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International methods of risk analysis, damage evaluation and social impact studies concerning dam-break accidents

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1. INTRODUCTION

This report is based on the answers to several questionnaires conducted in 1999 and 2000 by the author. In this study international research work has been identified and will be commented. A questionnaire on special dam safety related subjects has been sent out world wide to approximately 40 addresses. An Interim Report on answers received (8 Answers) has been issued on 01.09.1999. This work has been continued according to new answers (4) received before 31.07.2000. The results of this work are used in the RESCDAM project.

2. QUESTIONNAIRE ON SPECIAL DAM SAFETY RELATED SUBJECTS

The questionnaire was sent out on the October 5, 1998 and renewed on the September 30, 1999 and it contains three (3) question groups:

Question 1: *Depth-velocity dam-break floods danger level curves, specifications on the origin of the curves and related research.*

Question 2: *Parameters to define floating debris, its origin and effects on dam-break flooding.*

Question 3: *Dam-break flood emergency/rescue activities; planning-actions-training/exercising*

2.1 CONTENT OF QUESTION 1:

Depth-velocity dam-break floods danger level curves have been published by, for example USA and Australian dam safety and rescue authorities. The curves define danger levels (low danger, judgement zone and high danger areas) for different groups (people, vehicles and houses). No specific reports or references to research work, to accurately define how these curves have been derived and what are for example the structural specifications of buildings, cars and people confronted with the flood.

The detailed questions are:

Q 1.1 Do you have experience related to development and research on dam break flood danger levels caused by a combination of water depth and flow velocity?
Q 1.2 Can you provide background information on how the curves have been developed (theoretical considerations, laboratory tests, field tests, and observation during and after floods)?
Q 1.3 Do you have information on more accurate specifications on the endangered groups as for example people (age, experience with floods) or houses (which type of house, construction material etc.)?
Q 1.4 Do you have information on other infrastructure components as for example bridges or roads?
Q 1.5 Have you been considering other parameters effecting danger levels (mudflow, debris, cold water, ice etc)?
Q 1.6 Do you have any other comments or suggestions?

2.2 CONTENT OF QUESTION 2:

Parameters to define floating debris, its origin and effects on dam-break flooding. Floating debris is consisting of de-rooted trees and brushes, timber stored along the flood path, fences and lightly built wooden houses and bridges etc. These materials all together form a partially floating, partially submerged layer of debris, which is transported by the flood wave. Debris add to the danger of the flood wave by its collision forces with risk objects and by the cloggage danger at hydraulic structures or narrow areas along the flood path.

The detailed questions are:

Q 2.1 Do you know about flood and dam-break flood observations, including floating debris problems?
Q 2.2 Do you have experience on how to define areas and parameters effecting the creation of floating debris (type of forest, flow velocities, scouring velocities etc)?
Q 2.3 Do you have experience or methods available to define collision forces caused by floating debris to risk objects along the flood-path (houses and other structures, vehicles, people)?
Q 2.4 Do you have methods available to define the risk for cloggage by debris of hydraulic structures (bridges and weirs) as well as of river narrows and river bends along the flood-path?
Q 2.5 Do you have observations available how debris-jams are formed and what are the factors they are decayed or breached?
Q 2.6 Do you know about mathematical models capable to simulate debris effects together with flood routing?
Q 2.7 Do you have any other comments or suggestions?

2.3 CONTENT OF QUESTION 3:

Dam-break flood rescue activities: planning, actions and training. Preparing for actions during an event of very low probability for occurrence, as well as updating the skills needs a high investment. In the case of rescue activities priority has to be given for events with a higher probability for occurrence, as for example fire fighting or common (annual) flood prevention. It is therefore important to achieve an optimum of preparedness using a minimum of resources. Any existing experience with dam-break rescue action planning, dealing with special problems during rescue actions and training for the event is highly important.

The detailed questions are:

Q 3.1 Could you please state how the dam-break rescue action responsibilities are split between the dam-owner, the public rescue organization and possibly others in your country. Is this division of responsibility legislation based?
Q 3.2 How is the public rescue organization preparing themselves for a possible dam-break event?
Q 3.3 Are there any minimum requirement for equipment and tools to be used at dam-break rescue actions?
Q 3.5 Are there any training courses offered which could be joint by Finnish rescue officials and dam safety officials?
Q 3.6 Are there and which type of field exercises held on the possible dam-break event?
Q 3.7 Are there to your knowledge existing sociological studies or event descriptions on how people acted during dam-break floods, flash floods and natural flood situations with special attention to public response to early warning, rescue actions, evacuation etc?
Q 3.8 Are there special dam-break flood guidelines available in your country?
Q 3.9 Do you have any other comments or suggestions?

3. ORGANIZATIONS AND EXPERTS ANSWERING THE QUESTIONNAIRE

Organizations and experts answering the questionnaire before 31.03.2000 are listed in table 1:

Table 1 Organizations and experts providing answers and publications to the Questionnaire.

No:	Name of organization	Country	Name of expert
1.	Area de Mecanica de Fluides Centro Politecnico Superior	SPAIN	Pilar Garcia Navarro
2.	Australian Water Technology Ltd.	AUSTRALIA	Adrian Williams
3.	Babtie Group Ltd.,	UK	Alex MacDonald, Mary Teague
4.	Enel.Hydro, Polo Idraulico e Strutturale	ITALY	Gabriella Guiseppetti
5.	Middlesex University, Flood Hazard Research Centre	UK	Colin Green
6.	River Engineering Support, HR Wallingford Ltd.,	UK	Mark Morris, CADAM project
7.	Utah State University, Water Research Laboratory	USA	David S. Bowles
8.	Vattenfall, Hydropower	SWEDEN	Nils Johansson
9.	Statkraft engineering	NORWAY	Thor Åmdal
10.	Ministere de l'Industrie, Bureau d'Etude Technique et de Contrôle des Grands Barrages.	FRANCE	Patrick Le Delliou
11.	Ontario Power Generation	CANADA	Allan Kirkham, Grant Smith
12.	Federal Emergency Regulatory Commission (FERC)	USA	Kenneth Fearon
13.	Bureau of Reclamation	USA	Wayne Graham
14.	Environmental Management Pty.Ltd.	AUSTRALIA	Terry Lustig
15.	Finnish Environment Institute	FINLAND	Erkki Loukola

4. SUMMARIZING COMMENTS ON THE ANSWERS.

The main content of the answers is summarized in table 2. The general impression is that the importance to find answers to the questions is well understood by those answered the questionnaire. There are also research programs planned to be started or were under conduction. Although reference to research work has been made, concrete reports or published results were in many cases not available.

A valuable reference to question 1 was provided from the UK where the flood damage parameter has been developed by using historical dam-break flood damage and loss of life records of the Dale Dam-break event and the water depth and flow velocity information created by mathematical modeling (1D-DAMBRK). Improvements of existing methods and development of new ones to define the threat for loss of life caused by dam break floods is presently done by BUREC (Wayne Graham) and by the Utah State University (Professor David Bowles), both USA. The importance of other parameters like muddy or cold water, winter and ice, floating debris etc. were understood, but found to be to difficult to be considered at present in detail. The significant information on loss of life during dam-break and flash

flood events could be used together with event simulating accurate models to improve the flood damage parameters. As one part of the RESCDAM project physical modeling research is conducted in Helsinki on the flood damage parameters of people and buildings. A draft report on "Assessing Vulnerability to Flooding, May 2000" has been provided by its author Colin Green and a report on "Sustainable Floodplain-Management Plans, 13.12.1999" has been provided by Terry Lustig co-author. Both reports include valuable information which should be used when defining flood risks and when planning remedial measures. Both reports deal mainly with natural floods and their applicability to dam-break floods on initially dry areas will have to be discussed. In cases where the population at risk of dam-break floods has also to prepare for natural floods these reports include well applicable information.

At all answers it has been stated that considerations related to Question 2 (floating debris, ice, sediments etc) were of great importance and several research projects on these subjects are planned for the near future. At present considerations are rare and are at highest empirical approaches related to cloggage of bridge openings or secondary dam openings, located in the dam break flood course. A model to consider sediment problems during dam-break flooding is under development at BUREC (C.T.Yang and B.P.Greimann, dam-break unsteady flow and sediment transport, CADAM, Zaragoza, Spain, 18-19 November 1999). A research project on the Debris-Flow Characterization is under conduction by the Université catholique de Louvain , France and the University degli Studi di Trento, Italy. A sensitivity analysis approach how debris jams at bridges could effect flood situation at the RESCDAM pilot project is conducted at the Kyrkösjärvi reservoir dam-break flood analysis.

Answers related to Question 3 are greatly depending on the arrangements for rescue actions valid in the country concerned. Of the fifteen answers concerning ten countries, rescue actions concerning dam-break floods are only in Finland, France and Italy legally the full responsibility of rescue authorities at the provision of active assistance by the dam owner. In Australia, Canada, Norway and the USA Emergency Action Plans (EAP) are the (legal) responsibility of the dam-owner and the activities of the emergency/rescue organizations are developed in co-operation with all parties concerned. In Spain the areas of emergency action responsibilities are defined as the dam owner's at the near-dam area (2h-flood propagation area) and further downstream the responsibilities are with the governmental disaster prevention services. The rest of the countries have no clearly defined emergency arrangements in use. Long term experience in the arrangements of rescue activities (planning, training) is available in the USA.

Table 2a Main content of the answers 1-9

Organization	1	2	3	4	5	6	7	8	9
1) Danger level curves									
Q.1.1	Some		Some	No	yes	Yes	no	No	No
Q.1.2	No		Yes	No	yes	No	no	No	No
Q.1.3	No		No	No	some	Nato	1999	No	No
Q.1.4	No		No	No	some	Scour	no	No	No
Q.1.5	Future		Yes	1999	some	No	no	No	No
Q.1.6	No		No	No	no	Research	no	No	No
2) Special parameters (debris)									
Q.2.1	Rare		No	No		USBR	no	Yes	No
Q.2.2	No		Scour	No		No	no	Some	No
Q.2.3	No		No	No		Yes	no	No	No
Q.2.4	Possible		Modeling	No		Some	no	No	Considered
Q.2.5	No		No	No		No	no	Yes	No
Q.2.6	Yes		Modeling	Yes		No	no	Modeling	No
Q.2.7	No		No	Tests		No	no	No	No
3) Dam breach flood rescue									
Q.3.1	No	Governmt.	Dam owner+ Emerg.auth.	GOV.		Dam owner	Gov	No	Dam owner EAP/3a-emerg.case-police
Q.3.2	No	SES	Prep.exercise	No exp.		no exp.	Prep.	No	No
Q.3.3	No	no exp.	Not known	No exp.		no exp.	No exp.	No	No
Q.3.4	No	no exp.	No	No exp.		no exp.	FEMA	No	No
Q.3.5	No	no exp.	No	No exp.		no exp.	FEMA	No	No
Q.3.6	No	Simul.	No	No exp.		no exp.	Q.1,3	Yes	No
Q.3.7	Ref.	no exp.	Ref.	No exp.		Nato	Q.1,3	No	No
Q.3.8	No	No, future yes	Yes	Yes		No	Yes	No	No
Q.3.9	No	Ref.	No	Coop.		No	no	No	No

Table 2b Main content of the answers 10-15

Organization	10	11	12	13	14	15
1) Danger level curves						
Q.1.1	No	BUREC'88	BUREC'88	BUREC'88	BUREC'88	RESCDAM
Q.1.2	No	No	No	Yes	Australian curves, Sydney research	Yes
Q.1.3	No	No	No	Yes	Yes	Phys.mod
Q.1.4	No	No	No	Research	Yes	No
Q.1.5	No	No	No	Research	Yes	Future yes
Q.1.6	No	No	Incremental impacts study		Social aspect more important then technical	Co-operation
2) Special parameters (debris)						
Q.2.1	No	Photographs	Problem known	Problem known	No	Yes
Q.2.2	No	No	No	Research	No	Some
Q.2.3	No	No	No	No	Yes, standard	No
Q.2.4	No	No	Sens.analys	Research	1/3 chance of blocking	Sens.anal.
Q.2.5	No	Ice jams	No		No	Ice jams
Q.2.6	No	Reduce flow area	No		No	Sens.anal.
Q.2.7	No	Debris blockage research	Perform sensitivity analysis		Methods could use ecological principles	Co-operation
3) Dam breach flood rescue						
Q.3.1	Dam owner DBFA Civil defense EAP	Dam owner DBFA+EAP Emergency agenc.EAP	NWS, flood warning Dam owner EAP Local EM Warning Local Search and Rescue SEMA+FEMA	NWS, flood warning BUREC EAP Local EM Warning Local Search and Rescue SEMA+FEMA	EMS-NSW, Chas Keys	Dam owner DBFA Emerg.orgEAP Law based
Q.3.2	Co-operation	Co-operation EPRP	Co-operation EAP, Meetings	Co-operation EAP, Meetings	Probably pretty poorly	Co-oper. Planning, Exercises
Q.3.3	Sirens,light, communication equip.	List of tools, equipment etc, in EPRP	Rely on Emergency Response Agencies		No	Yes,Future intern. RESCDAM
Q.3.4	No	No	No		N/A	No
Q.3.5	No	No	FEMA course, FERC course Video		Not known	No
Q.3.6	No	Yes	Functional Exercises required, Full Scale not required		N/A	Yes
Q.3.7	No	No	No		Yes many studies available	No
Q.3.8	No	CDA Dam Safety guide	Yes, FEMA,FERC		ANCOLD	No
Q.3.9	No	No	No			No

5. DETAILED COMMENTS ON THE ANSWERS TO THE QUESTIONAIRE

5.1 QUESTION 1

Professor Pilar Garcia Navarro (1) stated that both water depth and flow velocity is under consideration when defining the flood damages by mathematical modelling. She also stated that the damage curves are developed by models and that at dam-break flood analysis prepared by her institute, floating debris is taken under consideration. Unfortunately no reference to publications have been provided.

Mrs. Mary Teague/Mr. Alex Macdonald, Babtie Group (3) stated that depth/velocity-damage curves are used without questioning their origin. If found to be necessary the clogging effect of floating debris on bridges is taken into consideration in model computations.

Professor Gabriella Guiseppetti, ENEL (4) stated in her answer that the Italian guidelines for dam-break flood simulation request that as results the maximum water depth combined with the higher flow velocities of the wave front are used. Damage parameters or curves are not in use. At present a research project is on its way where the problems of floating debris and erosion/sedimentation shall be defined.

Mr. Colin Green, Middlesex University (5) provided several important publications:

A)) L.Clausen and P.B.Clark, Intern.Conference on River Flood Hydraulics, 1990 "The Development of Criteria for Predicting Dam-break Flood Damages using Modelling of Historical Dam Failures" as well as his preliminary publication

B)) "Sai Kung, East Kowloon and Southern Lantau (Hongkong) Stormwater Master Plan – Methodology for flood risk and benefit-cost analysis".

Both publications introduce important methods to define damages and risks of several groups under risk. Also other references related to this work have been provided. Special characteristics of flooding in large cities, like Hongkong are, that men hole covers of sewerage systems are "blown open" by pressure in the sewerage system. Beside pollution of the floodwater, wading people can easily drop into these open manholes. An other matter to be considered in flooding of big cities that commonly parking garages, shopping centers, cinemas, metros etc. are located below street level and therefore need special considerations.

Mr. Mark Morris, Wallingford UK, CADAM-Research (6) took reference to article 5/A)). For more detailed information as reference the NATO-project on this subject was given (Prof. Betamio de Almeida, Portugal). Mr. Morris suggested that follow-up activities should be combined with the working programme of the CADAM-project.

Professor David S. Bowles, Utah State University (7) gave as reference USBR 1988, Downstream Hazard Classification Guidelines and ACER Technical Memorandum No.11. He also advised to get in contact with USA-officials (FEMA = Federal Emergency Management Agency and BUREC = Bureau of Reclamation). Prof. Bowles also stated that his institute was at present conducting research on 180 dam-break and flash flood events and those results of this work would be available in the year 2000.

Mr. Tor Åmdal, StatkraftKristiansand, Norway (9) gave a short description of the Norwegian practice on how to prepare a dam-break analysis. As reference he reported Ruud and Midttomme, European Club of ICOLD, Barcelona 1998, Norwegian Guidelines on Dam Break Analysis - From theory to practice. No comments were made on the depth-velocity dam-break flood danger level curves and it therefore has been assumed that they are not used in the Norwegian procedure.

Chief Engineer Patric Le Delliou, French Ministry of Industry, DRIRE RHONE ALPES-BETCGB, Grenoble, France (10) told in his answer that due to a change in the French legislation on emergency

planning, new calculations of dam-break floods are in progress for important dams. The flood wave has to be simulated as far as it presents a danger for the population, which practically corresponds with a natural flood of a ten years return period and a maximum water level of below 1 meter above the riverbanks. The difficulties to accurately simulate the flow velocities of the flood at each point of the flooded area were stated but no research on the depth-velocity dam-break flood danger level curves was known to the author.

Mr. Allan Kirkham and Mr. Grant Smith, Dam Safety Assessment, Ontario Power Generation, Ontario, Canada (11) stated that Ontario Power Generation generally uses the United States Bureau of Reclamation's depth-velocity flood danger level curves. No other research is under conduction or known by the authors.

Mr. Kenneth Fearon, Federal Energy Regulatory Commission (FERC)-USA (12) stated that the Bureau of Reclamation's depth-velocity flood danger level curves, published in the Downstream Hazard Classification Guidelines, 1988 are known by FERC, but that FERC is not using these curves or other similar ones to define the flood danger. Instead the concept of incremental impacts is conservatively used. FERC is concerned mainly with dams at a river course where natural floods are known by the population. In such cases the incremental impact of a dam-break flood above a natural flood is an important measure.

Mr. Wayne Graham, Bureau of Reclamation (BUREC) Denver, USA has provided his recently published report "A Procedure for Estimating Loss of Life Caused by Dam Failure", DSO-99-06, BUREC, September 1999. The method introduced is based on the statistical analysis of the loss of life caused by historical dam failures. Three main factors are reported to effect the loss of life resulting from dam failure (LOL):

1) the number of people occupying the dam failure flood plain (PAR=population at risk),
2)The amount of warning is provided to people exposed to dangerous flooding and
3)The severity of flooding.

The procedure to evaluate the loss of life due to dam failure is composed of 7 steps (see publication). The method itself does not take directly reference to any depth-velocity flood danger level curves which are used by BUREC in a different approach.

Dr. Terry Lustig, Environmental Management Pty.Ltd. Sydney, Australia stated that he had been using the "Australian" depth velocity danger level curves, which have been derived by a Committee. No new developments or research on this subject is known, except the research on the stability of a child in a flume (Water Research Laboratory at Manly Vale, Sydney). Relationships based on warning time and preparedness as well a level of preparedness of a community have been developed, but latest research indicated that the earlier values are too low. A method to define the level of risks for different infrastructure types is in use. Experience has been gained with the preparedness of a community against cyclones as well as related special coastal problems. It remains open whether this experience could be applicable to dam-break flood problems. The opinion of Dr. Lustig is that the social aspect of warning systems is more important than the technical ones.

Dr. Erkki Loukola, Finnish Environment Institute, Helsinki, Finland is in charge of the development of dam safety procedures in Finland. He is also the project manager of the RESCDAM project, which aims are the development of emergency/ rescue actions based on the risk analysis and the dam-break flood analysis. In Finland the fireguard is in charge of emergency actions as well as rescue activities during a dam-break flood event. The dam owner is in charge of emergency operations of the dam to mitigate the danger and damages of the event and in the case of its occurrence the dam owner has to assist and support the fireguard in his actions. In Finland the importance of early warning as a base for successful evacuations is well understood. It has been nevertheless found that the risk of the delay of a early detection of a dam-break is a remaining fact. This might cause that in all cases a complete evacuation of the endangered flood area will not be possible. Therefore besides emergency

arrangements preparedness has also to cover rescue actions during the flood situation. This makes it necessary to know the flood parameters and the resulting danger levels within the flood plain. A physical laboratory modeling research at the Helsinki University of Technology (HUT) is included in the RESCDAM project.

Suggestions for follow-up actions

The research on the loss of life caused by historical dam-break floods conducted by BUREC, USA as well as the method to evaluate the loss of life potential for a dam under consideration provide the statistical background for the risk for loss of life evaluation. Several aspects would nevertheless improve the quality of such an analysis. A modern mathematical flood modeling study can provide with relatively reliable 2D velocities and water-depths over the modeling area. In this way the dander levels can be defined for any decided location and it can be evacuated which areas are secure inside the buildings but insecure outside on the flood plain. In other areas also buildings would collapse and therefore would not provide shelters for the population at risk. In this way the areas endangered (specified by the danger levels) by the dam-break flood can be defined and used in the loss-of life analysis. It should be considered to model the historical case studied to crosscheck with the effect this refinement has on the quality of the analysis (see UK approach "Dale Dyke").

As a comparative set of information it should be suggest to researchers in the UK to use the damage information of the Dale-Dyke dam-break, but refine the flood modeling analysis with a 2-D approach so that flow velocities could be more accurately defined at the individual damage-location. Physical laboratory research on structural flood damages and life research with people in flowing water shall be conducted at the RESCDAM project. Results of this research are explained in the Helsinki University of Technology's part of this report.

Merging the different results of damage curves in Finland the preliminary use of DAMAGE PARAMETERS as stated in table 3 has been suggested. Water depth and flow velocity at the SITE to be analyzed should be defined accurately. In the case of near dam areas 2D modeling are recommended. Based on the model simulations the water depth D (m) and the flow velocity (m/s) are used to form the *Damage Parameter D x v (m^2/s)*. Changes of D and v in time should be considered to define the earliest time when critical damage values are reached.

Table 3. Critical structural damage and loss of life parameters applied to dam break flooding (preliminary set-up)

Risk for loss of life classes, damage classes of cars and houses	**Damage parameter D x v (m^2/s)**		
	Small damages, small danger	**Medium damages. Medium danger**	**Total damages, very high danger**
Passengers, children	< 0.1	0.10 - 0.25	> 0.25
Passenger, adults	< 0.3 - 0.5	0.30 - 0.70	> 0.7
Personal cars	< 0.3	0.50 - 0.60	> 0.6
Lightly constructed detached one family houses	< 1.5	1.30 - 2.50	> 2.50
Well constructed wooden houses	< 2.0 v>2.0 m/s	2.0-5.0 v>2.0m/s	> 5.00
Brick houses, concrete structures	< 3.0 v>3.0 m/s	3.0-7.0 v>2.0m/s	> 7.00

Note: For new information please look into the report of the Helsinki University of Technology attached to the final RESCDAM report.

5.2 QUESTION 2:

Professor Pilar Garcia Navarro (1) stated that additional flood problems related to floating debris are known, but only little accurate information was available. Prof. Garcia Navarro stated also the physical modeling of floating debris problems would be an interesting and challenging task.

Mrs. Mary Teague/Mr. Alex Macdonald, Babtie Group (3) stated that their organization used for flood modeling the UK-DAMBRK and/or Mike11 computer programs in standard approaches. Floating debris modeling is not included in these models and therefore it was not considered in the analysis and no experience was existing.

Professor Gabriella Guiseppetti, ENEL (4) stated in her answer that at present no experience was existing at ENEL, but that mathematical routines were under development to allow the simulation of these problems. The problematic of floating debris and the physics of the clogging process was stated and that physical modeling research should be done on this matter.

Mr. Mark Morris, Wallingford UK CADAM-Research (6) stated opinion that there was no way to accurately define the problem, only a collection of experience with certain cases could be collected.

Mr. Nils Johansson, Vattenfall, Hydropower (8) stated his interest in the subject and gave reference to the Swedish report “Drivgods vid dammar”, VASO dammkommitte, Energikontorets Förlagsservice S-101 52 Stockholm. A second reference was the publication "On Floating debris behavior in hydraulic models, Nils Johansson, Proceedings of the International Conference on Hydropower, July 25-28, 1995 San Francisco.

Mr. Tor Åmdal, StatkraftKristiansand, Norway (9) stated that little focus has been given on this subject in Norway. Blocking of the flood diversion works by debris has been discussed.

Chief Engineer Patric Le Delliou, French Ministry of Industry, DRIRE RHONE ALPES-BETCGB, Grenoble, France (10) stated that floating debris are not taken into account at DBFA in France. If found to be necessary the calculated consequences can be increased.

Mr. Allan Kirkham and Mr. Grant Smith, Dam Safety Assessment, Ontario Power Generation (OPG), Ontario, Canada (11) stated that the problem was known, but that most of the information available are photographs. Ice-jams are common in Canada and logjams were common in time when open timber floating was still using rivers. Research on logjams might be available, but difficult to identify. OPG takes debris jams at gates into consideration by reducing sluice/spillway capacity by a range of percentages. In recognition of the importance of this problem OPG is currently starting with a program to investigate a number of issues related to debris blockages.

Mr. Kenneth Fearon, Federal Energy Regulatory Commission (FERC)-USA (12) stated that under normal operational conditions floating debris are considered a maintenance problem. During large flood events, however, floating debris has the potential to cause problems for operation and thus is a dam safety concern. No specific guidance concerning debris is included in the FERC Engineering Guidelines.

Mr. Wayne Graham, Bureau of Reclamation (BUREC) Denver, USA (13) stated that the problem of floating debris and debris jams has been observed after many dam-breaks but no information (video tapes) are available on the creation of jams. No procedures are known to simulate debris originating problems and dam-break flood inundation maps, prepared by the BUREC does not include any considerations concerning floating debris. Erosion and transport and deposition of sediments during dam-break floods is a topic under research at BUREC (Greimann and Yang) and the first results of a

model capable to simulate these events has been published. Wayne Graham suggests that the effect debris could have on a dam-break flood inundation could be accounted for by adding a safety margin to the flood elevations, computed with "clean water". In the case of catastrophic dam failures (Vajont, St.Francis) the magnitude of the submergence by the flood wave is that large that floating debris ceases to be of importance.

Dr. Terry Lustig, Environmental Management Pty.Ltd. Sydney, Australia (14) stated that he had no experience with floating debris. His guess was that culverts have a 1/3 chance of blocking during a flood.

Dr. Erkki Loukola, Finnish Environment Institute, Helsinki, Finland (15) stated that in Finland there is experience with ice jams and this information could be used to develop a conception model for the accounting of debris problems during dam-break flooding. In Finland the debris problem during dam-break flooding is not only considered as a factor which might endanger dam operation, causing possibly a dam failure, but also secondary effect in the valley downstream from the dam. Bridges, river bends and narrow valley sections may be potential debris jam sites. These jamming effects could increase water surface elevations in parts of the valley significantly higher than under non-jammed situation.

Suggestions for follow-up actions:

Further contacts and follow-up with research projects to the stated sources shall be made. Among them contacts to Wayne Graham, BUREC, Prof. Luigi Natale, Pavia, Italy, Nils Johansson, Vattenfalls, Sweden, Prof. Gabriella Guiseppetti, ENEL, Italy and Mr. Allan Kirkham, Canada shall be renewed in depth. The suggestions of Wayne Graham to add safety margins to the computed inundation should be considered. A conceptual model of transport of the material and cloggage processes has been developed and its use is planned to be tested in a sensitivity analysis approach. Existing river-ice modeling routines could be applied to the dam-break case in winter. This case is of importance for countries like Finland where winter and ice conditions might last 3-6 months every year.

5.3 QUESTION 3:

Professor Pilar Garcia Navarro (1) stated that she had no specific knowledge on rescue arrangements, but that experience might be with Professor Betamio de Almeda, IST of Lisbon, Portugal, according to the earlier stated "NATO project.

Mr. Adrian Williams, Chairman ICOLD Dam Safety Committee (2) gave in his answer a covering description of the Australian, New South Wales dam flood rescue activities. An even more detailed description is available at the NSW, Dam Safety Committee DSC-web-site <www.damsafety.nws.gov.au>

Mrs. Mary Teague/Mr. Alex Macdonald, Babtie Group (3) stated that dam accidents are not included in the UK's legal rescue program. The dam owners are fully responsible for the observation as well as all remedial measures. If necessary the dam owner requests the help of the rescue organization (Police) for evacuation of the population under risk.

Professor Gabriella Guiseppetti, ENEL (4) stated that in Italy, in similar approach as in Finland in the case of dam break accidents the public rescue organization is legally in charge of the rescue arrangements. The dam owner is only in charge of the preparation of the dam-break flood analysis, as well as naturally for all other dam safety actions required for the dam in structural and operational

concern. No information on detailed rescue arrangements including planning training rescue exercises etc. was known by her. In Italy guidelines for dam break analysis were issued in 1995.

Mr. Colin Green, Middlesex University (5) did not comment questions related to rescue arrangements, but he provided his report 1993, "The Human Aspect of Flooding" as well as the Euroflood reports published in 1993 and 1994. These reports include important information on the social aspect of flooding as well as the people's reactions during flood situations.

Mr. Mark Morris, Wallingford UK CADAM-Research (6) stated in his answer that at present neither dam break alarms nor dam break flood rescue arrangements are within the UK's public program. As above for other sources suggested also professor Morris gave as reference Prof. Betamio Almeida, Portugal (NATO-project).

Professor David S. Bowles, Utah State University (7) stated that in USA and in Australia the dam owners were responsible to observe the dam-break situation and decide on the severeness of the event. If necessary they are responsible to inform the rescue organization, which again is responsible to alarm and evacuate the people concerned. FEMA, FERC, USACE and USBR have developed guidelines for rescue actions. Professor Bowles did not have any specific information on rescue equipment, training and rescue exercises but his assumption was that this information might be available from the organizations, stated above. References of publications were:

* FERC Engineering Guidelines
* US Bureau of Reclamation Report, DSO-98-004, Prediction of Embankment Dam Breach Parameters: A Literature Review and Needs Assessment.

Mr. Tor Åmdal, Statkraft Kristiansand, Norway (9) stated that the Norwegian Water Resources and Energy Administration (NVE) requires that dam-owners prepare Emergency Action Plans (EAPs) for accidents occurring in river-courses. These EAPs have to consider what could go wrong under natural circumstances e.g. storms, landslides, floods and operational failure. Dam break flood analyses are essential in EAPs. NVE requires all dam owners to train their EAP every 3 year. The police are responsible for warning people and for rescue actions if dam break occurs, but often the police are not familiar with dam break scenarios.

Chief Engineer Patric Le Delliou, French Ministry of Industry, DRIRE RHONE ALPES-BETCGB, Grenoble, France (10) stated that in France, in the case of a high dam, the dam-owner is legally responsible to install, operate and maintain an alarm system:

* The alarm system includes sirens immediately downstream of the dam
* Lightening of the downstream face of the dam
* The alerting of the authority (civil defense)

The authority (civil defense) is responsible for the rescue (planning, training etc.) in the valleys downstream of dams. The dam-owner prepares the DBFA and evaluate the possible supplementary dangers (e.g.Chemical Plants). The Civil Defense Administration prepares an emergency plan, called "Particular Plan of Intervention". There is no specific requirement for the civil defense.

Mr. Allan Kirkham and Mr. Grant Smith, Dam Safety Assessment, Ontario Power Generation (OPG), Ontario, Canada (11) stated that in Ontario as in the rest of Canada the dam owners are responsible to report any failure or incident to the appropriate authorities who will then organize the necessary actions, which may include evacuation. The dam owner is responsible for monitoring the situation at the dam and co-operating with the emergency agencies. OPG holds regular meetings with the public rescue organizations and other groups all understand OPG's (dam-owners Emergency Preparedness and Response Plans (EPRP) and that OPG's other plans and contact lists are up to date. Each EPRP contains a list of tools, equipment, and contractors available for use in case of a dam emergency. OPG uses different levels of testing and field exercises, varying from simple check of names and phone numbers to more extensive functional and tabletop exercises, which check people's reaction to a hypothetical

dam incident. No sociological studies on people's reactions in flood situations are known. The Canadian Dam Association has published the CDA Dam Safety Guidelines which contain, among other things; guidelines for dam assessments, flood routing and production of emergency action plans.

Mr. Kenneth Fearon, Federal Energy Regulatory Commission (FERC)-USA (12) introduced the mission of FERC which is to provide guidance and regulate the safety of dams for hydroelectric projects throughout the United States (over 2.600 dams). FERC regulated hydropower projects are required to develop Emergency Action Plans (EAPs) pursuant to the Code of Federal Regulations, Title 18, Part 12, Subpart C (18 CFR 12C). Non-federal dams not regulated by FERC are under the jurisdiction of State Dam Safety Offices, which have varying jurisdictional requirements. Responsibilities during dam-break rescue actions are nor necessarily mandated by any specific legislation, but are defined as follows for the majority of cases within the United States

* *The National Weather Service (NWS)* issues flood warnings and flood updates. They should be included as a participant in all EAPs.
* *The Dam Owner or assigned personnel* has the following primary responsibilities:
    1. Prepare and distribute an EAP, ensure its annual update and arrange for and conduct periodic testing of the EAP.
    2. Conduct annual drills for internal (dam owner/operator) personnel (i.e., emergency equipment, sirens, telephone numbers, etc.)
    3. Educate external (Emergency Response/Rescue) personnel regarding: facilities at the dam, terminology used during emergency notifications, flow conditions during emergency spillway releases or dam-break, and answer other questions (ensure that proper co-ordination and co-operation occur.
    4. Educate dam operators on emergency scenarios, when to implement the EAP, how to clearly communicate with external personnel during an emergency and when to terminate the EAP.
    5. Primary responsibility to notify state and local officials that an emergency is developing or has occurred.
    6. Generally is responsible for dissemination of public information during an emergency.
    7. Advise NWS of potential flooding due to an emergency at a dam (magnitude, duration etc.)
    8. Conduct and document, follow-up evaluations after an emergency or test.

* *The Local Emergency Management (EM) Agency* (usually county) has the responsibility, under statutory obligation, to warn the public and plan for evacuation. Local EMs usually establishes an Emergency Operations Center or Incident Command System to serve as the main distribution center for warning and evacuation activities.
* *The Local Search and Rescue (usually Police or Fire Department)* personnel have the responsibility to conduct the door-to-door evacuation of affected inhabitants and assist in other field operations activities. Note that the dam-owner should not assume the evacuation responsibility of government! However there may be situations in which routine notification and evacuation will not suffice. In this case, the dam owner and involved agencies should evaluate the situation and determine who should notify those person(s) located in harms way. In unusual situations, the dam owner may indeed assume the responsibility to notify a local resident.
* *The State Emergency Management Agency* provides assistance to local emergency managers and co-ordinates a State wide response.
* *The Federal Emergency Management Agency (FEMA)* has the responsibility to co-ordinate a national response to emergencies, provide financial assistance for emergency preparedness, provide emergency training of local and state agencies, establish policies and guidance for emergency response.

The FERC offers a 2-day training course entitled "EAP Exercise Design Course" to help dam owners test and evaluate their existing EAPs. Additional training courses on EAPs are offered by FEMA (1.5

days training Course). The FERC does not recommend field exercises (Full Scale Exercise) as the desired goal of an exercise program due to the potential for increased public safety concerns (field mobilization, accidents, incidents) and increased potential for panic of the public due to misinformation or belief that an actual emergency is underway and to a lesser extent the high costs of a Full Scale Exercise. Consequently the FERC requires that jurisdictional dam owners perform a Functional Exercise (approx. 40 held annually). The Functional Exercise is a timed, stressful exercise of the EAP that tests both, the response of the dam-owners personnel and of the emergency management community to a postulated dam emergency.

Mr. Wayne Graham, Bureau of Reclamation (BUREC) Denver, USA stated that BUREC's procedures are similar to those introduced by FERC (Ken Fearon). He nevertheless stated that each city, town or county places a different level of resources on planning for dam failure or other natural or man-made events. The warning of the citizens is not the responsibility of the dam owner. It is the local governments (city, town, county) responsibility and there might be different requirements on tools or equipment serving in emergencies. Training and exercising is at BUREC according to what FERC had reported except that BUREC does not conduct field exercises. In-office role playing and exercising is conducted. Wayne Graham provided a list of publications dealing with sociological research on what people did during flood events:

* "Warning--A Call to Actions, Warning and Disaster Response a Sociological Background," Benjamin F. McLuckie, National Weather Service, March 1977.
* "What People Did During the Big Thompson Flood," Eve Gruntfest, August 1977.
* "Get to High Ground! The Warning Process in the Colorado Floods, June 1965," Marti F. Worth and Benjamin F. McLuckie, Disaster Research Center, The Ohio State University.
* "That Day in June, Reflection on the Teton Dam Disaster, edited by Janet Thomas, et al., Published by Ricks College Press, Rexburg, Idaho, 1977.

There exist several Guidelines concerning Emergency Action Planning for Dam Safety in the USA. Reference has been given to Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners, 1998 Federal Emergency Management Agency, Mitigation Directorate, FEMA 64. Other references are ICODS (Interagency Committee on Dam Safety).

Dr. Terry Lustig, Environmental Management Pty.Ltd. Sydney, Australia stated that Mr. Chas Keys from the New South Wales, Emergency Management Services, Sydney Australia would be the correct person to answer questions related to emergency activities.

Dr. Erkki Loukola, Finnish Environment Institute, Helsinki, Finland stated: To determine and assess the risk arising from a dam, the regional environment center may order, whenever so required, the body which has had the dam built or the dam owner or holder to acquire or make an assessment of the risk posed by the dam, in particular to downstream population and property (hazard risk assessment). *The bases of this assessment are a Dam-break Flood Analysis (DBFA).* A dam referred to in this Dam Safety Act, and which in the event of an accident may manifestly endanger human life or health or manifestly seriously endanger the environment or property, must be included as *a risk site in the co-ordination plan referred to in the Fire and Rescue Services Act. The Emergency/ Rescue Action plan is the responsibility of the local rescue authority (Fire brigade) under the assistance by the dam-owner.* Supervision of the Dam Safety Act (DSA) and provisions and regulations issued by virtue of its rest with *the regional environment centers*, and the supreme supervision and guidance, the rescue services excluded, rest with the *Ministry of Agriculture and Forestry.* The rescue services come under the *Ministry of the Interior and the authorities subordinate to it* (provincial governments, municipal fire authorities). The following must be available in the event of an accident caused by a P dam (*high hazard dam*) to the extent required by the conditions:

- A plan concerning the measures to be applied to a water-body or hydraulic structures.
- An account of stock of materials kept for an accident.
- An account of the alarm system and communication links to the regional alarm center.
- An account of personnel of the dam owner or holder available in the event of an accident.
- An account of the other measures to be taken by the dam owner or holder, necessary to protect people and property

All activities are defined in the Dam Safety Code of Practice, issued by the Ministry of Agriculture and Forestry. It has been revised with new versions in 5 years intervals. The last version was published in 1997. See also www.vyh.fi/eng/orginfo/publica/electro/damsafet/damsafe.htm.