Environment Agency

learning from experience

Post-incident reporting for UK dams
2008 Annual Report

We are the Environment Agency. It's our job to look after your environment and make it a better place - for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

Published by:

Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

March 2009

ISBN: 978-1-84432-980-9

Foreword

Dams and reservoirs are an important part of our national infrastructure, providing a vital service in storing the country's water. However, without effective management, ongoing monitoring and adequate maintenance these reservoirs have the potential to cause extensive damage and even loss of life. Although it is very rare for a dam to fail, we know that there are serious incidents at UK reservoirs every year. We have produced this report to raise awareness of these incidents and share lessons learned with the reservoir industry.

We have just completed our second year of overseeing the post-incident reporting system. Building on the successes of last year's annual report, which was well received, this year's report provides a summary of incidents reported during 2008.

Post-incident reporting provides a single, co-ordinated point for gathering, analysing and sharing information about reservoir incidents and particular lessons that can be learned. A valuable tool for the industry, this information is also being used to inform research and development priorities. Our Flood Risk Science Team is managing various key research and development projects, which will improve levels of safety and reduce the risk to people and the environment.

Whilst post-incident reporting is still voluntary, I am delighted that the Pitt Review into the flooding of 2007 recommended implementing the changes to the Reservoirs Act that we proposed in our last biennial report. We expect post-incident reporting to be covered in the forthcoming Floods and Water Bill.

I would like to thank all of those within the reservoir industry who have contributed to and supported the post-incident reporting system during 2008. We look forward to continuing to play our part in developing the system and helping the industry improve reservoir safety.

Ian Hope

Ian Hope
Technical Manager - Reservoir Safety

Contents

1. Introduction

We have been running the post-incident reporting system for two years. We administer the system and collect information on incidents at both large raised reservoirs (reservoirs under the Reservoirs Act 1975) and small raised reservoirs (reservoirs not currently covered by reservoir safety legislation). The aim of the system is to:

- gather information on reservoir safety incidents;
- investigate incidents where appropriate;
- learn lessons from incidents;
- inform the reservoir industry of trends and key lessons learned;
- inform reservoir safety research and incident frequency data for quantitative risk assessment.

The purpose of this annual report to the reservoir industry is to provide information on the nature of the lessons learned over the last year and trends in the number and type of incidents that have occurred.

We prepare bulletins, when appropriate, to provide an insight into an incident or group of incidents where there are particular issues that should be shared with the reservoir industry. This year we have prepared bulletins on groundwater inflow and sheet piles which can be found at the back of this report and on our website.

Currently, post-incident reporting is a voluntary system. The Pitt Review into the 2007 summer floods recommended that the Government implement the changes to the Reservoirs Act 1975 proposed in our last biennial report. If these changes happen post-incident reporting for reservoirs will become a legal requirement.

The post-incident reporting system aims to promote learning. As well as reading about incidents that have occurred, we can also learn from safety measures that inspecting engineers recommend. In 2008 we commissioned Alan Warren of Halcrow Group Ltd to review the safety measures in nearly 500 inspecting engineer's reports and report on his findings.
A summary of this work is provided in section 4.

2. Analysis of the reported incidents

The following information is presented in this annual report:

- the number, type and severity of incidents that have occurred during 2008 and the previous four years;
- incident analysis in terms of threats to reservoirs and mechanisms of deterioration resulting from those threats;
- the main lessons that have been learned from the incidents;
- a brief summary of each incident and lessons learned where we have received completed post-incident report forms.

2.1 Severity and number of reported incidents 2004-2008

Incidents are recorded if they meet any of the three severity levels for reportable incidents (Table 1).

Table 2 and Figure 1 show the number and severity of incidents that have been reported between 2004 and 2008. They only include incidents where we have been able to gather enough information to assign an incident level (this is generally where we have received a completed post-incident report form).

There were seven incidents reported during 2008 to which we assigned an incident level. There were three level two incidents during 2008 and all of these occurred at small raised reservoirs.

Large raised (or statutory) reservoirs are those covered by the Reservoirs Act 1975. Small raised (or non-statutory) reservoirs are those with a capacity under 25,000m^3 and therefore not covered by the Reservoirs Act 1975.

Incident severity level	Definition of incident severity
One	Failure (uncontrolled sudden large release of retained water)
Two	Serious incident involving any of the following: • emergency drawdown • emergency works • serious operational failure in an emergency
Three	Any incident leading to: • an unscheduled visit by an inspecting engineer • a precautionary drawdown • unplanned physical works • human error leading to a major (adverse) change in operating procedures

Table 1. Reportable incidents

	2008	2004-07
Total number of incidents	7	27
Incidents at large raised reservoirs	4	20
Incidents at small raised reservoirs	3	7
Level 1 incident	0	2
Level 2 incident	3	9
Level 3 incident	4	16

Table 2. Incidents reported 2004-2008 showing severity level

Most of the incidents reported in 2008 occurred at category A or B reservoirs. The definition of dam categories can be found in appendix B.

The number of reported incidents decreased in 2008, returning to a similar level to 2006. This is probably because we did not see the same widespread and extreme flooding this year as in 2007.

The number of incidents reported in 2007 has increased slightly in this year's report. This is because some post-incident forms were submitted to us after the 2007 annual report was published and therefore we have included them here.

Figure 1. Incidents reported 2004-2008 showing severity level.

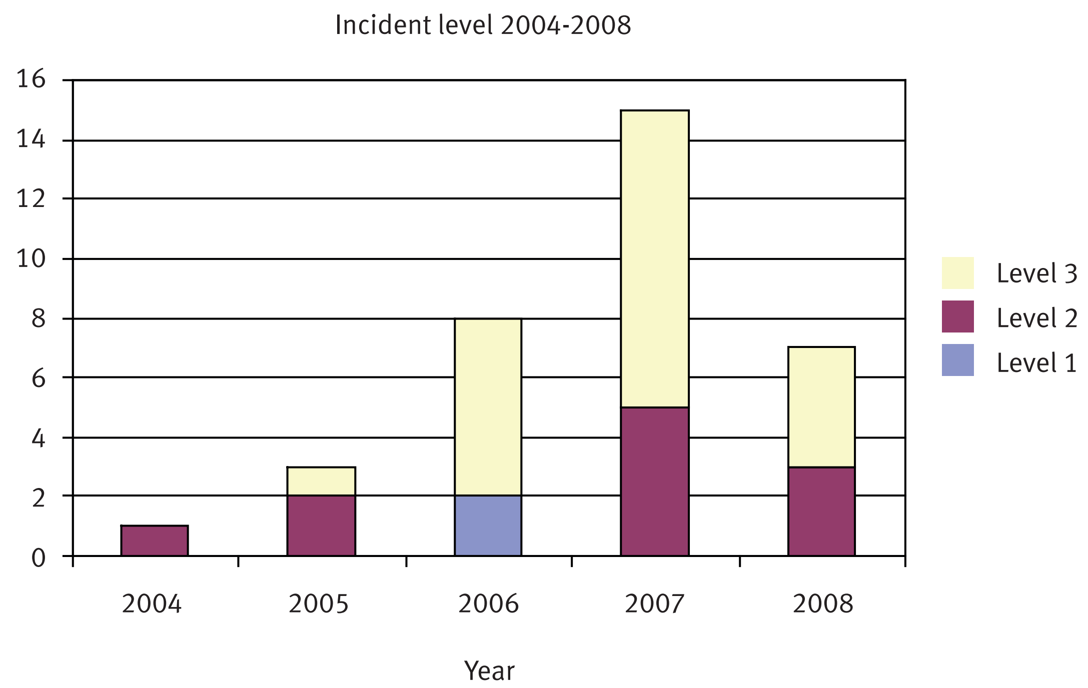


Figure 2. Incident Level and Dam Category for 2008
Refer to appendix B for definition of dam categories

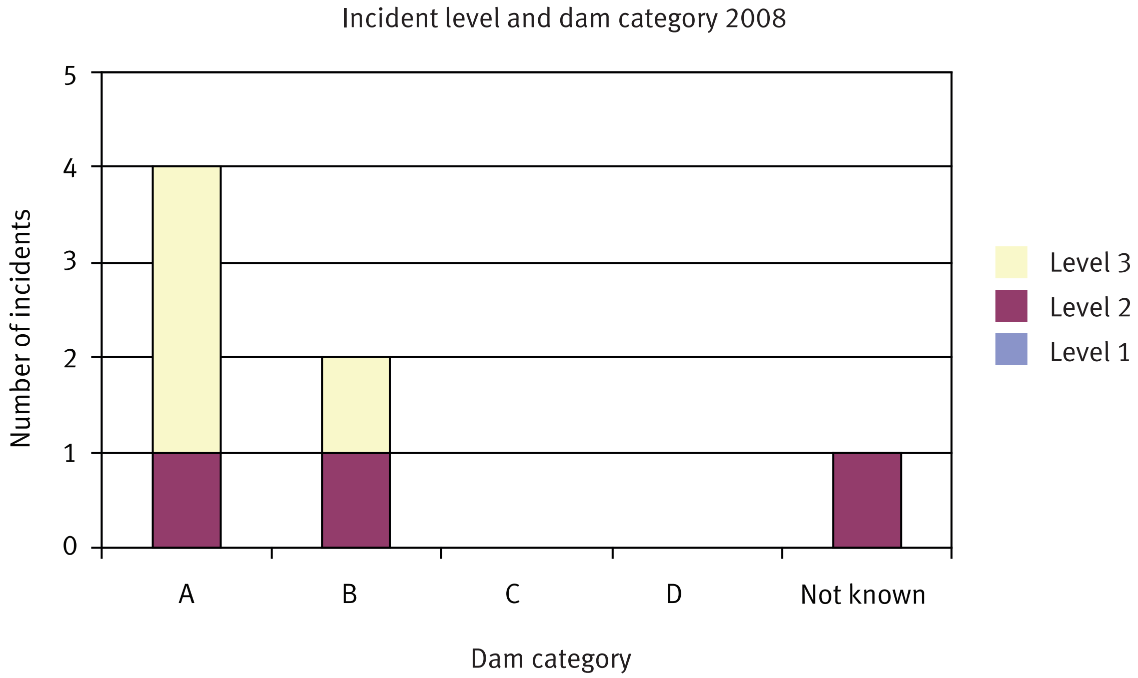
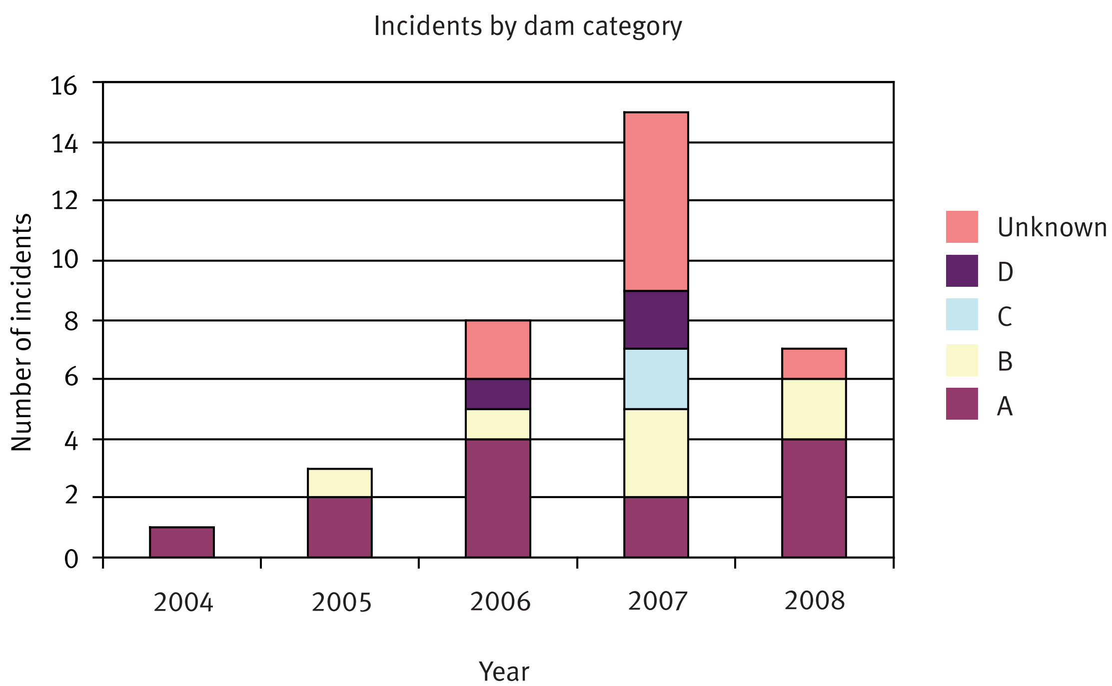


Figure 3. Distribution of incidents by year and dam category



2.2 Threats and mechanisms of deterioration

Tables 3 and 4 provide a summary of the reported incidents and include some characteristics of the dams, including dam category and height.

Summary of reported incidents 2004-2008

Statutory reservoirs

Incident No	Incident date	Incident severity	Date built	Dam height (m)	Dam category
35	Nov-04	2	1931	13	A
31	Jan-05	2	1911	27	A
29	Jun-05	3	1910	6	B
30	Jun-05	2	1882	20	A
317	Feb-06	3	1998	9	B
311	April-06	3	1974	20	A
304	Jun-06	3	1927	17	A
305	Jul-06	3	1750	4	D
301	Oct-06	3	1956	15	A
306	Dec-06	1	Not known	2	Not known
303	Dec-06	3	1815	11	A
324	Feb-07	3	1820	3	D
330	Mar-07	3	1969	20	A
323	May-07	3	1879	9	A
312	Jun-07	3	1800	3	D
308	Jun-07	2	1975	4	B
307	Jun-07	2	1875	14	A
309	Jun-07	3	1963	5	B
315	Jul-07	3	Not known	7	Not known
327	Aug-07	3	1760	6.5	B
326	Oct-07	3	1800	3	C
328	Jan-08	3	1950	3	A
329	Jan-08	3	1808	9	B
332	Aug-08	3	1815	11	A
333	Sep-08	3	1815	6	A

Table 3. Summary of reported incidents at statutory reservoirs

External threat	Internal threat	Mechanism of deterioration
n/a	Embankment stability	Internal erosion through embankment
n/a	Embankment stability	Internal erosion adjacent to appurtenant structure
Inflow flood	n/a	Erosion by overtopping
Inflow flood	n/a	Erosion by overtopping
Mining	n/a	Settlement
n/a	Appurtenant work stability	Pipework/culvert deterioration
n/a	Embankment stability	Internal erosion through embankment
n/a	Vegetation	Internal erosion adjacent to appurtenant structure
n/a	Embankment stability	Settlement/deformation
Other	n/a	Other
n/a	Embankment stability	Internal erosion adjacent to appurtenant structure
n/a	Embankment stability	Internal erosion through embankment
n/a	Embankment stability	None - the wet area was found not to relate to the reservoir
n/a	Embankment stability	Internal erosion adjacent to appurtenant structure
n/a	Embankment stability	Internal erosion adjacent to appurtenant structure
Inflow flood	n/a	Erosion by overtopping
Inflow flood	Appurtenant work stability	Damage to safety critical structures
Inflow flood	n/a	Erosion by overtopping
Inflow flood	Embankment stability	Pore water pressure - increase mass movement
n/a	Embankment stability	Internal erosion through embankment
Wind, trees	Vegetation	Wind damage - trees
Animals	n/a	Internal erosion through embankment
n/a	Embankment stability	n/a
n/a	Appurtenant work stability	Pipework/culvert deterioration
n/a	n/a	n/a

Non-statutory reservoirs

Incident No	Incident date	Incident severity	Date built	Dam height (m)	Dam category
302	May-06	1	1800	3.5	Not known
316	Jun-07	2	1920	5	Not known
322	Jun-07	2	1620	5	Not known
310	Jul-07	3	Not known	1.5	Not known
313	Jul-07	3	Not known	4	C
321	Jul-07	2	1920	5	Not known
325	Jan-08	2	Not known	13	A
335	Aug-08	2	1850	9	B
334	Sep-08	2	Not known	5	Not known

Table 4. Summary of reported incidents at non-statutory reservoirs

We have analysed reported incidents in terms of threats to dams and the mechanisms of deterioration resulting from those threats. Threats have been broadly divided into internal and external threats.

The internal threat categories used in the database include:

- instability associated with internal erosion of an embankment dam;
- slope instability associated with slip of an embankment dam;
- instability associated with appurtenant works;
- instability of the dam foundation;
- material deterioration (for example, corrosion);
- vegetation (for example, tree roots).

The external threat categories used in the database include:

- inflow - flood;
- inflow - direct rainfall;
- inflow - failure of upstream reservoir;
- seismic event;
- snow/ice;
- aircraft strike;
- vandalism;
- wind (wave generation);
- wind (tree damage);
- human error;
- animals;
- mining.

Tables 5 and 6 give a summary of incidents for 2008 and for 2004 - 2007 in terms of threats and mechanisms of deterioration.

The main external threat and mechanism of deterioration during 2008 was again inflow flood, resulting in external erosion by overtopping the embankment or spillway. All of the incidents of overtopping occurred at small raised reservoirs.

The main internal threat reported in 2008 and over the previous four years has been embankment stability. Internal erosion has been the mechanism of deterioration in eleven of the incidents reported in the past five years.

External threat	Internal threat	Mechanism of deterioration
Inflow flood	Embankment stability	Erosion by overtopping
Other	n/a	Erosion by overtopping
Inflow flood	n/a	Erosion by overtopping
Inflow flood	Abutment stability	Internal erosion through embankment
Inflow flood	n/a	Erosion by overtopping
Inflow flood	n/a	n/a
Inflow flood	Embankment stability	Erosion by overtopping
Inflow flood	n/a	Erosion by overtopping
Inflow flood	n/a	Erosion by overtopping

Internal and external threats		2008	2004-2007
External	Inflow flood	3	11
	Mining	0	1
	Wind, trees	1	0
	Animals	1	0
	Other	0	2
Internal	Embankment stability	2	12
	Appurtenant works stability	1	2
	Abutment stability	0	1
	Vegetation	0	2

Table 5. Summary of threats

Mechanism of deterioration	2008	2004-2007
Erosion by overtopping	3	7
Internal erosion through embankment	1	5
Internal erosion adjacent to appurtenant works	0	5
Pipework/culvert deterioration	1	1
Damage to safety critical structures	0	1
Pore water pressure increase mass movement	0	1
Settlement	0	2
Wind damage - trees	0	1
Other	0	1

Table 6. Mechanisms of deterioration

2.3 Types of lessons learned

The following conclusions are based on a relatively small database of incidents:

- Flood events still account for many of the incidents that occur, particularly at small raised reservoirs.
- Emergency action was needed at two small raised reservoirs in 2008, where earthfill embankments were overtopped and seriously damaged during flooding.
- A wide range of relatively minor incidents were reported at large raised reservoirs during 2008. These related to internal erosion, slope stability, and damage caused by animals and trees.

Incidents recorded in the database are classified on the basis of the type of lessons learned. The lessons learned are split into five categories as explained in Table 7 below. Categorising the lessons learned in this way makes it easier to highlight trends in incidents (see figure 4).

Type	Examples	Possible implications
Surveillance	Inadequate surveillance or processing of instrument observations.	Reservoirs require more or better monitoring and surveillance.
Operation	Malfunction or mis-use of reservoir control facilities.	Reservoirs require more or better trained staff or security against misuse.
Physical (current condition)	Inadequate performance due to deterioration of a design element by erosion, wear, weathering, corrosion, vandalism, poor maintenance, etc.	Reservoir components require better, more frequent maintenance.
Physical features (intrinsic)	Inadequate performance due to the original design and/or construction of a structure, or through changes in the loading (structural or hydraulic) experienced.	Reservoir components should be designed and built to meet current physical conditions.
Emergency planning	Incidents relating to the application of emergency planning provisions (alarms, evacuations, etc).	There is a need for more effective use of emergency planning provisions at reservoirs.

Table 7. Types of lessons that can be learned

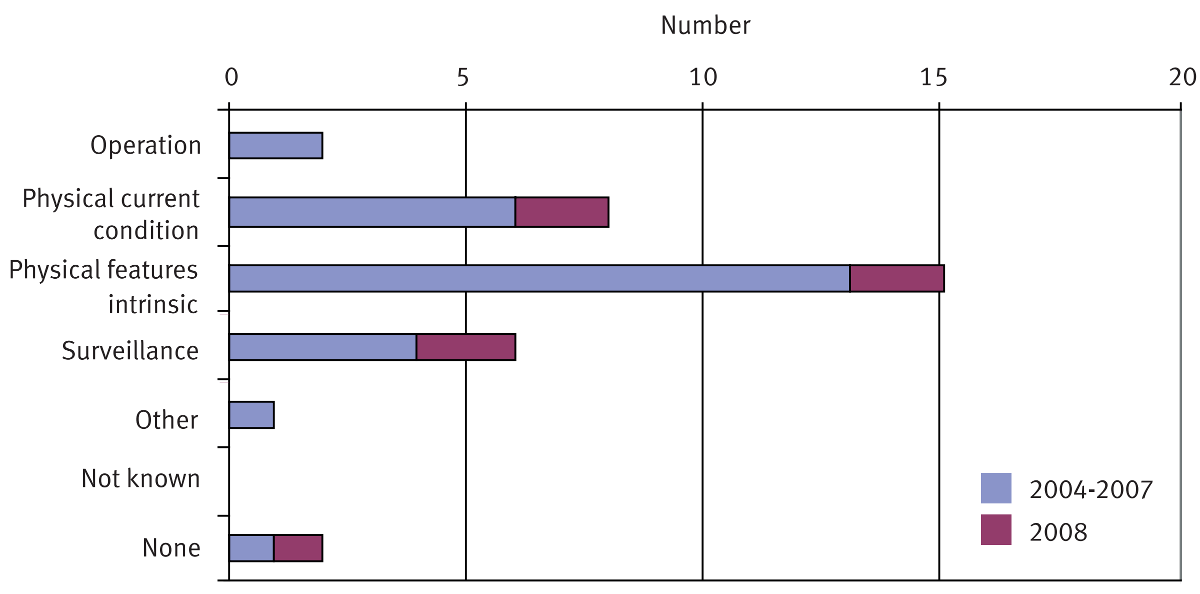


Figure 4. Lessons learned 2004-2008

Incident category and ID	Lesson learned	PIR annual report year
Operation		
301 (Sutton Bingham)	A slip in the upstream face occurred possibly due to relatively rapid drawdown of the reservoir water level. This incident highlighted the value of settlement monitoring. It also highlighted that drawdown facilities need to be sufficient to reduce the water level in a reservoir even at times of high inflow.	2007
304	The reservoir was operated with a very high water level and this led to leakage. The frequency of surveillance should be reviewed under such conditions and increased if appropriate. The leakage point can be some distance off the toe of the dam. Surveillance should cover areas beyond the immediate area of the toe to check for leakage paths through the dam foundation.	2007
Current physical condition		
35	Settlement and possible desiccation of the core led to leakage when the reservoir was filled to a higher level than had been experienced in recent times. This incident highlighted the need to carry out surveillance more often when a reservoir is filled above the 'normal' operating level.	2007
305	Internal erosion was initiated on the line of a spillway conduit. The incident underlines the value of addressing leakage problems as they arise. If the initial problem of leakage into the drop shaft had been solved, the subsequent more serious leakage path might not have developed.	2007
306	A length of the reservoir rim, which might have been either natural ground or a constructed section, failed. The incident underlines the need for good records of dam construction and the importance of regular surveillance, especially when the reservoir levels are unusually high.	2007
313	Settlement of the dam embankment caused a low spot on the dam crest which was then overtopped during a flood event. Seepage from a wet spot at the downstream toe of the dam steadily increased in the months following the flood event. The incident underlines the need for proper surveillance and maintenance of dam embankments. There is a need for increased surveillance when embankments experience hydrostatic pressure greater than they have in recent times.	2007
324	An erosion hole was found at the toe of the dam. The hole had not been identified earlier as it was obscured by vegetation. Make sure that vegetation does not prevent the dam being thoroughly inspected.	2007

Continued overleaf

Figure 8. Summary of 2007 lessons learned

Incident category and ID	Lesson learned	PIR annual report year
Intrinsic condition		
29	An unregistered reservoir was overtopped by a flood event leading to erosion of the downstream face. It was then found that this reservoir should have been registered. If the reservoir had been registered previously, the safety provisions of the Act may have averted the incident.	2007
30 (Boltby)	A flood event led to partial failure of the stepped masonry spillway channel and some erosion of the toe of the dam embankment. It is important to consider the risk of flows exceeding the capacity of spillway channels and, where appropriate, to consider erosion protection works. It would seem appropriate to carry out research into the performance of stepped masonry spillway channels.	2007
31 (Lower Carno)	Leakage of very turbid water was noted in the drainage system. When the leakage rate increased rapidly, an emergency drawdown was carried out. The incident shows how important regular, effective surveillance is.	2007
302	Failure of a dam embankment due to overtopping. Embankments and spillways need to be designed and built to appropriate standards.	2007
307 (Ulley)	Spillwater led to a partial collapse of the stepped masonry spillway channel and erosion of the adjacent section of the dam embankment. The incident highlights the need to observe and inspect masonry walls for vegetation and missing pointing. It also demonstrates that out-of-channel flow should not be allowed to occur where it could damage the structure of the dam.	2007
308 & 309	Flood damage arose to embankments which had been raised using steel sheet piles. This highlights the need for careful detailing of dam crest raising works to consider the effects of extreme flood events. The use of sheet piles to raise an embankment, which may be subject to overtopping, should be carefully considered and avoided if possible.	2007
311	Leakage arose from a tunnel under a dam. All tunnels under dams should be regularly inspected and any information on the design and inspection of these tunnels should be kept with the reservoir records.	2007
315	A section of river bank failed, slipping into an off-line flood storage reservoir. Established vegetation prevented the slope from being inspected, which could have shown signs of failure before the incident arose. The incident underlines the need for good ground investigation and site management when developing reservoir works.	2007
316	Reservoirs in catchments of groundwater dominated hydrology must adequately cater for the significant groundwater response that might arise following severe rainfall.	2007
321	A dam was almost overtopped during a flood event and the spillway capacity was found to be inadequate. The reservoir had previously been discontinued. The incident highlights the need for panel engineers to only certify a reservoir as discontinued if its safety provisions meet current best practice.	2007
322	The new owner of the reservoir was unaware of the inadequate spillway capacity and bottom outlet (drawdown) capacity. The incident shows the need for owners of small raised reservoirs to be aware of reservoir safety guidance.	2007

Incident category and ID	Lesson learned	PIR annual report year
Surveillance		
303	Increased leakage was found adjacent to a spillway structure on the downstream face of the dam. The incident highlights the need to carry out regular surveillance of any known points of seepage/leakage.	2007
310	A series of weirs, already in poor condition, were damaged by a flood event. The incident highlights that even small dams can pose a significant threat and need to be properly inspected and maintained.	2007
312	Leakage arose through the embankment and adjacent to a spillway structure. Undertakers need to regularly survey points of seepage so that changes are observed early.	2007
323	A wet area downstream of the dam had been attributed to groundwater. Increases in the water flow suggested that the water came from the reservoir. A proper seepage monitoring system would have helped to recognise the increase in seepage flow. Experience in visual surveillance is not always effectively passed on to new staff, so recording seepage flows is a better way of preserving the dam performance history.	2007
Other		
317	Subsidence due to mining led to a reduction in freeboard. This highlights the importance of being vigilant if mining activity is taking place near a dam.	2007

3. Reported incidents 2007-2008

Some of the incidents detailed in this section occurred during 2007, but were reported after last year's annual report had been published, so we have included them here.

Incident 325

Dam type	Culverted road embankment
Reservoir legal status	Non-statutory
Dam height (m)	13
Incident type	Inflow flood, embankment overtopped
Incident severity	2

During heavy rain, the valley upstream of a road embankment filled with water. The culvert through the embankment had become blocked with debris as there was no screen to stop it. The embankment overtopped which lead to part of the downstream face failing. This then blocked the culvert. There was significant risk of further slips which could have caused the complete failure of the embankment.

Apartments that had recently been built downstream of the embankment were evacuated and the Fire and Rescue service lowered the impounded water level by pumping.

Lessons learned

The culvert was blocked due to the lack of an effective debris screen. This shows the need for regular inspection and maintenance to ensure that blockages do not happen. This incident also highlights a problem with culverted road embankments which pose a risk to life but do not fall under the Reservoirs Act 1975.

Incident 326

Dam type	Earthfill embankment
Reservoir legal status	Large raised reservoir, impounding
Dam height (m)	3
Incident type	Embankment leakage
Incident severity	3

A leak through the embankment was heard and then seen. The supervising engineer investigated and discovered that the leak was where a large birch tree had been blown over in high winds four years before. It was decided to trench into the crest to find the leak and then install a cut-off. The leak was successfully repaired.

Lessons learned

Dams should be checked for damage caused by trees. Vegetation should be managed to allow effective routine surveillance.

Incident 327

Dam type	Earthfill embankment
Reservoir legal status	Large raised reservoir, impounding
Dam height (m)	6.5
Incident type	Embankment stability, leakage
Incident severity	3

A tractor fell into a hole in the crest. Leakage could be seen at the bottom of the hole. The reservoir was lowered until the leakage stopped. Investigation revealed that in the past the dam crest level had been raised, but the watertight core had not been raised at the same time.

Lessons learned

This case highlights the need for regular surveillance and to ensure that if an embankment is raised, the core is also raised.

Incident 328

Dam type	Earthfill embankment
Reservoir legal status	Large raised reservoir, impounding
Embankment height (m)	3
Incident type	Animal activity
Incident severity	3

During high river levels the riverside embankment associated with a flood storage reservoir partially breached. This was found to be due to water seeping into animal burrows in the river-side of the embankment. This caused internal erosion leading to a partial breach of the embankment. A sluice gate adjacent to the breach location was opened to allow the reservoir to fill from the river in an attempt to equalise water levels on both sides of the partial breach. This turned out to be unnecessary because river levels started to fall shortly after the breach occurred and the embankment was not fully breached over its entire depth.

Lessons learned

This incident highlights the importance of checking all reservoir embankments for damage from burrowing animals and repairing any damage found.

Incident 329

Dam type	Earthfill embankment
Reservoir legal status	Large raised reservoir, impounding
Dam height (m)	9
Incident type	Embankment stability, downstream slip
Incident severity	3

A historical rotational slip in the downstream face was noted and the reservoir level was held down by 600mm. High rainfall and valve operating problems caused the water level to rise and the slip reactivated. The slip threatened to block the spillway channel. The reservoir water level was lowered using the scour valve.

Lessons learned

This incident demonstrates that historical slips can be reactivated if water levels are not adequately controlled.

Incident 332

Dam type	Earthfill embankment
Reservoir legal status	Large raised reservoir, impounding
Dam height (m)	11
Incident type	Pipework deterioration
Incident severity	3

Discoloured water was seen discharging from the lower outlet pipe during a weekly visit. The upstream valve was closed immediately and a CCTV survey of the pipe was carried out. This revealed open joints in the pipe in two places, with debris within the open joints and seepage at one of them. It is believed that when the pipe was in operation, water turbulence was eroding material behind the open joints. The valve was closed and a revised emergency draw-down plan was drafted. The pipe will be relined if possible.

Lessons learned

This incident shows the importance of routine surveillance in identifying any issues early enough so appropriate action can be taken.

Incident 333

Dam type	Earthfill embankment
Reservoir legal status	Large raised reservoir, impounding
Dam height (m)	6
Incident type	Possible embankment leakage
Incident severity	3

Water was seen issuing from the toe of the dam during a routine site visit. The supervising engineer thought that it would be beneficial to lower the water level in the reservoir as a precaution. On further investigation, it was thought that the water might have tracked through the service ducts, possibly from the nearby river.

Lessons learned

This incident shows the importance of regular surveillance and the need for a thorough understanding of construction features

Incident 334

Dam type	Earthfill embankment
Reservoir legal status	Small raised reservoir
Dam height (m)	5
Incident type	Inflow flood, embankment overtopped
Incident severity	2

This non-statutory reservoir, used for fishing, had an overflow spillway at both the left and right abutment. The spillway sill level for both overflows had been raised using timber boards which in turn reduced the freeboard. The local authority, concerned with the stability of an adjacent road embankment had also reduced the capacity of one of the spillway channels. They provided a pipe within the original open channel. No flood study had reportedly been carried out despite the fact that there was a school downstream. The dam was subsequently overtopped in a flood event and the embankment was severely damaged over much of its length. Damage to the stilling area of one of the two spillways also arose, creating a large scour hole. Trees on the downstream face of the dam created deep erosion gullies around them. The reservoir was emptied using the bottom draw-off after the peak of the flood had passed.

Lessons learned

Adequate spillway capacity should be provided and maintained at all dams to a minimum standard appropriate for the downstream hazard. Spillway modifications should not be carried out without a proper flood safety assessment. Where overtopping occurs, trees and shrubs can cause deep erosion gullies on the downstream face of the dam

Incident 335

Dam type	Earthfill embankment
Reservoir legal status	Small raised reservoir
Dam height (m)	9
Incident type	Inflow flood, Embankment overtopped
Incident severity	2

This non-statutory reservoir had been leased to a local fishing club. As it was not subject to the terms of the Reservoirs Act 1975 there was no supervision by a panel engineer. During a heavy rainstorm the dam was overtopped. This caused serious erosion of the downstream face of the dam. A number of local residents were evacuated from their homes and roads were closed.

The situation was made worse by screens being placed across the overflow to retain fish and the outlet pipework not being maintained. The screens were removed from the overflow and the embankment dam was demolished.

Lessons learned

This incident shows how important regular supervision and maintenance is. It also highlights the value of emergency planning procedures.

4. Research and development activities

Responsibility for delivering reservoir safety research and development (R&D) for England and Wales has recently transferred to us from Defra. The research and development strategy, prepared by Atkins (under contract to Defra), can be found on our website. Where appropriate, the projects recommended by the strategy will be carried out by our Flood Risk Science Team as part of the joint Defra/ Environment Agency Flood and Coastal Erosion Risk Management Research and Development Programme.

This section summarises some of the research and development activities prompted by the post-incident reporting system.

4.1 Masonry stepped spillway research

Following the Ulley Reservoir incident in 2007, an incident investigation was carried out by Halcrow Group Ltd on our behalf to determine what might be learned. A key recommendation was to carry out research on the hydraulic behaviour of masonry stepped spillways and how certain flow conditions might lead to structural damage. We awarded this research contract to MWH in 2008. The work began in 2008 and is due to be completed in 2009.

MWH are currently gathering the information that will allow them to create a physical model of a masonry spillway. The results from the modelling will be used to help produce clear and easily available guidance on how the safe hydraulic capacity of such chutes should be assessed in terms of:

- overall hydraulic performance.
- localised hydrodynamic pressure loadings and suction effects.
- effect of condition of associated masonry.

4.2 Learning from historical dam incidents

There are currently a number of publications and papers available on historical dam failures and serious incidents but there is no single reference point for present information and points of learning. This project aims to produce a single document that will help those responsible for the safety of reservoirs; mainly panel engineers and reservoir owners. A contract was awarded in 2008 to Halcrow Group Ltd and the Building Research Establishment (BRE) to produce a document that will inform the UK reservoir industry of key incidents and dam failures which have shaped our industry and influenced best practice.

The specific objectives planned are:

- to promote the benefits of post-incident reporting and the use of the national database;
- to identify the 100 most significant incidents on the national database, in terms of impact and/or influence on the industry, from c.1800 to 2008;
- to classify these incidents by broad categories of incident type and lessons learned;
- to prepare summary descriptions for the 30 most significant incidents, drawing on readily available published information. This will aim to provide basic information on the dam characteristics, design and construction aspects, how the incident arose, how it was managed, and a summary of the damage that took place. Where appropriate, information will be added on the impact of the incident on the industry.

This work began in late 2008 and is due to be completed in early 2010.

4.3 Research on statutory safety measures

The post-incident reporting system aims to gather points of learning from dam incidents. Another way to investigate the vulnerability of the nation's stock of dams is to consider the nature and frequency of measures recommended in the interests of safety (essential safety measures). This provides an insight into the key issues identified by inspecting engineers under the provisions of the Reservoirs Act 1975. Halcrow Group Ltd was appointed in 2008 to carry out this research. They did this by reviewing the 491 Section 10 inspection reports for England and Wales that were submitted to us between 2004 and 2008. We provide a summary of the findings here. We will share more detailed results in 2009.

Statutory safety measures research: summary of results

Alan Warren, AR Panel Engineer, Halcrow Group Ltd

"When measures are recommended in the interests of safety, a copy of the report is sent to the enforcement authority. I was asked to look at the 491 reports sent to the Environment Agency for reservoirs in England in Wales between 2004 and 2008. This is the first opportunity the industry has had to make use of the centralisation of these reports and to see what we might learn from the safety recommendations made by inspecting engineers.

I approached this by piloting a draft categorisation on 285 recommendations from 90 Section 10 reports. I then reviewed the categories, re-categorised some of these 285 recommendations and continued to categorise the remaining 1087 recommendations from 401 reports.

The main categories used were the same as those used in the post-incident reporting system for the types of lessons that can be learned from incidents, but I also included categories for risk assessments, and research and investigations. The results are presented below.

Category		Total number of recommendations	Percentage of total	Percentage of categories 1- 5
1	Measures to address deterioration	313	22.8	33.4
2	Measures to improve intrinsic condition	273	19.9	29.1
3	Reservoir operation	234	17.1	25.0
4	Monitoring and surveillance	106	7.7	11.3
5	Other measures	11	0.8	1.2
6	Risk assessment and emergency planning	51	3.7	-
7	Research, investigations and studies	384	28.0	-
Total		**1372**	**100**	**100**

Table 9. Summary of statutory safety measures (2004-2008) by main categories

This allows us to compare the concerns being raised by inspecting engineers with the types of problems that, historically, have led to incidents. The figures in the last column can be used to make this comparison. Data for 230 incidents are available on the national database.

The great majority of these incidents occurred at large raised reservoirs. The capture of incidents arising at small raised reservoirs has only been significant since the post-incident reporting system began in 2007.

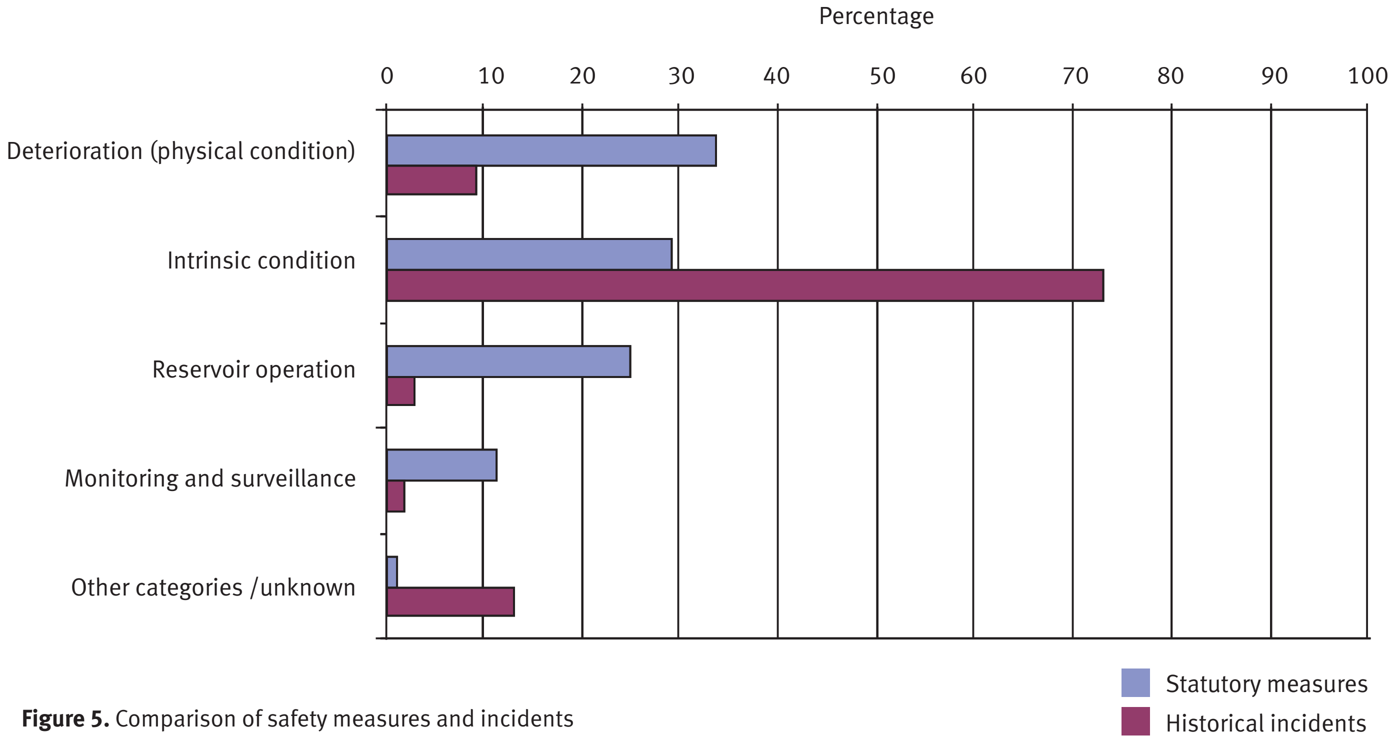


Figure 5. Comparison of safety measures and incidents

Clearly, the great majority of incidents are attributed to the intrinsic condition of the dam and associated structures. The incident categories are indicated in the table below according to three time periods. The periods relate to changes in reservoir safety legislation.

Care should be taken in interpreting the figures in table 10 as records have improved over time. For example, it is very likely that a far greater proportion of the incidents that happen in 2009 will be reported and entered in the database than the proportion achieved in, say, 1909

	Number of recorded incidents by date		
Incident category	**Pre-1930**	**1930-1985**	**Post 1985**
Deterioration	4	3	13
Intrinsic condition	41	63	64
Operation	1	1	5
Monitoring and surveillance	1	0	4
Other/not known	2	9	11
Total	**49**	**76**	**97**

Table 10. Recorded incidents by date and category

It is also interesting to consider the percentage of measures by owner category and to compare this with the percentage of the statutory reservoirs in England and Wales that they own.

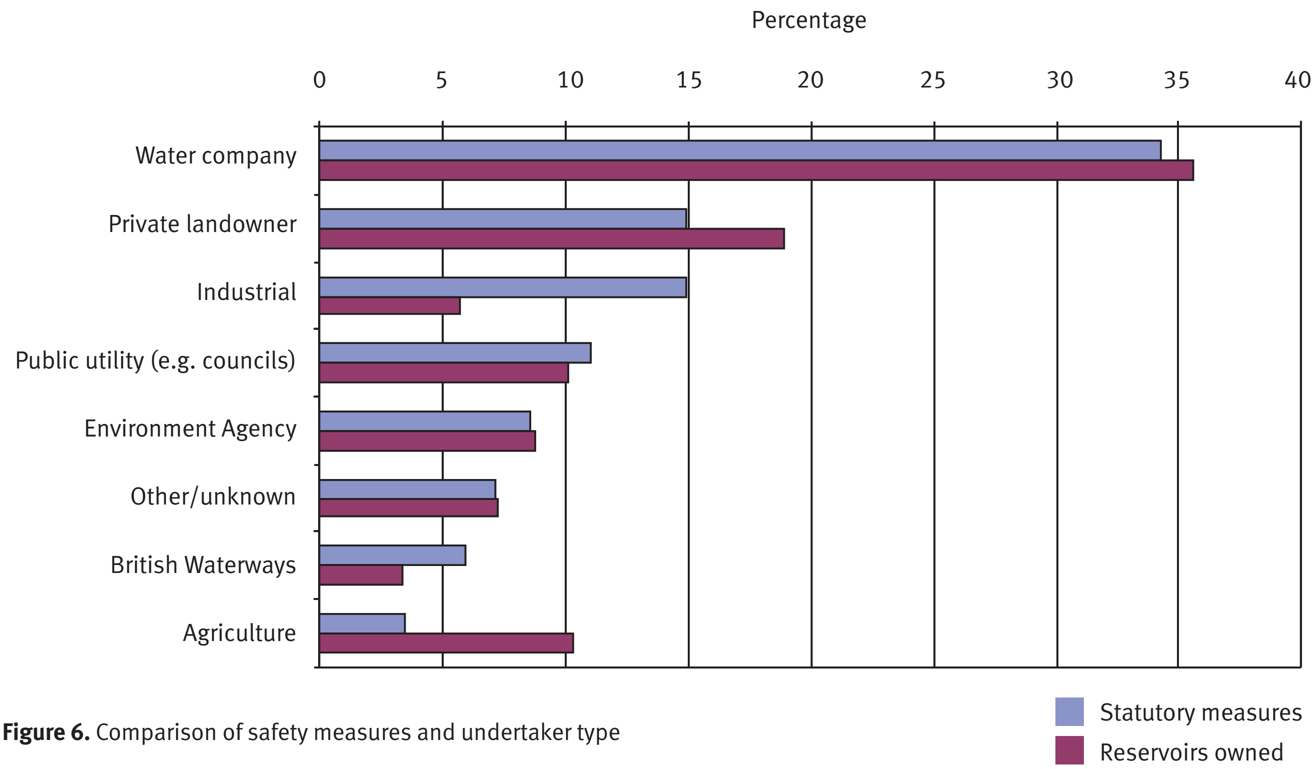


Figure 6. Comparison of safety measures and undertaker type

It should be noted that the comparisons partly reflect the typical age and type of dam and this makes it difficult to draw meaningful conclusions. Of all the results, perhaps the most surprising comparison is for reservoirs owned by industrial companies.

The breakdown of measures within each of the categories will be of interest to panel engineers and reservoir owners and this information will be published in the near future."

Case-study – Bruton dam flood storage reservoir

This case study demonstrates the importance of identifying and implementing safety measures to reduce the risk of possible future incidents.

Bruton flood storage reservoir is located on the River Brue about 2km upstream of Bruton, a town with a long history of flooding. The earthfill dam was built in the early 1980s to reduce the risks of flooding. The reservoir was designed to be kept empty under normal conditions, but during flooding the reservoir gradually impounds water and has an open spillway to allow the discharge of larger floods. Following inspections under the Reservoirs Act 1975 and various studies, the undertaker implemented a £2.6million programme of remedial and improvement works in 2008, designed by Black & Veatch to improve the functioning of the reservoir.

Impoundment event 29th May 08

The main reasons for the 2008 scheme were:

- The peak velocity of up to 11m/s on the spillway chute was much greater than the normally recognised limit of 8m/s recommended for the cellular concrete blockwork that formed the original surface protection.
- The trash screen at the upstream end of the culvert did not meet current standards regarding screen area or safe access.
- The storage capacity fell well short of that required to meet the original design standard, based on current hydrological appraisal methods.

The scheme therefore included the following measures in the interests of safety:

- upgrading the surface protection on the spillway using stepped blocks;
- building a new, larger screen structure at the upstream end of the culvert;
- raising the spillway crest by about 2m, with corresponding raising of the rest of the embankment crest.

Above: Spillway

5. Dam characteristics

The post-incident reporting database can hold information on a wide-range of dam characteristics as well as details of incidents. A detailed database of the characteristics of UK dams is important as it will allow the reservoir industry to make best use of the post-incident data.

We gather information on dam characteristics via a reservoir data sheet in one of two ways. If there is an incident at a dam, we ask the undertaker, supervising engineer or investigating engineer to complete a reservoir data sheet as well as a post-incident report form. This is the only way the data is collected for non-statutory reservoirs and reservoirs in Scotland and Northern Ireland.

For statutory reservoirs in England and Wales a reservoir data sheet is sent to the inspecting engineer when he is appointed to do the next statutory inspection of a reservoir. The inspecting engineer is asked to complete the form as part of his inspection and return it to us by email.

The proposed changes to the Reservoirs Act 1975 should help us improve the quality and scope of the data we hold for reservoirs in England and Wales. This would be useful for a range of reservoir-related research projects in the future.

6. Freedom of information

Some concern was expressed during the early stages of the post-incident reporting system that information provided to us about incidents would enter the public domain. This concern arose because, as a public body, we are subject to the Freedom of Information Act 2000 and the associated Environmental Information Regulations 2004.

Following the major floods of summer 2007 and a number of reservoir-related incidents that included the incident at Ulley, we received a number of requests from the media for post-incident report forms for other reservoirs. However, we did not release key information requested, such as dam location, as it could have adversely affected public safety and national security.

7. Enforcement

Our aim through post-incident reporting is to improve reservoir safety. We have given a commitment to the reservoir industry that we will not use information acquired through post-incident reporting to retrospectively initiate enforcement action under the Reservoirs Act 1975.

8. Mandatory post-incident reporting

In last year's report we stated that we did not believe that all incidents were being reported via the voluntary post-incident reporting system. We also discussed proposed changes to the Reservoirs Act 1975 published in our biennial report, which included introducing a mandatory system post-incident reporting.

The Pitt Review into the 2007 summer floods included a recommendation that the Government should implement the changes proposed in our biennial report. It is expected that these changes will be included in the draft Floods and Water Bill. The Government intends to consult on the draft Bill in spring 2009.

9. Acknowledgements

We would like to thank all those within the reservoir industry who have taken the time to contribute to the post-incident reporting system this year. We would like to acknowledge the support of Halcrow Group Ltd in producing this annual report. We would also like to thank Andrew Charles of the Building Research Establishment for reviewing this report.

We would like to thank Robert Mann & Renfrewshire Council for the photographs of incident number 335. We would also like to thank South West Water Ltd for the use of the photographs on the front cover and pages 2, 3, 4 and 22.

Appendix A: Reporting an incident

Details of how to report incidents, and an example of a post-incident report form are given in our publication *'Learning from Experience: Post-incident Reporting for UK Dams'*. This also gives more information on the voluntary post-incident reporting system and answers some of the most common questions we have received.

We deliberately use the term 'post-incident reporting' so that it is clear that this system does not concern incident management. If a problem arises at a reservoir you should follow the procedure outlined in the flow chart.

We can receive post-incident information at our Exeter office by phone, fax or email. Our contact details are at the back of this report. We suggest that you contact us as soon as possible after the incident is under control while the facts are still fresh in your mind. If the problem is likely to take some time to resolve, please let us know and we will call you back at a later date to find out more about the actions you have taken, and how effective they were.

Emergency event or incident
(For example high rainfall/flood, uncontrolled overtopping, structural failure, slumping, increased or new seepage or any other abnormal signs).

↓

Contact your supervising engineer
If you have a supervising engineer, contact him/her, as he/she will be able to advise you what to do next.

↓

Reporting the incident
If necessary, call the Environment Agency's Floodline on **0845 988 1188** or
Incident Hotline on **0800 807060**
(Available 24 hours a day, 7 days a week)

↓

Post-incident reporting
As soon as possible after the incident is under control, please contact the Reservoir Safety team on **01392 442001**
(Between 9am and 5pm Monday to Friday)

Appendix B: Dam Categories

Dam Category (from 'Floods and Reservoir Safety', Institution of Civil Engineers, 1996, 3rd edition)

Dam Category	Potential effect of a dam breach
A	Where a breach could endanger lives in a community*
B	Where a breach could (i) endanger lives not in a community or (ii) result in extensive damage
C	Where a breach would pose negligible risk to life and cause limited damage
D	Special cases where no loss of life can be foreseen as a result of a breach and very limited additional flood damage would be caused.

*A community in this context is considered to be 10 or more persons.

Appendix C: References

Charles J A (2005). Use of incident reporting and data collection in enhancing reservoir safety. Dams & Reservoirs, vol 15, no 3, November, pp 29-35.

Environment Agency (2007) Learning from Experience: Post-incident reporting for UK Dams. Environment Agency, Bristol.

Environment Agency (2007) Improving safety, protecting lives: Biennial report on reservoir safety 1 April 2005 – 31 March 2007. Environment Agency, Bristol.

Environment Agency (2008) Learning from Experience: Post-incident reporting for UK dams 2007 Annual Report. Environment Agency, Bristol. http://publications.environment-agency.gov.uk/pdf/GEHO0408BNSH-e-e.pdf

Gosden J D and Brown A J (2004). An incident reporting and investigation system for UK dams. Dams & Reservoirs, vol 14, no 1, March, pp 21-28.

Hamilton-King L J, Hope I M and Warren A L (2008). Post-incident reporting: learning from experience to promote reservoir safety. Proceedings of the 15th British Dam Society Conference. Thomas Telford, London.

Pitt, M. (2008) Learning lessons from the 2007 floods. An independent review by Sir Michael Pitt. Cabinet Office, London.

Skinner H D (2000). The use of historical data in assessing the risks posed by embankment dams. Dams & Reservoirs, vol 10, no 1, April, pp 9-12.

Tedd P, Skinner H D and Charles J A (2000). Developments in the British national dams database. Dams 2000. Proceedings of 11th British Dam Society Conference, pp 181-189. Thomas Telford, London.

Warren A L and Hope I M (2006). A new incident reporting system. Proceedings of 14th British Dam Society Conference, Durham, pp 27-36. Thomas Telford, London.

Appendix D:
CROSS - Confidential Reporting on Structural Safety

Major industries such as the maritime, aviation and medical professions, throughout the world have recognised the need to promote reporting systems to feedback 'lessons learned'. For major civil and structural engineering projects SCOSS (Standing Committee on Structural Safety) and CROSS (Confidential Reporting on Structural Safety) have been established.

Dr Alastair Soane, Director of CROSS

Confidential Reporting on Structural Safety (CROSS) is a programme from the Standing Committee on Structural Safety (SCOSS) for collecting, analysing, and publishing concerns about the safety of structures. It was launched in 2005 to learn from the experiences of engineers and others, for the benefit of the public and those in the construction industry. The techniques used stem from similar programmes in aviation but this is believed to be the first for an engineering discipline.

A fundamental, and very important, feature is to ensure that reports are dealt with in complete confidence and that the names of authors are not given or retained. Reports are only seen by one person, and after identifying features have been removed, they are reviewed by a panel of experts. These include representatives from consulting civil and structural engineers, contractors, local authority building control, central government, and the Health & Safety Executive, and they provide comments on the lessons that can be learned. Reports and comments are published on the internet in quarterly newsletters (www.scoss.org.uk/cross).

Reports have been about collapses, failures and potential failures of components, building control issues, and near misses amongst other topics. Design, construction, maintenance and demolition have all been subjects of interest, and there have been several cases of deaths and injuries. Following a death in Scotland from falling masonry, and a request from government to local authorities, there were 1,200 examples of objects that had fallen, or were in danger of falling, from buildings reported to CROSS.

An initial report can lead to further similar examples being submitted, which may form a trend. A major objective of the programme is to change behaviour when a trend is found and this is done in various ways. Recommendations may be made to suppliers of components or systems that have caused concern, the major Institutions are advised on the need to provide guidance for members, and representations are made to government departments and regulatory bodies about possible changes to improve safety.

There is considerable interest not only in the UK but also elsewhere. Reports are received from far afield, and in several countries there are plans for local versions. There are, of course, similarities with the reservoir safety scheme, and the organisers of both will work together in the future to exchange information to benefit both structural and infrastructure works.

Contact details

Incident reporting

Floodline 0845 988 1188 (24 hours)
Incident Hotline 0800 80 70 60 (24 hours)

Post-incident reporting

Please call us during normal office hours
(Monday-Friday 9am to 5pm) on 01392 442001.
Fax: 01392 444238

Or write to us at:
Reservoir Safety
Environment Agency
Manley House
Kestrel Way
Exeter
EX2 7LQ

Email: reservoirs@environment-agency.gov.uk
Website: www.environment-agency.gov.uk/reservoirsafety

Would you like to find out more about us, or about your environment?

Then call us on

08708 506 506 (Mon-Fri 8-6)

email

enquiries@environment-agency.gov.uk

or visit our website

www.environment-agency.gov.uk

incident hotline 0800 80 70 60 (24hrs)
floodline 0845 988 1188

Environment first: This publication is printed on paper made from 100 per cent previously used waste. By-products from making the pulp and paper are used for composting and fertiliser, for making cement and for generating energy.

GEHO0409BPCX-E-P