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Review of the Swedish System for Dam Safety

A Report to the Government

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1 The assignment

In its 2008 government directions, the Government gave the state-owned public utility Svenska Kraftnät this assignment:

"The state utility Svenska Kraftnät shall review the state's efforts for dam safety. The review should evaluate whether the current dam safety system corresponds with today's societal safety demands. The review should examine the need for society to regulate more explicitly the dam owners' self-regulation, as well as the extent, organization and competence requirements of supervision guidance and supervision. Another issue to be elucidated is how this supervision should be financed."

1.1 Background

Dam safety is regulated in several regulations, the Swedish Environmental Code and the Civil Protection Act being the two most important. The purport of these rules is that persons who pursue an activity or take a measure that is subject to the act is obliged to acquire the required knowledge, investigate and evaluate the risks related to the enterprise from a health and environment point of view, draw up and follow routines for self-regulation, as well as take the measures required and have preparedness in order to avoid damage.

The person in charge of maintenance of a dam – usually the owner – is obliged to maintain the dam. Should a dam failure nevertheless occur, is the owner strictly liable for damage caused by the dam failure.

To compensate for the lack of detailed rules about dam safety, the power and mining industries have drawn up technical guidelines for dam safety. These guidelines are very important as a support in the development of dam safety. They also function as a driver and support for the investments made by the dam owners to strengthen and maintain their structures.

The county administrative board is the operative supervisory authority for water operations, according to the Environmental Code, and dam safety is a part of this. The supervision comprises, among other things, checks that the regulatory framework and the terms of permits allotted are adhered to, and that action is taken, when needed, to make the persons operating a water structure rectify errors.

The county administrative boards are, according to the Swedish emergency management ordinance and the county administrative board instructions, responsible for the coordination in their individual county of the crisis preparedness and shall, according to the Civil Protection Act, be prepared also to take over the responsibility for the local rescue service, when needed. The municipality is responsible for the supervision of the compliance with the Civil Protection Act for dams classified as hazardous activity according to the Civil Protection Act.



Svenska Kraftnät shall promote dam safety in Sweden and act to reduce the risk of severe strain on society owing to dam failure or floods. This also comprises the role of being central authority for supervision guidance on issues related to dam safety. I.e. provide the county administrative boards with advice and support, and coordinate, follow-up and evaluate the supervision.

Occurrences like floods and dam failures have initiated government measures as well as initiatives by branch organizations, all furthering dam safety development. Two national investigations about dam safety have been carried out; "Dam Safety and Protection against Floods" (SOU 1987:64) and "River Safety" (SOU 1995:40).

The Swedish National Audit Office in its report "Safety at Hydropower Dams" (RR 2007:9) suggested that the Government should initiate a review of the Swedish system for dam safety. An investigation about legislative change was also put forward in the final report from the "Climate and Vulnerability Investigation" (SOU 2007:60).

A description more in detail of the handling of dam safety issues in Sweden since the start of the expansion era of hydropower is given in the background account attached to this report (appendix not available in english).



2 Introductory points

2.1 Terms

In this report *dam safety* refers to the prevention of dam failures, incorrect operation and other occurrences that could result in an uncontrolled and rapid discharge of retained water, as well as measures to limit the damage following such occurrences (dam failure preparedness).

Dam failure refers to a breach of a dam, part of a dam or its foundation, resulting in an uncontrolled and rapid discharge of retained water¹.

Dam refers to a construction intended to act as a barrier to retain or keep out water.

2.2 Society's safety demands

The assignment concerns an analysis of whether the current system for dam safety corresponds with society's safety demands of today.

The expansion of hydropower made the electrification of Sweden possible. Hydropower dams have consequently contributed to the development of a modern society.

Concurrently, the work to create a safer society has also been developed and met with increased attention, nationally as well as within the EU and internationally. The Swedish parliament has stated that the aim of the efforts to continually develop societal safety is to safeguard the population's life and health, as well as our society's basic values and functioning.

The development of society has resulted in technical and economic systems getting more and more important to the functioning of society in general. At the same time various activities have become increasingly more interconnected and interdependent. An extensive and prolonged power failure would for example result in nearly incalculable consequences through disturbances and failing functions in a great number of areas vital to society.

Systems vital to society must consequently be built, maintained and operated in a robust and resistant way. Weaknesses in these systems cannot however be entirely prevented or corrected, and so a proper preparedness to handle disturbances, serious accidents and crises must also be at hand.

Apart from the usefulness of dams, they also constitute a hazard to societal safety because of the possible consequences of a dam failure.

In the Government Bill "Preparedness against severe strain on society in peace-time" (Bill 1996/97:11) it is stated that the aim is that dam failures and resulting flooding causing damage to persons or more extensive damage to property should not occur.

In the Parliament Defence Committee report "Safety at Hydropower Dams" (2007/08:FöU5) it is stated that dam failures causing damage to people and more

¹ In this context "water" also refers to a mix of water and for example tailings as in the case of dams related to mining activities.



extensive damage to property should not occur, according to the Government and Parliament's aim for dam safety. Consequently the State authorities have a zero vision about dam failures causing loss of life, damage to persons or extensive property damage. The Parliament Defence Committee underlines the importance of safety at Sweden's hydropower dams being satisfactory and is noting very seriously the criticism put forward by the National Audit Office following its review of the State's measures for dam safety (2007/08:RRS5).

Even if the probability of a dam failure is very small, it might happen. International statistics on dam failure occurrences at large² dams shows that the probability of a dam failure is in the order of 1 per 10 000 per year. The consequences being so considerable, this calls for well established preparedness planning in society to be able to handle the consequences of a dam failure, apart from the necessity to prevent dam failures as far as possible.

2.3 Dam failure

At an estimated 200 dams in Sweden a dam failure would entail hazards to human life and health, the environment, activities vital to society and/or major economic damage. At some 20-30 of these dams a dam failure would result in particularly grave consequences. Here a dam failure would cause extensive flooding and damage to housing, hydropower stations, roads, power lines, telecom networks etc. along the entire stretch of the river, all the way down to the coast. It would bring about serious disturbances in activities vital to society.

So far Sweden has been spared from dam failures with exceptional consequences. In other countries the occurrence of a dam failure that resulted in major devastation and many fatalities has however rapidly changed the attitude among the public and politicians towards the risks associated with dams, from fairly unaware to awareness. This, in turn, has led to reinforced national measures to monitor and control dam safety, e.g. by establishing special regulations on dam safety.

In Britain, dam failures at the Eigg and Coedy dams in 1926 caused the death of 16 people and resulted in the drawing up of "Reservoirs Safety Provisions Act" in 1930. Failures in the Aznalcóllar mining dam in Spain in 1998 and in the Baie Mare mining dam in Romania in 2000 had extensive environmental consequences and resulted in the EU Directive on waste from the extractive industry, with the safety at mining dams being part of it (2006).

2.4 Dams in Sweden and classification of dams

There are some 10 000 dams in Sweden. A large share of dams where a dam failure would result in major consequences belong to enterprises within the hydropower and mining industries.

In these industries a system to categorize dams in various so-called consequence classes is used. This system, which was developed by the industries themselves, is based on an evaluation of the consequences that a dam failure would result in. In special guidelines for

² Large dams refers to dams with a minimum height of 15 m.



these industries (“RIDAS” for the hydropower industry and “GruvRIDAS” for the mining industry) the requirements on dam safety are related to the assessed consequences of a dam failure. Corresponding systems are usually found also in other countries.

There are four consequence classes in the Swedish system:

- **1A and 1B** – a dam failure could lead to loss of human lives or extensive damage to important societal installations, loss of important environmental values or extensive economic damage. Category **1A** refers to dams with a high probability of loss of many lives, very serious damage etc.
- **2** – a dam failure could lead to considerable damage to important societal installations and to environmental values, or considerable economic damage, but not loss of human lives.
- **3** – a dam failure would not lead to damage as previously described.

Svenska Kraftnät is at regular intervals compiling information about the Swedish dams. The compilations are based on the dam owners' yearly reporting on dam safety to the county administrative boards. According to the latest compilation, based on the 2008 reporting, there are 185 dam facilities in consequence classes 1A and 1B, and 293 in consequence class 2. The distribution across the country is seen in table 2.1 and figure 2.1.

There are an estimated more than 500 dam facilities in the country with one or more dams of consequence classes 1A, 1B or 2. Besides hydropower dams and dams used in mining this also comprises some canal dams used for shipping and a small number of flood protection dikes.

The majority of the dams in the highest consequence classes are found in the northern counties Norrbotten, Västerbotten, Jämtland, Västernorrland and Dalarna. There is however also a rather large number of dams with potentially serious consequences further to the south in Sweden, most of them in the county of Värmland and the Västra Götaland region.



Table 2.1 Number of dam facilities in various consequence classes and their distribution across counties³ Facilities on a county border are counted as half a facility in each county.

County /Län/	Number of dam facilities in each consequence class			
	1A	1B	2	Total 1A, 1B and 2
Norrbottn	12,5	4	5	21,5
Västerbotten	14	14	19	47
Jämtland	15	9	39	63
Västernorrland	7,5	8	29	44,5
Gävleborg	2	1	33	36
Dalarna	13	7	44	64
Västmanland		3*		3
Uppsala		6		6
Värmland	7	20,5	30,5	58
Örebro		9,5	32	41,5
Västra Götaland	1	16	15,5	32,5
Kronoberg	3	4	9	16
Jönköping		2	2	4
Kalmar			10	10
Blekinge			5	5
Halland	2	1	11	14
Skåne	1	1	9	11
Summa	78	106	293	477

*These dams have been categorized by their owners as belonging to consequence class 1, i. e. it is not stated whether they belong to class 1A or 1B.

The facilities of consequence class 1A are, with a few exceptions, found in the great, regulated hydropower rivers. Eight dam owners report that they have dams of consequence class 1A. They are the power producers Vattenfall, E.ON, Fortum, Statkraft and Skellefteå Kraft, the water regulation enterprises⁴ at rivers Dalälven, Ljusnan, Ljungan, Indalsälven, Ångermanälven and Umeälven, the mining company Boliden Mineral and Kristianstad municipality with flood defence dikes.

The dams of the first six owners are hydropower dams. Apart from the dams of consequence class 1A they also own a large majority of the dams of classes 1B and 2. An additional 18 dam owners report that they have one or more dams of class 1B but own no dams of class 1A.

³ In addition to the 17 counties in table 2.1 data is lacking from one county with a small number of dams in consequence class 2, and three counties have reported that there are no dams with significant consequences.

⁴ These six water regulation enterprises are managed within the same organisation.



All in all, therefore, 26 dam owners report that they have dams of consequence class 1A and/or 1B. A little more than 30 owners report that they have no dams of class 1A or 1B, but dams of class 2. The majority of these owners have only one or two facilities of class 2.

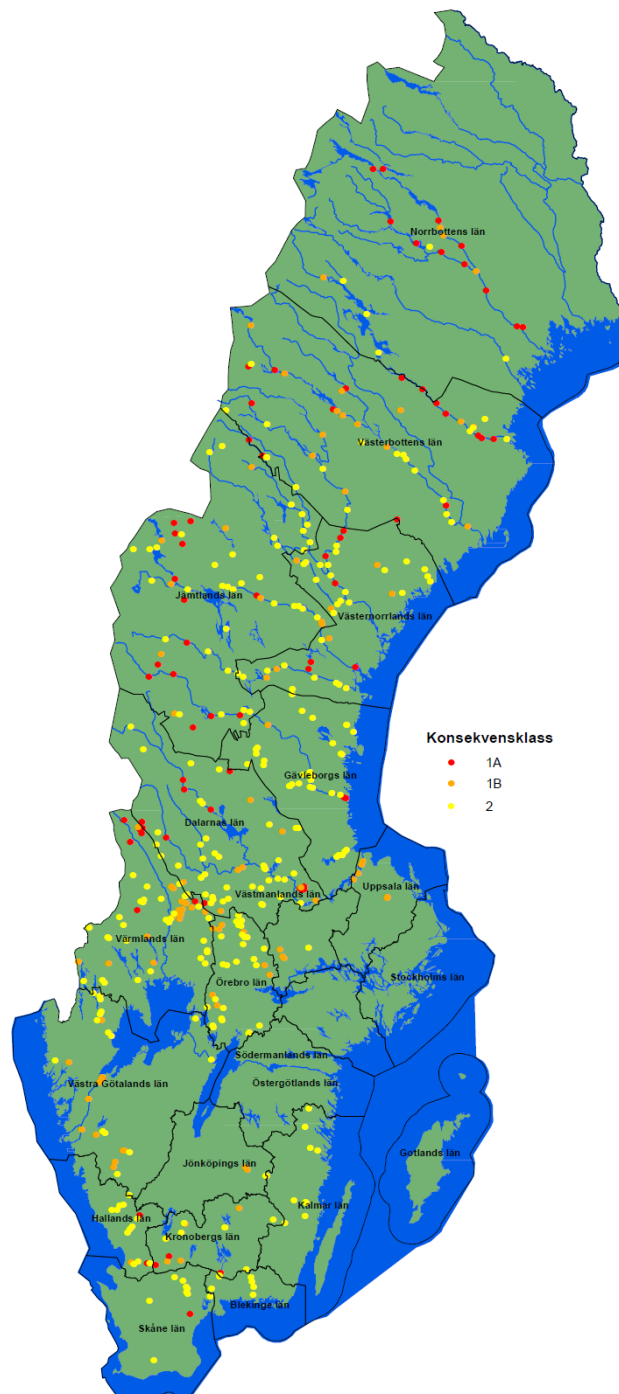


Figure 2.1 Dam facilities of the highest consequence classes 1A, 1B and 2.

2.5 Consequences of a dam failure in Sweden

A dam failure would have particularly grave consequences at a number of the dams in consequence class 1A. It would lead to exceptional occurrences and crises in society, for



example through serious disturbances in the power supply. Put together, a dam failure would result in a serious strain on society, i. e. lead to consequences that could jeopardize people's life and health and the functioning of society and its basic values.

It may be the total effect of all damage along a river or a single or a few damages that result in severe strain on society. These dams differ from the other dams of the highest consequence class 1A because of the great extension of the damage area downstream along the river valley and the consequences this would have for the region and the country.

Today criteria to define this particular category in consequence class 1A are lacking. The assessment of Svenska Kraftnät is however that this category comprises some 25 dam facilities in the counties Norrbotten, Västerbotten, Västernorrland, Jämtland, Dalarna, Värmland and the Västra Götaland region.

The majority of these cases are hydropower dams situated in the upper part of one of the major hydropower rivers, where a dam failure would lead to failures also in the downstream dams. The uncontrolled discharge of retained water would then result in flooding along the greater part of the length of the river, implying a risk of:

- loss of many human lives,
- destruction of many homes and property, cultural environment and workplaces,
- disturbances in the national power supply due to damage to the power grid and destroyed hydropower stations,
- disturbances in the transport system due to destroyed bridges along the river and other damage to roads and railways,
- destruction of infrastructure and widespread disturbances in other services vital to society, for example water supply, radio and telecom constructions and installations,
- severe environmental damage that cannot be healed for a long time, and
- very extensive economic damage.

To render the consequences of a dam failure at one of these dams more concrete, Svenska Kraftnät has studied the consequences of a simulated dam failure at the Lossen dam in the river Ljusnan. Based on dam failure calculations the propagation of the flood wave is described hour by hour along the river valley, with the consequences following such a flood. To illustrate the difference in comparison with the other, more "ordinary" dams of consequence class 1A, the consequences of a dam failure at Laforsen dam in river Ljusnan was also studied.

These two studies were carried out based on data produced in a project on coordinated preparedness planning and following interviews with the parties concerned. They are reported in a memorandum, "Consequences of dam failures in river Ljusnan – description of scenarios for Lossen and Laforsen dams" (Svenska Kraftnät 2009 – classified).



In the Lossen dam case the dam failure scenario indicates water flows of up to 20 000 m³/s, to be compared with the normal flow of a couple of hundred m³/s in the river. This would result in the necessity to evacuate some 9 000 people from their homes. The flood wave would reach some villages after just about one hour and so there is a risk that the inhabitants could not be evacuated in time.

This scenario would lead to roads and railways being inundated and many bridges across river Ljusnan impossible to pass, resulting in great disturbances in the transportation system. Also the power supply would be affected by widespread disturbances, locally and regionally, as well as on the national level. The telecommunications along Ljusnan would be largely knocked out and there is a risk that also the telecom connections between northern and southern Sweden would stop functioning.

The dam failure would lead to dams downstream in the main reaches of river Ljusnan breaking and their hydropower stations being destroyed. Also there would be damage to the environment and cultural values.

Obviously a dam failure at Lossen would lead to severe strain on society, locally and regionally as well as nationally. It would take many years and cost many billions of kronor to rebuild communities and infrastructure.

In the Laforsen dam case, the dam failure scenario indicates flows of up to 3 000 m³/s. The travelling time for the flood wave to the nearest community is only a couple of hours, and so there is also a risk in this case that everyone could not be evacuated in time. Some ten houses are at risk of being flooded. The dam failure would cause a flooding of roads and railways only to a minor extent. Except perhaps locally, power and telecom service supply would in all probability neither be affected.

The conclusion is that a dam failure at Laforsen accordingly would only have local consequences.



3 Dam safety and self-regulation

This chapter deals with overall dam safety rules including the dam owners' self-regulation. The Svenska Kraftnät proposals for more explicit and precise regulations are stated in section 3.5.

3.1 Current regulations

In Sweden there is no specific law on dam safety. Rather, several different statutes are applicable to the dam safety issue. Regulations in the Environmental Code applicable to dam safety are found in chapter 2, general consideration rules, chapter 11, activities in water and chapter 26, supervision. Some application instructions are found in the ordinance on operators' control .

It is a central principle in the Environmental Code that persons who pursue an activity or take a measure shall continuously plan and monitor the operations through self-regulation in order to counteract or prevent harm to other people's health or the environment. This implies that dam owners should have and follow a safety management system that is securing dam safety. Dam safety supervision comprises inspection of the company's organization and routines to secure dam safety, as well as inspection of individual dam facilities.

These rules imply that the person in charge of maintenance – usually the dam owner – is obliged to maintain the dam, in order to prevent damage to public and individual interests through a change in the water conditions. The dam owner himself is to draw up and follow self-regulation routines. He is to acquire the knowledge that is necessary in view of the nature and scope of the activity or measure, and investigate and assess risks emanating from the operation from a health and environmental point of view. If this is not considered unreasonable, he must implement protective measures, comply with restrictions and take any other precautions that are necessary in order to prevent, hinder or combat damage or detriment to human health or the environment as a result of the activity or measure.. Furthermore best possible technology shall be used in connection with professional activities to avoid damage. Should a dam failure however occur, then the person in charge of maintenance is strictly liable for damage following the dam failure.

The law (1994:847) about technical properties of constructions etc. are also applicable to dam constructions. Constructions erected or changed shall, on condition of normal maintenance, adhere to essential technical requirements on properties regarding load-bearing capacity, stability and durability, among other things, during its economically reasonable life span.

The ordinance (1994:1215) about technical properties of constructions etc. contains instructions about the application of the law on buildings (1994:847). The National Board of Housing, Building and Planning may issue instructions as to its application.

The Electricity Preparedness Act (1997:288) contains regulations about preparedness in production and transmission of, and trading in electricity. The directions regulate the



responsibility for the planning and other measures needed to meet the national power supply during heightened preparedness according to the law (1992:1403) about total defence and heightened preparedness. Anyone operating such an enterprise (owner or person entitled to operate it) is obliged to take the preparedness measures decided upon by Svenska Kraftät (Swedish National Grid) in their role as the authority responsible for power supply contingency planning. Decisions could for example concern measures regarding dams and compensation will be paid for costs for the measures after assessing the value of the measures to the enterprise in peace-time.

The law on security protection (1996:627) is applicable to state, local government and county administrative board operations, and to individuals if an enterprise is important to the national security or needs special protection against terrorism. In operations where the law is applicable, the security protection needed, in relation to the type, scope and other circumstances of the operations, must be at hand. This may refer to information security, restricted admittance and special security clearance.

The security protection ordinance (1996:633) states that authorities and others that the statute applies to shall investigate which information about their operations should be kept secret with regard to the national security and which constructions and installations require security protection with regard to the national security or the protection against terrorism. The results of this investigation (security analysis) must be documented. The security protection ordinance is not only applicable to authorities, but also to individuals, if an operation is important to the national security or needs special protection against terrorism.

The law on protection (2010:305) took effect July 1st, 2010, when the law (1990:217) on protection of constructions and installations vital to society etc. ceased to be in force. The new law contains regulations about certain measures for protection against sabotage, terrorism and espionage. It also regulates what could be decreed as protection objects (for example energy facilities) and regulates issues regarding ban on admittance and photographing, and the surveillance of protected objects.

The decision whether a facility supplying energy should be a protected object is made by the county administrative board. Decisions about protected objects usually imply that unauthorized persons cannot be admitted and also provides for increased possibilities of police protection etc.

Finally the following instructions and guidelines within power supply contingency and security protection have been drawn up by Svenska Kraftnät in cooperation with the industry:

- Handbook – Protection and security at energy companies
- Guideline for protected objects within the electricity supply
- Guideline for basic physical protection
- Guideline for physical area protection at power facilities



3.2 Guidelines

In the spring of 1985 the power industry and the Swedish Meteorological and Hydrological Institute formed the so-called "Committee for Design Flood Determination" to establish guiding principles for the determination of design floods at dam facilities. Its work resulted in a final report in 1990. A new edition of guidelines for the determination of design floods at dams was published in 2007, now under the responsibility of Svenska Kraftnät, SwedEnergy and SveMin.

According to the guidelines, the dams are categorized in design flood classes, depending on the consequences should a dam failure occur due to floods. The guidelines do not cover dams where a dam failure would not cause damage to anyone except the dam owner.

Table 3.1 Classification of dams in flood design categories

Design flood category	Type of risk following a dam failure
I	Not negligible probability of risk of loss of human life or injury to person; noteworthy probability of serious damage to important traffic routes, dams or comparable constructions, or important environmental values; considerable probability of major economic damage.
II	Not negligible probability of risk of damage to traffic routes, dams or comparable constructions, environmental values or property owned by someone other than the dam owner in cases not stated in design flood category I.

Dams in design flood category I should, without serious damage to the dam, be able to withstand and pass a very extreme flood sequence, assessed through hydrological modelling. The return period of the design floods cannot be stated, but comparisons with frequency analysis indicate that floods calculated in this manner on an average have a return period of more than 10 000 years.⁵

Dams in design flood category II should at the maximum water level be able to pass an incoming flood with a return period of at least 100 years. Category II dams should furthermore be adapted to a (higher) flood that is decided through a cost/benefit analysis. The lower requirements, as compared to dams in design flood category I, are motivated by the consequences for society if a category II dam fails being estimated as fairly limited and the risk of loss of human life considered negligible.

In 2004 Svenska Kraftnät and SwedEnergy established a system for the classification of dam safety defects, so-called standardized dam safety ratings.⁶ In cooperation with SveMin a review is currently carried out to elucidate the rating system. The common nomenclature and the systematic approach in assessing the importance of a defect to dam safety is, among other things, aiming at a more distinct communication between parties.

⁵ Follow-up of the Swedish Guidelines for Design Flood Determination for Dams (Svenska Kraftnät, Report 1:2008)

⁶ Bedömningsklasser för dammsäkerhet/Rating of dam safety defects (Svenska Kraftnät och Svensk Energi, 2004)



Table 3.2 Standardized dam safety rating

BK	Dam safety rating
BK5	Very large importance to dam safety
BK4	Large importance to dam safety
BK3	Moderate importance to dam safety
BK2	Small importance to dam safety
BK1	Very small importance to dam safety

3.2.1 The power industry guiding principles for dam safety

In 1997, the hydro power industry adopted the Hydro Power Industry Dam Safety Guidelines (RIDAS), which comprises a main document as well as more detailed application instructions.

The main contents of the Guiding Principles comprise:

- Basic principles
 - Dam safety policy
 - Quality assurance
- Consequence classification
- Organization, competence and documented working methods
- Operation and emergency preparedness planning
- Condition monitoring, reporting of defects and maintenance
- Dams, systems and construction
 - Embankment dams
 - Concrete dams
 - Discharge arrangements
- Dam safety auditing

It is stated in the opening sections that the individual member company shall adhere to the SwedEnergy dam safety policy and that the essence of the guiding principles should permeate and be a support for the dam safety work. The SwedEnergy dam safety policy reads as follows:

The dam safety work of the member companies is primarily aiming at protecting as far as possible people's life and health, but is also considering other protection requirements. The dam safety requirements should be related to possible consequences should a dam failure occur.

This focus implies that:



- *the probability of a dam failure threatening human lives shall be kept as small as to, as far as possible, eliminate this threat,*
- *the consequences, should a dam failure occur, shall as far as possible be reduced through good planning, and*
- *dam safety shall be kept at a level in accordance with good international standard.*

Dam safety work should be carried out using quality assurance and be characterized by continuous improvements.

3.2.2 The mining industry guiding principles for dam safety

The association of mining and minerals and metal producers in Sweden (SveMin) in 2007 published the mining industry's guiding principles for dam safety (GruvRIDAS). GruvRIDAS has been drawn up based on RIDAS and the mining industry in principle follows the same routines as the power industry. Since 2005, SveMin has the following dam safety policy for its member companies:

The dam safety work at the member companies is primarily aimed at the protection of health, safety and environment, but also considers other aspects. Observing the demands in laws and other regulations, the member companies undertake to follow the principles laid down in these guiding principles. In accordance with this aim shall

- *the demand on dam safety be set in relation to assessed consequences, should a dam failure occur,*
- *stability and safety to avoid dam failure be a decisive criterion when locating dams,*
- *dams be designed, built, monitored, maintained and after-treated in order to keep the probability of operational disturbances, damage and dam failure at the lowest possible level,*
- *consequences, should a dam failure occur, be reduced as far as possible through good planning and preventive measures,*
- *the anticipated life span of a dam be a guiding factor when designing dams, and*
- *dam safety be kept on a high international level.*

The member companies undertake to follow routines securing quality assurance and continuous development of the dam safety work. .

3.2.3 Consequence classification according to industry guidelines

The dam safety requirements are decided in relation to the assessed consequences of a dam failure in accordance with the power and mining industries' individual dam safety policies. Practically, it is presupposed that dam safety work is guided and prioritized by analyses of the condition of the dam facilities and the consequences, should a dam failure occur. Therefore, the member companies' dams must be classified through an assessment of the maximal damage that could follow a dam failure.



To this purpose the power industry has drawn up a system for consequence classification where the consequences of a dam failure are evaluated in relation to the probability of loss of human life or serious injury to persons, and damage to the environment, public installations, and other economic values.

There are four consequence classes in the classification system; 1A, 1B, 2 and 3, where 1A reflects the most serious consequences. When a dam failure would result in a not negligible probability of loss of human life or serious injury, the dam is classified in consequence class 1A or 1B.

Table 3.3 The RIDAS consequence classes in relation to the probability of loss of human life or serious injury and damage to the environment and public installations.

Consequence class	Consequence of a dam failure expressed as level of probability for resulting damage
1A	High probability of loss of human life. or High probability of very serious damage to important public installations, major environmental values or very great economic damage.
1B	The probability of loss of human life or serious injury is not negligible. or The probability is noteworthy of serious damage to important public installations, and major environmental values. or High probability of great economic damage.
2	The probability of noteworthy damage to public installations, and environmental values or economic damage, is not negligible.
3	The probability of resulting damage as previously described is negligible

3.3 Reviews by international expertise

Svenska Kraftnät has, in cooperation with the branch organization SwedEnergy, drawn up a model for so-called peer reviews of dams of the highest consequence class. The purpose was to evaluate whether dam safety at these dams was in accordance with high international standard, to evaluate also the review model and produce a better basis for the future dam safety work by the dam owners, as well as for the supervision by the authorities.

The review model implies that independent experts with special competence and international experiences from dam safety work review the dam safety of a dam. The review is carried out on an assignment from the dam owner, as a complement to the ordinary self-regulation, but with the authorities having the opportunity to follow and influence the process. The model also includes that the dam owner submits an action plan to the supervising authority describing how the observations in the expert review report will be handled.

Tests with peer reviews according to this model were carried out in 2006-2008 at the following dam facilities:

- Höljes in river Klarälven, Värmland county (Fortum)
- Suorva in river Stora Lule älv, Norrbotten county (Vattenfall)



- Hällby in river Ångermanälven, Västernorrland county (E.ON)
- Håckren in river Indalsälven, Jämtland county (Vattenregleringsföretagen)
- Ajaure in river Umeälven, Västerbotten county (Vattenfall)

In one of these cases the reviewers observed that neither dam safety, nor dam safety work corresponded to high international standard. In the other cases safety and safety work were considered in line with a high international standard, albeit there were some improvement needs.

The peer reviews confirmed many previously known needs for development. Among these were better documented routines for the direction and handling of the companies' dam safety work. In some cases the reviews resulted in a change of perspective on individual issues, the initiation of new studies and certain reprioritizations in the owner's plans, as is evident in the action plans submitted by the owners to the county administrative boards concerned, following each review.

The examiners furthermore found that the owners had high competence, but also that remarkably few people at their companies were working on dam safety. The examiners were hesitant to the frequent hiring of sub-contractors to handle key tasks in the managing of dams. Short contract times with possible change of sub-contractors was also considered unsuitable.

The opinion of Svenska Kraftnät is that the review model serves its purpose and has been efficient, albeit resource demanding for the owners, in deciding if safety at the individual facility complies with high international standard.

On the basis of experiences made, Svenska Kraftnät is currently working to draw up processes that would satisfy the needs of the county administrative boards to have a close insight into the safety at dams with particularly large consequences, should a dam failure occur. This is done in cooperation with the power industry and the aim is to adapt the owners' self-regulation routines so that the supervising authorities' need for insight is met within these routines.

3.4 The need for more explicit regulations

It is important to dam owners as well as society to develop dam safety. A more explicit set of regulations would support this development.

The restructuring and internationalization of the power industry has resulted in many dam facilities shifting owners in the last few years. An increasingly larger share of the dam facilities is today owned by companies that are part of international corporate groups. Norwegian Statkraft, Finnish Fortum and German E.ON for example own many of the hydropower plants in Sweden.

In many European countries the dam safety systems are based on a more active supervision by the authorities. Rather often there is a special dam safety legislation and regulation in detail by the authorities. One could fear that the management of corporate groups based in countries having such systems may consider the Swedish requirements



unclear, entailing a risk that the operator's responsibility for carrying out self-regulation is not fully observed.

The general rules of consideration for others in the Environmental Code and the rules about operators' self-regulation applies to all forms of enterprises including dams. The formulation of this set of rules however implies that there is ample space for interpretation and that a more precise guidance for dam safety work is lacking.

The national Dam Safety Investigation of 1995 proposed that safety aspects should be given more weight in permit examinations, in 1989 resulting in a regulation to that end being added to the then water act. The regulation, today in chapter 22, paragraph 25 of the Environmental Code, stipulates that court rulings on permits, when appropriate, shall contain directions as to the safety and other technical properties of the enterprise.

Only a few hydropower dams have been built after this regulation was introduced, and so it has had no influence on the majority of the hydropower dams. During the last few years, however, various details about construction, monitoring equipment etc. have been brought up in reconsiderations of permits in connection with safety-improving measures and, above all, mining dam permits. Such directions as to dam safety should however apply to all dams, regardless if the facility has been reconsidered for a new permit or not.

Internationally it is customary to classify dams according to the potential consequences that a dam failure could bring about. The intent of the classification is to lead the dam safety work to secure that resources are primarily directed to the most urgent safety needs. The classification provides the opportunity to put forth differentiated demands on dam safety, owner's self-regulation, reporting to the authorities etc. for dams of the various classes. More stringent demands could be made on dams with potentially severe consequences, should a dam failure occur.

The industry guidelines (RIDAS) together with the guidelines for the determination of design floods have become drivers for the upgrading of existing dams and the on-going modernizing of dam safety work. The guidelines are very important in supporting and pushing on the development of the dam safety work into a modern safety culture. The dam owner's self-regulation, as described in RIDAS, does however not distinguish between dams where a dam failure could result in severe strain on society and other high failure consequence dams.

Svenska Kraftnät is of the opinion that the initiative to draw up guiding principles for the hydropower industry has been commendable, but that the resources set aside to continuously develop and keep these guiding principles up to date are insufficient. Furthermore it is unsatisfactory that there is no publicly communicated review of the guiding principles. It must be ensured that the interpretation of the regulations that is made through the guidelines actually conforms with the legislator's demands, that the guidelines include all aspects important to dam safety, and that they reflect a high international dam safety standard. Svenska Kraftnät is of the opinion that a quality assured and reinforced engagement in the further development of the guidelines is most important.



Availability of competence and knowledge are necessary prerequisites in dam safety work. Investments in research and development has been made by the power industry for decades and by the authorities in later years, through collaboration via the research and development organisation Elforsk AB, among other things.

These research and development investments have had great importance for the development of dam safety. One example is the major efforts made at the end of the 1980's, resulting in the guidelines for determination of design floods for dams, followed in the 1990's by a programme with a large number of investigations and development projects aiming at establishing a foundation for a safe and efficient adaption of the Swedish dams to the new guidelines. Other important examples are development projects for coordinated emergency preparedness planning for dam failure, studies related to leakage problems at existing embankment dams, monitoring methods etc. during the beginning of the 21st century.

The joint investments made by universities, industry and authorities since 2005 through the Swedish Hydropower Centre (Svenskt Vattenkraftcentrum) to secure long-term availability of qualified engineering competence was evaluated by an independent group of experts in 2008. Their conclusion was that this programme is important, well formulated and well thought-out, and has had a good start that promises well for the future.

3.5 Proposals

The lack of explicit dam safety regulations and the limited number of lack of competent personnel is currently the limiting factors for the pace of the development of dam safety work.

Svenska Kraftnät is of the opinion that the Swedish state should draw up and introduce a special set of regulations that clarifies the implications for dam safety of the Environmental Code. This is urgent especially at dams that in case of a dam failure could inflict very grave consequences, implying severe strain on society.

Svenska Kraftnät therefore thinks that a binding, consequence-based classification system should be introduced in Sweden. All dams should be classified in accordance with the potential consequences of a dam failure and such a system should be part of the regulatory framework.

The system could be based on the two design flood classes introduced in the guidelines for design flood determination and on the RIDAS consequence classification system. A special class must however be established for facilities where the potential consequences of a dam failure could imply severe strain on society, beyond the consequences that dams of consequence class 1A could bring about.

Table 3.4 presents a draft classification system. Here, the dams are classified in four categories, based on an investigation of potential consequences, should a dam failure occur.



Table 3.4. Draft classification system with four categories, based on an investigation of potential consequences, should a dam failure occur.

Category	Potential consequences of a dam failure
1A Severe strain on society	Severe strain on society through the total effects of damage along the river, or particular consequences of a single or a few damage instances, including loss of human life, the destruction of many people's home, of cultural environment and workplaces, disturbances in the country's power supply, disturbances in communications and transport, destruction of or considerable damage to other important public installation, serious damage to the environment and/or very great economic damage.
1B Large consequences	Loss of human life or injury to person, serious damage to important traffic route, dam or comparable facilities, or important environmental values, or great economic damage.
2 Moderate consequences	Noteworthy damage to traffic route, dam or comparable facility, property or environmental value.
3 Small consequences	Small/negligible consequences.

The power industry, the mining industry and other dam owners who have already classed their dams should be able to translate their present consequence classification into the proposed classification without difficulty. However, in addition the small group of dams of the present consequence class 1A that would belong to the new category 1A, with a potential of causing severe strain on society in the event of a failure, must be distinguished.

The data that is available to decide which dams should belong to this top category are incomplete as of today. However the data for this classification is becoming gradually better through on-going development projects in the major hydropower rivers, including dam breach modelling and production of consequence analyses as a part of basis for coordinated emergency preparedness planning for floods and dam failures.

3.5.1 Guiding principles for the safety work

A new set of regulations should establish guiding principles for the safety work, related to the various categories. These principles should also be related to the aims of society and the requirements of the Environmental Code on activities that could bring about damage or harm to people's health and/or the environment, or damage to individual or public interests.

Category 1A

A dam failure at dams of the top layer of the present consequence class 1A could result in severe strain on society. Dams of this category should be designed to be able to handle the worst conceivable load scenarios without breaking. The probability of a dam failure should be kept at the lowest possible level, in view of present knowledge and available technology. These principles should be in force as far as this cannot be considered unreasonable. The potential consequences following a dam failure being so considerable, anything else would be impossible to defend, ethically, economically or functionally.



Category 1B

The potential consequences following a dam failure would be severe at dams of the current 1B and 1A consequence classes, besides the aforementioned top layer. Dams of this category should, as far as reasonable, be designed to withstand the worst conceivable load scenarios without breaking. The probability of a dam failure should be kept at the lowest reasonable level, in view of present knowledge and available technology. When assessing how far-reaching the measures to prevent a dam failure should be to be considered reasonable, one has to observe possible limitation of damage through emergency preparedness planning, e.g. plans securing an evacuation of people from the flood area.

Category 2

The potential consequences following a dam failure are small at dams of the current consequence class 2. The probability of a dam failure should be kept at the lowest reasonable level, implying a lowest acceptable safety level that must always be kept, as well as a raised safety level to withstand more unusual loads and circumstances, to be kept if this is not considered unreasonable. The costs of additional safety measures would then be weighed against the costs of potential damage following a dam failure after unusual loads or circumstances. This principle is today applied at dams of design flood class II when determining design floods.

In the event of a dam failure, strict third party damages liability is applicable, the established safety level notwithstanding.

3.5.2 The self-regulation requirements

The obligation for dam owners, according to the Environmental Code and the Civil Protection Act, to plan and control his operations in order to counteract or prevent harm to people's health or effects on the environment needs to be developed and clarified.

The EU Directive 2006/21/EG about the handling of waste from the extractive industry, referring among other things to mining dams, comprises the important items which should be part of a modern safety management system for hazardous activities and should therefore be used as a starting point in these endeavours.

For dams with significant consequences, should a dam failure occur (categories 1A, 1B and 2), the dam owner must draw up a strategy to prevent dam failure and diminish the consequences of a dam failure, as well as introduce a safety management system to implement this strategy.

The dam safety strategy should comprise the dam owner's overall targets and principles for action as to control of the risk of a dam failure with significant consequences. The dam safety strategy and the safety management system should be proportionate to the owner's dam(s) and the consequences that a dam failure would bring about.

The safety management system should comprise the part of the general management system that includes organizational structure, distribution of responsibilities and methods, procedures, processes and resources needed to implement the dam safety strategy.



The following aspects should be part of the safety management system:

- Organization and personell. Tasks, area of responsibility and competence requirements of staff taking part in the handling of dam safety at all levels of the organization and, where appropriate, the sub-contractor's organization. Training need identification for this personnel and provision of the training deemed necessary.
- Identification and assessment of serious risks related to dam safety. Adopt and implement procedures for a systematic identification of serious risks arising during normal and unusual operation conditions, as well as assess their probability and level of severity.
- Operation, condition monitoring and maintenance. Adopt and implement procedures for safe operation, condition monitoring and maintenance of the dam facility.
- Handling of alterations. Adopt and implement procedures for the planning and implementation of alterations at existing dams or construction of new dams.
- Planning for emergency situations. Adopt and implement procedures to identify predictable emergency situations through a systematic analysis and draw up, test and keep up to date preparedness plans that could be utilized in such emergency situations.
- Audit and review. Adopt and implement procedures for a regular and systematic assessment of the dam safety strategy and the safety management system in relation to aims, efficiency, suitability and observance, and update when needed.

3.5.3 Reporting to the authorities

The so far applied yearly reporting routine containing only basic information is not a sufficient basis for the supervision of dams with particularly severe failure consequences.

Svenska Kraftnät is of the opinion that the regular reporting should be increased to a more in-depth dam safety reporting for dams where a dam failure could cause severe strain on society (category 1A). The owner's self-regulation routines should include the task to regularly compile and document the status on dam safety and emergency action planning at each individual dams. Such a documentation would have an important function in the owner's dam safety work and also constitute an important basis for the authorities' supervision.

At other dams, where a dam failure could result in noteworthy consequences (categories 1B and 2), the scope of the reporting could correspond with the existing routine for yearly reporting drawn up by Svenska Kraftnät, which is used in a majority of the counties since a few years back.

The intention is that the dam owners' reporting of basic key information shall provide the supervising authorities with an up-to-date overview of the dam safety situation in the county. Uniform routines in the basic reporting implies a rational handling for major dam owners with facilities in more than one county.



Svenska Kraftnät is of the opinion that the supervision guiding authority should have the right to issue directives more in detail about the reporting from the dam owners to the authorities.

3.5.4 Support for provision of knowledge and competence

Research and development are a prerequisite for building and upholding knowledge and competence, and so secure long-term dam safety. Cooperation between the industry and authorities is considered as having an important role to produce and disseminate knowledge, in the short term as well as the long term. This applies to research and development within concrete technical issues as well as development projects with wide societal perspectives.

The State should consequently continue to support research and development, to

- contribute to knowledge, work methods and competence being upheld and developed, and made available and utilized,
- stimulate the industry to reinforce even further its investments in research and development, and
- promote a comprehensive view and a societal perspective on the development.

Svenska Kraftnät recommends that the joint endeavours by the Swedish Hydropower Centre should continue at its present extent at least.

3.5.5 Analysis of the damages liability after dam failures

A strict damages liability is applicable, according to chapter 11, section 18 of the Environmental Code, to damage following a dam failure. A dam failure could in some cases result in damage corresponding to very high amounts of money, exceeding what is insurable.

The owner of such a dam could be a limited liability company being part of a corporate group, with the parent company in Sweden or another country, and what is applicable regarding piercing of the corporate veil is unclear. The scope and purport of the damages liability after a dam failure should be analysed more in depth and elucidate what is applicable regarding piercing of the corporate veil in national and international corporate groups, as well as damages to injured persons if the economic resources of the dam owning company, with or without insurance, are insufficient for covering the damage.



4 Supervision and supervision guidance

This chapter deals with scope, organization and competence requirements in supervision and supervision guidance. The proposals from Svenska Kraftnät are found in section 4.5.

4.1 Current regulations

The county administrative boards are the supervising authorities for activities in water according to the Environmental Code, and dam safety is part of this. The county administrative boards are consequently the authorities performing the operative supervision directly in relation to the dam owners. This comprises control as to the observance of various regulations, measures to bring about necessary corrections by the owner, assessment whether conditions in permits for water activities are sufficient, and advice and information to the owners.

Svenska Kraftnät is, according to the statute (1998:900) about supervision in accordance with the Environmental Code, responsible for the supervision guidance on issues related to dam safety, according to chapter 11 of the Environmental Code. The supervision guidance could be seen as part of Svenska Kraftnät's broader assignment to promote dam safety in Sweden and work to diminish the risks of severe strain on society through dam failure or floods.

Supervision guidance implies that Svenska Kraftnät is to evaluate, follow up and coordinate the operative supervision by the county administrative boards, and provide them with support and advice.

Supervision of the observance of the Civil Protection Act (2003:778) and statutes that have been promulgated based on this law is exercised by the local municipalities within their geographical area and within the county by the county administrative board. This implies that the municipality or a county administrative board – if they cannot come to terms with the dam owner – have the option to prescribe that the owner, within reasonable limits, shall provide or pay for a completion of the local municipalities resources to carry out efficient rescue operations.

The county administrative boards decide which facilities and installations, among them dams, are to be considered as hazardous facilities according to chapter 2, section 4 of the Civil Protection Act. The Swedish Civil Contingencies Agency exercises the central supervisory authority and is the supervision guidance authority according to the Civil Protection Act.

4.2 Current supervision and supervision guidance

Svenska Kraftnät's guidance of the operative supervision of dam safety has, among other things, been carried out through a guidance handbook published in 2003 and, after an update in 2007, having the title "Handbook for Dam Safety – operators self-regulation and authority supervision". Furthermore seminars are arranged for county administrative board staff on dam safety, dam failure emergency preparedness planning and dam safety



supervision. Svenska Kraftnät also takes part in courses and seminars on dam safety arranged by SwedEnergy, STF Engineer Training and SwedCOLD, among others, and in development projects managed by Elforsk AB.

The handbook describes the routine for a yearly dam safety reporting from dam owners introduced in 2003, which in the opinion of Svenska Kraftnät should be applied at all dams that could pose a safety risk, whether they are used for hydropower production, mining, protection against floods, or some other purpose.

Among other things, the yearly dam safety reporting provides information about which persons are responsible for dam safety, the consequence classification of dams, which self-regulation has been carried out by the operator and whether there are manuals for operations, condition monitoring and maintenance. The reports also comprise information about identified defects influencing dam safety at dams that are important from a safety point of view and about the dam owner's planned and completed measures motivated by these defects.

The supervisory authorities are recommended to follow up the information provided by the dam owners in their yearly dam safety reports. Among other things this applies to the dam owners having handled identified serious weaknesses in a satisfactory way and consequence classification being correct. The reporting provides a county administrative board with a basis for prioritizing additional supervision and also improves the transparency for the individual citizen.

The supervision is mainly made up of the collection and survey of the dam owners' yearly reports and, to a varying extent, oral and written follow-up contacts. The county administrative board in general has a dialogue with the owner with regard to serious defects reported and sometimes there is a demand or injunction for written documentation, as for example action and time plans to correct defects. In some counties there are recurrent meetings with dam owners, supervision site visits, participation in the reporting of in-depth evaluations of dam safety and inspections of certain dam facilities.

The county administrative boards pass the dam owners' reports to Svenska Kraftnät which each year makes a national compilation as part of its assignment to follow up and evaluate the supervision. During the last few years practically all counties with dams of safety importance have applied these routines. They cover hydropower dams quite well, but the reporting from mining dams and other types of dams is more incomplete.

4.3 Supervision resources and competence

In 2008 Svenska Kraftnät carried out an inquiry which showed that dam safety is included as an unspecified part of water activities in the county administrative boards' supervision plans. The dam safety supervision is usually handled by water/environment officials without experience of dam safety work at their previous positions.

The county administrative boards' resources for supervision of water activities are limited. In general the answers to the enquiry state that no time, or very little time is used for supervision initiated by the officials themselves. Only a few county administrative boards



say that one or more months have been used for this purpose. All in all the supervision of dam safety by the county administrative boards obviously is very limited, but what is carried out is mainly in line with the recommendations in the Svenska Kraftnät handbook.

As for supervision guidance there is a demand for recurrent courses and seminars on concrete guidance about working methods in supervision and an exchange of experiences. Individual support has so far not been asked for. Svenska Kraftnät, since 1998 having 1-2 persons working with dam safety issues, on the other hand has not set aside resources for that purpose.

It is in the national interest to have a very high safety level at dams with particularly severe consequences, should a dam failure occur (the top layer of dams in the present consequence class 1A). A qualified supervision of dam safety at dams in this category should include reviews of the safety of the facilities, as well as reviews of the safety management systems and self-regulation routines of the owning companies.

The testing of so-called peer reviews of selected dams of the highest consequence class has reinforced the opinion of Svenska Kraftnät that even if experts are engaged for the review as such, it is necessary for the supervising authorities to have their own competence and experience of the factual matter, and enough resources to be able to carry out their supervising tasks in a satisfactory way. Personell is needed with knowledge and competence within dam construction and modern dam safety work, and of the development going on nationally and internationally. Legal competence is also required at the supervising authorities, in order to be able to act efficiently to bring about corrections by the owner when needed.

In the case of other dams with noteworthy consequences, should a dam failure occur (dams of the present consequence class 1A, with the exception of the top layer, and of classes 1B and 2) Svenska Kraftnät is of the opinion that the supervision could be kept at a more general level. It could be based on routines for yearly dam safety reports, of approximately the present scope, and a follow-up of these. The broad basis of experiences at the county administrative board environment and crisis management units would – completed with further training in dam safety and supervision guidance measures – provide satisfactory competence for this task.

At dams with limited consequences in case of a dam failure it is in the opinion of Svenska Kraftnät not motivated to require regular reporting on dam safety to the supervisory authorities.

4.4 The organization of supervision and supervision guidance

Out of Sweden's about 10 000 dams some 200 dam facilities in 15 counties are classified as belonging to consequence classes 1A and 1B, and more than 300 dam facilities in at least 18 counties to consequence class 2. At the rest of the dams, dam safety is considered to be of minor importance.



The great number of dams implies a great number of complaints from the public, e.g. opinions about water regulation where dam safety is just one aspect among several others under the supervisory authority of the county administrative boards. These various aspects must be weighed against each other and so it is an advantage if the same authority has the supervising authority over all the aspects.

It is furthermore an advantage if the supervisory authority over water activities, including dam safety and the role of the county administrative board to act as the primary authority in consultation matters in permit cases according to chapter 6, section 5 in the Environmental Code, are found in the same authority organization. The same applies to notification cases according to section 19 of the statute (1998:1388) regarding water activities etc., prescribing that a notification must be made to the supervisory authority.

There are also points of contact between the function of the county administrative boards to supervise dam safety according to the Environmental Code and their regional coordination responsibility for issues regarding crisis management according to the statute (2006:942) about emergency preparedness and raised preparedness, and their coordinating functions within emergency preparedness (in this case dam failures) in accordance with the statute (2003:789) about protection against accidents.

The fact that these functions are concentrated to each county administrative board is providing the prerequisites to develop and uphold a competence built on several individuals with similar or completing competence profiles, to handle these broader functions.

For the more specialized dam safety supervision that, according to Svenska Kraftnät, should be carried out at dams that in case of a dam failure could cause particularly severe consequences and strain on society, a rather great reinforcement of competence and resources is required, in the opinion of Svenska Kraftnät.

As previously pointed out, the dams of the top layer of consequence class 1A hold an exceptional position. All these dams are among the consequence class 1A dams owned by the six biggest owner organizations in the hydropower branch and situated in ten counties (see table 4.1). These six owners had, according to the yearly reporting on dam safety in 2008, 71 of the 78 dams of consequence class 1A, 78 of 103 dams of consequence class 1B and 201 of 293 dams of consequence class 2.



Table 4.1 Number of dams of consequence class 1A, their distribution in the counties and the largest dam owners in the hydropower industry [7].

Dam owner	Number of dams of RIDAS consequence class 1A	Distributed in number of counties
Vattenfall	21	5 (AC, BD, O, Y, Z)
Fortum	21	4 (S, W, X, Z)
The Östersund water regulation enterprises (Dalälvens, Ljungans, Ljusnans, Indalsälvens, Ångermanälvens and Umeälvens Vattenregleringsföretag)	13	2 (AC, Z)
Statkraft	9	5 (AC, Z, G, N, Y)
Skellefteå Kraft	3	2 (AC, BD)
E.ON	4	2 (G, Y)

A central part of the supervision of these dams is the inspection of the owners' self-regulation systems, where the dam safety strategy and the safety management system with organisation, distribution of responsibilities, and methods and resources for the dam safety work are included. Since the owners mentioned, apart from the dams with the severest consequences in case of a dam failure, also are responsible for the main part of the rest of Sweden's dams of the highest consequence classes, such a qualified supervision by the companies' safety management system and dam safety routines would also benefit a great part of the total number of high consequence dams in Sweden.

Since each dam owner with dams of this category normally owns dams in several counties, the supervising responsibility for each company is shared between several county administrative boards. Then it is obviously necessary that the supervision is coordinated between these counties. One way of organizing this could be that the supervision guiding authority coordinates the supervision and is an advisor to the operative supervising authorities in factual issues on dam safety and dam safety work, to complete the legal and general authority competence of the county administrative boards.

4.5 Proposals

Svenska Kraftnät proposes that the dam safety supervision and the supervision guidance be additionally developed and reinforced. This is particularly important at the rather few dams that in the case of a dam failure could cause severe strain on society.

Expert reviews could provide a better basis for the supervision, but today it is the view of Svenska Kraftnät that the opportunities for the supervising authorities to take advantage of such reviews and follow up the owners' action plans are limited due to lack of resources and competence with regard to the factual issues.

It is consequently the impression of Svenska Kraftnät that too limited resources are set aside today for dam safety supervision. Since dam safety is only a small part of the officials' work at the county administrative board, it is furthermore difficult to build and



uphold knowledge and experience in this area. In some cases staff turnover also contributes to the difficulties.

The assessment of Svenska Kraftnät is furthermore that the county administrative boards' handling of incoming water issues, public complaints etc. and the following of and participation in permit trials at the environmental court today are prioritized, at the expense of dam safety supervision.

There is a great need for measures to develop competence and working methods for a more qualified supervision. Reinforced supervision guidance and expert support in individual cases is also considered especially important at dams with particularly severe consequences, should a dam failure occur.

In some countries the operative supervision of dams is handled by a central authority. This could be a way of ensuring that the supervision receives the necessary resources and has a satisfactory competence. As described in previous sections, several reasons tell that the operative supervision responsibility should continue to rest with the county administrative boards. The solution to the current lack of resources and competence is not primarily organizational changes. Instead, it is about adhering to section 7 of the statute (1998:900) about supervision in accordance with the Environmental Code, i.e. to "*allocate resources that to a sufficient extent correspond to the need for supervision and have staff with adequate competence for the supervising work*".

Svenska Kraftnät also anticipates that a regional reform, where a great number of county administrative boards is replaced by a smaller number of regions, will be favourable from a resource and competence point of view.

To strengthen the county administrative boards/regions in their role as operative dam safety supervising authorities, the supervision guidance should be developed and reinforced. This could for example be carried out through regular seminars and concrete guidance regarding supervision work. The coordination between counties/regions as to the supervision of dam owning companies should also be the responsibility of the supervision guidance authority.

There should be a basis at the supervision guidance authority for developing operations characterized by a broad and deep dam safety competence. The establishing of a defined group with high competence should per se provide an important enticement to attract competent personnel and limit the vulnerability to staff turnover.

A corresponding basis for continuously keeping a staff with necessary competence within this area in counties with dams of this category is lacking. Furthermore the work volume within the field is not enough to motivate the establishing of such groups at several places in Sweden.

Which supervisory initiatives are available, according to current regulations, to attain corrections when needed, has been elucidated in the Svenska Kraftnät handbook. It is however the opinion of Svenska Kraftnät that a specialized study should be made in order



to establish if these possibilities are adequate to attain necessary action in order to achieve acceptable dam safety within reasonable time, and temporary measures awaiting that.

At dams with severe consequences in case of a dam failure it should for example be clarified whether the supervising authority has the option to order dam owners to temporarily lower the dam water level, in case the owner is unable to demonstrate that the dam safety is satisfactory at a high reservoir water level. Legislation permitting such prescriptions and temporary restrictions on water levels, awaiting necessary action being taken by the owner to comply with the safety requirements, is found in several other countries.

Svenska Kraftnät is the dam safety supervision guidance authority. The supervision guidance is part of the assignment to promote dam safety in Sweden which rests with Svenska Kraftnät according to the statute. This task comprises the following dam safety issues:

- follow the effects of climate change and follow and take part in the dam safety development in Sweden,
- work to make the possibilities of limiting damage as a result of high floods being developed and made the most of,
- report on a regular basis to the government about this development and, when needed, propose necessary measures,
- pay attention to the need for research,
- be responsible for the supervision guidance in accordance with the statute (1998:900) about supervision in accordance with the Environmental Code, and
- when required consult with the authorities and organizations concerned.

The most important dams being hydropower dams, the dam safety task has a certain connection with the Svenska Kraftnät responsibility area of being also power supply contingency planning authority. This task must however be considered as being somewhat foreign to the species. The ambition should be to place pure authority tasks with national administrative authorities, and not with national public utilities.

It is however not self-evident where a central dam safety authority function would best fit in within the Swedish authorities structure. Svenska Kraftnät recommends that the supervision guidance responsibility and the other aforementioned tasks within the dam safety area are transferred from the public utility Svenska Kraftnät to a national administrative authority, for example the Swedish Civil Contingencies Agency (MSB).

This proposal concurs with the central responsibility for supervision guidance already placed with MSB in relation to the Civil Protection Act and some issues regarding activities hazardous to the environment, in accordance with chapter 9 in the Environmental Code. MSB furthermore has the supervision over issues concerning the coordination between various branches of the national rescue services, as well as important tasks in rescue management and alerts to the public.



A dam failure may affect several municipalities and counties along a river valley and result in the evacuation of large areas. The proposal that MSB should take over the central dam safety supervision guidance would imply that the central authority tasks of preventing dam failure, as well as dam failure emergency preparedness planning, would be placed with a single authority.



5 Emergency preparedness for dam failure

5.1 Background

Emergency preparedness planning for dam failure aims at preventing, if possible, an initiated failure mode from evolving into a dam failure. If a dam failure cannot be avoided, preparedness is also required to limit the damages. To handle the acute phase, i.e. the first hours and days following the failure of a large dam, preparedness is above all needed to evacuate and block areas where the approaching flood makes it hazardous to stay, and also preparedness to limit the effects on important societal functions like power supply, telecommunications and transports.

Dam failure in the major hydropower rivers could result in inundation, damage and disturbances along a vast stretch of the river. This implies that several local municipalities and counties, as well as other authorities and dam owners, are affected in case of a dam failure. Dam failure preparedness in many cases consequently requires a coordinated preparedness planning, among dam owners, local governments, county administrative boards, and other stakeholders. The public having received information about the planning beforehand is also a requirement.

Figure 5.1 illustrates the responsibility areas of the most important parties in minimizing the direct damage following a dam failure, including among other things the preventing of, as far as possible, fatalities and the protection of property and the environment. Their respective responsibilities are however not limited to the acute phase; there must also be an ability to handle the crisis and the reconstruction.



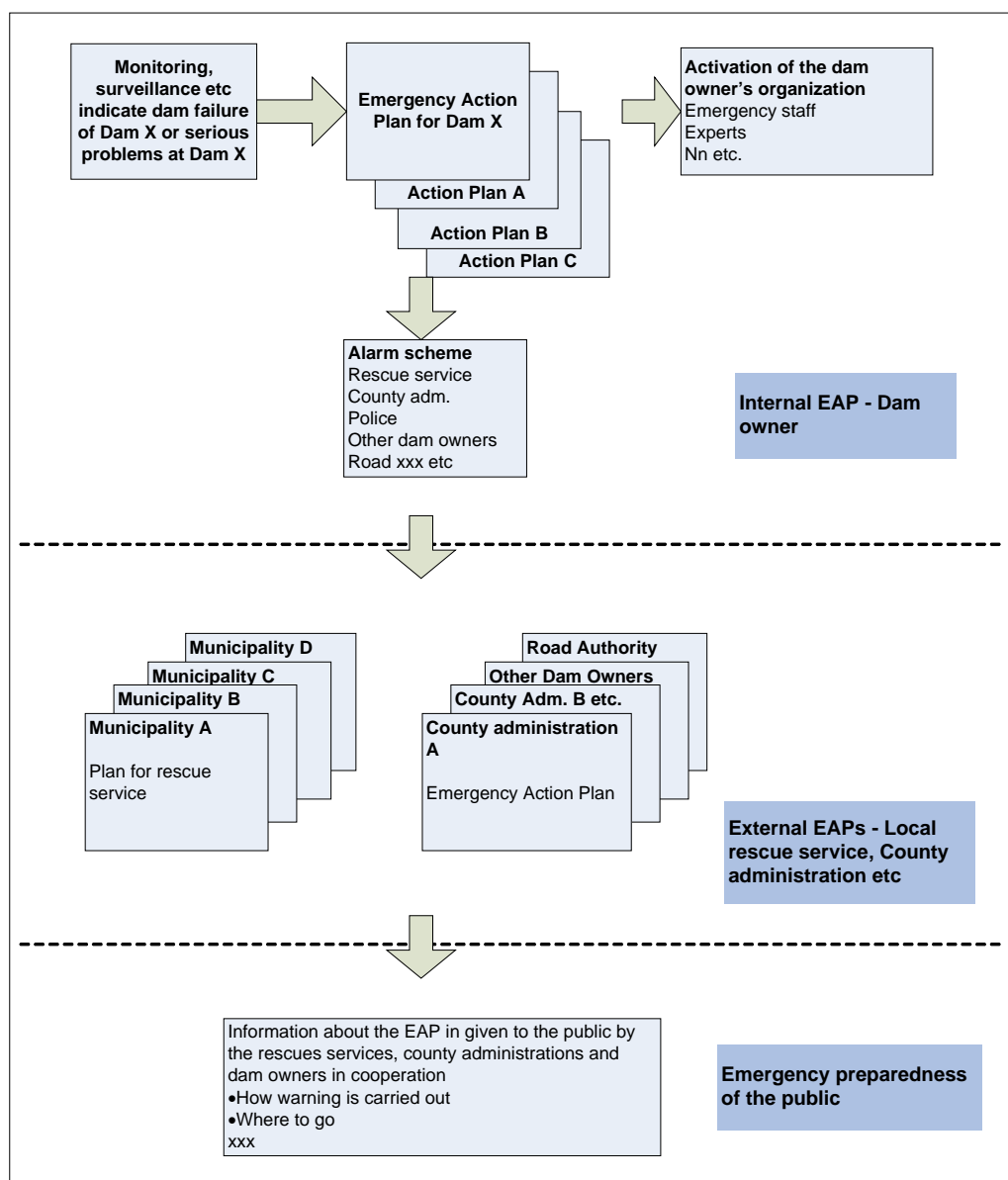


Figure 5.1 Coordinated emergency preparedness planning for dam failure.

5.2 Current rules

Chapter 2, section 3 of the Environmental Code deals with the precautionary principle and the demand for best available technology for persons who pursue an activity or take a measure (dam owners). They shall implement protective measures, comply with restrictions and carry out any other precautions that are necessary to prevent, hinder or combat damage or detriment to human health or the environment as a result of the activity or measure. These demands are applicable to the extent that it cannot be considered unreasonable to comply with them.

From the regulations in chapter 2 in the Civil Protection Act follows that owners of dams that have been classified as hazardous enterprises – i.e. an enterprise that could cause



severe damage to people or the environment – are obliged to, within a reasonable scope, keep or pay for preparedness with staff and property, and moreover take the measures necessary to prevent or limit such damage. He who is operating the enterprise is obliged to analyse the risks of such accidents.

Dams that could cause severe damage to people or the environment following a dam failure are included in the obligations concerning hazardous enterprises.

The hydropower industry guidelines (RIDAS) among other things state that dam owners should have a good preparedness to handle situations that could lead to a dam failure or in some other way result in an uncontrolled discharge from the reservoir implying risk of serious damage to people, the environment and valuable property, and in case of a dam failure minimize the consequences thereof. Rules and routines for work methods and measures in such situations must be established and documented in a preparedness plan. To accomplish an efficient emergency preparedness planning, coordination, planning, information and communication must be carried out with other parties that will be concerned in case of damage caused by the dam.

The law (2006:554) on municipality and county councils measures before and during extraordinary occurrences in peace-time and raised preparedness deals with occurrences that differ from the normal, imply a serious disturbance or imminent risk of a serious disturbance of important societal functions, requiring prompt action by a municipality or a county council. The municipality are to analyze which extraordinary occurrences could happen in the municipality in peace-time, and how these occurrences could affect their operations. The result of this is to be evaluated and compiled in a risk and vulnerability analysis. For each term of office a plan for the handling of extraordinary occurrences must be established. Cooperation and coordination are also included as important preparatory items.

Finally the Civil Protection Law requires that the local municipalities plan and organize in a way to make possible a rescue operation commenced within acceptable time and carried out in an efficient way. The public is to be informed about how alerts and information are disseminated in case of serious accidents. The municipality must have an action plan on preventive work and an action program for their rescue services.

The county administrative boards are coordinators for the crisis management within their geographical area and are required to work for coordination and a common direction of the measures needed, before, during and after a crisis.

It is the county administrative board's special responsibility that a regional common operational picture is compiled in crisis situations and that the persons responsible for the county preparedness are provided with support in planning, risk and vulnerability analyses, training and practice.

Regional risk and vulnerability analyses that could be used as a basis for the crisis preparedness measures by the county administrative board and others are to be made. The county administrative boards are to follow up the application by the local governments of the law on measures by local governments and county administrative boards before and



during extraordinary occurrences in peace-time and during raised preparedness. The preparedness measures taken by local municipalities and county administrative boards are to be reported yearly to MSB, the Swedish Civil Contingencies Agency, and at the same time an assessment of the effects of the measures taken is to be reported.

The county administrative board has a geographical area responsibility to diminish the vulnerability of society and to develop a good ability to handle peace-time crisis situations. Emergency preparedness for the failure of a dam with severe consequence is an important example of an area where a county administrative board must be able to take a coordinating responsibility for coordinating the operations by local municipalities, county councils and authorities.

If major rescue operations are needed, then the county administrative board may take over responsibility for the rescue services in affected municipalities, in accordance with the ordinance (2003:789) on civil protection against accidents. If more than one county is affected by the rescue operations, the county administrative boards concerned may agree as to which county administrative board shall take over the responsibility for the rescue services in municipalities. A county administrative board shall, after consulting with the municipalities in the county and with authorities concerned, make the plans needed for this purpose and inform the public about the contents of these plans.

At the request of a rescue leader, national authorities are obliged to take part in rescue operations with personnel and property if the authority has suitable resources and this does not seriously hamper its ordinary activities. The defence forces may place resources at disposal in situations of severe strain on society and the police forces have their special obligations, for example to assist the rescue leader if needed during infringement on individual rights, for example in blocking and evacuation of areas threatened by a dam failure. Also other national authorities as for example Svenska Kraftnät and the Swedish Transport Administration may be affected by a dam failure and therefore have a part responsibility for the total preparedness for dam failure.

5.3 Coordinated emergency preparedness planning

A coordinated preparedness planning must be made for rivers with dams where a dam failure could result in severe consequences. The reason is that areas that could be inundated in case of a dam failure often are partly the same for several dams and that dam failures at certain dams could result in damage along a major part of a river valley.

This implies that several municipalities and counties could be affected. Warnings to the public which areas could be affected and be inundated in case of a dam failure, and what measures should be taken by the public, should obviously be communicated at about the same time along the whole river and consider dam failures at all these dams.

Coordinated emergency preparedness planning has been under development during the last five years. In the so-called peer reviews (section 3.3) the evaluation was that the coordinated emergency preparedness for dam failure is still weak, but also that the on-going development will result in improvements.



In 2005 Elforsk concluded a pilot project for the development of coordinated dam failure emergency preparedness planning, with the river Ljusnan as an example.⁷ In this project, a planning basis for all parties concerned was drawn up, including among other things inundation maps and tables showing the propagation of the flood wave along the river following a dam failure. Also an alarm plan was drawn up, showing which persons should be alerted in various critical situations. Furthermore an example of an information brochure for the citizens along the river was produced. This brochure among other things showed maps of areas at risk of being inundated, information on how to act and where to go after an alert about a dam failure.

Using the Ljusnan pilot project as a model, the work to develop the emergency preparedness planning has started in another six of the major hydropower rivers, Luleälven, Ljungan, Göta älv, Dalälven, Indalsälven and Skellefteälven. The dam owners have common planning bases drawn up, and then preparedness plans are established and coordinated by dam owners, local governments, county administrative boards and others. This development is supported through grants from Svenska Kraftnät to the production of the common planning basis.

To achieve the most urgent aim of the preparedness, saving lives, it is important that the public in the risk area is informed about the danger and on how to act in case of a dam failure. Systems to communicate an alert to the public are also of outmost importance. Since it was river Ljusnan that constituted the pilot case to development of coordinated emergency preparedness planning, it was also here it was first understood that the issue of how to alert the public had not advanced enough.

Following an effort through an injunction by the municipalities along Ljusnan to make the dam owners produce a solution to the alarm issue, Svenska Kraftnät was asked by the Coordination committee for information during extreme floods etc. to start consultations with the Swedish Civil Contingencies Agency, county administrative boards, local municipalities and dam owners, since this issue should be solved in a national perspective. This resulted in a report, "Warning to the public in case of dam failures; A study of needs and opportunities" (Elforsk 09:53).

In this project responsibilities and roles, the need for warnings and technical alert warning solutions were studied. It resulted in recommendations as to how a coordinated introduction of special warning systems could take place along regulated rivers. The study also led to conclusions as to during which circumstances there should be special dam failure warning systems, and which available technical systems were best corresponding with the requirements regarding alert needs and reliability.

To create a more reliable basis for the continued development within this areas, a continued development project is now carried out by Elforsk. This includes among other things a pilot study of a whole river (Ljungan) and studies of the design in detail of the alarm systems preferred. Svenska Kraftnät, MSB, county administrative boards, local municipalities and dam owners are taking part in this project.

⁷ Beredningsplanering för dammbrott – Ett pilotprojekt i Ljusnan (Elforsk 05:38)



The main reason for the previous passiveness in this area is that models with the necessary comprehensive view have been lacking. To draw up the methods and carry out a pilot project along a river has been considered quite decisive for the fine development of today. The measures by Svenska Kraftnät to stimulate this have been considered as having a positive effect on the pace of the development and the aim is that coordinated emergency preparedness planning shall be developed for the ten major hydropower rivers during the next five year period.

5.4 Conclusions

Many parties are already or will be involved in the development of coordinated dam failure emergency preparedness planning in Sweden. The county administrative boards have a key role as coordinators, and so it is important that there are resources enough for this purpose at the county administrative boards. For many dam owners and authorities this work implies new tasks where they have no previous experience.

The capacity and competence of dam owners, consultants, local governments and county administrative boards are considered the factors limiting the pace of the development of a coordinated dam failure emergency preparedness planning. Consequently there is a need for an extended exercise programme, and for the collection and dissemination of the knowledge and experience gradually being built up, to render the work more efficient and secure uniformity.

The regulations about emergency preparedness at hazardous activities in chapter 2, section 4 of the Civil Protection Act are concrete, but the interpretation of their meaning with regard to dam failure has not been undisputed.

Svenska Kraftnät has been informed that there have been differing opinions about the signification of some of these regulations, something that has hampered the development of a coordinated preparedness. The uncertainties have contributed to the municipality focusing on supervision according to the Civil Protection Act through inspections, but it has been difficult to find constructive forms for this, something that has drawn upon the resources of dam owners as well as local municipalities.

The background of this regulation may be that it has not been considered reasonable that the individual municipality should dimension its rescue service according to special risks that differ from the normal risks in the district. The aim of the regulation is therefore that the local municipality resources could be completed, to make it possible to conduct efficient rescue operations following for example a dam failure.

The need to complete municipality resources to make efficient rescue operations possible should be clarified in each municipality. This implies that the needs for rescue operations (for example warnings and help to the public) must be identified, using the planning basis for each dam with dam failure flood wave propagations and properties (times etc.) stated by the dam owner as a starting point. Then the ability of the municipality to meet the rescue operation needs identified and which completions are possibly needed is studied. The municipality and the owner of the dam then have to agree on how to satisfy a possible need for completions.



The supervision concept in this context means that the municipality or the county administrative board have the option of ordering the dam owner to keep or pay for, to a reasonable extent, a completion of municipality resources to render possible efficient rescue operations, in case an agreement has not been reached. If measures should be taken in a municipality or rural district other than where the dam is located, the injunction could be made by the county administrative board.



6 Financing

Today the Svenska Kraftnät activities within dam safety are financed by funding from the electricity preparedness appropriation (appropriation 1:12, ap. 1). The electricity preparedness appropriation in turn is financed by a electricity preparedness fee paid by the holders of grid concessions.

Svenska Kraftnät's dam safety activities have during the last few years been carried out by two persons. In 2009 the cost was some SEK 12.5 M and in 2010 it is expected to be about SEK 15.5 M (table 6.1).

Table 6.1 Cost of Svenska Kraftnät's exercise of authority within dam safety.

Activity	2009 MSEK	2010 MSEK
Support to competence provision, Swedish Hydropower Centre	2.5	2.5
Support to dam safety research and development projects	3	4
Support to development of planning basis for coordinated dam failure preparedness at the ten major hydropower rivers	4	4,5
Costs of development of supervisory methods and resources etc.	0.5	1
Own staff costs	2.5	3.5
Sum:	12.5	15.5

The county administrative board supervision of water activities in accordance with chapter 11 of the Environmental Code is financed by general appropriations. The fee for the supervision shall, according to the ordinance (1998:940) on fees for examination and supervision in accordance with the Environmental Code, be paid by the water enterprise operator at a fee of SEK 800 per hour, following a special decision by the county administrative board. The county administrative boards have however not established routines for charging these fees, and so the opportunity to charge the dam owners has been utilized only to a minor degree.

The Swedish Environmental Protection Agency has been assigned the task of proposing new fees for the examination and supervision of water activities according to the Environmental Code. These fees shall according to the Government as far as possible correspond to the costs connected with the examination and supervision. The Environmental Protection Agency is also to propose to the Cabinet Office and the Ministries alterations in the current reporting systems on costs and income from fees.

6.1 Proposal

A well-functioning fee system is an important requirement for the supervision.

It is natural that electricity preparedness funding is used to finance the central supervision guidance. Power preparedness funds are however mainly used to finance measures taken



in accordance with the power preparedness law. To finance the entire dam safety assignment with power preparedness funds is consequently not self-evident, even if the dam safety issues to a large extent are related to hydropower dams.

Svenska Kraftnät recommends (see section 4.5) that the responsibility for the supervision guidance is transferred from Svenska Kraftnät to the Swedish Civil Contingency Agency. The financing should then come from appropriation 2:4 ap.5 Crisis Management. This appropriation is intended to finance measures strengthening the total preparedness and ability in society to withstand serious occurrences and crises in sectors vital to society.

The county administrative boards have so far utilized the opportunity to charge the dam owners only to a very small extent. It is the opinion of Svenska Kraftnät that uniform routines now must be drawn up and applied to charge the hourly fees for dam safety supervision in accordance with today's financing system.

Svenska Kraftnät does not consider it advisable in the current situation to introduce a standard fee for dam safety supervision. In Svenska Kraftnät's view, the introduction of a standard fee presupposes that there are definitions and criteria established by the State forming a basis for the supervision and the charging of fees.



7 A summary of the proposals

Svenska Kraftnät is of the opinion that dam safety needs development and that the present dam safety system does not correspond to the safety requirements that society today must make.

Reinforced national efforts are primarily motivated by the existence of dams that could in case of a dam failure, apart from endangering the life and health of many people, also cause serious disturbances in many sectors vital to society. It is particularly important that society has an expert insight in and control of the safety at these dams.

Today the supervision of dam safety is weak and guiding principles and elaborate regulations regarding dam safety work are lacking. Furthermore an elucidation of the real purport of the dam owner self-regulation is lacking.

Svenska Kraftnät's view is that the availability of dam safety competence in Sweden is limiting the development of dam safety and the building of preparedness related to dam failures. Continued efforts to promote and support knowledge development and competence provision on at least the present level are important.

In order to promote dam safety and stimulate the pace of development Svenska Kraftnät proposes a special set of regulations elucidating the signification of the Environmental Code in the dam safety area. This is particularly important in relation to dams where a dam failure could result in very severe consequences.

Svenska Kraftnät proposes

- that more explicit dam safety regulations are introduced as a complement to the more overall rules of the Environmental Code,
- that all dam facilities are compulsory classified according to the consequences that a dam failure could produce,
- that guiding principles are established for the dam safety work at the various categories of dams,
- that the requirements on the dam owner's strategy and management system for dam safety and documented routines for self-regulation are defined exactly,
- that the scope of the dam safety reporting is adapted to which category dams are belonging to,
- that the supervision guidance authority is given regulatory right regarding dam owners' reporting to the supervising authorities,
- that the State shall also in the future support dam safety research and development,
- that the scope and signification of dam owner liability to damages following a dam failure (including piercing of the corporate veil in national and international corporate groups, and liability to compensation for victims when the damage, with



or without insurance, surpasses the economic capacity of the owning company) is clarified,

- that the options of the supervising authority to order temporary safety measures at dams with severe consequences are clarified,
- that the availability of resources adapted to the needs and general authority competence are secured at the county administrative boards,
- that uniform routines for the charging of hourly dam supervision fees are introduced,
- that the supervision is reinforced by way of the supervision guidance authority supporting the county administrative boards with routines and competence for the supervision of dams with particularly severe dam failure consequences and coordinating the supervision of dam safety work at the owner companies concerned,
- that the availability of specialized dam safety competence and resources for taking part in individual supervision cases are secured at the supervision guidance authority,
- that the central supervision guidance with regard to the application of the Environmental Code on dam safety issues and other dam safety responsibilities are transferred from Svenska Kraftnät to the Civil Contingencies Agency (MSB),
- that the dam safety operations of MSB are financed by preparedness funds from appropriation 2:3 ap. 5 Crisis Management.

7.1 Consequences for the dam owners

The proposals imply no change in the formal responsibility of the dam owners, as compared to present conditions. But the implications for dam safety of current legislation is made clear.

A more explicit and more supportive set of regulations should result in increased resources being placed with dam safety in general and especially with dams with particularly severe consequences in case of a dam failure. Such an elucidation of the set of regulations should therefore promote an important development.

Resources will also be needed for the reporting to and communication with the supervising authorities. These tasks should however be very limited, as compared to the operator's self-regulation work.

7.2 Consequences for the county administrative boards/regions

The proposals imply no increase of county administrative board responsibilities as compared to current conditions, but increased resources must be diverted to the supervision of dam safety at dams with very severe consequences, should a dam failure occur. It is also necessary that county administrative boards divert sufficient resources to



permit cases regarding this category of dams and to carry out its coordinating role for dam failure preparedness in rivers with dams with severe consequences in case of a dam failure.

The competence and resources needed for these dam safety related tasks must be secured at the county administrative boards. Considering the limited number of dams of this category in Sweden, the work-load at the individual county administrative board for the supervision of dam safety at these dams should however at an average constitute only a small part of a year's work. The work-load could however vary strongly over time, because of occurrences, the handling of reports and action programs, and when needed measures aiming to persuade the dam owner to make corrections.

A future regional reform, resulting in a smaller number of larger counties, would probably be favourable from a resources and competence point of view. As a complement to the authority competence of the county administrative board, the availability of the specialized competence needed for the operative supervision could probably be solved organizationally through increased support from the supervision guidance authority.

7.3 Consequences for the supervision guidance authority

It is proposed that the Civil Contingencies Agency (MSB) take over the dam safety assignment from Svenska Kraftnät, which includes the central supervision guidance regarding the application of the Environmental Code on dam safety issues. This change implies that authority tasks regarding both the prevention of dam failures and the dam failure emergency preparedness are concentrated at MSB, something considered favourable for dam safety development as well as the development of coordinated emergency preparedness planning.

The reinforced supervision particularly at dams with especially severe consequences in case of a dam failure requires increased resources at the supervision guidance authority. The increased work efforts in the supervision guidance required are comprising, among other things, the development of routines for dams with particularly severe consequences, support for the county administrative boards' operative supervision of these dams and a coordination of the supervision of the owner companies' dam safety management systems.

Taken together this means that the resources at the central authority MSB need strengthening. It is proposed that this is financed by crisis management funds from appropriation 2:4.

