

Peer Review of Swedish High Consequence Dams

Test of a model for “special examination” of dam safety

- **A compilation of facts and experiences from 5 reviews performed in 2006 - 2008**

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Preface

The purpose of this memo is to compile the facts and experiences from the 2006-2008 test period of a model for “special examination” of dam safety.

The memo has been written by the members of the project team and is stating the views of this team. The members were:

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This memo is intended for the hydropower industry, consultants and authorities. In the hydropower industry, the facts and experiences produced by the project will be managed by the Swedenergy dam safety committee.

Summary

In the Swedish hydropower industry, there was an on-going discussion regarding how it could best be verified that Swedish dam safety work is corresponding to a high international standard. From a supervisory point of view, Svenska Kraftnät underlined the need for society to have a clear insight into the safety at dams where a failure could result in particularly severe consequences. To study the prospects of meeting the requirements of the hydropower industry, as well as those of society, a project team comprising members from Swedenergy and Svenska Kraftnät drew up a model for a so-called peer review of dams in the highest consequence class. This model implies that independent experts with specialized competence and international experiences of dam safety work will review the safety at a dam facility. The review is made under an assignment from the dam owner, as a complement to the ordinary surveillance, but with the authorities having an insight and the option of influencing the process.

During 2006-2008, a trial and development period of peer reviews was carried out at five dams (Höljes, Suorva, Hällby, Häckren och Ajaure). The intention was to clarify whether the dam safety work was corresponding to a high international standard, to evaluate the peer review model and to provide a basis for the dam owners' future dam safety work and the supervision of the authorities. The joint view of the project team is that the review model worked as intended and was efficient when deciding whether the safety of the individual dam corresponded to a high international standard.

The reviews showed cases where dam safety and dam safety work corresponded to a high international standard, as well as one case failing to correspond to this standard. The review where the dam safety was not approved resulted in measures undertaken at the dam, as well as organizational measures within the company. The other reviews showed no improvement needs that were unknown to the owners; they rather confirmed that the owners in general are prioritizing the correct areas. In some cases the reviews resulted in a change of perspective regarding individual issues and in some a change of focus in the owners' planning. Important areas that were in several reviews identified as needing further efforts were, i.a.:

- Discharge safety, with special regard to analysis of the reliability and margins of the discharge system, and preparedness in view of a possible failing opening of gates during floods
- Instrumentation and monitoring
- Support systems and routines for the evaluation and handling of measuring data
- Routines for the managing and handling of the company's dam safety work
- Documentation and handling of archives
- Co-ordinated emergency preparedness planning for dam failures (continuing the development already in progress)

The reviewers stated that the dam owners had a high level of competence, but also considered it remarkable that so few persons were engaged in dam safety work. The reviewers expressed their doubts as to the outsourcing of key tasks in the operation of dams (dam measurements e.g.) and considered short contract periods with possible change of operation contractors unsuitable.

The supervising staff of the county administrative boards concerned considered the review a valuable basis for their supervision and Svenska Kraftnät considered the model an excellent instrument for providing the supervising authority with a qualified analysis of dam safety. This authority however needs a high level of competence to fully understand the documentation, expert statements etc., in order to be able to evaluate and follow up the dam owners plans for the amendment of weaknesses noticed.

It is the intention of the project team to continue its work during the autumn of 2009 and establish, on the basis of experiences made, methods for comparisons with a high international standard and also establish how the supervising authority's need for a deep-going insight into the safety at high consequence dams could best be met.

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Appendix

Appendix 1 Dam Safety – Pilot Project ”Special Examination”, dated Jan. 14th, 2008

References

Höljes Dam Safety Review, 2006-11-07

Panel: Kaare Höeg, Des Hartford, Karl Rytters

Peer review of Dam Safety at Suorva Dams, 2007-11-16

Panel: Kaare Höeg, Jan-Jacques Fry, Robin Charlwood

Peer Dam Safety Review of Hällby Dam, Sweden, 2008-10-22

Panel: Markus Aufleger, Mona Bechai, Ole John Berthelsen, Ignacio Escuder

Häckren Dam Safety Review, 2008-12-05

Panel: Kaare Höeg, Cássio Viotti, Åke Engström, Markus Aufleger

Peer review of Dam Safety at Ajaure Dam, 2008-12-19

Panel: Nelson Pinto, Robin Charlwood, Pål Mellquist, Ray Stewart

1. Background

In the common dam safety policy of the Swedish hydropower industry it is among other things stated that dam safety should be kept at a high international level. Verifying that current dam safety work, carried out by the member companies, is actually complying with this policy has been a topic of discussions in the hydropower industry. As a complement to the present surveillance routines, the idea of introducing some form of peer review of dams in the highest consequence class, involving experts with a specialized competence and international experiences of dam safety work was put forward.

A dam failure at about 20-30 of the Swedish dams would result in very grave consequences and affect society severely. For this category, Svenska Kraftnät considers it especially important that society, through the supervising authority, has a qualified control of dam safety. The complexity of these issues in reality requires that the review of dam safety and the dam owner's safety work is carried out with the support of expert competence.

To investigate the possibilities of using some kind of "special examination", in order to meet the dam owners' as well as society's needs for a comparison of Swedish dam safety with a high international standard, Svenska Kraftnät and Swedenergy decided to jointly carry out a pilot project in 2005 aiming at the development and testing of a model for this purpose.

As part of the pilot project, Fortum had a review of the Trängslet dam carried out by international expertise. Based on this review, discussions about needs and methods of peer reviews were held in a reference group with representatives of the hydropower industry and the authorities. The reference group unanimously stated that the review had been useful and the pilot project resulted in a proposal for a model for international expert reviews as part of the Swedish dam safety work. The review at Trängslet was however not considered enough to produce a sufficient basis for a general model and so it was decided to implement a trial and development period where the proposed model would be tested on five selected dams during 2006-2008. Issues put forward as being important to follow up and discuss further during the trial period were:

- Balance between the self-regulation of the dam owners' and supervision
- Funding of the reviews
- If the reviews could be considered independent
- Selection of dams
- What should be evaluated
- Status of the expert report
- How the expert report should be used
- Secrecy issues

A project team with representatives of the hydropower industry and Svenska Kraftnät was following the trial period and continuously compared experiences. At follow-up project team meetings after each review, also the county administrative board concerned was invited to take part and express their views. Smaller elucidations and modifications of the document describing the model, see App. 1, were made from time to time. The task of the project team was also to compile facts and experiences emanating from the concluded trial and development period and to jointly evaluate them, which has been done in this report.

2. Trial and development period 2006-2008

A trial and development period with peer reviews of five selected dam facilities was carried out during 2006-2008. The aim was to:

- Establish whether dam safety at these dams was corresponding to a high international standard
- Evaluate the model for peer reviews
- Provide a better basis for the continued dam safety work by the dam owners and for the supervision by the authorities

The dam owners ordered the reviews and had them carried out as part of their self-regulation, also with opportunities for the supervising authorities to follow and influence the process. The reviews were carried out in accordance with the model description in the report "Dam Safety. Pilot Project – Special Examination", see App. 1.

Below facts and experiences from the trial period are discussed and strong as well as weak qualities of the model are reported. The basic information has been:

- The final expert reports from the reviews
- The dam owners' action plans, drawn up after the reviews and sent to the county administrative boards
- A memo from each of the participating dam owners and from Svenska Kraftnät, stating the most important experiences of the reviews
- Views put forward by the participating county administrative boards
- Opinions forwarded by the reviewers

2.1. Selection of dams to be reviewed

In the interest of the dam owners, as well as of the supervising authorities, dams that could cause especially severe consequences in case of a dam failure were in the focus of the reviews, implying a selection of dams in the highest consequence class. The selection of dams to be examined was made by the dam owners. Svenska Kraftnät had the opportunity of influencing the dam owners' selection and also did so. Dams within "the upper layer" of consequence class 1A were consistently chosen. To secure a distribution of dams around the country, facilities at various rivers and in various counties were chosen. The following reviews were carried out:

- Höljes dam, river Klarälven, owned by Fortum, 2006
- Suorva dam, Stora Lule river, owned by Vattenfall, 2007
- Hällby dam, river Ångermanälven, owned by E.ON, 2008
- Håckren dam, river Indalsälven, owned by Vattenregleringsföretagen, 2008
- Ajaure dam, river Umeälven, owned by Vattenfall, 2008

All dams reviewed were large embankment dams. At most of the facilities, projects for an adaption to the new design flood guidelines and RIDAS, the Hydropower Industry Dam Safety Guidelines, had been carried out or were being finalized. At several facilities an updating of the instrumentation was going on or planned, resulting in the reviewers in some cases being especially asked about their opinions regarding these plans. At one of the facilities the review was carried out in an opening stage of the upgrading of the dam and the planning for this work was included in the documentation for the review.

During the pilot project the possibility of establishing criteria for and make a list of dams that should be subject to this kind of review was discussed. This issue was however analyzed no further.

2.2. Application and function of the review model

Trust between authorities and dam owners is important, and so the system for dam safety in Sweden must be functional and inspire confidence, and also comprise a qualified monitoring function covering dams with particularly severe dam failure consequences. The public expects society to have control of activities that could result in such consequences.

The reviews were carried out as part of the dam owners' self-regulation. The main principle that the owner is to carry out the surveillance needed to secure dam safety is important and it should also be underlined that the responsibility for dam safety rests with no-one else than the dam owner. Through an open process, where the authorities have an insight and the opportunity to express their opinions, and through the engaging of independent and qualified reviewers, the model would make a contribution to the public trust in society's supervision of dam safety.

The model produced in the pilot project was based on the review being completely funded by the dam owner. The question was raised whether this could result in the trust in the independence of the reviewers being weakened. Basically this question is about all parties concerned needing confidence in the integrity, ethics etc. of qualified experts. The view of the project team is that the open process, where the authorities also may express opinions about the dam owner's choice of experts, have access to the same documentation as the experts, may question the reviewers etc., constitute important factors in strengthening confidence in the model. During the trial period these options were utilized and the representatives of the authorities concerned stated that they had received ample opportunities of insight and influence.

The reviewers also think that the model made possible an independent review and at the same time provided the authorities with insight and the opportunity to subsequently check that necessary measures had been carried out. Without exception the reviewers liked the modus operandi of Swedish authorities and dam owners, working in common to give society insight into the dam safety work and the efforts to secure adequate dam safety. Their general impression was that the upgrading of the facilities during latter years means a raising of the dam safety standard and the peer review tests were labelled a fine example of the current excellent development in Sweden.

The joint opinion of the project team is that the review model fulfilled its objective and that it was efficient in deciding whether the safety of the individual facility corresponded to a high international standard. The reviews have shown cases confirming adequate dam safety and dam safety work corresponding to this standard, and also a case where a high international standard had not been attained.

Below an evaluation more in detail follows, and a compilation of facts and experiences linked to the nine main items that are included in the review model. (The description of the individual measures of the model, as it was intended to be carried out, are written in italics).

1. Review program

A review program is written by the owner. The county administrative board and Svenska Kraftnät are given the opportunity to express their views of the programme. Scope and quality of the owner's dam safety work is to be evaluated. Four general issues should always be analyzed:

- Does the dam comply with the requirements of a high international standard for high consequence dams in terms of construction, operational records and programmes for operation, condition monitoring and maintenance?

- *Have enough investigations been made to secure an adequate assessment of dam safety?*
- *Have required measures been taken in view of the results of investigations made?*
- *Has the reviewing team any other comments regarding the dam safety?*

These four questions have been seen as somewhat overlapping and some of the peers have stated that they cannot be answered with a simple yes or no. In a couple of cases a rewriting and addition to the instructions for the expert panel was made, to clarify that the reviewers should consider the owner's development plans and priorities for the facility, and to secure that a specific issue was attended to.

Afterwards it was observed that the wording of the four issues should have an overhaul and that the dam owner should have the opportunity to make minor adaptations in the instructions to the expert panel, to secure that the review of a specific facility is made in an efficient manner; it is however important that possible adaptations are made in agreement with all parties concerned.

The objective was to check Swedish dam safety against "a high international standard". The latter not being an unambiguous or documented notion, the intention was to make this check against the experts' own perception of what could be regarded a high international standard. It must be stated that this is a moving target and that "high international standard" not necessarily means an even safety level, since the development of various dam safety aspects has not come equally far.

To examine the safety of an individual facility concurrently with the company's dam safety work was seen as complicated. The reviewers remarked that in their opinion the owner in some reviews had attached too much weight to the description of the company's overall risk handling, at the expense of the specific conditions at the individual dam.

2. Selection of expert team

An expert team of three experts is selected by the dam owner. At least two of the experts should come from a country other than Sweden. The authorities are given the opportunity to express their opinion of the owner's selection of experts. The composition of the expert team is made so as to secure all relevant aspects of dam safety at the individual dam being reviewed in a competent manner.

In total, 14 experts took part in the five reviews. Two were Swedes, three Norwegians, three were from other European countries, four from North America and two from South America. The reviewers had no previous link to the individual dam, for example having made a comprehensive dam safety review or having projected and/or taken part in measures increasing dam safety etc. The authorities had the opportunity of giving their opinion on the selection of the experts and Svenska Kraftnät also did this.

The composition of the panels is most important and the experts need to complete each other, to be able to cover all safety aspects at a specific dam. Three of the panels consisted of four experts, since it proved difficult to cover all aspects with three experts only.

The reviews being made by international expert panels was generally considered a good idea. One drawback was however that this meant extensive preparatory work for the owners, who had to translate all the necessary documentation, see below. Some dam owners also contended that the seminars being held in English was hampering the discussions.

3. Providing documentation for the review

The Comprehensive Safety Review, the Operation, Monitoring and Maintenance manual, risk analyses etc. are translated into English and the experts are provided with this documentation. The county administrative board and Svenska Kraftnät are also provided with the same documentation.

The dam owners underlined that a review as such implies that one cannot arrive unprepared. The preparations per se had meant a quality assurance of the documentation and a better grasp of the totality. Besides the work of translating the documentation, the production of presentations and the participation in the seminars, the preparations had in many cases comprised a thorough quest for and survey of "all" documentation. This resulted in additional documentation appearing that in some cases indicated circumstances that led to new investigations etc. The preparations had, as one of the owners put it, included the writing down of a complete "safety analysis" which to a large extent previously only existed in the head; and so a risk analysis of some years standing was updated with the measures that had really been taken, to get an up-to-date picture of the safety of the facility.

The reviewers underlined that the owners must prepare the review by providing, well beforehand, all relevant documentation, including main drawings, photos from the construction period etc., but not all available documentation. Usually the documentation was delivered well before the introductory seminar, but in one case the final documentation was not provided until at this seminar, something that made preparations more difficult for reviewers and authorities. Several reviewers pointed out that it would have been most valuable if the owners had provided a failure mode analysis of the facility. This would have contributed to placing the focus of the review on the safety of the facility, quickly guiding the reviewers to the main issues and the owner's priorities and decisions on the matter.

The reviews at Höljes, Håckren and Hällby resulted in costs in the order of some 1.5 MSEK for reviewers and consultancy services (consultants were utilized during the preparations for e.g. translation of some 20-30 documents about the facility, the company and the Swedish system, and for making some completing investigations). Adding to this was the owner's own preparations and participation in the seminars, accounting for some 5-8 man-months per review. The total cost for one review was estimated at some 2-2.5 MSEK.

At Ajaure and Suorva the dam owner made more extensive preparations by carrying out or bringing forward a number of investigations, later to be included in the documentation, but also increasing the costs. At these seminars, considerably more participants from the company's own staff were also participating.

4. Questions from the expert team before the review

The expert team sends a list of questions, specifying which issues they want to have clarified by the dam owner during the introductory seminar. The list is sent to the dam owner, the county administrative board and Svenska Kraftnät.

This option was used only to a limited extent.

5. Introductory seminar and site visit

A seminar with a visit to the site is arranged. Beside the dam owner and the expert team, the county administrative board, Svenska Kraftnät and others that the dam owner wants to invite are participating. Also the local government, being the supervisory authority in accordance with the Swedish law on protection against accidents, is invited. The dam owner describes dam safety and the dam safety work in general in the company and at the dam in question, and answers the questions that the expert team has requested to be answered.

A seminar with a site visit included was held at all reviews. Its duration was about 2-3 days. At some reviews, time of their own and an extra visit to the site were also fit into the schedule for the panel. The total time of the seminar week consequently was between two and five days.

Presentations of the Swedish dam safety work system and the internal dam safety work of the participating dam owner opened the seminar, each lasting about two hours. The dam owner then for some five hours described the dam and the dam safety work at the facility. In this connection, the dam was visited for a few hours. The dam owner concurrently answered the questions that the expert panel and the authorities wanted clarified. Finally the panel presented its preliminary considerations and comments on the company's dam safety work and the state of the dam.

The experts had in general requested more time for the questions pertaining to the local facility. Following advice from the experts, the programme for the introductory seminar at the concluding reviews was drawn up as follows:

- Day 1-2. The experts met with the dam owner at the facility and so had the opportunity of jointly studying the documentation and visiting the facility in the company of the owner. The owner also provided requested completing information from the archives and answered questions.
- Day 3-4. The owner presented the Swedish dam safety system and the company's dam safety work in general, and at the local facility. The official programme was then concluded with a summing-up of the reviewers impressions so far.

The number of participants in the seminars varied between more than 20 and more than 60 persons, distributed according to the table below. The majority, about half of the participants, were company staff comprising management, dam safety staff and operative staff. Svenska Kraftnät (SvK, below) and the county administrative boards (LS, below) concerned were present at all reviews, as well as representatives of the consultancies engaged in safety-increasing measures at the dam in question. Also representatives of the municipality (local emergency agency, RTJ), of other dam owners in Swedenergy, of the Swedish Meteorological and Hydrological Institute (SMHI), and of the universities (LTU) were present.

The participants in the introductory seminars were distributed according to this table:

Facility reviewed	Participants									Total No.
	Number in panel	Owner	Other owners incl. Swedenergy	Consul.	LS	SvK	RTJ	SMHI	LTU	
Höljes	3	8	3	5	1	2	1			23
Suorva	3	34	8	6	2	3	2	1	3	62
Hällby	4	15	5	5	1	2		2		34
Häckren	4	12	12	3	2	2	1	2		38
Ajåure	4	38	4	7	2	2	1	2	1	61

6. Preliminary report of the expert team

The expert team writes a preliminary report, to be sent to the owner within about a month after the seminar. The owners send copies to the county administrative board and Svenska Kraftnät, after having made an assessment of the need for secrecy and marking possible items that the owner considers should be classified. The dam owner and the authorities then have the opportunity of giving their views on the report before the final seminar. Possible explanations and views regarding the preliminary report are sent from the owner to the reviewers, possible explanations and views from the authorities are sent to the owner and forwarded to the reviewers.

This point mainly worked as intended. The objective of giving views on the preliminary report was to clarify, as far as possible, uncertainties before the final seminar. In some cases, the reviewers also revised the preliminary report after having exchanged views before the final seminar.

7. Final seminar

About a month after the owner received the preliminary report, a meeting to present and discuss the preliminary report is convened. The expert team, the dam owner, the county administrative board, Svenska Kraftnät and others that the owner would perhaps invite participate in the seminar, and the municipality is also invited.

This point also mainly worked as intended. The meetings to present and discuss the preliminary report were held about a month after the owner received the report. At the seminars, the expert team, the owner, the county administrative board, Svenska Kraftnät and others, invited by the dam owner, participated; all in all around 25 persons. At each meeting the reviewers presented their preliminary report and then questions and opinions from owner and authorities were discussed. These meetings served an important purpose, securing the status and credibility of the final report. In addition to the first review, there were special points at the agenda of the meeting where dam owner and authorities, in the presence of everyone, had the opportunity to raise their questions and give their views on the reviewers' report before they determined the final one.

At the final seminars, the participants were distributed according to the following table:

Facility examined	Participants									Total number
	Number in panel	Owner	Other owners, Swed-energy	Consult.	LS	SvK	Elforsk	RTJ	SMHI	
Höljes	3	10	2	4	1	2			1	23
Suorva	3	14	3	2	2	2	1			27
Hällby	4	11	3	1	2	2	1			24
Häckren	4	8	5	5	1	2				25
Ajaure	4	14	3	1	2	2	1			27

8. Final report from the expert team

The expert team draws up a final report, to be sent without unnecessary delay to the owner. The owner, in turn, sends copies to the county administrative board and Svenska Kraftnät within two weeks after having received the final report. The owner makes an assessment of the need for secrecy, marking items that the owner considers should be classified before the report is sent on.

The scope and structure of the final reports varied, since there were no instructions about this. In general, the reports comprised some 20-30 pages, with the Hällby report of some 80 pages a distinct exception. This bigger size to a large extent depended on a more extensive description of the facility and its history, as compared to the other reports, and also general descriptions of guidelines in other countries pertaining to the organizing of dam safety work and a description of the development of working procedures based on risk. The outline of the reports was adapted to the issues specific for the individual facility, this also being a necessity. But a common main structure would have simplified the comparison between them.

In one of the final reports the owner made an assessment of the need for secrecy regarding some items and figures, and these were indicated to the authorities before the report was sent.

The final report contained the views of the experts and their recommendations to the dam owner. There were instances when different reviewers had slightly diverging views on factual matters and some of the reviewers also had opinions as to how this could be handled. If there are differing opinions within the expert team, the project team is agreed that these should be stated, since in the end it is always the owners and the authorities who are evaluating the conclusions. In the description of the model it would be possible to draw up the principles as to how possible differing opinions within the panel could be accounted for. It is desirable that discussions on issues where the panel has failed to reach a common standpoint are reported.

9. The dam owners' action plans

Following the review, the dam owners should respond to the final report from the expert team. The dam owner draws up an action plan, describing how various views in this report are to be handled. A copy of the action plan should be sent to the county administrative board within about a month after the final report from the expert group has been distributed.

Action plans were written and forwarded to the county administrative boards, to serve as a foundation for their follow-up of the dam safety work. In some cases, the dam owners have sent completing information to the supervising authority, to update it on how the work according to the action plan is progressing. The time spent by the county administrative boards to follow up action plans was a few days at the most.

2.3. Safety at the reviewed dams

With one exception, dam safety at the facilities reviewed was on the whole considered corresponding to a high international standard. In general, the dam owners were aware of the technical deficiencies at the individual facility, but some issues that were previously not attended to were also found. Even if there are differences between the individual facilities, fairly similar views recurred at a majority of them. One may also observe that, at all facilities reviewed, work remains to be done before all parts of them will attain an adequate international dam standard for high consequence facilities. This especially pertains to the instrumentation and monitoring, and the discharge function at the dams. These issues are included in a number of important development areas highlighted during the reviews and stated in a summary below.

Impervious core, filter and junctions

The built-in weakness constituted by the junctions between earth fill and vertical concrete constructions in embankment dams, is one example of previously known

deficiencies related to the construction of the reviewed dams. To lower the risk of leakage in this interface, it was common to install sheet piles, anchored in the concrete. This makes the distance longer for a leakage, but at the same time the sheet pile wall constitutes a hindrance to an efficient compacting of the core material, possibly increasing the risk of leakage. At some of the dams there were signs of an insufficient sealing function, while at other dams this is a potential deficiency that requires continuous monitoring.

At some of the dams it was discovered that the filter materials between the sealing material and the supporting shoulder material were all too coarse, increasing the risk of transport of fines in case of a leakage through the impervious core. The principle stated in RIDAS, to determine a design leakage at embankment dams, implies that the dam should be able to withstand a situation with a heavily damaged impervious core without this developing into a dam failure. The experts observed that the usual method in Sweden, to strengthen dams with a completing, coarse supporting berm on the downstream slope, is considerably improving safety in terms of their ability to withstand a heavy leakage. In one case the panel stated that the supporting rock fill berm meant that the dam complied with dam safety requirements with a relatively great margin. The expert panels however stressed the importance of an instrumentation adapted to the functions and also well-functioning routines to handle measurement data, as well as emergency preparedness plans to handle this kind of scenarios. Based on information emanating from new instrumentation, measures to diminish also the risk of a leakage being initiated could become an option. These could for example include the construction of a diaphragm wall or grouting.

Erosion protection (rip-rap)

At all examined dams, deficiencies in up-stream erosion protection had motivated counter-measures. A common counter-measure is to strengthen or rebuild under dimensioned rip-rap. The rebuilding in many cases means that the rip-rap complies, with a margin, with the requirements on this construction from a dam safety point of view.

Instrumentation

A function-adapted instrumentation and "performance based surveillance" should be configured to detect, as early as possible, faults and/or changes that in the long run could result in a dam failure. To secure the correct aspects being monitored, failure mode analysis should be utilized when planning new instrumentation.

In general, there is a need to upgrade the leakage surveillance (where great importance should be attached also to the separation of leaking water from the dam, from rain-water and groundwater flows from the surroundings, turbidity etc.), level of pore water pressure (in water gauges), instrumentation at junctions between embankment dam and concrete dam, uplift measurement at concrete constructions as input data for control calculations of stability etc. At many facilities, upgrading and automation of measurements is going on, but much work remains before "a high international standard" has been achieved when it comes to the instrumentation as such and the working methods for the handling and evaluation of measurements.

Discharge

At all the examined dams, spillways were equipped with floodgates, a solution normally used at Swedish dams. The expert panels, in general, advocate a conservative attitude towards this type of gated spillways, in several cases criticizing that the consequences of e. g. one gate being impossible to open at extreme flows not having been analyzed in detail when designing the discharge capacity. One way of analyzing this is for example

to calculate the return time for a flow that would, with one gate out of order, result in overtopping of the dam. Also the possibilities of emergency draw-down of the reservoir should be elucidated.

Apart from uncertainties regarding the reliability of gates, the floating debris issue and the risk of erosion should be regarded when the dams are adapted to design floods. Deficiencies in the analyses of these issues occur and in several cases a full-scale discharge tests and/or model tests have not been carried out.

When there are great divergences from the wished-for discharge capacity, it is advisable that the reservoir be handled conservatively, awaiting measures, unless the owner is able to demonstrate that it is justifiable to accept the risks temporarily at normal operation.

Design flood

In several reviews, issues related to calculation of the design flood were raised and have also been studied in a separate review of the Swedish guidelines for design floods at dams. So, for example, it was proposed at one of the reviews that one might consider calculating the design flood using an alternative method, such as Probable Maximum Flood, PMF, and compare to the value established at the dams concerned. At one facility it was observed that the fact had not been taken into account that observed flows had increased after the design flood was calculated and that at a revision the latest data from the last period of time had not been used. The expert panels also pointed out that a control of the design flood in reality is not carried out in connection with the comprehensive dam safety reviews.

Seismic loads

Seismic loads have traditionally not been regarded a necessary design basis for Swedish dams. Considering the low probabilities utilized in other areas of dam safety work, a check should be made if seismic loads, using the same level of improbability, should be taken into account in the case of the highest dams and related equipment.

2.4. Dam safety work and companies' development plans

The reviewed dam owners observed that their dam safety work, including some documented plans for upgrading works, on the whole was approved. At some reviews the expert panel stated that part of the dam safety work is at the fore, also when comparing internationally. In one case, the dam safety work by the owner on several fundamental points was not approved.

The dam owners thought that the reviews have contributed to put focus dam safety issues within the owner's organisation, and have highlighted the need for sufficient resources in order to attain a dam safety that corresponds to a high international standard. The reviews have however also identified a number of areas that need development and this has contributed to e.g. reorganizations and resources being allocated to identified weak areas.

The reviews found no weak areas that were unknown to the owners, but the findings led to a change of priorities in their planning; both higher priority for some issues and lower priority for others. The reviews consequently have contributed to a certain change of perspective on certain weaknesses. Furthermore the balance between various measures to increase dam safety was in some cases questioned and the reviewers pointed out that differing safety margins/safety philosophies have been used for various kinds of

measures. Generally a need for development and in some cases increased attention to the areas below was underlined:

Routines for the managing and handling of the company's dam safety work

The reviewers point out the need for a documented safety management system. Considerable differences as to how far the owners have come in these efforts were demonstrated. The safety culture of the owning company is important and each individual at the company must be part of that safety culture. The reviewers were hesitant to an outsourcing of key tasks in the operation of dams, e.g. dam measurements. They maintained that this could make it more difficult to arrive at the same safety culture and that short contract periods (a few years) with possible change of operation contractors would be unsuitable.

The expert panels contended that too few people in the owning companies were working on dam safety. One example of this was the fact that, according to the reviewers, the persons with dam technology competence, in several cases handled an all too great number of high consequence facilities.

Documentation and handling of archives

Another area in need of development is how information about facilities is to be documented. Several dam owners said that it had been a heavy task, prior to the reviews, to produce facility documentation and to document decisions about the dam that were previously for the most part "held in the head". At one of the reviews, lacking routines were found in the collecting and analysis of the archives, in connection with comprehensive dam safety reviews, the explanation being in part that the external consultants were not able to have an overall responsibility, as the assignment was divided between them.

Routines for the collection and evaluation of measuring data

Supporting systems and methods of work when handling measuring data and evaluating measurements need development, as is the work with deep and systematic analysis to configure the instrumentation so that all conceivable failure modes (weaknesses and uncertainties) are monitored, giving continuous information about the performance of the dam. Continuous analysis and interpretation of measuring data by qualified staff is essential to follow up the state of the dam.

Emergency preparedness planning

The coordinated emergency preparedness planning for a possible dam failure was considered rather unsatisfactory, but the development initiated some years ago utilizing the Ljusnan pilot project as a model was considered quite good. Where deficiencies were found, it was recommended that a basic coordinated emergency preparedness planning with the municipalities, the county administrative board etc. be rapidly developed and communicated. It was not advisable to wait for the development of detailed planning information from the upcoming/ongoing river-for-river coordinated emergency development projects. The reviewers also underlined the need for recurrent training according to the plans and the development of control mechanisms for the handling of documents when keeping the emergency plans up-to-date.

Surveillance

All in all, the frequency of comprehensive dam safety evaluations, and the level of detail of inspections, are not up to international standards. Shorter intervals between the comprehensive reviews should be considered for the highest consequence classes, or the

inspections be made more in detail, comprising also a systematic review and assessment of safety with regard to all conceivable failure modes influencing safety.

Risk based working methods

Dam owners had advanced to different stages in the development and implementation of risk based working methods, systems for the handling and management of their dam safety work and the governing documents in this respect. Good as well as bad examples were found. Working methods based on risk is not an international standard yet, but it is an increasing trend and it was recommended that this solution be utilized. To render it even more useful, failure mode analysis should also be linked to the consequence analysis.

Handling of shortcomings

The dam owners should develop and maintain support systems for the handling of shortcomings, e.g. a “dam safety data base” containing information about source and description of a deficiency, an evaluation of it from a safety point of view, status of an action plan and measures intended, etc.

The Swedenergy incident reporting system should be developed further. The analysis of error frequency, the process for learning from incidents etc. needs to be strengthened.

Dam security och public safety

There is a need to evaluate the risk and carry out measures related to antagonistic threats against dams (dam security) and public safety. There is an international trend to handle dam safety and security, and in some cases also public safety, in a centralized manner.

2.5. Industry guidelines and guidelines for design flood

As a side-effect, the reviews also resulted in RIDAS and its applicatory recommendations being partly reviewed. Some areas where RIDAS should be developed were noted, as the objective is that the application of the guidelines will result in a high international standard being attained or surpassed. This is in line with the working method for continuous improvements described in RIDAS. Areas noted where RIDAS should be developed were e.g. PTO, safety management and discharge safety.

In comparison with other countries it was noted that Sweden has:

- Many more dam-toe reinforcements
- Fewer measures against potential weaknesses in dam body/foundation
- More rip-rap reinforcements
- Less extensive dam instrumentations
- Longer time period between comprehensive dam safety evaluations

The question of the safety level in the Swedish design flood guidelines, as compared to the guidelines in other countries, was also studied and found to be well adapted to Swedish conditions. It was stated that the design flood was lower than the PMF, but in general higher than the 10,000 year flood. The reviewers recommended that the intervals should be stated for when new calculations of the design flood at a river should be made. The discussions showed that it is most important to analyze the reliability of the discharge arrangements and continue to follow up the design flood issue.

2.6. Competence and the utilization of independent expertise

The review on Swedish dam safety work against an internationally adequate standard on the whole yielded a positive result and the reviewers also emphasized that the level of competence was very good. However the availability of competence, in terms of the number of competent engineers, was a limiting factor and in comparison with international staffing also the number of staff in the dam owner's organization with dam safety tasks appeared to be remarkably few. Furthermore the service companies had few persons to maintain the facilities and they often must travel great distances to the facilities.

One of the reviewers pointed out that a side-effect, and also the perhaps most valuable result of the trial period, was that a wide range of dam owners, authorities and consultants had taken part in the seminars. This had meant an opportunity of building competence for all parties concerned, insight into each other's working methods and a check on Swedish dam safety work against international practice.

The trial period meant an independent review of the facilities and the owning companies. In some respects, the review implied a new and different view on Swedish dam safety work. The lesson was that independent reviewers are important. One question discussed within the project team was to which extent it is necessary that the reviewers come from abroad or, alternatively, have an extensive international experience.

In the project team both pros and cons for using foreign reviewers, and for carrying out the reviews in English, were put forward. The opinions whether the advantages outweighed the disadvantages differed within the team. One owner representative underlined that the reviews per se result in the companies getting international contacts and international cooperation increasing. This in turn results in development of the activities, which is an indication that the industry should have a system that encourages such international exchange. Others maintained that, provided RIDAS is reviewed internationally and possible amendments made, the need to use foreign experts in every individual review would decrease.

Some reviewers contended that the future need of utilizing foreign experts would decrease since the reviews showed that there are competent owners and dam engineers in Sweden. They maintained that it would be suitable and an advantage to use foreign experts in the first place to review specific aspects where the number of similar cases is limited and experiences consequently also are limited. As for benchmarking against a high international standard, it is natural to use international experts, this however primarily regarding management issues with the owner and not technical issues pertaining to all dams.

2.7. Secrecy issues

In the pilot project, the dam owners expressed their concern that sensitive information could become public as the authorities study documents in connection with peer reviews according to the proposed model. The dam owners should analyze if the documentation contains information that should be classified and, if so, inform the authorities what this information is and also which sections of the Swedish secrecy laws would be applicable. It would primarily be chapter 2, paragraph 2 of this law, about secrecy to protect the security of the realm and chapter 5, paragraph 8., about secrecy pertaining to authorities' risk and vulnerability analyses, among other things.

When someone requests information, it is the authority concerned that decides if the information requested is to be classified. Before handing over information, the dam owner cannot lay down conditions that the supervising authority shall classify it. The supervising authority has the right to demand information and documents necessary for the supervision.

An analysis of the need for secrecy in the complete documentation is difficult and time-consuming. Various ways of diminishing the risk of an uncontrolled dissemination of the documentation were discussed, but without reaching a functioning solution. Among other things it was discussed if the authority could access the documents needed for an inspection by visiting the owner, instead of having it forwarded to the authority.

During the trial period it was mainly the need for secrecy around the final expert report that was analyzed. In the case of one of the final reports, the owner found that there was a need for secrecy and also stated which sections this applied to.

Also the need to classify the basic documentation (the comprehensive dam safety evaluation, the Operation, Monitoring and Maintenance manual, risk analyses, etc.) forwarded to authorities was discussed, without resulting in any conclusions on the analysis of the secrecy needs of these documents. Routines regarding the handling of the documentation by the reviewers were not discussed by the project team.

3. Conclusions

The present model for a peer review was on the whole adhered to and the opinion of the project team is that it served its purpose and was efficient, albeit resource-demanding, in deciding whether the safety at individual facilities corresponded to a high international standard or not.

The reviews showed cases confirming dam safety and dam safety work at a high international standard, as well as one case where a high international standard was not attained. Obviously there are differences between the facilities and the owners in the reviews, but a fairly good picture was received as to dam safety and dam safety work at these facilities compared to a high international standard. Swedish dam safety work (as appearing in the reviews) was found to be at level with high international practice, with one exception. In the reviews there were however examples of areas where development work remains in order to reach a high international standard. Some examples are:

- Discharge safety, analysis and philosophy regarding reliability of discharge systems and malfunction margins, questions about emergency preparedness and sustainability during for example gate problems and protracted floods.
- Instrumentation and monitoring, and working methods regarding what is to be measured and the handling and evaluation of measuring data. This especially applies to the monitoring of embankment dams where defects in the design of junctions and filters are increasing the risk of leakage.
- Documentation of facilities and the dam owner's dam safety work routines.
- Documentation of the owner's analysis and priorities regarding actions and decisions at the facility. Increased use of risk-based working methods was generally advocated.
- Coordinated emergency preparedness planning in case of dam failure (finishing the on-going development).

- Periodicity for comprehensive dam safety evaluation and the comprehensiveness of inspections.

The reviewers found that the owners had a high competence, but that rather few people are engaged in dam safety work. There were also examples of so-called dam technical experts being responsible for a too great number of dams, a majority of these in consequence classes 1A or 1B, according to the reviewers. They were also hesitant towards the outsourcing of key tasks in the maintenance of the dams, e.g. dam measurements. The reviewers contended that this could make it difficult to attain a common safety culture and that short-term contracts with possible change of operational contractors was inexpedient.

All in all, the reviews implied an increased awareness of the dam safety status and the owners' dam safety work at the reviewed dams, and the reviews should be seen as an important investment for the future. The four reviews where the owners were approved showed no to the owner unknown "weak aspects", but rather confirmed that the owners were prioritizing the right areas for upgrading and that research and development were aiming in the right direction. The owners' action plans, forwarded to the county administrative board after the reviews, however showed that there had been some change of priorities in the owners' plans and new studies of specific aspects initiated, following the reviews. The review resulting in the dam safety work of the owner failing, resulted in new measures at the facility, as well as measures of an organizational nature.

The supervising staff at the county administrative boards concerned found the reviews to be a valuable basis for their supervision and Svenska Kraftnät considers the model a good instrument for providing the supervising authority with a qualified analysis of dam safety. The supervising authority must however possess a high competence to fully understand documentation, expert opinions etc. in order to be able to evaluate and follow up an owner's action plans to take care of deficiencies calling for attention.

During the autumn of 2009 the project team intends to, based on experiences made, carry on its work identifying methods for comparisons with a high international standard and also analyze how supervising authority needs for a deeper insight into the safety at high consequence dams could best be met.