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Asplan Viak

Suldal Pilot River Basin

Provisional Article 5 Report
pursuant to the Water Framework Directive

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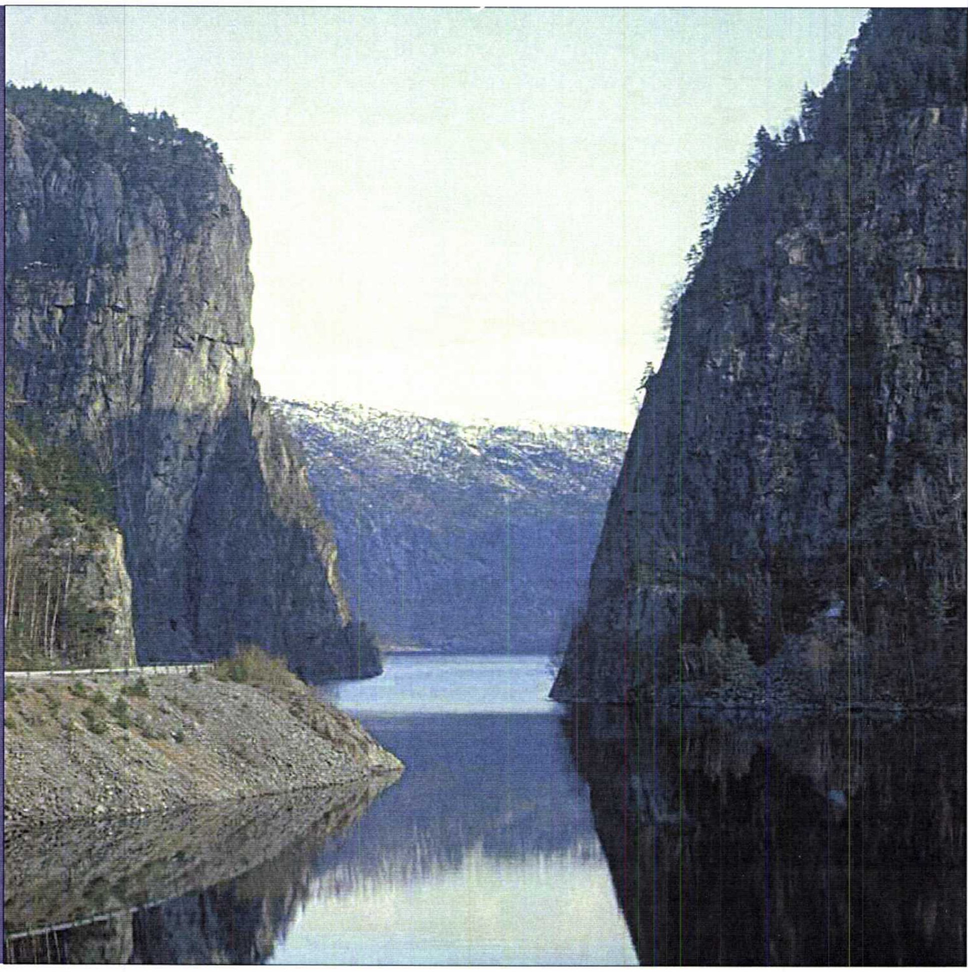

REPORT

SULDAL PILOT RIVER BASIN, NORWAY

Provisional Article 5 Report pursuant to the Water Framework Directive

14 June 2004

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1 INTRODUCTION

1.1 Background

Working group 2B

Norway participates in the network of Pilot River Basins (PRB) under working group 4.1 (now WG 2B) of the Common Implementation Strategy (CIS) of the Water Framework Directive (WFD).

Suldal River Basin

The Suldal River Basin with coastal areas has been selected as a pilot basin. The river basin is small to medium sized at 1461 km2, and has large areas of pristine nature. A wide range of typical Norwegian interests and pressures are present in the study area. The river basin is heavily impacted by hydropower production. Intensive fish farming, industrial development and sea transportation are important pressures in the coastal areas. Large research and management projects have been carried out in the river basin, mostly connected with the impact of hydropower on aquatic ecology and wild salmon in particular. A description of the study area can be found in earlier reports, but a short summary is given here. The basin area and basin transfer schemes from the south are shown in Figure 1.

Human activity

The River Suldal runs through the municipality Suldal, with a population of approx. 3900, but only 2500 live within the boundaries of the river basin, which corresponds to a population density of about 1.7 inh./km^2. About 1200 persons live in the municipal centre Sand, located at the estuary. Agriculture is dominant in the valleys, but the cultivated area is very limited by steep and rocky terrain over most of the basin. In addition fishing and hunting are important in the area. Tourism is of great importance to the community. Much of this activity is connected to the main river.

River Suldal

The River Suldal is one of Norway's most famous Atlantic salmon rivers, known for especially large fish. Angling is mainly concentrated in the river below lake Suldalsvatn. Different constructions have been built in and along the river to improve the angling, such as fish ladders and platforms to improve the access to the best fishing grounds.

Agriculture

The river is to some small extent used by farmers for irrigation and water supply for animals. The river is slightly 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 sediment to the river.

Guidance documents

Guidance documents and toolboxes from at least five working groups under the CIS and horizontal guidance on identification of water bodies will be tested specifically. The rest of the guidance documents will be used when appropriate.

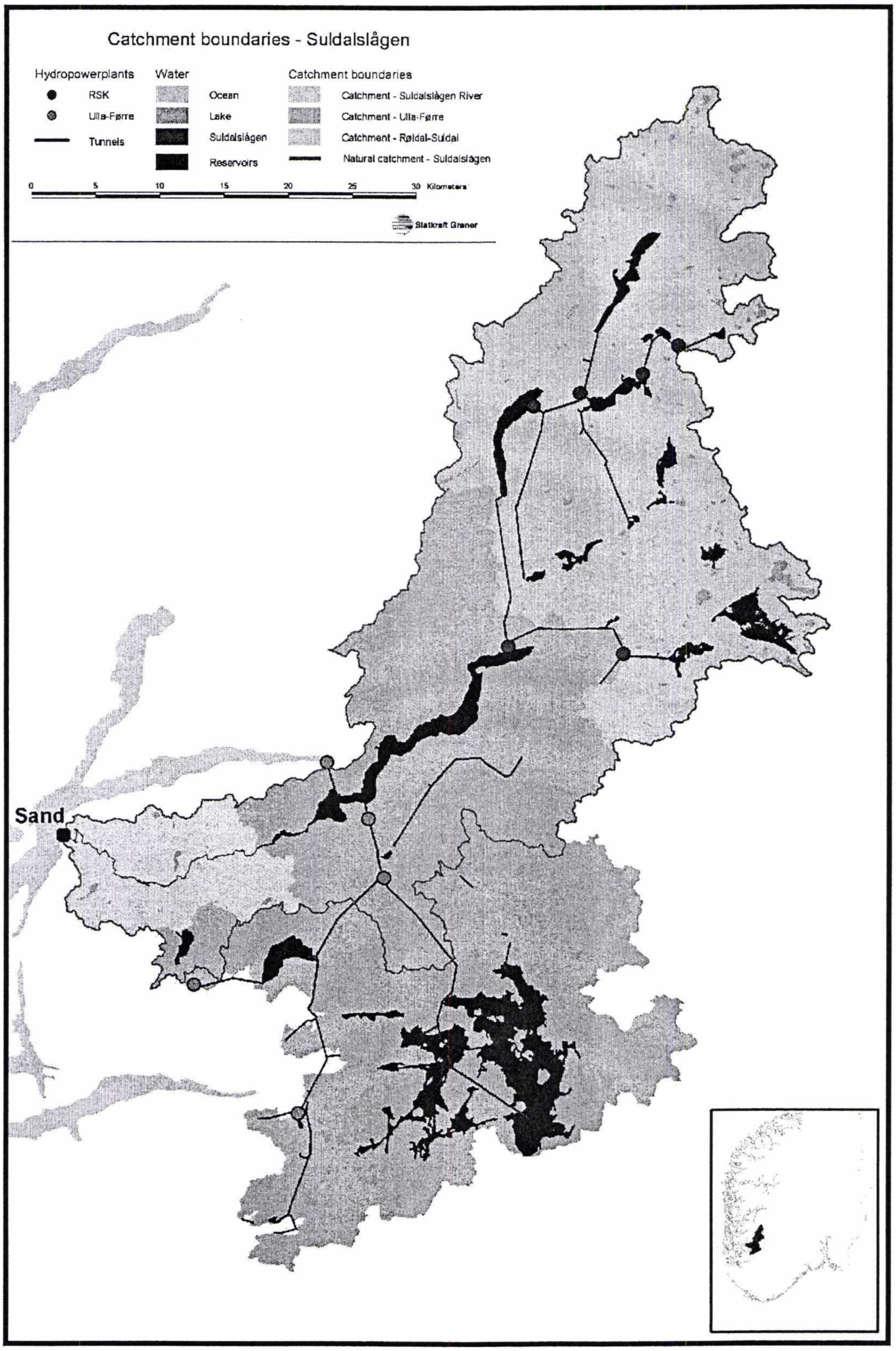
National Study

A Norwegian trial characterisation study was carried out in the Suldal River Basin until June 2003, and further tested on 8 river basin districts during late 2003. (See references 1 and 2 in Norwegian only). Characterisation of water bodies according to article 5 has been the main focus of the national project

ACRONYMS

CIS	Common Implementation Strategy
GWh	Gigawatt hours (one million kWh)
kWh	kilowatt hour (unit of electrical energy)
HMWB	Highly Modified Water Bodies
HRWL	Highest Regulated Water Level
KOSTRA	Database for Municipality reporting to SSB (Kommune –Stat) -
LRWL	Lowest Regulated Water Level
masl	metres above sea level
MW	Megawatt (unit of power capacity)
PRB	Pilot River Basin
SSB	The Norwegian Bureau of Statistics (Statistisk Sentral Byrå)
WFD	Water Framework Directive

Figure 1: Map of Suldalslågen with transfers and hydropower plants



PRB Studies

The Suldal River Basin is the Norwegian river basin among many Pilot River Basins selected by Member States for pilot studies on implementation of the WFD. To date there have been two reports on progress under Phase 1a of the PRB study program (references 3 and 4). This report describes a continuation of the work on characterisation, and builds on the previous reports presented under the PRB studies. For more information on PRB studies, contact Anja Skiple Ibrekk , asi@nve.no.

Status in Norway

Although there has been a delay in formal decision making according to the implementation program set out in the WFD, Norway has progressed quite far with the practical side of implementation. At the time of writing in May 2004, the national and regional authorities for implementing the WFD in Norway have not been decided, but a decision is expected soon. As a consequence of this delay, the exact sub-division of the country into water regions and river basin districts has not been finalised, and the appropriate legal regulations have not yet been amended. However, work on characterisation is now in full swing, led by an inter-departmental working group from all relevant directorates, and the entire country is expected to be covered by a preliminary characterisation of all water bodies not at risk by the late summer of 2004.

GIS application

The preliminary characterisation is being executed using a specially designed GIS application, which uses national databases to sytemise data and to divide the country into water bodies. A skilled user trained in the principles and criteria defined in the WFD is able to use national databases to delineate water bodies, apply typology criteria, designate candidate HMWBs, and register whether the water body has any conceivable risk of not achieving the WFD objective of good ecological status in 2015. Clearly, this is a rapid and rough approach designed primarily to identify and screen out all water bodies in the pristine areas of Norway, where there is no significant risk of not meeting the WFD objectives. This approach simply sorts out water bodies into three groups; those clearly not at risk, those with some possible risk and HMWBs. The objective is to register by the simplified techniques all of the first group in large tracts of pristine land, while the second and third groups will udergo a proper characterisation later in 2004 by the regional and local authorities.

Advantages

The advantage of this approach in Norway, is that it is expected that more than half of the land area and open coastal area will be characterised and registered simply and cost-effectively at the national level, while the remainder will be examined at a greater level of detail at the local level where greater local knowledge is available, and a participatory approach is required.

1.2 Purpose

Not coastal waters

The purpose of this project is to test the following guidance documents regarding the requirements in the characterisation process in a river basin in Norway. The testing has in general not yet been carried out for coastal areas.

- *Horizontal guidance on identification of water bodies (HORIZONTAL)*
- *Guidance document on analysis of pressures and impacts (WG 2.1-IMPRESS)*
- *Guidance document on identification of artificial and heavily modified water bodies (WG 2.2- HMWB)*
- *Guidance document on establishing reference conditions and ecological status class boundaries for inland surface waters (WG 2.3 - REFCOND)*

Guidance documents on the economic aspects of characterization (WG 2.6 –WATECO)

This report

The report is divided into seven chapters according to the above five parts of ther process, plus an introductory chapter and a rough analysis of the risk of not achieving good ecological status in 2015. The result is a mixture of a description of the characterisation process for Suldal River Basin and some comments on the testing of the above guidelines. This includes some descriptions on how the WFD is adapted to Norwegian circumstances in general.

Answers

Separate documents contain the questions posed under the Terms of Reference, together with answers provided by the Norwegian authorities describing their experience in applying the relevant CIS guidance documents in the Norwegian characterisation process.

1.3 Executing institutions

This study

This PRB study has been supervised by the Norwegian Water Resources and Energy Directorate (NVE), and executed by NVK MULTICONSULT AS, which is the daughter company of the MULTICONSULT concern specialising in natural resources management. The assignment was carried out with Rådgivende Biologer as sub-consultant for aquatic ecology and Asplan Viak as sub-consultant on groundwater.

1.4 National Databses in Norway

National GIS-database

All catchments in Norway are divided into small river stretches. At every confluence, new units are established, following each of the tributaries. The network has overlay to the lake database and the database on catchment areas referred to in the following paragraphs, making it easy to connect river stretches with the attached lakes and sub-catchments. Through lakes, the river network is contiguous, following the mid-line as a "hypothetical river" running through the lake.

Sub-basins (REGINE) This database is system of sub-catchments, each with a unique number, and systemised such as to allow the later sub-division into smaller sub-catchments (where and when required) without disturbing the original numbers. All units comprise of sub-catchments which are delineated by one or two points, the upper and lower point along the river stretch in the unit, or the outflow points along a coastal area. Each sub-basin is defined by the watershed boundary surrounding the cathchment between these one or two points.The following characteristics are attached to each unit:

- *Unique ID*
- *Area of the specific unit (km2)*
- *Average annual runoff (1961-1990) (million m3 pr. year)*
- *Average specific runoff (1930-1960)(liter/second/km2)*
- *Average specific runoff (1961-1990)(liter/second/km2)*
- *Total area of the basin above the point in question (km2)*
- *Average annual runoff including the basin above (1961-1990) (million m3 pr. year)*
- *Name of the river or water body*
- *Name of the sub-basin*
- *Stretch "from… to…" (name on the lowest point of the unit, and name on the upper point of the unit).*

Lake register All lakes with a surface area larger than 0,025 km² have been given a specific number and registered in a database. 240,000 lakes have unique numbers in the database. The database provides information about the following characteristics of the lakes:

- *Unique ID*
- *Name*
- *Area*
- *Altitude*
- *Circumference*
- *Connection to catchment area number in REGINE.*

River Network A third database contains spatial data on all rivers and streams marked on 1:50 000 scale maps. These are delineated geographically and divided up into many reaches, about 2 million nationwide, which are linked together to form the river network database. Each small reach can be assigned a variety of data attributes, but not all of these are useful at present. The topology of the river system is defined in the database such that flow direction is recognised, and all downstream points can be related to upstream parts of the river network. Thus the River Network database may be a powerful tool for future implementation of the WFD.

Definition of WBs

These are the three main databases used for delineating all water bodies. They have been developed and are updated by the Norwegian Water Resources and Energy Directorate (NVE). Additional themes and databases from other sources are superimposed to assist in the process, such as the border for marine sediment, the treeline, the existence of hydropower dams, intakes and tunnels etc., as described later and shown in Maps 1,4 and 7.

1.5 Typology

System B used

Two national projects have worked out a typology for Norwegian rivers, lakes and coastal waters. System B is selected for the differentiation into type. The mainland is divided into 6 eco-regions, which is further subdivided into 23 lake types and 25 river types. Some types are only present in some of the eco-regions. The Suldal river basin belongs to the eco-region Western Norway. The preliminary type numbering system is given in Appendix 1.

Reference datasheets

For all types, specific data sheets will be prepared, describing the expected composition of species for each type in its pristine natural state. A reference site will be established for each water type. The criteria used in the differentiation are as follows:

Table .1.1 -Criteria used for assigning water bodies to types (type No. is defined in Appendix1)

Eco-region	Eastern Norway, Southern Norway, Western Norway, Mid-Norway, Northern Norway (except Finnmark), Finnmark county
Climatic region	Lowland – below border of marine sedimentation Boreal – forest areas Mountain – above the tree border
Alkilinity/ geology	Calcium-level Extremely Low-Calcium conditions, < 1 mg/l Low-Calcium conditions, 1-4 mg/l High-Calcium conditions, > 4 mg/l
Turbidity/ colour	Humus-level Low: < 30 mgPt/l High: > 30 mgPt/l (slow running, turbid, low humus, high-Ca water is a special type, 9. Turbidity from glacial meltwater may determine additional types)
Size (rivers)	Small/medium: 10 – 1000 km² Large: > 1000 km²
Size (lakes)	Small/ medium: Surface area < 5 km² Large: Surface area > 5 km²

Steep basins

However, within such fast flowing river basins as Suldal, all water bodies will naturally be dominated by the high altitude water qualities of cold and clear water with very low nutrient content and low alkalinity. Determination of ecosystem type can not be based blindly on the position above sea level. The lowland ecosystems in Suldal (and most of western Norway) are therefore much more similar to mountain types than lowland systems without any high altitude drainage basin.

1.6 Presentation Meeting in the Suldal Municipality

Information

Mid- way through the study, a presentation meeting was held at Sand, the largest population centre in Suldal municipality. This meeting gave the local and regional authorities an overview of the current state of work on implementing the WFD, and on the Suldal PRB Study in particular. Some time was spent on discussion and feedback from the local authorities on factual information about the river basin and some of the more important water bodies. The minutes are given in Appendix 4.

2 IDENTIFICATION OF WATER BODIES

2.1 Step 1. Delineate the boundaries of surface water categories

Sub-catchments

To reduce the number of water bodies to a more convenient number for management and presentation purposes, the "REGINE" system of sub-catchment areas was used first, in order to define sub-catchments within the total catchment area of Suldal River Basin. The sub-catchments were defined as aggregates of REGINE-units (Maps 1, 4 and 7), and generally selected to be of a size 10-100 km^2. Suldal river basin was sub-divided into 43 such sub-catchments. The main tributary confluences and locations of lakes, dams and stream intakes are natural points to use in dividing up into sub-catchments.

Later sub-division

If the later analysis of pressures and impacts shows moderate status or below for small sub-catchments, they should be used to separate out smaller water bodies, only if this is found to be convenient for either local, regional or national nature management authorities. The same will be done for smaller sub-catchments showing specifically important biological interests. Otherwise the sub-basin will stand as a single water body as described below.

Large lakes

All lakes greater than 0.5 km^2 were separated as water bodies from their sub-catchments, and some few smaller lakes which are regulated by dams, or have special importance in water management, for instance in wetland nature reserves, were also identified as separate water bodies.

Small lakes

Most small lakes were left as an integral part of the river tributary system within a "sub-catchment water body" (see below). The same applies to marshland or bogs, such that all surface water in a sub-catchment was considered as one single water body (except larger lakes than 0.5 km^2).

River Network

The river network database contains a very large number of small units that are useful for data storage but not for presentation purposes, and there must be considerable aggregation of these units in order to arrive at a practical number of river water bodies for implementation of the WFD. Where we wish to define reaches of a main river as single water bodies, the upper and lower point was defined and the individual units in the river network were aggregated to define one water body. However, this approach is unsuitable for defining a small number of water bodies in the upper parts of the basin, where there are few pressures and a small number of water bodies is preferred for effective water management.

Sub-catchment WBs

Instead, Norway has defined a "sub-catchment water body" as all surface water within a specified sub-catchment draining to the lower boundary of the sub-catchment or the next water body (i.e. a main river, a coastline or large lake). This water body assumes the category of river, even though it may contain small lakes or marshes which have different characteristics to a river. An alternative name for such a water body could be "tributary water body", but this name implies only one tributary and the exclusion of small lakes. In fact the sub-catchment water body may have many tributaries aggregated into it, and all small lakes must be included to avoid the laborious sub-division of much of pristine mountain land into numerous unimportant water bodies. This report refers to such water bodies as **sub-catchment water bodies**. The methodology is still being refined through this and other pilot studies. For instance integration of coastal water bodies with small coastal sub-catchments remains to be tested, and is outside the scope of this report.

2.2 Step 2. Delineate the boundaries of surface water types

Typology

The second layer to be put on the initial map of water bodies is normally the typology of water bodies. The preliminary Norwegian typology criteria were used on all the water bodies established in step 1 of the identification process.

Climatic regions

Lowland areas were defined as areas below 65 metres above sea level. This is the approximate upper level of deposition of marine sediments in Suldal River Basin after the last glacial period. The upper altitude of forest in the Suldal River Basin is approximately 700 metres above sea level. The forest line is quite difficult to define in the Suldal River Basin because the bedrocks have a very thin and discontinuous soil cover. Accordingly large areas below 700 m are without forest. Norway has not yet decided how literally the use of height zones as borders between climatic regions will be taken, and to what extent this will be applied to distinguish between water types. For the time being, the height zones of lowland (below 65m in Suldal) and forest (about 700 m in Suldal) have been applied literally.

Ca (alkilinity)

The geological classification of typology was based on existing water quality parameters from different locations in the river basin. Data on mean annual concentration of calcium were available from quite few of the total number of water bodies. Because the existing measurements mostly represent the lower parts of the Suldal river basin, it is anticipated to find even lower values of calcium at high altitudes. More data have to be collected from different sources and expert local judgement must be used later to subdivide water bodies into the category < 1 mg Ca/l and the category between 1 and 4 mg Ca/l. In the present classification it is assumed that values higher than 4 mg/l can be due to the effect of liming, and natural conditions for all water bodies within the drainage area are predominantly classified to have < 1 mg Ca/l, i.e. "very low-calcium" waters.

Humus

All waters in the basin are generally found to be low in humus, and are transparent or "clear". There is no glacial runoff in the catchment and there is therefore a low turbidity throughout the catchment.

Delineation

The uniform water quality throughout the Suldal basin meant that water quality never influenced the delineation of water bodies, or caused sub-division of larger water bodies.

2.3 Step 3. Delineate boundaries using distinct physical features

GIS tools

The GIS-based tools on freshwater described in chapter 2.1, except the river network, are gathered in a GIS tool named NVE Atlas. This database provides information about dams, reservoirs, water intakes, diversions, hydropower plants, penstocks, tunnels and other physical constructions such as flood protection bunds and channels. By use of this database, characteristics about every specific use may be gathered, and provisional water bodies may be outlined. This first step is a screening to localise hydromorphological pressures, which may lead to identification as heavily modified water bodies. The HMWB identification were focused on hydropower developments because this is the main user interest of the Suldal river basin.

Regulated lakes

All regulated lakes in Norway are numbered and stored in a database maintained by NVE. Regulated lakes larger than 0.5 km^2 were defined as separate water bodies in step 1 of the identification.

Contiguity

The contiguity of the river system is maintained by a river network database (Elvenett- River Network) which comprises more than 2 million small stretches of river linked together by topology which allows the flow of water from mountain to sea to be uniquely defined in the GIS database. Data for each river and each lake within these aggregated water bodies is connected to the underlying River Network system where every single river stretch and lake is separate units. The river network forms the baseline in the map and may be used to identify smaller water bodies whenever it is required.

Resulting maps

The results of this process are shown in Maps 1,4 and 7. It is necessary to read further in the following chapter to find further explanation as to how delineation was affected by HMWB designation.

2.4 Groundwater

Methods

The Norwegian Geological Survey (NGU) has carried out investigations in the lower part of the basin resulting in delineation of some probable aquifers (see Map No. 9 and reference list in bibliography).

Glacifluvial aquifers

Sediment deposits in the bottom of the valley of Suldal River Basin provide considerable potential for groundwater extraction. The limits of glacifluvial groundwater bodies follow the natural geological boundary between hard rock and glacial, alluvial and/or marine deposits (silt and clay) in the lowland. These groundwater bodies, in this case open aquifers, which can sustain extraction of more than about 5 l/sec per well, have been separated from the surrounding rock, and are shown by dark green areas in Map 9.

Larger aquifers

Along the bottom of the valley one can partly find thick deposits from the Quaternary period due to different stages of the retracting time of the inland- ice, for instance near Sand and Nesflaten. Below the marine limit (about 65 masl near Sand) the deposits are dominated by fine-grained soils. The upper limit is about 400 masl in Røldal. These deposits are mainly open or semi-open aquifers in contact with the river in the bottom of the valley or minor rivers coming from the valley sides.

Hard rock aquifer

Hard rock, which covers most of the area, is mainly composed of different gneisses and granite. In some places one can find overlaying sedimentary rock, such as phyllite, quartz and mylonite. In average one can expect a normal yield from each well of 0.1 to 0.3 l/sec. All such hard rock is considered to be one single groundwater water body, since the further sub-division into different aquifers would be extremely complex in view of the complex tectonics affecting groundwater flows in hard rock throughout Norway.

Distinct WBs

With respect to earlier investigations and geological interpretation of fluvial and glacifluvial deposits, four distinct groundwater bodies have been identified as listed in Table 2.1. Each is separated from the surrounding hard rock water body called Suldal River Basin bedrock. Groundwater in the glacifluvial deposits is utilised for potable supply, and is of good quality, with low values of nitrates, low buffer capacity and relatively low pH.

Table 2.1 Groundwater bodies identified in the Suldal River Basin:

Name of Groundwater body	**Type**	**Approximate depth in m. or size in km^2**
Røldal	Glacifluvial	>30m
Roaldkvam	Glacifluvial	>10m
Suldalsosen	Glacifluvial	>20m
Sand	Glacifluvial	>20m
Suldal River Basin bed-rock	Hard rock	1461 sq.km over all of the Suldal River Basin

3 HEAVILY MODIFIED WATER BODIES (HMWB)

3.1 Hydropower

Two schemes

Two large hydropower schemes (Røldal-Suldal and Ulla-Førre) lie within the Suldal River Basin. They generate approx. 6 % of the total electricity production in Norway. These hydropower plants comprise of a series of complex systems of small dams and transfer tunnels, which collect the water from several rivers and streams at different altitudes, before utilising this water in several underground power plants. The power plant and reservoir details are listed in Appendix 2, and shown in Figure 1 and Maps 1, 4 and 7.

Røldal-Suldal

The Røldal-Suldal Hydropower Scheme, in the northern part of the watercourse, consists of 7 power stations and 16 reservoirs. The major part of the system came into operation between 1965 and 1970. All these plants are owned and operated by the power company Hydro Energy. Mean annual electricity production is over 3000 GWh. The main collection system lies to the east of Lake Røldalvatn and collects 7 rivers at around 780-680 m altitude before releasing the water from Røldal power station into the north-eastern corner of the lake. Above this, a new collection system takes water from around 1150-1050 m altitude and utilises the head down to the upper level of the first system at 680 m through Novle power station (40 MW).

Recent additions

In recent decades, two smaller power plants were constructed on the high mountain plateau to utilise water from regulated mountain lakes in power plants named Middyr (1.3 MW) and Svandalsflona (20 MW).

Suldal I (306 MW)

The difference in level from lake Røldalsvatn (380 m) and lake Suldalsvatn (68 m) is utilised through a tunnel leading to Suldal I power plant at the northern tip of Suldalsvatn. This also includes water from Langavatn when the water level in Røldalsvatn is sufficiently low.

Suldal II (150 MW)

To the east of this power station, there is another tunnel collection system from 5 rivers at around 650-640 m which leads water to the same power station at Suldal II, but with separate turbines to cope with the higher head. Above this we find a new power plant called Kvandal, which utilises the water from large reservoirs in Holmavatn and Sandavatn lakes, as well as a sub-basin transfer of water from Dypetjern in the north via Isvatn and Litlavatn lakes. The discharge from the Røldal-Suldal hydropower system ends up as inflow to the northern end of Lake Suldalsvatn

Ulla-Førre

The Ulla-Førre Hydropower Scheme consists of 7 reservoirs, located both mainly outside the Suldal River Basin to the south (see Figure 1). The reservoir Blåsjø at 1050 m a.s.l., contains the largest reservoir volume in Norway, with a volume of 3105 mill. m^3. Furthermore there are 4 power stations and 3 pump stations within the Ulla-Førre power system. The power stations came into operation between 1980 and 1986. This system is owned and operated by the Norwegian state power company, Statkraft SF

Inter-basin transfers	Water is diverted from other rivers to the Suldal River Basin through the Ulla-Førre system. The lowermost power station, Hylen located in the inner end of the fjord Hylsfjorden, to the north of Lake Suldalsvatn, utilises the head between the lake and the sea. Through this station a large volume of water is diverted from the river Suldalslågen. The mean annual electricity production of the Ulla-Førre scheme is 4550 GWh.
Kvildal (1240 MW).	To the south of lake Suldalsvatn we find another tunnel collection system at a level of 650-610m, collecting all the small rivers draining into the south-eastern side of the lake, which collects water in Lake Lauvastølvatn before utilising the head down to Suldalsvatn in Kvildal hydropower plant
Saurdal (640 MW),	Yet again we find another power plant above this, named Saurdal, which utilises water collected at around 1070 m in the high mountain plateau to the south. This collection system is largely outside of the Suldal River basin, but is remarkable for containing one of Norway's largest reservoirs, the Lake Blåsjø, which provides superannual storage for hydropower production. It is an essential component of the Norwegian power system, being one of the few reservoirs capable of storing water in reserve for a series of several consecutive dry years.
Blåsjø reservoir	The lake and surrounding river basin has not been characterised as part of this PRB project, but it should be noted that the water from this lake is led into the southern shore of Lake Suldalsvatn and then out again on the opposite northern shore to be utilised in Hylen power plant at the eastern tip of Hylsfjord. This water comes from a high mountain catchment to the south and is released mainly in winter months. The waters draining into lake Mosvatn to the south of Suldal river are also transferred south to enter the southern collection system before being returned to Suldalsvatn lake.
Seasonal regulation	Most of the energy production is heavily concentrated in winter months, meaning that river flows are unnaturally high in winter, and unnaturally low in summer. Furthermore there are considerable changes in river and lake temperatures due to the extensive collection and transfer systems, as well as withdrawal of water from deep reservoirs with temperatures above freezing being released into rivers and lakes where ice is normally formed.
Flood flows	Snowmelt is stored in high altitude dams during summer in northern parts of the natural river basin. Spring flooding was reduced to less than half the natural flood magnitude, and summer discharge in the River Suldal was also reduced.
Monitoring impacts	An extensive research has been carried out during the last 30 years to monitor any effects of the hydroelectric regulations, both regarding water quality and biological effects. Especially so in the lower parts, connected to the famous salmon river, Suldal.
Small hydropower	In addition to the two hydropower schemes mentioned above, Sand small hydropower station (1.3 MW) is located in the tributary Heimsåna to the south of Sand town centre. In addition there are at least

ten mini-hydro schemes recently awarded concessions, and in various stages of design and construction. Common for all of these is the fact that the stream water is utilised in a short steep stretch of the stream without significant seasonal regulation. Since all of these have undergone environmental assessment as part of the concession review process, none of these appear to have individual impacts of such significance that the status of the relevant river water body can be considered at risk. However, the cumulative impact of many plants on the same river or within a small sub-catchment remains to be tested. The WFD procedures will examine such cumulative impacts when they are applied at the regional and local level, but no attempt has been made at the national level preliminary characterisation, since the small scale of conflict caused by small hydropower plants is deemed to be a local matter.

3.2 Norwegian Heavily Modified Water Body (HMWB) Guidelines

Norwegian guidelines

The PRB project has provided a good example of how the Norwegian guidelines for preliminary identification of HMWB are utilised. Most of the small rivers located downstream of tunnel collection systems are dammed by small dams with no release of bypass flows. Only peak flood flows overtop these dams for a few days each year, and the streams are essentially dry below the dams. Thus all of these small streams are clear candidates for HMWB designation. In almost all cases the supplementary flow entering from tributaries below the dam is insufficient to return the flow to natural condition before the stream enters the lake or main river below. Thus, in most cases the entire stream is categorised as one HMWB.

Regulated lakes

One HMWB criteria which has been adopted throughout the basin is that of lake regulation greater than 3m. This applies to almost all regulated lakes with the exception of Suldalsvatn and Mosvatn. Whatever data that has been collected so far on lake ecology, confirms that these lakes still maintain good ecological status, while all other heavily regulated lakes have totally altered littoral zone conditions and cannot be made to resemble natural lakes. It should be noted however, that there are no regulated lakes in the Suldal basin with an annual drawdown of between 2 and 7 m. Lakes with more than 5-7m drawdown are always severely modified ecologically. Between 2 and 5m is an area where marginal changes in ecology can be expected and the designation of HMWB may be open for review, but no such examples are found in the Suldal basin.

4 TYPOLOGY AND REFERENCE CONDITIONS

Altitude/climate

The Suldal river basin is located in the Western Norway Eco-region. The basin is dominated by high altitude areas, transacted by sparsely populated rural areas in the lower part of the valleys. Steep gradients in river morphology through the narrow boreal zone, make the water quality dominated by the original high altitudes.

Water quality

Water quality is characterised by calcium content less than 1 mg Ca/l and very low concentration of humus substances and organic matter. All rivers are therefore in general of the type **clear (non-humified) and very low in calcium content**. The same typology criteria apply to all the large and small lakes in the river basin. The water quality is generally typical for streams descending fast from the **high mountain** areas of southern and western Norway, although **boreal and lowland** types also occur.

Size

Most rivers in Suldal, with the exception of the Suldal River from Lake Suldalsvatn to the fjord outlet, come in the size category **small/medium**, as do all lakes with the exception of Suldalsvatn.

Experience

The preliminary assignment of types to water bodies has been relatively simple throughout the Suldal basin with very few types encountered. Further detailed typology may be required once the regional authorities examine water quality in more detail. Thus it is difficult to comment on the suitability of the different types being used, and the reference conditions ascribed to each type. Experience must be gained from characterisation process locally before further constructive comments can be made.

Steep rivers

The nature of rivers in western Norway is typically steep and rapid flowing, descending from high mountain altitudes to the sea over a short distance, and Suldal River Basin is no exception in this regard. In such a situation, one can easily question the assignment of altitude types based on the use of thematic map data or simple contours representing the borders between high-mountain, boreal and lowland zones. Such a mechanical process will not take account of the fact that water quality and temperature etc. will remain representative of the upper part of the catchment quite far downstream in the river system, and high-mountain types should dominate the typology. For this and other reasons, the typology of Norwegian water bodies is still under review, even though the type system described above is being followed for the present.

"Average type"

The delineation between mountain and boreal areas crosses many of the rivers in Suldal river basin. It would not seem appropriate to make a clear division into new water bodies at each point the river enters the forest. Thus the use of map theme on forest area has been used sparingly to delineate separate water bodies. Rather an approach has been used where the dominant climatic region has been applied as the parameter for determining the chosen type for the entire water body, without dividing the water body into two water bodies at the forest boundary.

5 PRESSURES AND IMPACTS

5.1 Summary of pressures

Sewage discharge

The sewage from the municipality centre Sand at the river mouth is collected and led to the fjord without any extensive treatment. The other population centres are very sparse and low density. Each has separate discharges mainly led to ground infiltration.

Agriculture

The Suldal basin contains only very limited areas of agricultural activity, mostly situated in Røldal around the lake Røldalsvatnet and along the lower parts of the River Suldal. Run-off from agricultural areas has minimal impact, and only very locally affects water quality.

Acidification

Large parts of western and southern Norway have received large amounts of acidic precipitation during the previous century, and extensive liming has been considered necessary to ensure reasonable water quality for the salmon within the River Suldal. At present, several of the local tributaries to the river have been limed, as well as the outlet from lake Suldalsvatnet.

Airborne pollution

There are several industrial smelters in neighbouring valleys to the west (Odda and Sauda). Some pollutants from these smelters can be airborne and affect the water quality in Suldal. There have been no investigations designed to map such effects in Suldal, but there are no grounds to suspect such pollution problems in future years after more attention has recently been paid to airborne emissions.

Aquaculture

Norwegian fish farming industry produce salmon in several locations both in the coastal areas and within the fjord outside the Suldal River basin. Effects of extensive escape of reared fish and a large increase in parasite production, especially salmon lice, have been monitored and found to have severe effects on populations of both wild salmon and sea trout within this region in western Norway.

Traffic

The roads within the river basin are not subjected to heavy traffic, and even though they mainly are located close to the rivers, the risk of accidents resulting in a severe pollution is low. The main road along the lake Røldalsvatnet is the only significant road with a corresponding risk of accident.

Sports Fishing

The River Suldal was one of the most famous Norwegian salmon rivers and as early as in 1164 ad. King Magnus dedicated the fishing rights to the church. The largest salmon ever caught was 34 kg, and the annual maximum overall catches were registered in 1964 when 7980 kg were brought ashore. During the 1990ies, the salmon population was diminished and restrictions were introduced. The present fishing within the river removes on average 40-50 % of the brood stock.

5.2 Protected Areas

National Park The upper parts of the river basin lie within the National Park of the Hardangervidda (high plateau), and are thus fully protected from future pressures (see Map 1). There is a national highway (No.11) passing below the park, which is one of the main mountain passes crossing from west to east Norway.

Landscape protection A lower level of protection is afforded to high mountain areas to the east and southern parts of the Suldal basin, see Maps 4 and 7. This is nevertheless sufficient to prevent most human activities, which might threaten water body status. Large construction works are forbidden, and changes to forest and agricultural land are strictly regulated or forbidden, although these particular areas lie above the treeline.

Nature Reserve There is a small nature reserve on the Drotninghei heathland in the western part of the river basin.

National Protection Plan The Hamrabø sub-basin drains into the northern shore of Lake Suldalsvatn, and is permanently protected from hydropower development under the fourth national protection plan against hydropower.

Potable water sources There is currently no protection granted to catchments of potable water sources, but the possibility of such has come under discussion locally.

5.3 Physical Alterations in River Suldal

Hydropower Most of the physical alterations in the basin are due to the construction of hydropower plants, as shown in Maps 2 and 5 and described previously. Some more detailed information on the important Suldal River is given below.

Dam at Suldalsosen The most important physical alteration is due to the dam at Suldalsosen, the outlet to Lake Suldalsvatn, causing a disruption of river continuum and change of downstream flow. The dam has several large gates to provide discharge into the River Suldal. The reservoir Suldalsvatn is operated between Highest Regulated Water Level (HRWL) at 68.5 masl and Lowest Regulated Water Level (LRWL) at 67.0 masl, 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 HRWL 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 Røldal-Suldal and Ulla-Førre hydropower plants.

Fish ladders 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 andronomous brown trout to pass the waterfall and enter the river for spawning.

Liming installations

Four installations for liming along the main river; at the dam in the outlet of Lake Suldalsvatn, and in three tributaries below the dam. In addition there is liming of one tributary catchment. The physical alteration of the river channel to establish the liming installations are relatively minor, and can be disregarded as a hydromorphological alteration, although the chemical quality is clearly altered at these locations.

5.4 Assessment of Resulting Impacts

5.4.1 Flow conditions in the River Suldal

Transfer to Hylen

The Hylen hydropower station has rules for operation, which instruct it to release a minimum discharge to the River Suldal. This discharge varies from at least 12 m^3/s in the winter to at least 150 m^3/s during the snowmelt 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 Suldal. The main objective of the new operational rules is to improve the conditions for the Atlantic salmon.

Flow measurements

Mean monthly flows out of Lake Suldalsvatn, at Suldalsosen, for the three periods with different hydrological regimes are shown in the diagram in Figure 2.The flow conditions today after completion of the Ulla-Førre hydropower scheme are compared to natural conditions. In addition the flows in the period 1967 – 80 are shown, after the Røldal-Suldal Power Plant came into operation, but before construction of Ulla-Førre. The flow distribution in the period 1967-80 (RSK HPP in Figure 2) was quite different from both natural conditions and today's conditions. Especially the winter flows were large, and the flow variation throughout the year was much less than today.

Monitoring

Today there are discharge-gauging stations at this location and at the river outlet at Sand. 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. Hydrographs from three typical years are shown in Figure 3.

Recent flow regime

Natural flows at Sand have 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. The changes from natural to today's conditions at Suldalsosen can be summarised as an approximate doubling of winter flows from natural conditions, but otherwise a halving of the mean monthly flow due to diversion of water through the Hylen power plant. Flow data can be seen in Figures 2 and 3, and are given in more detail in earlier studies. The flow conditions during the winter are today quite similar to the natural situation, but with less variability. During the rest of the year, however, the flows are now significantly reduced.

Current flood regime The occurrence of large floods is strongly reduced from peak flows of 600-700 m³/s at any time from June to December (both snowmelt and autumn storm floods occurred) to a peak flow of 270 m³/s since the operation of the Ulla-Førre scheme started in 1980.

Figure 2: Seasonal flow, three hydrological regimes

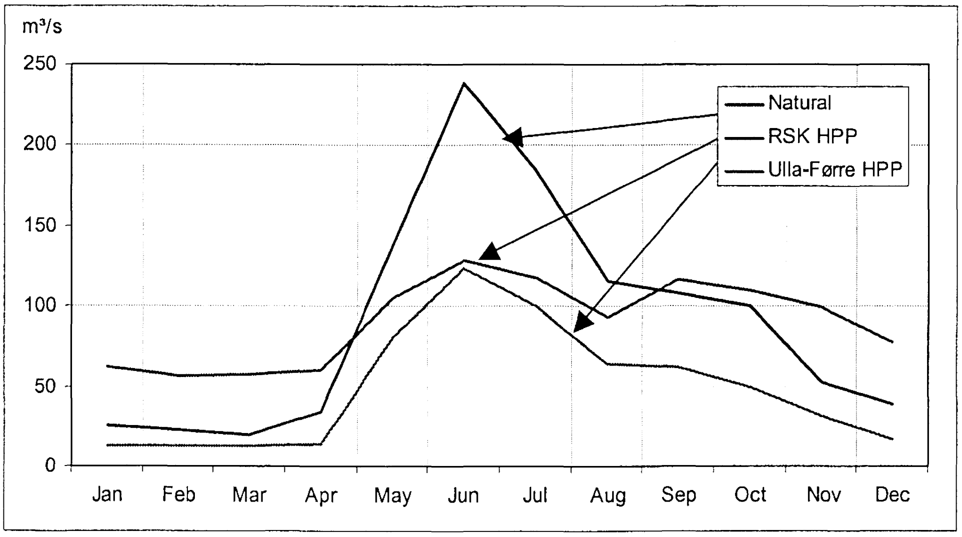
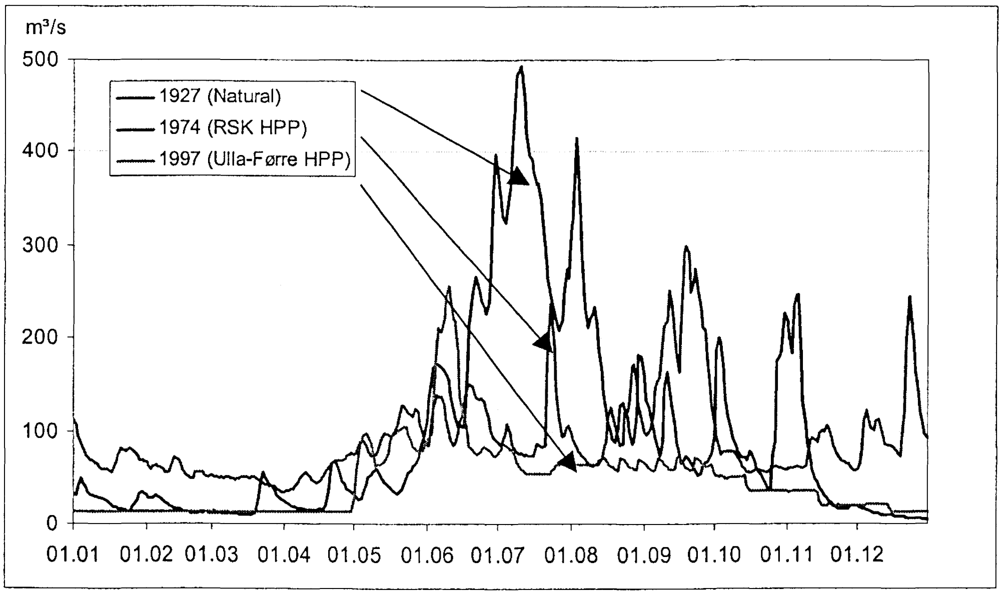


Figure 3: River Suldalslågen at Suldalsosen – Three Typical "Normal" Years



5.4.2 *Water temperature in the Suldal River*

Comparisons

Water temperature has been measured at two sites in the Suldal River; at Suldalsosen since 1962 and at Sand since 1972. The two periods with hydropower plants in operation, 1967 to 1980 with Røldal-Suldal and 1981 to present with both Røldal-Suldal and Ulla Førre, 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 Stordalsvatnet, in a nearby river which is unaffected by hydropower development, in order to describe natural variations in water temperature in the region.

Seasonal temp.

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 about 1 degree Celsius lower today compared with natural conditions, peaking at around 11 deg C in August.

River ice

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 Røldal-Suldal scheme in operation, hardly any river ice at all occurred. Since 1981, with the Ulla-Førre scheme in operation, the winter flow has been reduced to a level 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.

5.4.3 *Sediment transport in the Suldal River*

Investigations

During the nineties the transport 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.

Reduced transport

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.

5.5 Surface water quality

Suldal River

The Suldal River 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 on rivers, in addition to terrestrial and lake liming in the unregulated local sub-catchments.

pH and alkalinity

The Røldal-Suldal regulation did not change the water quality in Suldal River, but the effect of the general acidification in this region in the period 1970-1980 was 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 Suldal River. A general increase in conductivity has become a normal situation at Sand compared to the outlet from lake Suldalsvatn. After the water in the reservoir Blåsjø has been transferred to Lake Suldalsvatn (from 1986), the alkalinity has declined gradually in River Suldal at Suldalsosen to a level <15µekv/l. Today the most critical period for the water quality in River Suldal 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.

Acid water

In addition to the regional acidification, the regulation of the river for hydropower purposes has led to a steady decline in pH and alkalinity. 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, as the decline in Atlantic juvenile fish density during the nineties probably was related to shortage of spawners - to a large degree caused by factors in the ocean.

Nutrients

Nutrient elements have been measured in River Suldal sporadically in the period 1981-1988 and more systematically since 1990. Generally low levels of both nitrogen and phosphorus have 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 River Suldal has become richer in nutrients since the regulation impact even if the recipient capacity has been reduced.

Toxic pollutants

Toxic substances such as heavy metals and synthetic pollutants have been measured in River Suldal since 1990. Examples of measured concentrations of Heavy metals, Lindane and PCBs are given in earlier studies. In the whole period of measurements only very low concentrations have been measured. The observations are from river water only, not from biota or sediments. No data exists from before the regulation impact.

5.6 Groundwater quality

Temperature

In-situ temperature in glacifluvial groundwater bodies has been found to be relatively constant over the year, indicating long residence times. The very small extractions that occur offer no threat to the sustainability of the resources and the aquifers are given "high quantitative status".

Quality

Bacteriological quality is excellent, but the water has relatively low pH and low buffer capacity. Analysis of nitrates from all aquifers shows low values, indicating that little or no infiltration has occurred from agricultural runoff where fertiliser is used, despite some agricultural land overlying the aquifers. There does exist a registered deposit of DDT on the aquifer at Sand, but this is old and undisturbed, and represents only a minor local threat. Therefore all groundwater is assigned to the "good physico-chemical status" classification.

6 ECONOMIC ASPECTS

6.1 Trend analysis

Polulation Statistics

The Norwegian Bureau of Statistics (SSB) publish census details at the level of school areas in each municipality, and projections of population growth at aggregate municipality level, and these can be used to determine demographic trends regionally and basin-wise. The only operation which is required to convert this data to corresponding projections for the river basin is to examine the GIS maps showing population distribution and make approximate adjustments to redefine the statistics for the basin in question. Since most of the population live in the valleys, this is not difficult in western Norway.

Suldal

The freshwater part of the Suldal River basin encompasses only two municipalities, Suldal and Odda, although the county border between Rogaland and Hordaland also follows the border between these two. About 2500 of the Suldal population of 3923 live within the river basin, while only 500 of the Odda population live in Røldal and its surroundings, within the basin. It is therefore calculated that the 2002 population in Suldal River Basin was about 3000.

Population trends

SSB projections show approximately stable or slightly declining populations, so it can be anticipated that the population will also number 3000 in 2015, and that there will be a slight local shift towards the semi-urban centres of Sand and Røldal.

Agriculture

Agriculture statistics show that in 1999 Suldal municipality had 31 500 da total agricultural area, although some of this will be outside the river basin along the coast. The Odda municipality has negligible agricultural area in comparison (small area around Røldal). This is an increase of 6000 da from 1989, but more recent statistics may show a reversal of this growth trend. From 1989 to 1999, the statistics reveal a change in cultivation from full cultivation to grazing and fodder production. In addition there is a marked trend towards larger farm units, with average size increasing from 50 to 100 da approximately. Grain and potato production has almost ceased. It is expected that the area of cultivated land in remote valleys such as Suldal will rather decrease than increase in the period up to 2015, but this will be studied in a national analysis of agricultural trends recently started.

Industry

There are very few industrial enterprises in the Suldal basin, and the few that exist are small local service-related enterprises with negligible or very local pollution problems. There is not expected to be any significant alteration of this pattern up to 2015, although the Suldal municipality plan predicts rather pessimistically that 85% of today's enterprises may close down by 2020.

6.2 Water supply

Waterworks

There are 5 registered publically-owned waterworks in the basin, located at Sand, Suldalsosen, Mosrøysane, Nesflaten and Røldal. The combined public supply from Suldal municipality (i.e. excluding Røldal but including some waterworks lying outside the basin) in recent years has been approximately 385 000 m^3 p.a., equivalent to 152 m^3 per connected person. This comprises 45% to private households, 21 % to industry, commerce and other activities and 34 % leakage from the piped networks. Much of the rural population is supplied from private wells or springs and is not included in these statistics. The supply is from groundwater at Sand, Røldal and Suldalsosen, and has no chemical treatment, since the water is of good quality. The supply at Nesflaten is from surface water.

6.3 Sewage

Public sewage

Suldal municipality has a total of 50 km of sewage pipes and 11 small sewage works, of which only 2 discharge to freshwater recipients inside the Suldal River basin. Municipality sewage works cover about 65 % of the population, i.e 2000 inhabitants. Most have simple mechanical or natural treatment, before discharging to the river or lake as recipient. Total Phosphorus discharge from sewage is of the order of 1.2 tonnes annually, but this is spread over 2 locations, and is therefore not a significant threat to any of the water bodies used as recipient. Most of the discharge from the population at Sand goes directly to the sea from Sand treatment works, and the population of Røldal (Odda municipality) have a small sewage treatment works which discharges into lake Røldalsvatn.

Private

Most private sewage is located in spread farming communities and collected in septic tanks and transported for treatment at the public works. Even untreated sewage discharge in some few locations represents only a very local pollution without threatening the ecological status of the water bodies nearby. In all cases the capacity of the recipient water body is good, and no water bodies are considered to be particularly vulnerable to such small-scale sewage discharges.

6.4 Cost recovery for water services

Water services

The data on financial cost recovery for water services is already supplied by SSB at the municipality level (KOSTRA database). For the purpose of this study, it is necessary to assume that level of cost recovery is uniform throughout the municipality, such that cost recovery for part of the municipality within the basin can be inferred from the data given for the entire municipality. In the case of Suldal, this is quite probably the case, with about 65% of the population living within the basin. In the case of Odda, most of the population live outside the Suldal basin, and for the one small water supply scheme which lies in Odda district (Røldal) specific data cannot be extracted. We therefore infer that the case for this water supply scheme is similar to the average for Suldal, and use the data for Suldal municipality as an indicator of cost recovery for the entire Suldal basin.

Cost recovery

The level of cost recovery for water supply and sewage services is shown in Table 6.1 below. It should be added that water leakage rate is measured at 34%, near the average for the region, and that this is not accounting for the poor level of cost recovery.

Table 6.1 Water and sewage sector statistics from Suldal municipality

	Suldal	Rogaland county
Cost recovery in Water supply	17%	91%
Cost recovery in Sewage	38%	78%
Income per m^3 supplied	23.6 kr (2.9 Euro)	4.9 kr (0.6 Euro)

Water supply

The low cost recovery level of 17% for public water supply in Suldal, is possibly related to the high cost of supplying very small and highly dispersed populations, such as those found in Suldal river basin. The same statistics show that income generated per m^3 supplied in Suldal is five times higher than the average for Rogaland county, but tariff levels are less than 70% of the county average. It is possibly politically difficult for the local council to raise the tariff for water supply much higher to improve their cost recovery level in the water supply sector. There probably will continue to be a cross-sectoral subsidising of the water supply sector in such municipalities as Suldal, with high per capita income from hydropower taxes, and high cost of providing potable water to their sparse population. Since this does not represent a threat to any water resources, there is no reason to report this low cost recovery in Suldal as especially problematic regarding the principles of the WFD.

Sewage

For municipalities in western Norway, it is important to distinguish between sewage outfalls to coastal waters and those to inland waters. The population centre Sand is typical for many coastal communities, and has currently two sewage outfalls to the fjord. Sewage outfalls from other population centres are inland, and of very small scale. It is therefore difficult to determine the consequences of cost recovery in the sewage sector since the different plants have widely differing treatments and costs. Nevertheless, the level of cost recovery in Suldal of 38% is rather low, and some investment in sewage treatment may be required in the period up to 2015.

6.5 Economic analysis of water use

Hydropower

Hydropower is by far the most important water user in the Suldal River Basin. It generates by far the largest income of all water users for the municipality. Hydropower has a very high proportion of capital costs compared with operation and maintenance costs. Most of the capital costs are now “sunk” costs in the Suldal basin, since the projects were constructed as far back as in the 1960s and 1970s. The operating life of the plants is 60-100 years, and there are not expected to be major rehabilitation or decommissioning costs in the next decade. Thus it can be expected that continued water use for hydropower production in the period up to 2015 could be justified through an economic analysis. The question is how should such an analysis be set up, and whether it should be applied at the national level, river basin level or at the level of the individual hydropower scheme. No guidance documentation exists on the subject of economic analysis of hydropower according to the requirements of the WFD, but economic analysis has been used extensively in the planning and decision making process for hydropower development in Norway for many decades prior to the introduction of the WFD. However, it is debatable whether all environmental costs have been internalised in previous economic analyses, and the WFD principles will certainly help in re-assessing environmental costs.

Important principle

The valuation of resource and environmental cost of water is the most important question to be considered in such an analysis. In some way, the environmental cost of water use for hydropower production can be roughly quantified by examining the cost of environmental programs and mitigating measures implemented in connection with the hydropower development. Some few studies have also been done on defining the public willingness to pay for environmental programs. However, it is uncertain if this covers all the cost to society of the development, and some additional cost would seem appropriate to add for loss of esthetic value of natural rivers, any loss in biodiversity incurred, and other environmental values not easily quantified.

Resource costs

The cost of utilising water as a resource depends on its value for alternative water use, both now and in the future, including its use to sustain a natural environment. In river basins where there is scarcity of water and considerable competition for use of the water resources, the resource cost of water is rather high, and not negligible as has often been the case in past economic analysis methods. However, the Suldal river basin is a typical example of a river basin in western Norway, where water resources are not scarce, and competition for water use is limited. Both the domestic and industrial water supply and agricultural sectors use water only in very small quantities, and there is no scarcity of water due to the wet climatic conditions and abundance of surface and groundwater near all the demand centres.

Waterfall rights

To some extent there is already a mechanism in Norway for financial compensation for resource costs in the payment of fees for waterfall rights, which is made on taking a stretch of river into use for hydropower production. These rights are part of the landowner rights under Norwegian law, and can be transferred or leased to the developer against payment of a fee. This fee is additional to fees for purchase or lease of land paid by the same developer, and to taxes imposed on the developer by the local municipality.

Competing use

In practice, the only competition to hydropower for surface water resources in Suldal is from the fishing, recreational and environmental sectors. In the absence of a better method of valuation of resource and environmental costs, it is therefore recommended that the average annual expenditure on environmental programs be used as a first estimate of the total environmental and resource costs of hydropower water use. Unfortunately, time and budget constraints do not permit the reliable estimation of these figures in this phase of the PRB study. A national research project on the subject of the economics of water use for hydropower is recommended.

Minimum flows

There are strict requirements for minimum environmental flow releases from Suldalsvatn lake to the Suldal River. These are shown graphically in figure 4 and are currently under review. The purpose of these requirements is to improve conditions for the wild Atlantic salmon, which inhabits the river. This is a good example of a set of measures being employed to mitigate the negative effect of hydropower on the ecological status of the Suldal River. Such measures will be reviewed under the process of implementing the WFD in coming years. At this stage it is sufficient to register that there is a user conflict between hydropower and environmental/recreational fishing interests, and that the calculation of economic cost for both users is a complex exercise outside the scope of this study.

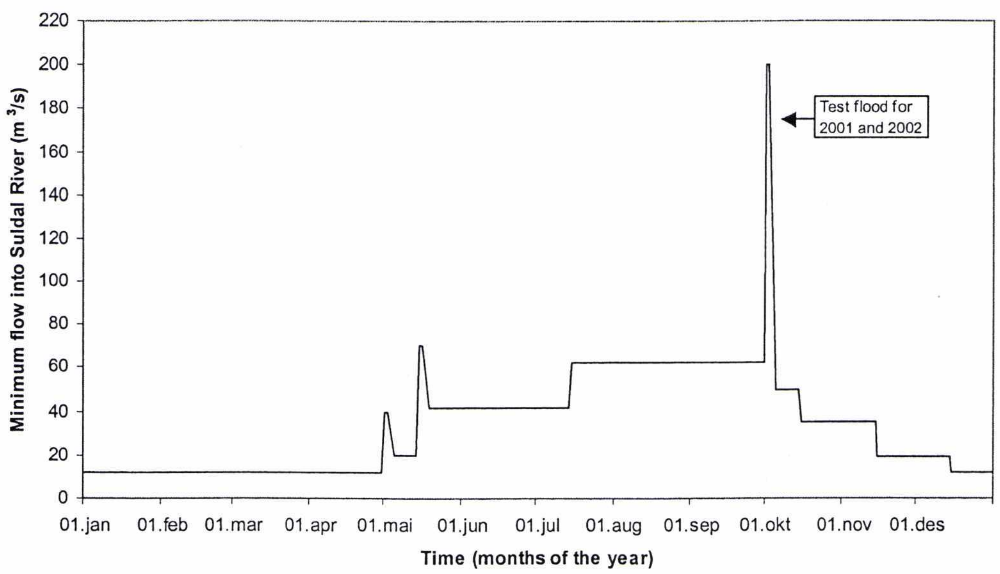
Scale

Nevertheless, it is of interest to use the Suldal PRB to examine the scale of economic values and costs represented by hydropower development in western Norway. Some comparative figures can be of great value in gaining an overview of the economics, prior to starting the more specific analyses required at later stages of the WFD implementation process.

Income

Revenues from energy generation are relatively easy to quantify in Norway after the introduction of a free market in trading of electricity in 1990. There is a market for long-term contracts, and a more volatile spot market for trading of energy the following day. The price paid in the long-term market for energy traded in say 2005 gives a good indication of the long term value attached to gross firm energy supplied anywhere on the main transmission grid. Currently that is 0.23 kr/kWh as an average for the year, although winter prices are naturally higher than spring and summer prices. Taking only the Røldal Suldal development scheme, which uses water resources from entirely within the Suldal basin, the average annual income from gross energy sales will be 3131 (GWh p.a.) x 0.23 million NOK = 720 million NOK p.a. (nearly 90 million Euros p.a.).

Figure 4: Minimum flow into Suldal River from Suldalsvatn through the year



O & M costs

Operation and maintenance costs are more difficult to estimate without contacting the owners, and such costs are probably not going to be released by the owners in a competitive market situation. However experience from other hydropower companies in Norway indicates that economic O&M costs (excluding taxes) for such a scheme would lie lower than 20 million NOK annually, i.e less than 3%of the annual income. The greatest cost for hydropower companies is capital costs.

Capital costs

The capital cost could be measured as the replacement value in today's money of building the power scheme. This does not seem to be a relevant approach in terms of the questions asked by the WFD economic analysis of water use for existing hydropower schemes. When the investment is a sunk cost, only the cost to society of continuing to use water for hydropower purposes is relevant. The other possibility of not using water for hydropower would involve decommissioning costs to remove the dams and power plants, and that is not a realistic proposition for such relatively modern and well-functioning plants as Røldal Suldal. Thus for the first analysis of water use in existing hydropower schemes, it is sufficient to demonstrate the great difference between annual income (720 million NOK) and total costs including environmental and resource costs (in total perhaps around 5% of annual income from the Røldal-Suldal scheme).

Mitigation measures

Some measures to improve ecological status of HMWBs involve the alternative use of water for environmental purposes, commonly referred to as environmental flows or releases. The economics of such releases will be examined in future years as part of the detailed economic analysis of alternative measures. The Suldal river provides a good example of such releases, since it is possible to weigh the costs and benefits to all sectors of releasing water from Lake Suldalsvatn either through Hylen power plant or down Suldal River. This is however an exercise for future studies.

New hydropower

The economic analysis must include the capital cost of developing new hydropower in the river basin, and is therefore more complex than the analysis described above for the existing Røldal-Suldal scheme. Such analysis techniques need to be reviewed in light of the WFD requirement to include them in river basin plans in coming years. There is, however, a thorough process of review already incorporated in the application and granting of new concessions for hydropower development, and it is probable that this review already follows the spirit of the WFD in weighing the benefits and costs in different sectors, before granting a concession to schemes with substantial economic net benefit to society. There are several plans for expanding the Røldal-Suldal scheme with new power plants, transfer tunnels and regulating reservoirs, with a total of more than 120 MW new capacity planned in the long-term. None of these schemes has reached the stage of a preparatory notification of the official planning process, which is the first sign of realistic planning being completed in the immediate few years. Several, or even all of these schemes may never be realised. The procedures currently in place in Norway for providing permits for new hydropower schemes, both large and small, will probably be reviewed in the next few years in the light of the WFD requirements.

Mini-hydro

Only mini- and micro-hydropower schemes are exempt from a full and time-consuming concession application process. For such small schemes there is already a national planning system, which screens out only those schemes with good economics and minor negative impact on the environment. There are many plans for mini-hydro development in Suldal River basin, probably more than 20 separate projects at different stages of planning. The current register of mini- and micro hydro projects lists 10 permits for construction of such schemes, although there is no updated data on how many are under construction.

Conclusion

The Suldal basin demonstrates that the continued use of water for hydropower production in existing schemes is of great economic benefit, but that more detailed examination of mitigation measures such as environmental releases is required in a macro-economic perspective. The Suldal River below the lake Suldalsvatn is a good case for such studies.

Other uses

The economics of water use for potable water supply may be examined for certain groundwater WBs which are utilised today for that purpose. Such analysis must be done at the local municipality level as part of the overall river basin planning process, and is not possible at the river basin scale, which this report deals with. The same applies to the use of rivers, lakes and fjords as recipients for sewage outfalls. Before attempting such analysis, it is rational to examine first which water bodies have a real risk of not attaining good status in 2015, and applying the economic examination of water use specifically to those water bodies "at risk", rather than considering the use of water generally for each sector throughout the basin. The next chapter therefore describes the process of determining current status and risk of not attaining good status.

7 STATUS AND RISK

7.1 Ranking of pressures

Hydropower

Clearly the past hydropower development is and always has been by far the most significant pressure within the Suldal River Basin, and must be considered to be a **major** pressure. Modern-day plans to extend the hydropower schemes and add mini-hydro plants on small tributaries will also represent a future pressure.

Other pressures

Present pressures from nutrient loading from sewage and agricultural run off is considered to be **insignificant**. Present pressure from acidification is considered to be **minor**, and is mostly due to transfer of waters of very low alkalinity. The pressures from aquaculture on the salmon populations is considered to be **minor**. However, lethal levels of salmon lice for the migrating smolts in this region were observed especially during the late nineties, but measures taken have reduced this problem at present.

7.2 Description of current status in Suldal Rver

Water quality

In general, the Suldal River Basin is oligotrophic and has a very low conductivity and alkalinity. The concentrations of nutrients such as phosphorous (<4µg P/l) and nitrogen (<200 µg N/l) are low, except for local sections subject to periodic agricultural run off. The pH is normally around pH 6.0, and seldom below 5.3. The alkalinity is very low (0-40 µekv/l) and also concentrations of reactive labile aluminium are low (normally 10-20 µg Al/l). This fraction of the aluminium compounds can damage the salmon gills and is the most common cause of fish mortality in acidic waters.

Fish populations

Dominant fish species within the river basin are resident populations of brown trout (*Salmo trutta*). However, in the River Suldalslågen Atlantic salmon (*Salmo salar*) is the dominating fish species besides anadromous brown trout (*Salmo trutta*). In addition three spined sticklebacks (*Gasterosteus aculeatus*), eel (*Anguilla anguilla*) and also resident Arctic charr (*Salvelinus alpinus*) are found in Lake Suldalsvatnet.

River Suldal

River Suldal has been the subject of extensive scientific investigations and monitoring over the last 35 years. The hydromorphology is modified, and the water quality is changed to a certain extent, mainly due to importing of waters with low alkalinity from the mountains to the south which drain into the Blåsjø reservoir. However, liming of both the river and some of its tributaries has reduced such problems for the ecosystems, and other aspects of water quality are not deviating from the natural conditions.

Acidification

The Suldal River Basin has received large depositions of acidification during the last century, and the fish populations have been at risk in the most sensitive lakes, as has much of western Norway in general. Liming was also considered necessary to ensure adequate water quality for the salmon within the River Suldal. As the fish population was in the danger of being affected, both the main river and some of the most acidified tributaries have been limed since 1998.

Effect on fish

However, no clear negative effects from acid water are seen on the fish populations within the river. Detailed studies done by the University of Oslo have documented that naturally occurring fingerlings of salmon and trout in the most acidified tributaries to River Suldal show insignificant levels of damages to fish gills. This is the initial indicator of the effect on these fish of biologically significant acidification levels. The decline in Atlantic juvenile fish densities during the 1990ies is probably mainly related to shortage of spawners, and regarded to a large degree as being caused by factors in the ocean.

Reduced Sulphur

Due to the effect of international treaties on reductions of emissions, the depositions of sulphurous acidifying agents (sulphuric acid) have been reduced to less than 40% of the 1980-levels, at the peak of acidification. In spite of rather stable deposition levels of nitrous components (nitric acid), water quality has generally improved in the region and resident trout populations within previously affected lakes in western Norway, have responded by increased survival of offspring.

Further reductions

The acidification level will be further reduced in the near future towards 2015, but not as much as the previous 25 years. Improvements in recruitment within natural populations of salmon and trout in western Norway seem to mirror the improvement in water quality closely, indicating that acidification in 2015 most probably will be a minor factor within the moderately affected water bodies where salmon still survive.

Liming

Reduced river flow especially during winter, can also increase the relative importance of water from slightly more acidic tributaries below the Lake Suldalsvatnet. Since the fish population was in danger of being affected, extensive liming has been carried out since 1998.

Wild salmon

The population of salmon has been reduced during the nineties, but at present both the recruitment and the overall smolt production seem to approach the natural carrying capacity of the river system. In spite of a clear shortage of spawners in the population, reflected both in low catches and in the number of adult fish counted annually within the river, the sparse spawning population seems to be able to produce sufficient numbers of fertilized eggs to fulfil the carrying capacity of the river. The causes of negative impacts on the salmon populations can also be found in the sea, (fish farming in the fjord, sea-lice etc.), and also follow to some extent the climatic variations between years.

Benthos

The production of benthic invertebrates has increased significantly the last few years in comparison with the levels of the previous decades, but the reason for this is not well understood.

Moss

Moss growth on river substrate has increased after the hydropower regulations, probably due to reduced floods and increased winter low flows. 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 (Heggenes and Saltveit, 2002).

Status

At present it is possible that the River Suldal has good ecological status, showing only minor deviations from the natural conditions in overall ecological aspects, in spite of major modifications in hydromorphology. However, there is no doubt that the river has been modified by upstream regulation and diversion of flow to Hylen power plant and into Hylsfjord. The major impacts from the hydropower reservoir regulations are related to hydrology, sedimentation regime and the transfer of waters of low alkalinity. The direct biological effects are less significant.

Mitigating measures

However, the reason for this is that a series of measures have already been introduced to improve ecological status, and as such the present status can be viewed as typical of the expected result of mitigating measures applied during implementation of all of the WFD processes. Nevertheless, it is far from certain that the current program of measures is optimal, and it is necessary to go through all the WFD steps to test which alternative measures are cost effective. Therefore we choose to consider the Suldal River as a candidate for HMWB identification at this stage, so that the impact of hydropower can be separated from the impact of mitigating measures already imposed (minimum flows, artificial floods, liming etc). If we were to define the river as a natural water body at this stage, it may not be given the attention it deserves in the following stages of the WFD implementation process.

7.3 Current status of other water bodies

Lake Suldalsvatn

Lake Suldalsvatn is poor in nutrients and elements in general, and clearly oligotrophic. The water quality is monitored periodically by sampling. The populations of stationary brown trout and arctic char have been investigated, and nearly 10 metric tons of arctic char have been removed through intensive cultivating the last three years. The probable ecological status is **Good**, despite the fact that the lake has a dam with fish passes at its outlet, and 1,5 m annual regulation of water level. A significant flow of water occurs across the lower middle part of the lake from the outlet to the Kvildal hydropower station to the intake for the transfer tunnel to Hylen power station. There is no evidence that this local change in hydraulic load influences the ecology of the lake in any significant way.

Tributaries

Tributaries in the lower part of the basin vary in water quality, and have only been subject to sporadic collection of biological data, mainly fish. The following tributaries have some data on water quality, indicating **high** ecological status; Hiimsåna, Fossåna, Kvæstadbekken, Stråpåna, Vekåna, Lavastøl, Saurdal, and Hamrabøåna. Although there is lack of data elsewhere in the river basin, there is nothing to suggest that the status should be anything other than **high** or in the case of local or occasional acidification, good. Naturally this does not apply to heavily modified water bodies (HMWB) shown as such in the Maps 3,6 and 8 enclosed herewith. These are now a separate category and status classes have not yet been assessed, but are thought generally to be **moderate or worse.**

Tributaries with liming

The tributaries Mosåna, Tveitliåna, Steinsåna and Tjøstheimåna are all limed periodically to raise the pH and protect existing fish stocks, mainly salmon and trout. Due to the occasional acidification of these tributaries, it is possible to characterise these as **good** status, but not lower, unless there is evidence of clear loss of species or other severe ecological impacts.

Lowest tributaries

The tributaries Hanakambekken and Brommelandsbekken suffer from occasional significant pollution from agricultural runoff. Benthic fauna are then influenced. During such times they have periodically reduced status, but generally good status otherwise. Studies on fingerlings of salmon and trout in Brommelandsbekken by University of Oslo, confirm **good** status despite the occasional agricultural pollution.

All others

Most of the other water bodies in the river basin are considered to have **high** ecological status, except for the candidates identified as preliminary HMWB. The present situation is in close accordance to the natural status of all the ecosystems not exposed to flow regulation.

HMWBs

For the candidate HMWBs, the river ecosystems are apparently more influenced than the lake ecosystems, but it is likely that the great majority of both of these will be confirmed as HMWB in later stages of the process. The heavy regulation of most lakes (see Appendix 5) and the total drying out of most diverted rivers leave little doubt that these bodies are "heavily modified".

7.4 Classification of Current Ecological Status and that in 2015

Current status

In the following tables we have summarised our evaluation of current ecological status based on drafts of recent summary reports from March 2004. All classifications are based on expert judgement, and deviate slightly from the previously presented evaluations by Johansen et al. (2002) based on status in year 2000. The result of this evaluation is shown in Maps 3,6 and 8. These maps demonstrate that there are no significant risks associated with pollution, and that the HMWB category is dominating the water bodies affected by development of hydropower and dams. HMWB-category water bodies have not been assessed for risk in 2015.

Acidification

Acidification is not considered sufficient to constitute a significant risk in 2015, even though some precautionary liming is currently taking place in the lower part of the basin. Note that the most affected water body, the Suldal River, is provisionally categorised as HMWB and the status has not been assessed.

Table 7.1 Summary of evaluation of ecological status – Suldal River

Biological elements	Status	Comments
Phytoplankton	High	Originates mainly from Lake Suldalsvatnet
Phytobenthos	Moderate	Significant changes in the balance between species - filamentous green algae has gained ground at the cost of other species. No species lost.
Macrophytes	Good	A general increase in moss cover is observed within the region of western Norway during the last 10 years, also in River Suldal. Liverwort cover seems at least to have doubled.
Benthic invertebrate fauna	Good	Affected by moss cover changes. Increases in abundance of nearly all groups are observed since 2001. No species loss recorded.
Fish fauna	Good	Collapse of Atlantic salmon spawning population in early nineties. Mainly due to reduced survival at sea of the migrating salmon. Present recruitment and smolt production seem in accordance with sustainable capacity of the river. Thus, the main pressures on salmon population are located outside the Suldal river basin.

Hydrological elements	Status	Comments
Hydrological regime	Moderate	Greatly reduced flood regimes has resulted in increased moss cover and adverse substrate changes.
River continuity	Moderate	Dam acts as upward migration obstacle into the lake
Morphological conditions	Moderate	Substrate changes due to increased siltation, and river bed armouring after reduced peak floods.

Physical-chemical elements	Status	Comments
General conditions	Good	Slightly affected by acidification, mitigated by liming. Deposition of acid precipitation has reduced to less than 40% of the 1980 levels, and is expected to further decline.
Specific synthetic pollutants	Good	Lindane detected, but in low concentrations.
Specific non synthetic pollutants	High	None

7.5 Risk of not achieving Good Status in 2015

Risk assessment

Table 7.2 summarises the simple methodology used for assessing the risk of not meeting level of "good status" by 2015. The sign **+** (plus) indicates that at least one of the pressures have significant impact or that at least one of the chemical or biological elements have moderate or lower status. The sign **-** (minus) indicates that no significant impacts have been registered, and there is no reason to believe that any significant pressures exist, even when no data are available. The sign **?** (question mark) reflects situations with no data, but where some possible pressures may be having a negative impact, i.e. a probable **+** (plus) would have been the outcome if any data had been available.

Conclusion on risk

The risk of not achieving good status in natural water bodies has been evaluated simply by considering each of the quality elements (columns) in turn for each water body. If one of these is found to contain a plus sign, then the water body is automatically considered to be at risk (even though the risk may be small considering the vulnerability of the water body). This is the philosophy of "one out - all out". This is a highly simplified methodology, which needs to be refined before the final characterisation is completed. None of the natural water bodies in Suldal River Basin were found to be "at risk", after applying this method.

HMWB

The conclusion regarding HMWBs is that the pressures due to hydropower have resulted in many water bodies being provisionally categorised as HMWB candidates, where neither ecological status or risk (of not achieving Good Ecological Potential) have yet been assessed. This work will come later in the WFD implementation process. Since the designation of HMWB is only provisional and not final, it can be concluded that the HMWBs identified so far are "possibly at risk", and the symbol HMWB in the final column should be interpreted as such in Table 7.2 below. Norway has just started to consider how to define Good Ecological Potential, and it is probable that many of the provisional HMWBs identified so far, will meet the goal of Good Ecological Potential, and therefore be shown later to be "not at risk". Typical examples of this might be heavily regulated lakes where stocking of fish is already carried out as a mitigating measure, and Good Ecological Potential may be achieved already, through this and other measures such as restricting summer drawdown.

No real test

The result of this risk assessment is shown in Maps 3,6 and 8, where it can be seen that most of the river basin (except the HMWB candidates identified) is coloured green, i.e. considered not at risk. Unfortunately this methodology cannot be said to have been properly tested in the Suldal River basin. The reason is that there is an absence of all significant pressures other than hydropower, and acid precipitation to a small and diminishing degree. No pressures due to urbanisation, household or industrial waste, agricultural pollution, introduced species etc. exist to a significant degree in the basin, and all natural water bodies are concluded to be "not at risk" The methodology of assessing risk remains therefore essentially untried.

Table 7.2 Assessment of risk of failing good status in 2015

Water body		Pressures	Qua	Physico-chemical status	Biological status	Risk of not achieving GES
Ground-Water	Galcifluvial aquifers	-	-	-	N/A	Not at risk
	Bedrock aquifers	-	-	-	N/A	Not at risk
Lakes	Natural	-	N/A	-	-	Not at risk
	HMWB	+	N/A	-	?	HMWB
Rivers	Natural	-	N/A	-	-	Not at risk
	HMWB	+	N/A	-	?	HMWB
Subcatch-	Natural	-	N/A	-	-	Not at risk
	HMWB	+	N/A	-	?	HMWB

N/A – Not applicable

Water body lists

All water bodies have been given a unique identity number and entered into a simple database. The results are listed in Appendix 5 which gives the main characteristics of each water body. They have also been separated into the two categories “natural” and “candidate HMWBs” for further treatment at the local level. It can be seen that there are a great number of candidate HMWBs due to the considerable modification of the natural state of many rivers and lakes due to hydropower schemes.

Future work

The methodology described above has assessed in general the risk of not achieving good status in 2015 on a “river basin overview” basis, based mainly on data available at the national level through databases and some research reports. This methodology will be refined and the results reviewed later, when the regional authorities have been identified and are given a mandate to look more carefully at each water body. However, the lack of significant pressures within the Suldal River Basin (with the exception of hydropower) means that very little change is expected in the results of this characterisation after the coming review made by the local authorities.

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Bibliography related to groundwater (in Norwegian only):

Publisher	Year	Title	Report nr.
NGU	1992	Grunnvann i Suldal kommune (GiN)	92.098
NGU	1981	Vannressurskart "Grunnvann i løsavsetninger", kartblad Sand ("blå serie")	25
NGU	1997	Grunnvannsundersøkelser - Erfjord/Hålandsdalen, Nesflaten og Suldalsosen	97.041
NGU	1992	Grunnvann i Odda kommune (GiN)	92.138
NGU	1998	Oppfølgende boringer etter grunnvann på Nesflaten i Suldal kommune	98.042
Asplan Viak	1996	Vannverk Røldal	95521

LIST OF APPENDICES

Appendix 1 - Table showing different type numbers according to preliminary typology criteria used in Norway. The typology is currently being reviewed, and the distinction between slow and fast flowing rivers may be removed.

Under the preliminary typology system, there are 23 different types of lake, numbered 1-23, and 25 different types of river, numbered 1-25, with each number given in one of the cells in the tables below, showing what the general characteristics of the particular type are. For instance, **lake type No. 17** is in the boreal climatic zone, appears under the column low calcium and clear, and is a large lake, >5km^2.

LAKES 1-10 =lowland		Very low Ca <1 mg Ca		Low Ca 1-4 mg Ca		High Ca > 4 mg Ca	
11-20=boreal 21-23=mountain		clear <30 mg Pt/l	humus >30 mg Pt/l	clear <30 mg Pt/l	humus >30 mg Pt/l	clear <30 mg Pt/l	humus >30 mg Pt/l
small	<5km^2	10	11	1+12	2+13	3+14	4+15
large	>5km^2	5+16		6+**17**	7+18	8+19	9+20
All sizes	-	21		22+23			

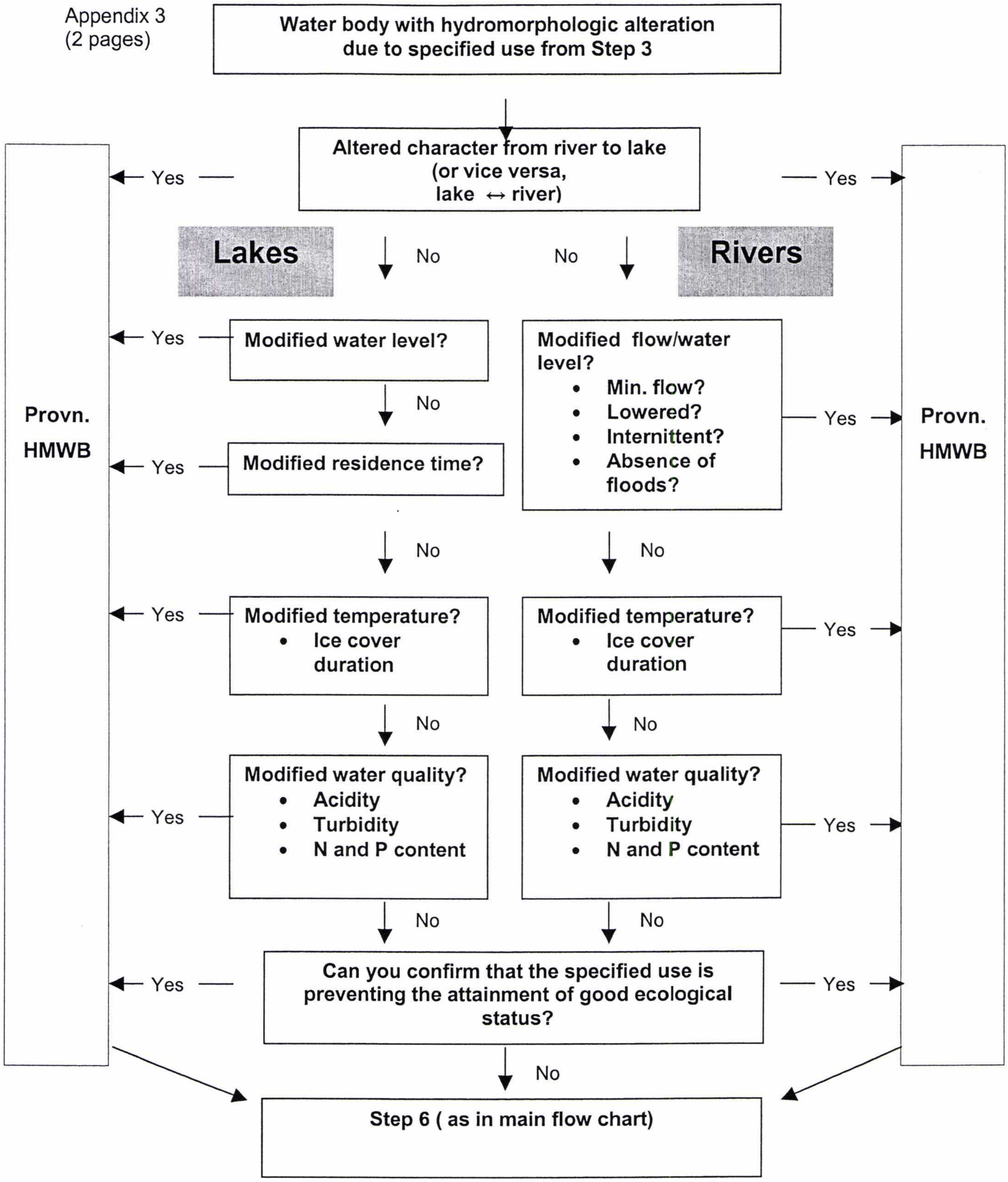
RIVERS 1-13=lowland 9=turbid		Very low Ca <1 mg Ca		Low Ca 1-4 mg Ca		High Ca > 4 mg Ca	
14-21=boreal 22-25=mountain		clear <30 mg Pt/l	humus >30 mg Pt/l	clear <30 mg Pt/l	humus >30 mg Pt/l	clear <30 mg Pt/l	humus >30 mg Pt/l
small/ med	Slow	14+22		1+16+24	3	5+9+18	7?!
10-1000km^2	Fast	15+23		2+17+25	4	6+19	8
large	Slow			10		12+20	
>1000km^2	Fast			11		13+21	

Appendix 2 - Details of reservoirs and hydropower plants in Suldal river basin

Reservoir name	HRWL	LRWL	Depth of Regulated Zone (m)
Valldalen	745.00	665.00	80.00
Votnavatn	1020.00	975.00	45.00
Reinsvatn	1020.00		44.00
Reinshølen	1020.00		44.00
Gauthellervatn	1020.00		42.00
Stavsvatn	1020.00		42.00
Grunnavatn	1020.00		13.00
Røldalsvatn	380.00	363.00	17.00
Vasstølvatn	753.00	732.50	20.50
Finnabuvatn ('76)	908.00	893.00	15.00
Sandvatn	950.00	924.00	26.00
Holmavatn	1058,00	1048.00	10.00
Isvatn	1295.00	1282.00	10.00
Kvanndalen Inntaksbasseng	630.00	620.00	10.00
Nupstjørn	1302.00	1285.00	20.00
Øst. Middyrvatn	1230.50	1190.00	40.50
V.Middyrvatn	1217.50	1190.00	27.50
Kaldevatn('76)	1205.00	1183.00	22.00
Kvanndalstjørn	1216.80	1215.80	1.00
Djupetjørn	1167.20	1146.40	20.80
Grubbedalstjørn Indre	1078.80	1045.00	33.80
Grubbedalstjørn Midtre	1070.00	1045.00	25.00
Bleskestadelv Inntak	640.00	635.00	5.00
Salttjørn('77)	967.96	967.50	0

Power plant name	REGINE Sub – catchment No.	Catchment Area (km^2)	Total Reservoir Volume Upstream (Mm^2)	Annual Average Inflow (Mm^3)	Gross head (m)	Capacity installed (MW)	Yearly avge production. (GWh p.a.)	Started operation
KVILLDAL	036.B12	855.0	3411.4	2542.9	536.5	1240.0	3516.5	1981
SAURDAL	036.B1B	411.9	3112.0	1209.8	437.0	640.0	1291.0	1985
SULDAL I	036.B9	566.6	651.9	1321.0	306.0	160.0	1049.6	1965
RØLDAL	036.E30	422.3	536.9	974.4	365.0	160.0	866.9	1966
HYLEN	036.21	2003.1	4301.3	5064.5	68.0	160.0	921.6	1980
SULDAL II	036.B9	224.2	194.0	475.3	559.0	150.0	751.2	1967
NOVLE	036.F0	119.9	210.2	292.6	275.0	40.0	234.5	1967
KVANNDAL	036.BRA	99.7	194.0	205.1	314.0	40.0	181.7	1967
SVANDALSFLONA	036.FB	24.4	38.0	53.1	200.0	20.0	41.3	1977
MIDDYR	036.G1E	12.3	10.0	26.3	66.0	1.3	5.2	1981
SAND	036.A10	7.7		22.5	329.0	1.3	10.1	1936

Appendix 3
(2 pages)



Specific criteria are described below:

1. Rivers which are impounded to form a lake with a surface area greater than 0,5 km^{2}, or raise water level more than 5 m (or vice versa – lakes to river).

2. Artificial alteration of water level by more than 0.5m in a wetland.

LAKES ONLY:

3. Lakes which have been raised more than 10m above natural water level.

4. Lakes with an active annual regulation zone of 3m or more.

5. Lakes which can change form oligotrophic to eutrophic or vice versa due to a change in hydraulic load by a factor of 5.0 or more, due to artificial transfers between catchments (primarily for lowland lakes

6. Increased turbidity in salmon rivers due to water transfers which result in mixing of turbid water into previously clear water(from < 0,5 FTU to > 2,0 FTU).

RIVERS ONLY

7. Small rivers where an upstream dam removes all water for at least part of the year. This HM water body should be extended downstream until the catchment area for undisturbed inflow has returned to at least 75% of the natural catchment area.

8. For all rivers below a dam where a minimum environmental flow is required, but which is lower than the natural minimum flow without the dam, measured as the flow with 95% percentile excedence, (Q_{95}), the following two alternatives . When the minimum flow is below 20% av $Q_{95,}$ the water body is automatically a HMWB candidate. For values between 20% and 100% of $Q_{95,}$ the designation should be based on expert judgment based on current knowledge and data availability.

9. Flow discharges, which are regulated by more than 5% per hour relative to maximum turbine flow.

10. Rivers which no longer experience than the natural average annual flood more than once every 20 years due to upstream storage.

11. If a river water body which is normally covered with ice becomes free from ice cover and no longer has a water temperature below +1° C as a result of water intakes in deep reservoirs or other physical changes to the watercourse.

12. Water bodies which normally contain wild salmon, but have a pH which has been reduced by more than 0,5 to a value below 5,5 as a result of the upstream import of water from outside the natural catchment.

13. If rivers with salmon have had their turbidity changed from "clear" (turbidity < 0,5 FTU) to "turbid" (turbidity > 2,0 FTU) as a result of the upstream import of water from outside the natural catchment..

14. Artificially channelled rivers and rivers with sluices for boat traffic, which are affected for more than 1 km total length or where alterations affect more than 50% of the total length of the water body (measured along both banks).

15. In a stream that is affected by urbanization in more than 50% of its total catchment area, or more than 50% of its channel length is affected by culverts, pipes, roughness alteration, man-made alterations in vegetation/substrate etc.

Appendix 4 - Report from local meeting at Sand in Suldal
Held on 17th March 2004

Participants

Kåre Paulsen, Statkraft SF, the state power company and owner of Ulla- Føre Power Scheme
John Jastrey, environmental manager of the municipality of Suldal
Åshild Skeie, Håvard Kambo & Jarl Inge Alne, Regional office of Norwegian Food Safety Authority
Øyvind Vårvik, Suldal River owner association
Anja Skiple Ibrekk, Norwegian Water Resources and Energy Directorate
Geir Helge Johnsen, consultant

Agenda

1) Presentation of the water framework directive and status for the pilot river basin project in Suldal, by A.S.Ibrekk
2) Presentation of the process of characterisation of water bodies PRB phase 1a report in Suldal river basin, by G.H.Johnsen
3) General discussion and local comments on the PRB project and WFD

Local comments on the WFD

1) Local concern that the implementation of another central directive would further minimize local influence and utilization on the local natural resources
2) It seems to be difficult to understand the implications of the Water Framework Directive for others than experts
3) The local environmental manager stated that much of this work could have been carried out better and cheaper locally. He also wished to referee the final report from the characterisation process

Important information supplied

1) Emissions to air from the metalindustry within the county could have impacts on the water quality
2) The road through Røldal and along Lake Røldalsvatnet is exposed to rather "heavy" traffic, and the risk of accidents with transportation of dangerous cargo must be evaluated.
3) Tourism implies danger of transferring viral or bacterial contamination to the region.
4) Assessment of risk regarding emissions from accidents on power plants already exists.

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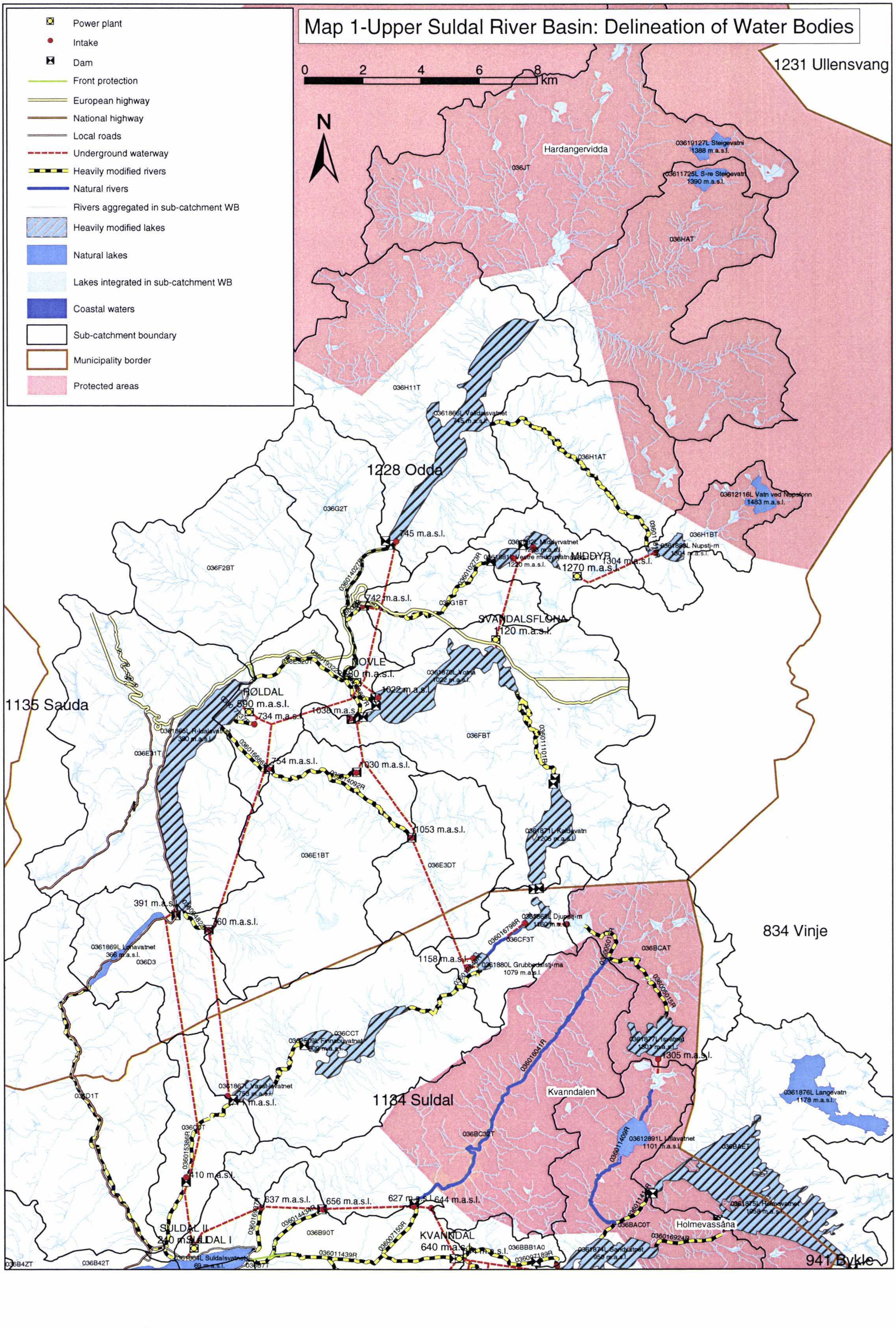
Appendix 5a LAKE WATER BODIES - BASIN No. 036 (SULDAL)

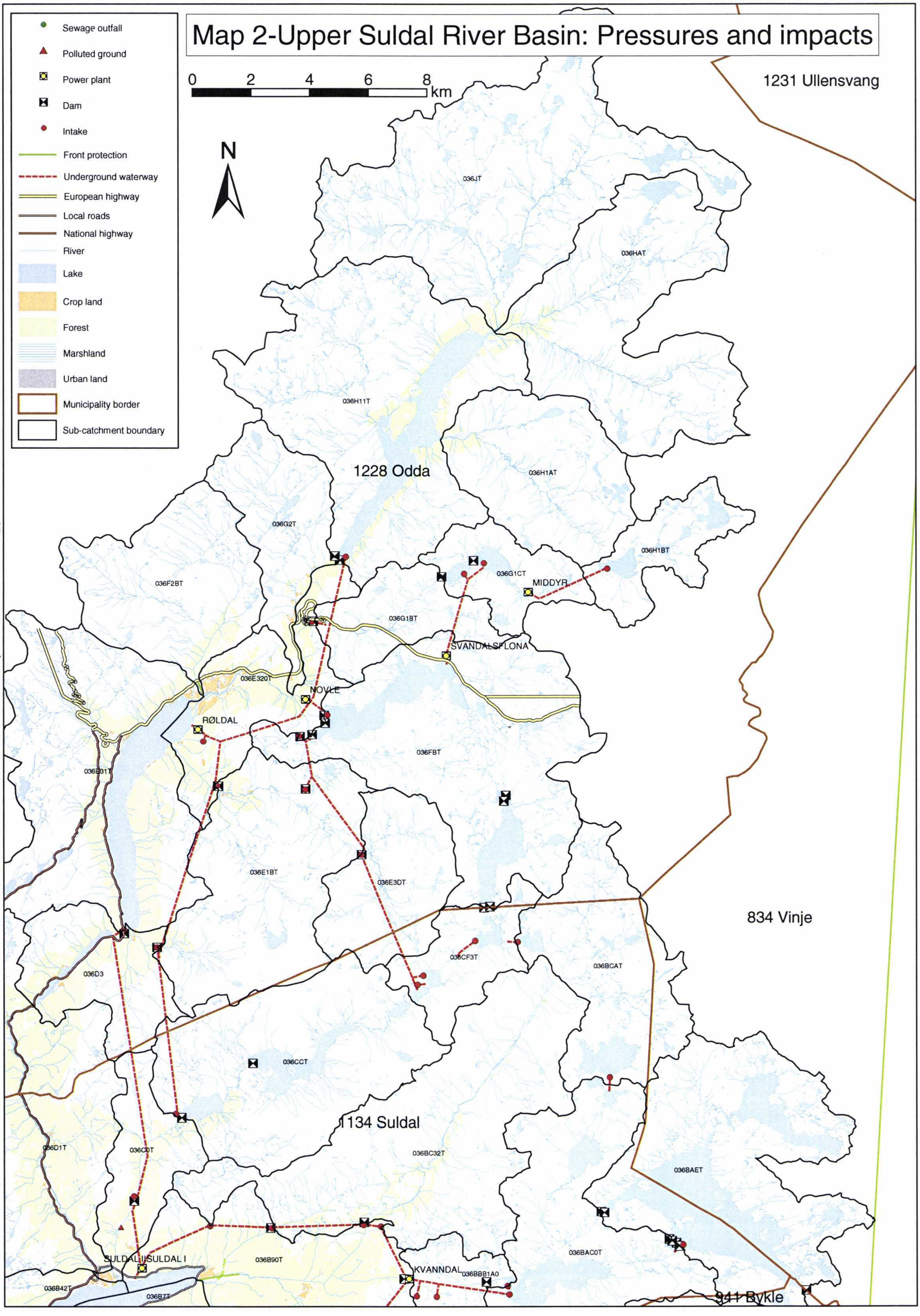
Identity No.	Name	Sub-basin No. (REGINE)	Lake No.	Reservoir No.	Area (km2)	Høyde (m.o.h.)	Volume (mill m^3)	Elevation (masl.)/ HRWL	Elevation (masl)/ LRWL	Depth of regulated zone (m)	Category
0361864L	Suldalsvatnet	036.B11	1864	576	27,66	69	44,0	68,50	67,00	1,50	N
0361875L	Holmavatnet	036.BAE	1875	585	10,98	1058	112,0	1058,00	1046,00	12,00	HMWB
0361865L	Røldalsvatnet	036.E31	1865	577	7,03	380	115,0	380,00	363,00	17,00	HMWB
0361866L	Valldalsvatnet	036.H11	1866	578	6,81	745	290,0	745,00	675,00	70,00	HMWB
0361870L	Votna	036.FB	1870	581	4,61	1022	119,0	1020,00	975,00	45,00	HMWB
0361874L	Sandvatnet	036.BAC0	1874	584	3,26	950	66,0	950,00	924,00	26,00	HMWB
0361876L	Langevatn	036.BAF	1876		3,03	1178		1178			N
0361871L	Kaldevatn	036.FD	1871	582	2,79	1205	36,5	1205,00	1183,00	22,00	HMWB
0362509L	Finnabuvatnet	036.CE	2509	777	2,56	909	25,7	908,00	893,00	15,00	HMWB
0361872L	Mosvatnet	036.A1B3	1872	583	1,85	518	3,0	518,20	516,20	2,00	N
0361877L	Isvatnet	036.BCB	1877	586	1,80	1301	16,0	1295,00	1285,00	10,00	HMWB
03612891L	Litlavatnet	036.BACZ	12891		1,03	1101		1101			N
0361885L	Lauvastølvatnet	036.B1AB	1885	591	0,88	605	8,0	605,00	590,00	15,00	HMWB
03623777L	Midtvatnet	036.B5C7	23777		0,83	1195		1195			N
0361888L	Lovravatnet	036.1A	1888		0,83	0		0			N
0361882L	Middyrvatnet	036.G1D	1882	589	0,83	1233	21,2	1230,50	1190,00	40,50	HMWB
0361867L	Vasstølsvatnet	036.CC	1867	579	0,75	753	11,0	753,00	732,50	20,50	HMWB
03612116L	Vatn ved Nupsfonn	036.H1C	12116		0,68	1483		1483			N
0361883L	Nupstjørn	036.H1B	1883	590	0,66	1304	10,0	1302,00	1285,00	17,00	HMWB
03611725L	Søre Steigevatn	036.HB	11725		0,63	1390		1390			N
0361869L	Lonavatnet	036.D3	1869		0,60	366		366			N
03619127L	Steigevatni	036.J	19127		0,58	1388		1388			N
0361868L	Djupetjørn	036.CH	1868	580	0,57	1160	7,5	1167,20	1146,40	20,80	HMWB
03623830L	Ritlandsvatnet	036.A23	23830		0,51	71		71			N
03623931L	Heimsvatnet	036.A11B	23931	2100	0,47	375	0,0	374,61	367,50	7,11	HMWB
0361881L	Vestre middyrvatn	036.G1C	1881	588	0,40	1220	6,8	1217,50	1190,00	27,50	HMWB
0361880L	Grubbedalstjørna	036.CF5	1880	587	0,25	1079	9,2	1078,80	1045,00	33,80	HMWB
	NO OF WATER BODIES		27								
HMWB	16										
NAT	11										

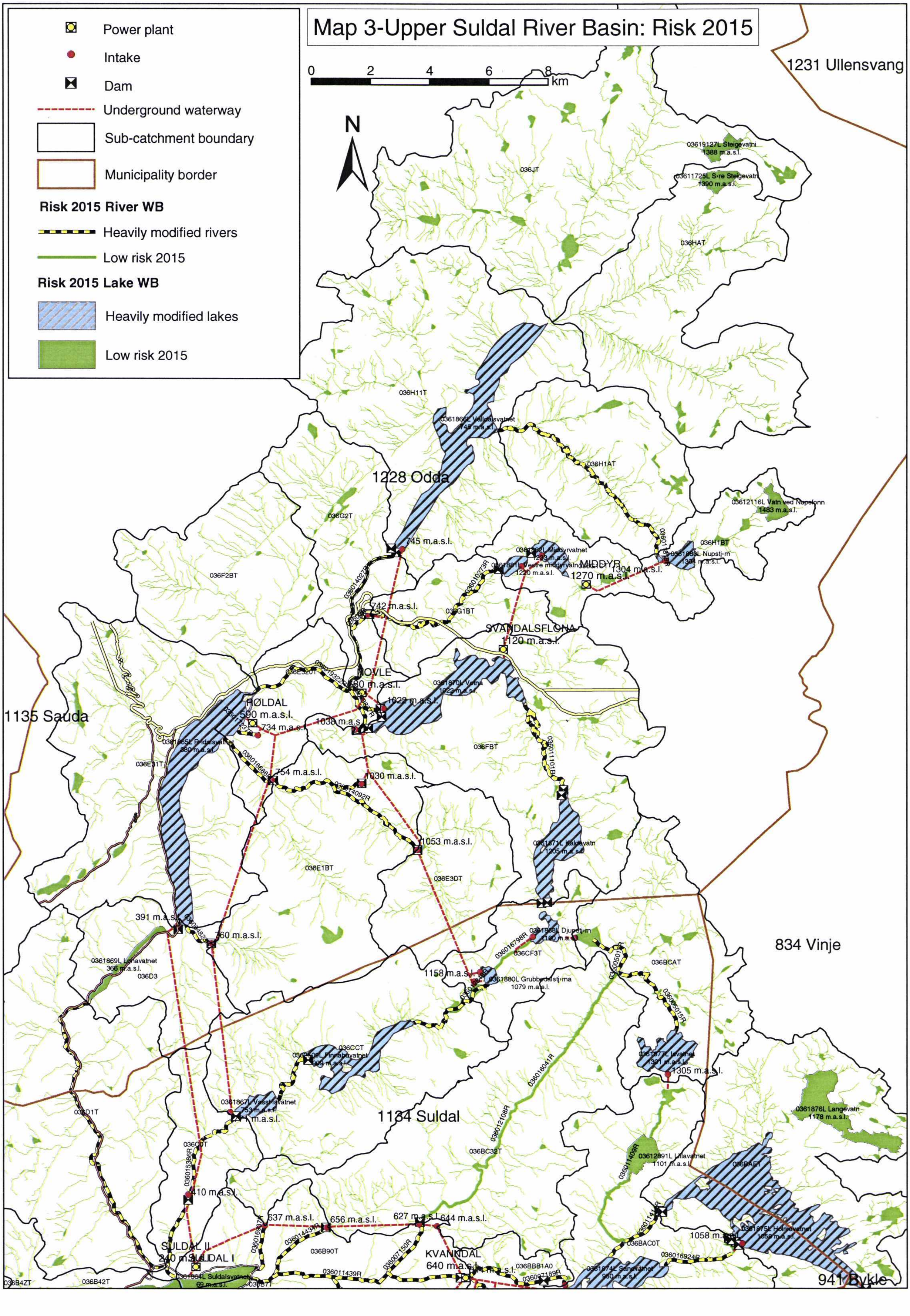
Appendix 5b	River Water Bodies in Suldal River Basin - No. 038					
Identity No.	Name	FROM M.A.S.L.	TO M.A.S.L.	Category	Comment on where water diverted etc.	Length (km)
036019309R	SULDALSLÅGEN NEDRE	0	50	HMWB	NAT AT Q MIN	15,56
036014828R	HEIMSÅNA	20	370	HMWB	INTO SAND	2,38
036015524R	MOSÅNA	30	510	HMWB	MOSVATN SENT SOUTH	5,21
036019364R	KVILLDALSÅA NEDRE	69	670	HMWB	INTO KVILLDAL, Q MIN IN SUMMER	8,85
036018214R	KVILLDASLSÅA ØST	220	600	HMWB	INTO KVILLDAL, Q MIN IN SUMMER	3,07
036009475R	KVILLDALSÅA ØVRE	670	972	N		4,75
036015579R	ELV STRANDDALSV TIL PJÅKEV	972	1067	HMWB	INTO SAURDAL	4,70
036017154R	ELV LANGAVATN TIL BEKKEINNTAK	799	1080-1100	HMWB	INTO SAURDAL	5,67
036017363R	STEINSVIKEBEKKKEN	69	900	HMWB	INTO KVILLDAL	2,34
036018225R	ELV ROLLEVSJUVET	69	822	HMWB	INTO KVILLDAL	3,78
036015462R	EIVINDSÅA	69	660	HMWB	INTO KVILLDAL	1,85
036017506R	STORÅA	69	660	HMWB	INTO KVILLDAL	11,29
036016937R	ELV NORD FOR ROALDKVAM	69	640	HMWB	INTO SULDAL II	1,95
036011439R	ROALDKVAMSÅA	69	640	HMWB	INTO SULDAL II	8,23
036014434R	TVERRÅA	80	640	HMWB	INTO SULDAL II	2,58
036016202R	BLESKESTADÅNA	130	650	HMWB	INTO KVANNDAL	4,10
036007189R	HAVREÅA	640	950	HMWB	INTO KVANNDAL	4,56
036016924R	HOLMAVASSÅNA	950	1058	HMWB	ABSENCE OF FLOODS?	2,99
036011414R	ELV SANDVATN TIL HOLMEVATN	950	1058	HMWB	ABSENCE OF FLOODS?	2,88
036011409R	ELV SANDVATN TIL DJUPETJØRNANE	950	1295	N		6,42
036007150R	KVANNDALSÅNA NEDRE	240	630	HMWB	INTO SULDAL II	2,21
036016041R	KVANNDALSÅNA ØVRE	700	870	N		7,12
036005015R	ELV KVANNDALSÅNA - ISVATN	870	1301	HMWB	ISVATN SENT SOUTH	3,59
036005013R	KVANNDALSÅNA ØVRE	870	1215	HMWB	INTO NOVLE	2,43
036015386R	STØLSÅA	69	753	HMWB		6,38
036011295R	ELV VASSTLØSV TIL FINNABUV	753	909	HMWB		2,50
036012849R	ELV GRUBBEDALEN NEDRE	909	1079	HMWB	INTO NOVLE	4,52
036016798R	ELV GRUBBEDALEN ØVRE	1079	1160	N		1,84
036017493R	BRATTLANDSDALÅA	69	366	HMWB	INTO SULDAL I	13,35
036004823R	ELV BOTNEN	380	760	HMWB	INTO RØLDAL	1,06
036016686R	GRYTØYREELVA	380	750	HMWB	INTO RØLDAL	2,25
036014092R	AUSTMANNABEKKEN SAUEKROKANE	750	1030	HMWB	INTO NOVLE	8,63
036019322R	STORELVA NOVLEFOSS	380	1022	HMWB	INTO NOVLE + RØLDAL	5,81
036014027R	VALLDALSELVA	520	745	HMWB	INTO RØLDAL	6,02
036010273R	RISBUELVA ØVRE	740	1220	HMWB	SENT TO SVANDALSFLONA	7,96
036011819R	KVESSO	745	1304	HMWB	SENT TO MIDDYR	11,62
036011101R	KALDEVASSELVA	1022	1205	HMWB	SMALL FLOW ALTERATION	6,28
036007225R	ELV KVANNDAL KRV - INNTAK	640	960	HMWB	INTO KVANNDAL	2,09
036017237R	ELV TVEITA	380	740	HMWB	INTO RØLDAL	1,39
036003807R	ELV FOSSEN	520	1060	HMWB		1,85
036018193R	SULDALSLÅGEN ØVRE	50	70	HMWB	NAT AT Q MIN	8,11
036012108R	KVANNDALSÅNA MIDTRE	630	700	N		6,68
03600R	RISBUELVA NEDRE	600	740	HMWB	SENT TO SVANDALSFLONA	0,80
	HMWB	38			SUM	217,62
	NAT	5				
	SUM	43				

Appendix 5c	Sub-Catchment River Water Bodies in Suldal River Basin - No. 038			
Identity No.	Name	From lowest point	To highest point	Area (km2)
036A110T	SULDALSLÅGEN 1	SANDSFJORDEN	SAMLØP HEIMSÅNA	25,32
036A11AT	HEIMSÅNA	SAMLØP SULDALSLÅGEN		9,03
036A120T	SULDALSLÅGEN 2	SAMLØP HEIMSÅNA	SAMLØP MOSÅNA	30,80
036A1A0T	MOSÅNA	SAMLØP SULDALSLÅGEN	UTLØP MOSVATNET	11,12
036A1B1T	MOSVATNET	UTLØP MOSVATN		23,84
036A3T	SULDALSLÅGEN 3	SAMLØP MOSÅNA	UTLØP SULDALSVATN	59,11
036B11T	SULDALSVATNET 1	UTLØP SULDALSVATN	UTLØP KVILLDALSÅNA	25,07
036B2T	SULDALSVATNET 2	UTLØP SULDALSVATN	UTLØP HAMRABØÅNA	45,61
036B1A0T	KVILLDALSÅNA NEDRE	UTLØP KVILLDALSÅNA	INNTAK SAURDAL	14,18
036B1C1T	KVILLDALSÅNA ØVRE	INNTAK SAURDAL		32,69
036B1ABT	LAUVASTØLVATNET	INNTAK LAUVASTØLVATNET		34,69
036B121T	SULDALSVATNET 3	UTLÅP KVILLDALSÅNA	UTLØP STEINEVIKBEKKEN	21,02
036B4ZT	HAMRABØÅNA	UTLØP HAMRABØÅNA		42,34
036B122T	SULDALSVATNET 4	UTLØP STEINEVIKBEKKEN	UTLØP STORÅNA	51,90
036B7T	SULDALSVATNET 5	UTLØP ROALDKVAMSÅNA		12,52
036B42T	SULDALSVATNET 6	UTLØP HAMRABØÅNA	UTLØP BRATTLANDSDALÅNA	24,71
036D1T	BRATTLANDSDALÅNA	UTLØP BRATTLANDSDALÅNA	UTLØP LONAVATNET	63,46
036B90T	ROALDKVAMSÅNA	UTLØP SULDALSVATNET	SAMLØP KVANNDAL HAVREÅNA	44,02
036BABT	BLESKESTADSÅNA	INNTAK	UTLØP SANDVATN	37,73
036C0T	STØLSÅNA NEDRE	SAMLØP BRATTLAND STØLSÅ	VASSTØLSVATNET	14,42
036JT	GRØNO	UTLØP VALLDALSVATNET		66,66
036HAT	MIDDALSELVA	SAMLØP GRØNO		46,49
036BBB1A0	HAVREÅNA	INNTAK KVANNDAL	SANDVATN	7,92
036H1AT	KVESSO	UTLØP VALLDALSVATNET		27,48
036H1BT	NUPSTJØRN	UTLØP NUPSTJØRN		12,31
036H11T	VALLDALSVATNET	UTLØP VALLDALSVATNET	INNLØP VALLDALSVATNET	63,50
036F2BT	TUFTAELVA	SAMLØP STOR TUFTAELVA		29,16
036G1BT	RISBUELVA	INNTAK	UTLØP MIDDYRVATN	13,95
036G1CT	MIDDYRVATNA	UTLØP MIDDYRVATN		12,07
036FBT	VOTNA/ KALDEVATN	VOTNAVATN	KALDEVATN	58,04
036E3DT	GRYTØYRELVA ØVRE	INNTAK		20,18
036E1BT	GRYTØYRELVA NEDRE	INNTAK	INNTAK	40,97
036E31T	RØLDALSVATNET	UTLØP RØLDALSVATNET	INNLØP RØLDALSVATNET	57,76
036D3	LONAVATNET	UTLØP LONAVATNET	UTLØP LONAVATNET	18,54
036CCT	STØLSÅNA MIDTRE	VASSTØLSVATNET	HEIMRE GRUBBADALSTJØRN	46,09
036CF3T	STØLSÅNA ØVRE	HEIMRE GRUBBADALSTJØRN	DJUPETJØRN	13,04
036BCAT	KVANNDALSÅNA ØVRE	SAMLØP KVANNDAL ISÅNA		30,17
036BC32T	KVANNDALSÅNA NEDRE	INNTAK	SAMLØP KVANNDAL ISÅNA	57,73
036BAC0T	SANDVATNET	UTLØP SANDVATN	UTLØP HOLMAVATN	38,22
036BAET	HOLMAVATNET	UTLØP HOLMAVATN		54,19
036B51BT	EIVIND-GAUKSTØLSÅNA	EIVINDÅNA	GAUKSTØLSÅNA	83,80
036G2T	STORELVA 2	SAMLØP STORE KALDEVASSE	UTLØP VALLDALSVATNET	18,54
036E320T	STORELVA	INNLØP RØLDALSVATNET	UTLØP VALLDALSVATNET	21,44
				1461,8
	NO OF WATER BODIES	43		

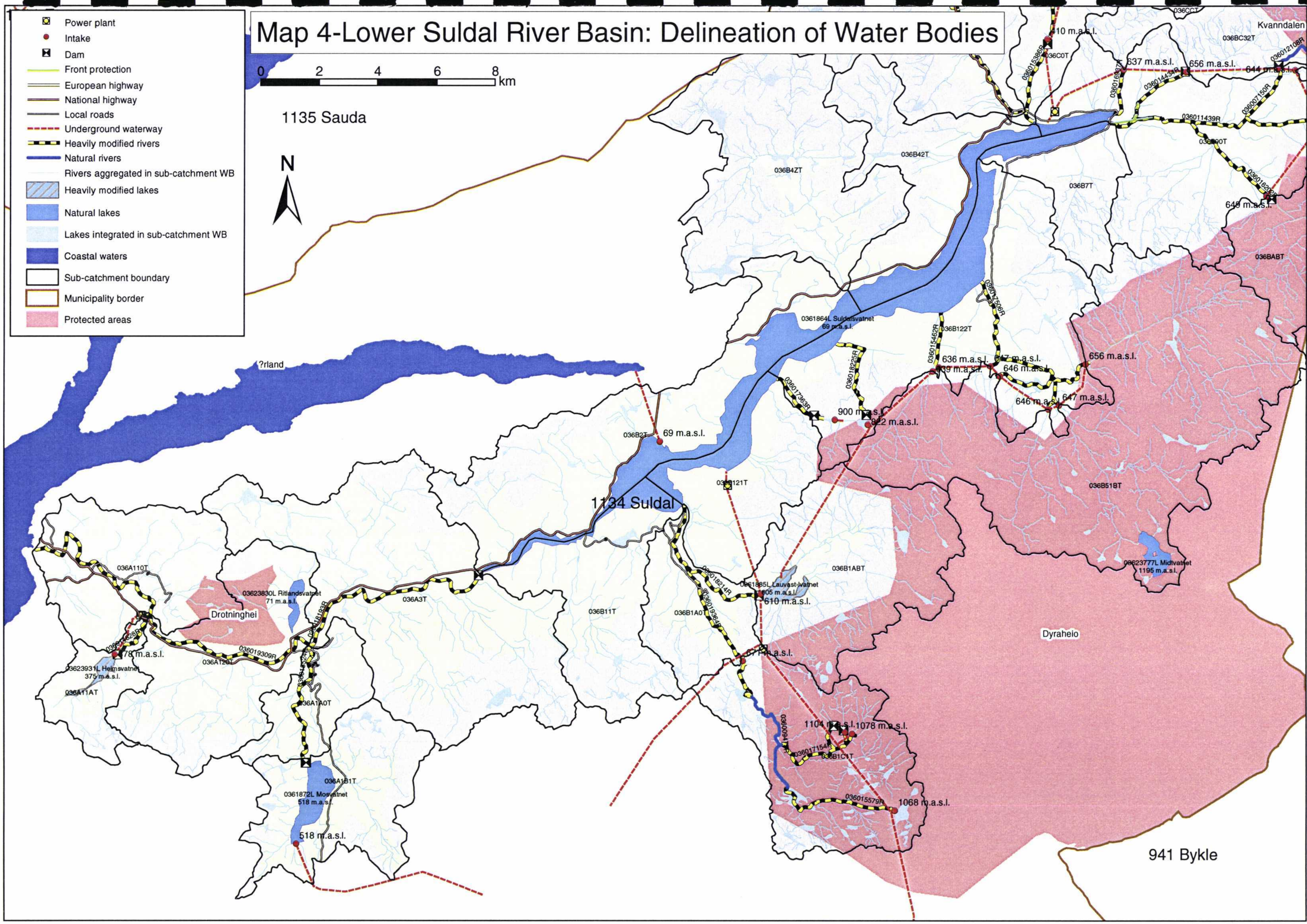


Map 1-Upper Suldal River Basin: Delineation of Water Bodies
Power plant
Intake
Dam
Front protection
European highway
National highway
Local roads
Underground waterway
Heavily modified rivers
Natural rivers
Rivers aggregated in sub-catchment WB
Heavily modified lakes
Natural lakes
Lakes integrated in sub-catchment WB
Coastal waters
Sub-catchment boundary
Municipality border
Protected areas
0 2 4 6 8 km
N
1231 Ullensvang
Hardangervidda
036JT
036HAT
036H11T
1228 Odda
036H1AT
036G2T
036F2BT
745 m.a.s.l.
MIDDYR
1270 m.a.s.l.
1304 m.a.s.l.
036H1BT
742 m.a.s.l.
036G1BT
SVANDALSFLONA
1120 m.a.s.l.
NOVLE
1022 m.a.s.l.
RØLDAL
590 m.a.s.l.
734 m.a.s.l.
1038 m.a.s.l.
1135 Sauda
036E31T
036FBT
754 m.a.s.l.
1030 m.a.s.l.
1053 m.a.s.l.
036E1BT
036E3DT
391 m.a.s.l.
760 m.a.s.l.
036D3
036CF3T
1158 m.a.s.l.
036BCAT
834 Vinje
036CCT
1305 m.a.s.l.
Kvanndalen
1134 Suldal
036D1T
036BC32T
410 m.a.s.l.
637 m.a.s.l.
656 m.a.s.l.
627 m.a.s.l.
644 m.a.s.l.
SULDAL II
SULDAL I
KVANNDAL
640 m.a.s.l.
036B90T
036BACOT
Holmevassåna
036B4ZT
036B42T
941 Bykle


Map 2-Upper Suldal River Basin: Pressures and impacts
Sewage outfall
Polluted ground
Power plant
Dam
Intake
Front protection
Underground waterway
European highway
Local roads
National highway
River
Lake
Crop land
Forest
Marshland
Urban land
Municipality border
Sub-catchment boundary
0 2 4 6 8 km
N
1231 Ullensvang
1228 Odda
834 Vinje
1134 Suldal
941 Bykle
036JT
036HAT
036H11T
036H1AT
036G2T
036H1BT
036F2BT
036G1CT
MIDDYR
036G1BT
SVANDALSFLONA
036E320T
NOVLE
RØLDAL
036FBT
036E1BT
036E3DT
036CF3T
036BCAT
036D3
036CCT
036D1T
036C0T
036BC32T
036BAET
SULDAL II
SULDAL I
036B90T
KVANNDAL
036BBB1A0
036BAC0T
036B42T
036B7T



Map 3-Upper Suldal River Basin: Risk 2015
Power plant
Intake
Dam
Underground waterway
Sub-catchment boundary
Municipality border
Risk 2015 River WB
Heavily modified rivers
Low risk 2015
Risk 2015 Lake WB
Heavily modified lakes
Low risk 2015
0 2 4 6 8 km
N
1231 Ullensvang
1228 Odda
1135 Sauda
834 Vinje
1134 Suldal
941 Bykle
HØLDAL
590 m.a.s.l.
RØVLE
SVANDALSFLONA
1120 m.a.s.l.
MIDDYR
1270 m.a.s.l.
SULDAL II
SULDAL I
KVANNDAL
640 m.a.s.l.
745 m.a.s.l.
742 m.a.s.l.
1304 m.a.s.l.
734 m.a.s.l.
1038 m.a.s.l.
1022 m.a.s.l.
754 m.a.s.l.
1030 m.a.s.l.
1053 m.a.s.l.
391 m.a.s.l.
760 m.a.s.l.
1158 m.a.s.l.
1305 m.a.s.l.
410 m.a.s.l.
637 m.a.s.l.
656 m.a.s.l.
627 m.a.s.l.
644 m.a.s.l.
1058 m.a.s.l.


Map 4-Lower Suldal River Basin: Delineation of Water Bodies
Power plant
Intake
Dam
Front protection
European highway
National highway
Local roads
Underground waterway
Heavily modified rivers
Natural rivers
Rivers aggregated in sub-catchment WB
Heavily modified lakes
Natural lakes
Lakes integrated in sub-catchment WB
Coastal waters
Sub-catchment boundary
Municipality border
Protected areas
0 2 4 6 8 km
N
1135 Sauda
1134 Suldal
941 Bykle
Kvanndalen
?rland
Drotninghei
Dyraheio
0361864L Suldalsvatnet
69 m.a.s.l.
69 m.a.s.l.
0361872L Mosvatnet
518 m.a.s.l.
518 m.a.s.l.
0362383OL Ritlandsvatnet
71 m.a.s.l.
0362393IL Helmsvatnet
375 m.a.s.l.
0362377L Midtvatnet
1195 m.a.s.l.
610 m.a.s.l.
1078 m.a.s.l.
1068 m.a.s.l.
637 m.a.s.l.
656 m.a.s.l.
656 m.a.s.l.
636 m.a.s.l.
646 m.a.s.l.
647 m.a.s.l.
822 m.a.s.l.
036A110T
036A3T
036A120T
036A11AT
036A1A0T
036A1B1T
036B11T
036B1A0T
036B1ABT
036B2T
036B4ZT
036B42T
036B7T
036B122T
036B51BT
036BABT
036BC32T
036C0T
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036019309R
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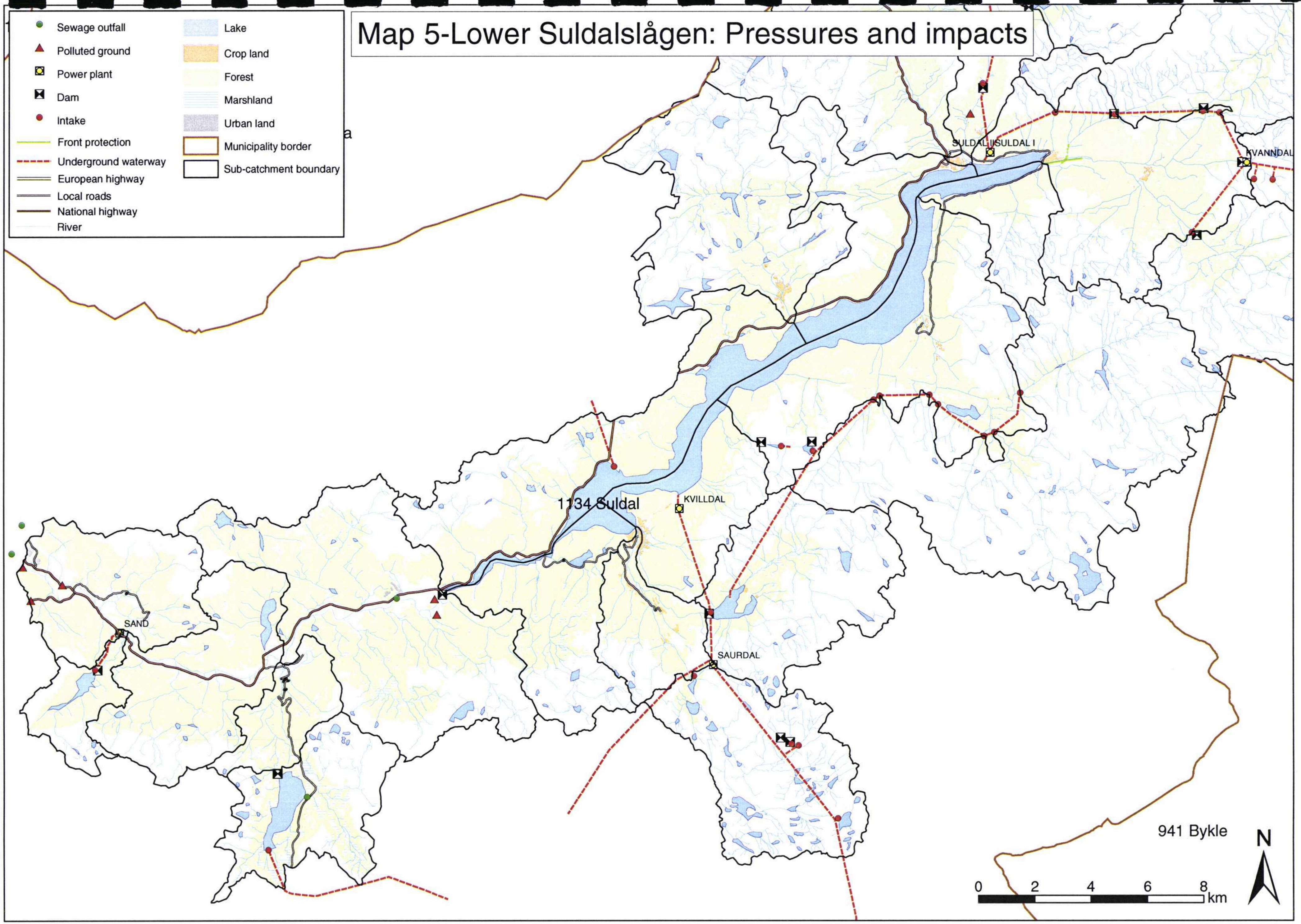
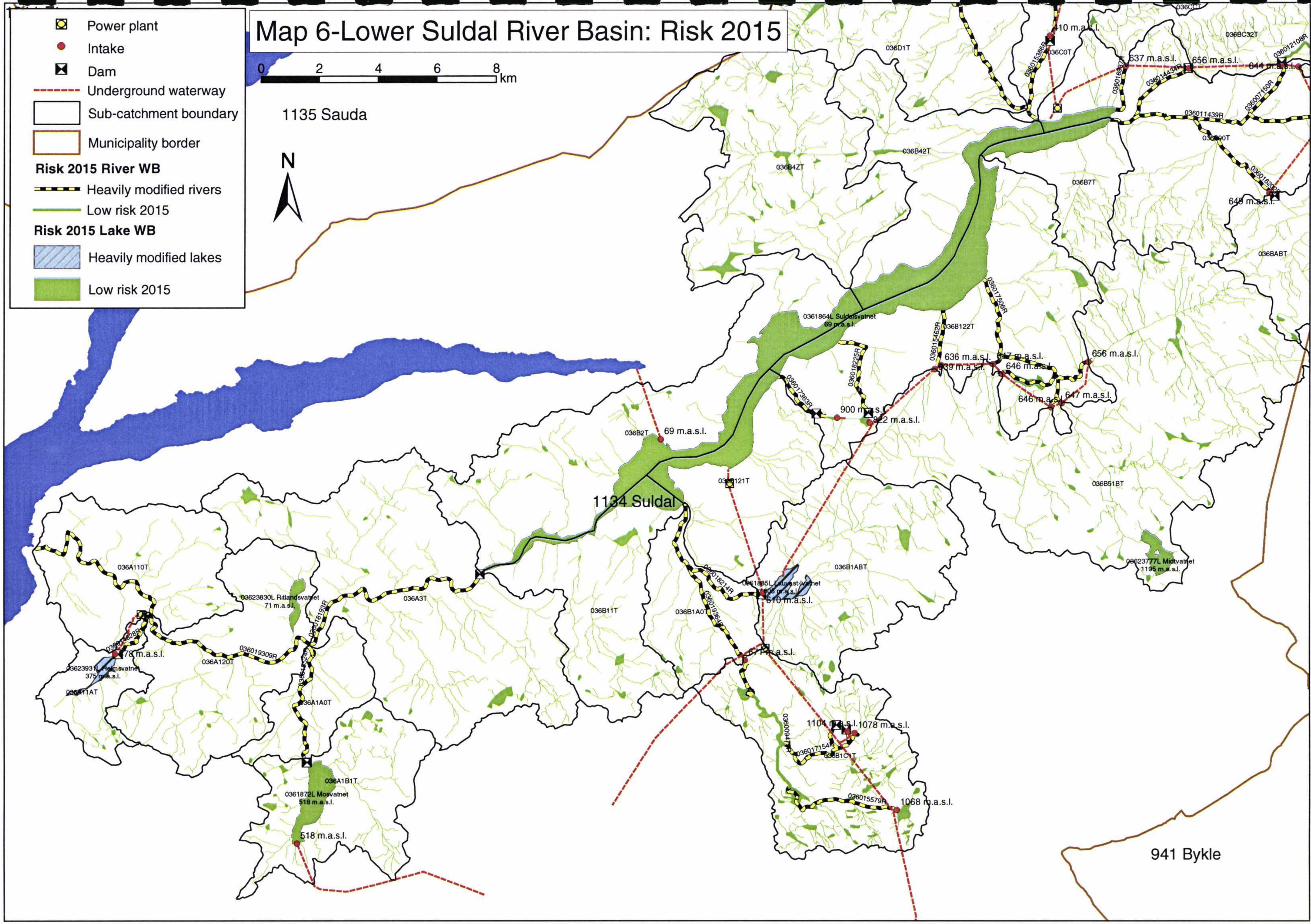
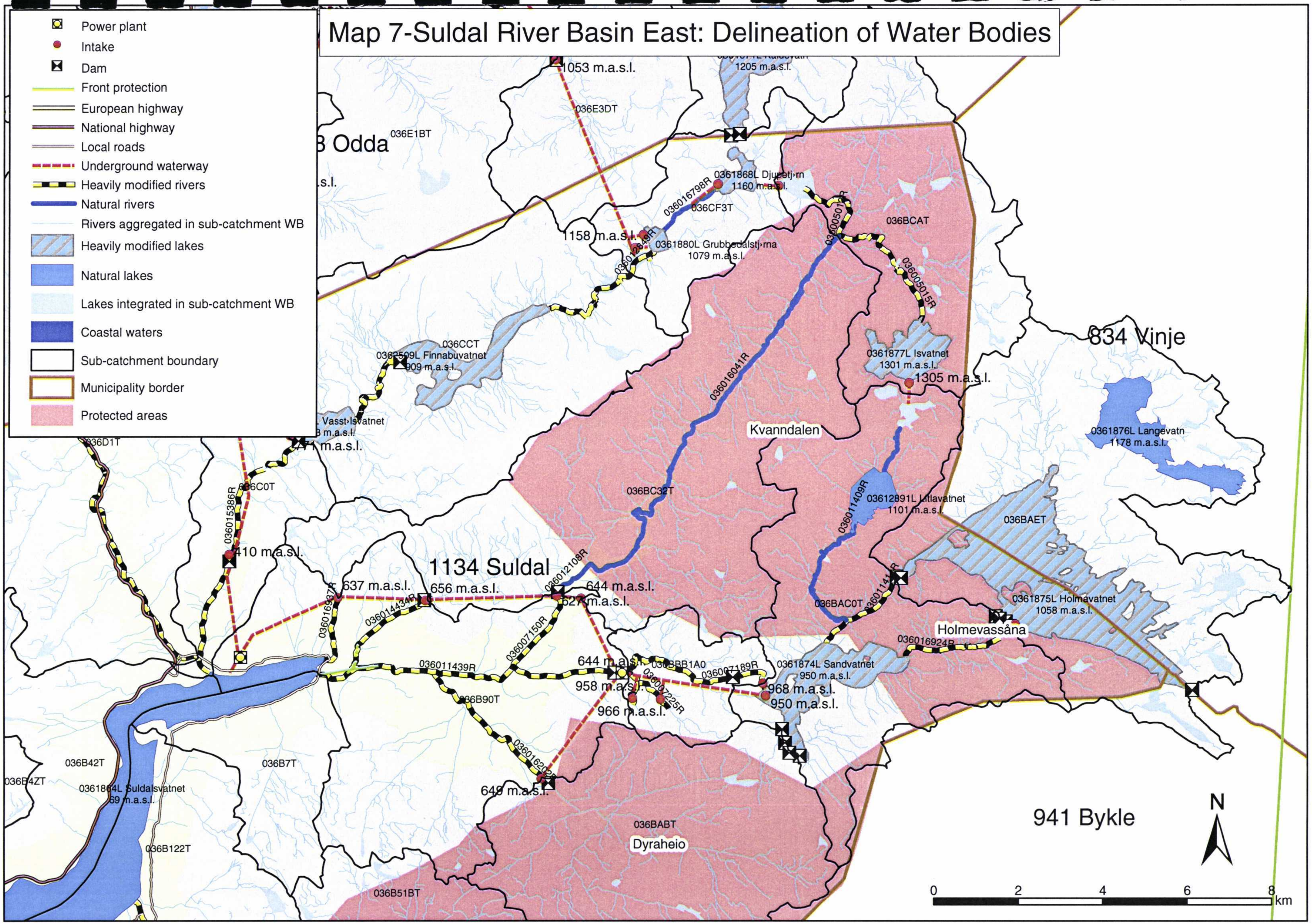
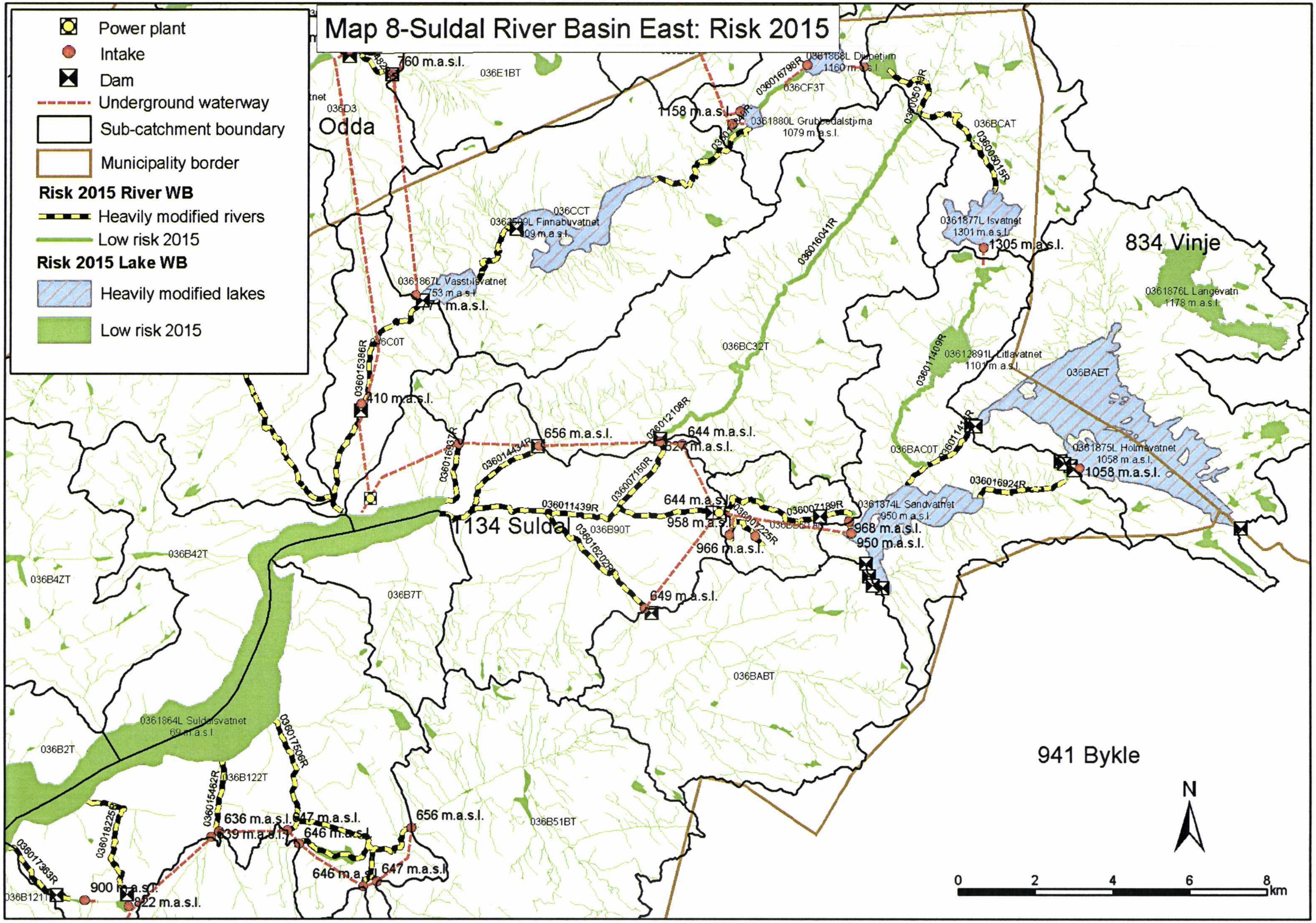
036015462R


Map 5-Lower Suldalslågen: Pressures and impacts
Sewage outfall
Polluted ground
Power plant
Dam
Intake
Front protection
Underground waterway
European highway
Local roads
National highway
River
Lake
Crop land
Forest
Marshland
Urban land
Municipality border
Sub-catchment boundary
SULDAL II
SULDAL I
KVANNDAL
KVILLDAL
1134 Suldal
SAND
SAURDAL
941 Bykle
0 2 4 6 8 km
N

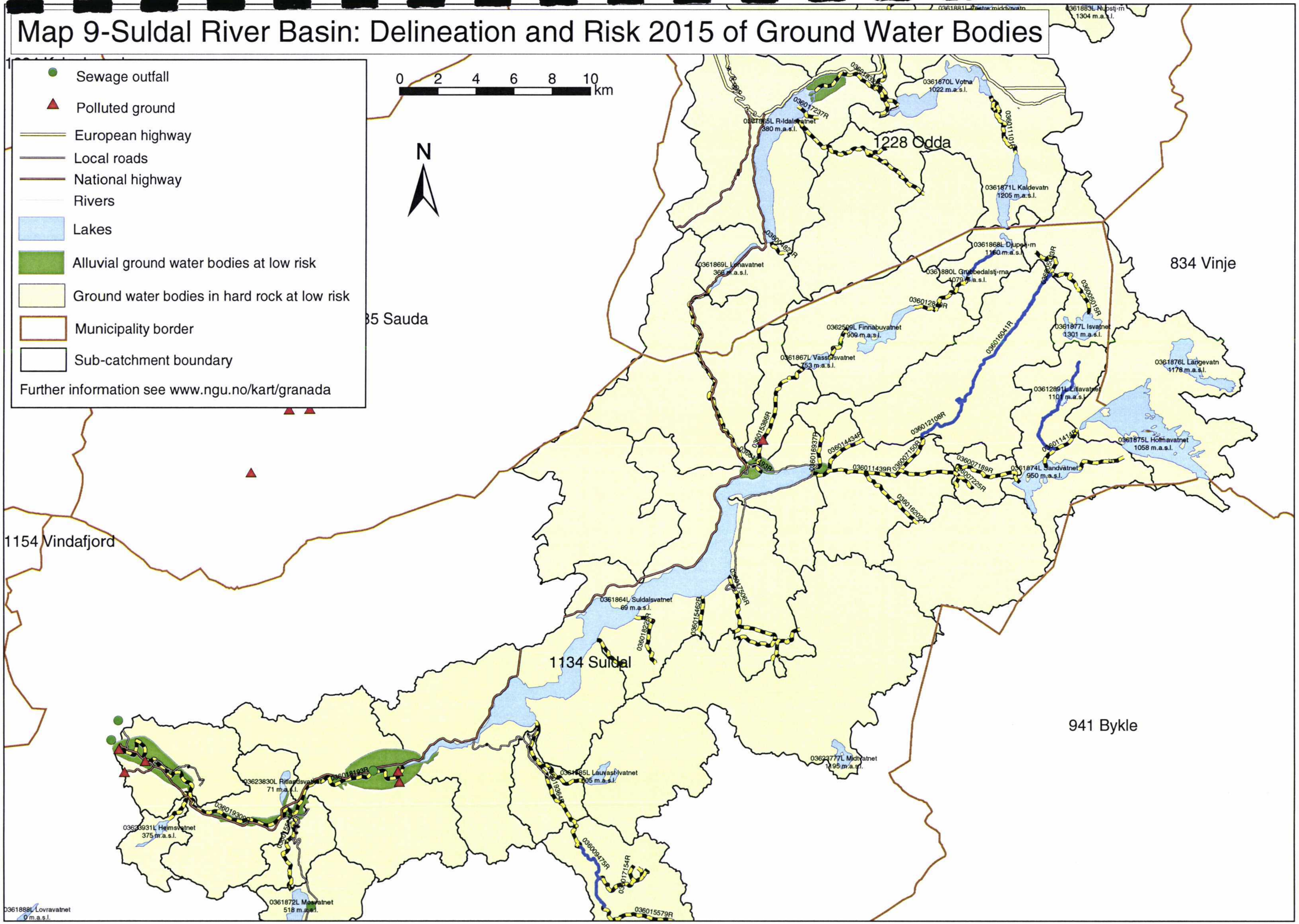

Map 6-Lower Suldal River Basin: Risk 2015
Power plant
Intake
Dam
Underground waterway
Sub-catchment boundary
Municipality border
Risk 2015 River WB
Heavily modified rivers
Low risk 2015
Risk 2015 Lake WB
Heavily modified lakes
Low risk 2015
0 2 4 6 8 km
N
1135 Sauda
1134 Suldal
941 Bykle
0361864L Suldalsvatnet
69 m.a.s.l.
69 m.a.s.l.
637 m.a.s.l.
656 m.a.s.l.
636 m.a.s.l.
646 m.a.s.l.
656 m.a.s.l.
646 m.a.s.l.
647 m.a.s.l.
900 m.a.s.l.
610 m.a.s.l.
1078 m.a.s.l.
1068 m.a.s.l.
518 m.a.s.l.
0361872L Mosvatnet
518 m.a.s.l.
03623830L Ritlandsvatnet
71 m.a.s.l.
036A110T
036A3T
036A120T
036A1A0T
036A1B1T
036B11T
036B1A0T
036B1ABT
036B51BT
036B7T
036BABT
036B4ZT
036B42T
036B122T
036B2T
036D1T
036C0T
036BC32T
1195 m.a.s.l.

Map 7-Suldal River Basin East: Delineation of Water Bodies




Map 8-Suldal River Basin East: Risk 2015
Power plant
Intake
Dam
Underground waterway
Sub-catchment boundary
Municipality border
Risk 2015 River WB
Heavily modified rivers
Low risk 2015
Risk 2015 Lake WB
Heavily modified lakes
Low risk 2015
Odda
834 Vinje
1134 Suldal
941 Bykle
N
0 2 4 6 8 km

Map 9-Suldal River Basin: Delineation and Risk 2015 of Ground Water Bodies



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