegian Environmental Quality Standards for Biodiversity and Nature Conservation

Parameter	Norm "Suited"	Comment
Water quality		
Suspended matter	< 1.3 x nat. cond	Within
Phosphorous	< 1.3 x nat. cond	Probably within
Algae concentration	< 1.3 x nat. cond	Probably within
Nature conservation		
Flow regime	90 -110% of nat.	Outside
Channelisation	none	Within
Levees and embankments	< 100 m	Probably outside, but not a prominent feature
Riparian vegetation, length	>90% of nat.	Probably outside
Riparian vegetation, depth	>50% of nat	Outside, due to agricultural use of flood plains
River bed mining	<5%	Within

9 Definition of Good Ecological Potential

No attempt on defining Good Ecological Potential (GEP) boundary values for individual quality elements has been carried out at this stage. The present common understanding of this concept is not good enough to allow establishment of such definitions. A few illustrations is given in Chapter 9.2.

9.1 Mitigating measures needed to obtain GEP and MEP

By the present mitigating activities in the water body (releases at Suldalsosen Dam, operation strategy of the Hylen power plant, liming operations), most characterisation elements are at good or maximum ecological potential, with the possible exception of hydromorphological elements and temperature.

Using an adapted version of the "Swedish template", Table 8 indicates mitigating measures necessary to obtain Maximum Ecological Potential and Good Ecological Potential.

Table 8 Mitigating activities necessary to obtain Maximum Ecological Potential and Good Ecological Potential

Measure	Target area	MEP	GEP
Water flow and water-level fluctuations			
Restoring flood regime		(✓)	(✓)
Decreasing flow during summer to winter			
Introduce minimum flows	Downstream dams		
Habitat improvements			
Terrace tributary outlets	Reservoirs	n.a.	n.a.
Reduce erosion in riparian zone			
Reduce erosion in tributaries		✓	
Instream habitat improvement	River	✓	✓
Seed and plant species			
Organism and nutrient transport			
Build fish passages	Dams	✓	(✓)
Co-ordinated spillway releases	Multiple dams	n.a.	n.a
Remove dam	Dams		
Reduce nutrient content in effluents			

9.2 Discussion and Conclusions

It is unclear from the WFD and the discussion papers what the acceptable changes to the ecosystem in a Heavily Modified Water Body or Artificial Water Body are. In Suldalslågen, a suite of mitigating measures are already in force, and although the abundance and balance of many species has changed, the species composition of the ecosystems seem to be fairly close to the natural. There are breeding grounds and spawning grounds available, although the areas of these have been reduced through siltation and extension of the areas covered with liverworts, and also to some extent by reduced flow. Possibilities for fish passage past the dam has been reduced, but the dam is not a total barrier to fish migrating upstream. On the other hand, the former breeding and spawing grounds in the rivers higher up in the catchment (outside the water body discussed here) has to a large degree been destroyed, so the building of fish passages will not improve the anadromous fish population. Whether this situation could be identified as conforming to GEP or not, is not imminently evident.

What seems fairly clear, is that the water body is in a transitional state to a situation where spreading of liverworts and siltation in the long run could endanger the local Atlantic salmon population. Even if the river could be restocked in the future, it is felt that this is a situation not conforming with GEP. To avoid such development, habitat improvements - either through mechanical methods or through restoring the flood regime - would be called for.

10 Conclusions, Options and Recommendations

The designation process for the water body in question is to some extent inconclusive. The ecological impacts are mainly caused by the changed flow regime. A full restoration of the natural regime could be considered unrealistic due to disproportionate costs and also a difficult environmental payoff - local improvements vs substitution of CO_2-free energy production with less environmentally friendly production. This would call for designation as Heavily Modified. On the other hand, it may be possible to mitigate the adverse effects by restoring parts of the flood regime, an option that gives far less energy production loss. It is however unclear whether a 50% reduction of the flow can be considered to be reconcilable with a Good Ecological Status, even if the ecosystems are generally consistent with natural conditions.

If the water body is designated as Heavily Modified, it is not evident whether it can be considered to possess Good Ecological Potential in the present regime of compensating flows - especially as it is in a transitional state that could endanger key species as Atlantic Salmon in the long run.

A number of unsolved problems and questions have risen during the project. Some central ones are listed below:

1. In many cases it will not be easy to separate biological effects of physical alterations from other impacts like acidification, land use changes, and - for anadromous species - pressures in the ocean.
2. Most Norwegian reservoirs are dammed or tapped natural lakes. On what degree of regulation does it pass from being a modified to an artificial water body?
3. Are changes in flow regime relevant to classification of ecological status and - in particular - ecological potential if the ecosystem composition remains close to the natural?
4. In the present case, there seems to have been no loss of species due to the influence of the physical alterations, but the abundance and balance between species have been altered. Whether this qualifies for a classification of the relevant biological quality hydromorphological elements as "good", "moderate" or "poor" ecological status is not self evident.
5. After a river regulation, the affected water bodies will be in a transitional state due to the changes in the hydrological and temperature regime for a long period. The ecological status is thus most likely also under change.
6. Definition of good ecological potential will probably have more important economical and ecological consequences than the definition of good ecological status, but is very poorly specified when it come to ecosystem composition, population sizes, migration possibilities etc.
7. River regulation influences water temperature and ice conditions as well as flow regime. Maximum ecological potential does not allow for temperature deviations resulting from modification according to the wording under "Physiochemical elements", while hydromorphological changes are conditionally accepted (WFD

1.2.5). On the other hand, the wording under "Biological quality elements: " ... given the physical conditions which result from the artificial or heavily modified characteristics" could be interpreted as allowing for temperature changes - as water temperature is a physical condition. The significance of this inconsistency is unclear, but it could lead to the possibility that biological changes that could be acceptable within "good ecological potential" under flow regime changes could be rejected as unacceptable if caused by temperature changes.

8. Assessment of "other environmental options" is very difficult when it comes to hydropower, as the substitution could be from a wide range of sources: New hydropower (usually less environmentally friendly), thermal (CO_2 emissions), nuclear power (radiation hazards), wind, solar and bio energy. In most cases, restrictions of hydropower use will reduce the value of other energy sources, as hydropower is used for balancing load - from base load sources (thermal, nuclear) and from unpredictable sources (wind, solar). The economics and environmental impacts of these substitutions are very complex, and differs whether a scheme is considered isolated or in combination with others.

Recommendations

Classification of ecological status

At the present stage of development of ecological status characterisation, we have adhered to and recommend the following generic classification for biological quality elements:

- Good status: Species composition, abundance and balance close to undisturbed conditions.
- Moderate status: No loss of key species, but major deviations from abundance and balance under undisturbed conditions
- Poor status: Loss of key species or threat of loss of key species.

Classification of ecological potential

- Good ecological potential: No loss of key species.

Flow requirements

The Norwegian Water Resources Act contains general guidelines on minimum flow requirements, linked to low flow statistics for undisturbed conditions. These are not binding for modifications requiring concession. If flow requirements enter Good Ecological Potential definitions, it would be a natural starting point for Norway to explore whether this existing minimum flow requirement could be useful for defining GEP.

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Annexes

Annex 1 Monthly flows in river Suldalslågen at Suldalsosen and at Sand, natural conditions compared with regulated conditions

	Suldalsosen			Sand		
	Natural conditions (1905-64)	Regulated with RSK (1967-80)	Regulated with Ulla-Førre (1981-00)	Natural conditions Calculated	Regulated with RSK (1967-80)	Regulated with Ulla-Førre (1981-00)
	Mean (m³/s)	Mean (m³/s)	Mean (m³/s)	Mean (m³/s)	Mean (m³/s)	Mean (m³/s)
January	25,5	62,2	12,8	37,8	69,0	25,1
February	22,1	56,6	13,0	33,9	62,8	24,8
March	19,7	57,5	12,8	29,1	68,3	22,2
April	33,9	60,5	13,9	43,5	70,3	23,5
May	138,4	105,0	80,9	149,3	117,9	91,8
June	238,0	128,0	124,0	246,0	138,7	132,0
July	184,9	117,7	100,0	190,9	125,9	106,0
August	115,4	93,1	64,4	123,1	100,1	72,1
September	108,0	116,9	62,2	117,7	130,9	71,9
October	100,6	110,3	49,3	114,0	126,7	62,7
November	52,6	99,2	31,3	64,3	117,0	43,0
December	39,3	78,2	16,5	51,1	94,6	28,3
Year	90,2	90,6	48,6	100,4	102,0	58,8

Annex 2 Observed flows in river Suldalslågen at Suldalsosen, natural conditions compared with conditions today

	Natural conditions (1905-64)			Regulated conditions (1981-2000)					
	Min	Mean	Max	Min		Mean		Max	
	(m³/s)	(m³/s)	(m³/s)	(m³/s)	%	(m³/s)	%	(m³/s)	%
January	4,2	25,5	288,7	7,7	183	12,8	50	29,9	10
February	3,8	22,1	376,9	7,9	208	13,0	59	60,2	16
March	3,3	19,7	172,1	7,9	239	12,8	65	51,9	30
April	4,8	33,9	229,2	9,7	202	13,9	41	92,1	40
May	11,1	138,4	514,0	11,5	104	80,9	58	265,2	52
June	69,8	238,0	606,5	20,3	29	124,0	52	266,4	44
July	32,0	184,9	660,6	46,8	146	100,0	54	271,6	41
August	13,5	115,4	480,4	23,1	171	64,4	56	187,8	39
September	12,3	108,0	660,6	33,3	271	62,2	58	113,7	17
October	6,7	100,6	683,6	12,8	191	49,3	49	230,3	34
November	6,7	52,6	628,5	11,4	170	31,3	60	179,5	29
December	5,2	39,3	663,9	10,4	200	16,5	42	165,6	25
Year		90,2				48,6	54		

Annex 3 Degree-day Sums (May to October)

	Suldalsosen	Sand	Stordalsvatnet
1962	1407		
1963	1726		
1964	1423		
1965	1623		
1966	1572		
1967	1284		
1968	1635		
1969	1686		2309
1970	1570		2084
1971	1576		2133
1972	1672	1732	2173
1973	1515	1627	2022
1974	1623	1732	2154
1975	1619	1744	2227
1976	1522	1622	2270
1977	1653	1769	2252
1978	1674	1751	2216
1979	1373	1447	1849
1980	1661	1739	2346
1981	1484	1561	2112
1982	1553	1629	2173
1983	1402	1491	2037
1984	1536	1654	2286
1985	1540	1611	2179
1986	1337	1428	1983
1987	1392	1506	2078
1988	1737	1814	2275
1989	1365	1504	2126
1990	1377	1454	2192
1991	1509	1629	2265
1992	1440	1536	2201
1993	1325	1409	2084
1994	1314	1476	2113
1995	1553	1703	2210
1996	1297	1419	2162
1997	1629	1741	2377
1998	1500	1635	2159
1999	1478	1612	2334
2000	1444	1601	2197

Annex 4 Different species in the Phytoplankton community of Lake Suldalsvatn in 1988

Chrysophyceae:	**Bacillariophyceae:**
Bitrichia chodatii	*Achnanthes sp.*
Chromulina sp.	*Cyclotella spp.*
Chrysochromulina parva	*Tabellaria flocculosa*
Chrysolykos skujai	**Cryptophyceae:**
Dinobryon borgei	Crytaulax vulgaris
Dinobryon crenulatum	*Cryptomonas marssonii*
Dinobryon cylindricum v. alpinum	*Cryptomonas spp.*
Dinobryon sociale v. americanum	*Katablepharis ovalis*
Kephyrion boreale	*Rhodomonas lacustris*
Kephyrion litorale	Dinophyceae:
Mallomonas cf. maiorensis	Gymnodinium cf. lacustris
Monochrysis agilissima	*Gymnodinium sp.*
Ochromonas sp. (3,5-4µm)	*Peridinium inconspicuum*
Pseudokephyrion alaskanium	**Chlorophyceae:**
Pseudokephyrion entzii	*Elaothrix gelatinosa*
Spinoferomonas sp.	*Koliella sp.*
	Monoraphidium griffithii
µ-algae	*Monoraphidium komarkovae*
	Oocystis submarina v. variabilis

Annex 5 Taxa of benthic algae recorded in Suldalslågen in the period 1998-2000

Cyanobacteria (Cyanophyceae)	
Aphanocapsa spp.	Lyngbya kuetzingii
Calothrix gypsophila	Lyngbya spp.
Calothrix spp.	Microcoleus spp.
Chamaesiphon confervicola	Phormidium hetropolare
Chamaesiphon confervicola var elongata	Phormidium spp.
Chamaesiphon spp.	Pulvinaria spp.
Chroococcus spp.	Schizothrix sp2
Clastidium setigerum	Schizothrix spp.
Coleodesmium sagarmathae	Scytonema mirabile
Cyanophanon mirabile	Scytonematopsis starmach
Gloeocapsa sanguinea	Stigonema mamillosum
Homoeothrix janthina	Tolypothrix penicillata (Plectonematype)
Homoeothrix nordstedtii f. salisburgensi	unidentified coccale Cyanobacteria
Homoeothrix spp.	unidentified trichale Cyanobacteria
Green algae (Chlorophyceae)	
Binuclearia tectorum	Netrium spp.
Bulbochaete spp.	Oedogonium a (5-11u)
Closterium spp.	Oedogonium b (13-18u)
Cosmarium spp.	Oedogonium d (29-32u)
Euastrum spp.	Penium spp.
Gymnozyga moniliformis	Radiofilium irregulare
Hormidium flaccidum	Spirogyra a (20-42u,1K,L)
Hormidium montanum	Spirogyra sp1 (11-20u,1K,R)
Hormidium rivulare	Staurodesmus spp.
Microspora palustris	Teilingia excavatum
Microspora palustris var minor	Temnogametun spp.
Microspora spp.	Tetraspora cylindrica
Mougeotia a (6 -12u)	unidentified, Chaetphoraceae
Mougeotia a/b (10-18u)	Zygnema a (16-20u)
Mougeotia c (21- ?)	Zygnema b (22-25u)
Mougeotia spp.	Zygogonium sp3 (17-19u)
(Chrysophyceae)	
Hydrurus foetidus	
Red algae (Rhodophyceae)	
Lemanea sp (borealis?)	Lemanea spp.
Lemanea fucina	
Diatoms (Bacillariophyceae)	
Achnanthes helvetica	Fragilaria capucina
Achnanthes kriegeri	Fragilaria capucina v. gracilis cf.
Achnanthes levanderi	Fragilaria spp.
Achnanthes marginulata	Frustulia rhomboides v. r.
Achnanthes minutissima	Frustulia rhomboides v. saxonica
Achnanthes spp.	Gomphonema gracile

Aulacoseira distans v. nivalis	Gomphonema parvulum v. parvulum
Aulacoseira sp.	Navicula angusta
Brachysira brebissoni	Navicula bremensis
Brachysira styriaca	Navicula leptostriata
Brachysira vitrea	Navicula radiosa v. radiosa
Cymbella descripta	Navicula spp.
Cymbella falaisensis cf.	Neidium affine v. affine
Cymbella hebridica	Nitzschia spp.
Cymbella lunata	Peronia fibula
Cymbella minuta	Pinnularia abaujensis v. linearis
Cymbella perpusilla	Pinnularia biceps var. biceps
Diatoma anceps	Pinnularia microstauron
Eunotia curvata	Pinnularia rupestris
Eunotia exigua	Pinnularia subcapitata v. hilseana
Eunotia incisa	Stenopterobia sigmatella
Eunotia naegelii	Surirella delicatissima
Eunotia praerupta	Surirella roba cf.
Eunotia rhomboidea	Surirella spp.
Eunotia spp.	Tabellaria flocculosa agg.
Eunotia tenella	Tabellaria quadriseptata
Eunotia vanheurckii	

Annex 6 Mosses and liverworts recorded in Suldalslågen in the period 1960-2000. The different investigations have had different purposes surveying the mosses and liverworts. Species in bold font are dominant or important in permanent water covered areas

Species	Observation year
Blindia acuta	1988, 1998-2000
Bryum pseudotriquetrum	1988
Dicranella palustris	1988
Drepanocladus exannulatus	1988
Fontinalis sp.	1974
Fontinalis antipyretica	1981-1986, **1988, 1998-2000**
Fontinalis dalecarlica	1960-1962,1981-1986, **1988, 1998-2000**
Fontinalis squamosa	1981-1986, **1988, 1998-2000**
Hygrohypnum ochraceum	1981-1986, 1998-2000
Polytrichum commune	**1988, 1998-2000**
Racomitrium aciculare	1981-1986, 1998-2000
Sphagnum sp.	1998-2000
Meesia triquetra	1981-1986
Cephalozia sp.	1988
Marsupella sp.	1974
Marsupella aquatica*	**1988, 1998-2000**
*Marsupella emarginata**	1960-1962, 1981-1986
Nardia compressa	1981-1986, 1988, 1998-2000
Scapania cf. dentata	1981-1986
Scapania undulta	1981-1986, **1988, 1998-2000**

*) *Marsupella aquatica* and *Marsupella emarginata* are closely related and may be mixed up with each other during the period.

Annex 7 Macrophytes recorded in Suldalslågen 1974-2000. Species in bold font are dominant or important in permanent water covered areas.

Species	Observation year
Potamogeton polygonifolius	1974
Sparganium angustifolium	1974
Sparganium minimum	1974
Alopecurus aequalis	1974, 1998-2000
Elocharis acicularis	1974
Ranunculus reptans	1974, 1998-2000
Subularia acuatica	1974, 1998-2000
Callitriche hamulata	**1974, 1988, 1998-2000**
Callitriche verna	1974
Callitriche stagnalis	1974
Juncus supinus	**1974, 1988, 1998-2000**
Myriophyllum alterniflorum	1974, 1998-2000
Utricularia intermedia	1974
Utricularia vulgaris	1974

Annex 8 Number of species from different benthic invertebrate groups with indication of their abundance in the River Suldalslågen during different periods. + rare; ++ common; +++ abundant; - not present; . not identified

	1961-62	1978-79	1983-84	1986-88	1992-94	1997-00
PLECOPTERA						
Amphinemura borealis	+++	++	+++	+++	+++	++
Amphinemura standfussi	+	+	+	+	+	+
Amphinemura sulcicollis	+	+	+	+	+	++
Brachyptera risi	+	+	+	+	+	+
Capnia atra		-	+	-	-	-
Diura nanseni	+++	+	+	++	+	++
Isoperla grammatica	++	+	+	+	+	+
Leuctra fusca	++	+	+	+	++	++
Leuctra hippopus	+	+	+	+	+	+
Leuctra nigra		-	+	+	+	+
Nemoura cinerea	+	+	+	+	+	+
Protonemura meyeri		+	+	+	+	+
Siphonoperla burmeisteri	+	+	+	+	+	+
Taeniopteryx nebulosa	+	-	+	+	+	+
EPHEMEROPTERA						
Ameletus inopinatus	+	.	+	-	-	+
Baëtis rhodani	+++	+++	+	+++	++	+++
Ephemerella aurivillii	+	.	+	++	+	+
Ephemerella mucronata		.	-	+	+	-
Heptagenia dalecarlica		.	-	+	-	-
Heptagenia sulphurea	+	.	-	+	-	-
Leptophlebia marginata		.	+	-	-	-
TRICHOPTERA						
Apatania sp.		.	.	.	++	+
Chaeopteryx sp.	++	.	.	.	+	+
Crunoecia irrorata		.	.	.	-	+
Halesus digitatus	+	.	.	.	-	+
Halesus radiatus	+	.	.	.	-	+
Hydropsyche augustipennis	+	.	.	.	-	+
Hydropsyche pellucidula						
Hydropsyche siltalai		.	.	.	+	+
Hydroptila sp.		.	.	.	+	-
Lepidostoma hirtum	++	.	.	.	+	+
Limnephilus sp.		.	.	.	+	-
Oxyethira sp.	+	.	.	.	+	+
Plectrocnemia conspersa	++	.	.	.	+	+
*Polycentropus flavomaculatus**	+++	+++	++	++	+	++
Potamophylax latipennis		.	.	.	-	+
Rhyacophila nubila	++	.	.	.	+	++
Sericostoma personatum		.	.	.	-	+
COLEOPTERA						

Elmis aenae		.	.	.	+	-
Limnius volckmari		.	.	.	+	+
CHIRONOMIDAE						
Tanypodinae						
Ablabesmyia sp.	.	.	.	.	+	.
Conchapelopia sp.	.	.	.	.	+++	.
Macropelopia sp.	.	.	.	.	+	.
Nilotanypus sp.	.	.	.	.	++	.
Trissopelopia sp.	.	.	.	.	+	.
Zavrelimyia sp.	.	.	.	.	+	.
Diamesinae						
Diamesa sp.	.	.	.	.	+	.
Potthastia longimana	.	.	.	.	+	.
Prodiamesinae						
Prodiamesa olivacea	.	.	.	.	+	.
Orthocladiinae						
Corynoneura lobata	.	.	.	.	+	.
Cricotopus sp.	.	.	.	.	+	.
Eukiefferiella gr. brehmi	.	.	.	.	+	.
Eukiefferiella gr. claripennis	.	.	.	.	+	.
Eukiefferiella gr. devonica	.	.	.	.	++	.
Eukiefferiella gr. gracei	.	.	.	.	+++	.
Georthocladius luteicornis	.	.	.	.	+	.
Heleniella sp.	.	.	.	.	+	.
Heterotrissocladius marcidus	.	.	.	.	+	.
Nanocladius sp.	.	.	.	.	+	.
Orthocladius sp.	.	.	.	.	+++	.
Psectrocladius sp.	.	.	.	.	+	.
Rheocricotopus sp.	.	.	.	.	+	.
Rheosmittia sp.	.	.	.	.	+	.
Symposiocladius lignicola	.	.	.	.	+	.
Synorthocladius semivirens	.	.	.	.	+	.
Thienemanniella sp.	.	.	.	.	++	.
Tvetenia calvescens	.	.	.	.	+++	.
Chironominae						
Demicryptochironomus vulneratus	.	.	.	.	+	.
Micropsectra sp.	.	.	.	.	++	.
Polypedilum sp.	.	.	.	.	+	.
Rheotanytarsus sp.	.	.	.	.	+	.
Stempellinella sp.	.	.	.	.	+	.
Tanytarsus sp.	.	.	.	.	+	.
EMPIDIDAE						
Chelifera sp.	.	.	.	.	+	+
Wiedemannia sp.	.	.	.	.	+	+
TIPULIDAE						
Tipula sp.	++	.	.	.	+	+

LIMONIIDAE						
Dicranota sp.	+	.	.	.	++	+
Elaeophila sp.	.	.	.	.	+	-
Molophilus sp.	.	.	.	.	+	-
Ormosia sp.	.	.	.	.	+	+
Pedicia rivosa	.	.	.	.	+	+
GASTROPODA						
Lymnaea peregra		+	+	+	+	+
BIVALVIA						
Pisidium sp.		++	+	+	+	+
OLIGOCHAETA						
Chaetogaster diastrophus	.	.	.	.	+	-
Cognettia sphagnetorum	.	.	.	.	+++	+++
Cernosvitoviella sp.	.	.	.	.	-	+
Dendrobaena sp.	.	.	.	.	++	++
Eiseniella tetraedra	.	.	.	.	+	+
Lumbriculus variegatus	.	.	.	.	+	+
Nais barbata	.	.	.	.	-	-
Nais communis	.	.	.	.	-	+
Rhyacodrilus coccineus	.	.	.	.	-	-
Stylodrilus heringianus	.	.	.	.	++	++

Annex 9 Concentrations of chemical elements in Suldalslågen at Suldalsosen (the outlet of Lake Suldalsvatn) and Suldalslågen at Sand (the outlet into the sea) in the period October 1999 – September 2000

	Colour	Turb	Cond	pH	Alk	Ca	Mg	Na	K	SO4	Cl	NO3	Si	Ala	Alo	Ali	NH4
	OD-410 nm	FTU	mS/m		µekv/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	mg/l	µg/l	µg/l	µg/l	µg/l
Suldalslågen at Suldalsosen																	
min	0,005	0,10	1,28	5,94	9	0,71	0,12	0,86	0,09	0,12	1,37	43	0,28	5	1	1	0
average	0,010	0,21	1,56	6,10	18	0,80	0,19	1,17	0,14	1,31	2,42	155	0,36	11	5	6	0,2
max	0,015	0,38	1,94	6,29	34	0,89	0,31	1,54	0,21	2,27	3,47	191	0,43	23	12	14	1,6
Suldalslågen at Sand																	
min	0,005	0,10	1,42	5,85	12	0,70	0,14	1,02	0,12	0,21	1,77	49	0,28	5	0	1	0
average	0,016	0,41	2,08	6,25	27	1,09	0,26	1,57	0,22	1,55	3,43	221	0,50	16	10	7	0,2
max	0,041	2,10	3,11	6,46	43	1,54	0,49	2,92	0,38	2,74	7,00	397	0,87	34	25	19	3,7

Annex 10 Measured concentrations of Lindane and PCBs in Suldalslågen in 1998

Date	Gamma HCH (lindane) ng/l	PCB (The following Congeners) IUPAC NOS 28 ng/l	52 ng/l	101 ng/l	118 ng/l	138 ng/l	153 ng/l	180 ng/l
980217	0,12	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03