Environment Agency

learning from experience

Post-incident reporting for UK dams
2007 Annual Report

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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 2008

ISBN: 978-1-84432-866-6

Foreword

'Dams and reservoirs are an essential asset of great benefit to modern society, storing most of the nation's water. But, they can also potentially cause great damage and 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. After our first year administering the post-incident reporting system, this annual report provides an opportunity to inform the reservoir industry about the incidents reported during 2007. The report demonstrates the valuable contribution that incident reporting makes to understanding and improving the long term safety of UK reservoirs'.

Ian Hope
Technical Manager - Reservoir Safety

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1. Introduction

The post-incident reporting system, developed by Halcrow Group Ltd and the Building Research Establishment (BRE), began in January 2007. The new incident database has been developed from the existing BRE database and draws on research for Defra by KBR Consultants.

The system is administered by the Environment Agency under the guidance of an independent all reservoirs panel engineer. 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;
- provide information that can contribute to 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.

Post-incident investigations have been carried out for the most serious or complex incidents and where permission has been gained from the dam owner. Each investigation was carried out by a qualified civil engineer to explore the root cause of the incident. A post-incident investigation has been carried out for four reservoir incidents to date.

We will prepare bulletins when appropriate to provide an insight into an incident or groups of incidents where there are particular points of learning that should be shared with the reservoir industry. We have prepared a bulletin on masonry spillways which is in Appendix D. We will publish further bulletins as necessary and these will be available on our website.

The database holds information on dam characteristics as well as information on incidents. You can contact us if you would like more information from the database. Our contact details are inside the back cover.

Details of how to report an incident can be found in Appendix A.

BRE began developing the National Dams Database in 1988 as part of the Government's Reservoir Safety Research Programme. This included compiling data on dam failures and incidents, and remedial works. The data has been transferred to the new Environment Agency post-incident database and will allow historical data to be used together with future reports on failures and incidents.

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 2007 and the previous three 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 completed post-incident report forms have been received.

2.1 Severity and number of reported incidents 2004 to 2007

Incidents are entered on the database if they are considered reportable. Table 1 defines the three severity levels for reportable incidents.

Table 2 and Figure 1 show the number and severity of incidents that have been reported during 2004 to 2007. They only include incidents where we have been able to gather enough information to assign an incident level (generally where we have received a completed post-incident report form).

There were twelve incidents reported during 2007 to which we assigned an incident level. Eleven of the twelve incidents occurred at embankment dams.

The two level 1 incidents reported in the period 2004 to 2007 occurred at a non-statutory reservoir and at a statutory reservoir in Scotland.

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

	2007	2004-06
Total number of incidents	12	12
Incidents at statutory reservoirs	7	11
Incidents at non-statutory reservoirs	5	1
Level 1 incident	0	2
Level 2 incident	5	3
Level 3 incident	7	7

Table 2. Incidents reported 2004-2007 showing severity level

Incidents reported in 2007 at statutory reservoirs were evenly split amongst categories A to D (Figure 2). Most non-statutory reservoirs do not have a dam category assigned and these are reported as 'unknown'.

The number of reported incidents has increased each year since 2004 (Figure 3), partly as a result of an increase in the level of incident reporting, and because of reports of incidents on non-statutory dams that suffered the effects of the extreme rainfall events during June and July 2007.

Although post-incident reporting did not formally begin until January 2007, we have been recording reported incidents since October 2004 when we became the enforcement authority for the Reservoirs Act 1975. During 2007 we have attempted to follow up incidents reported in previous years to obtain relevant information.

Figure 1. Incidents reported 2004-2007 showing severity level.

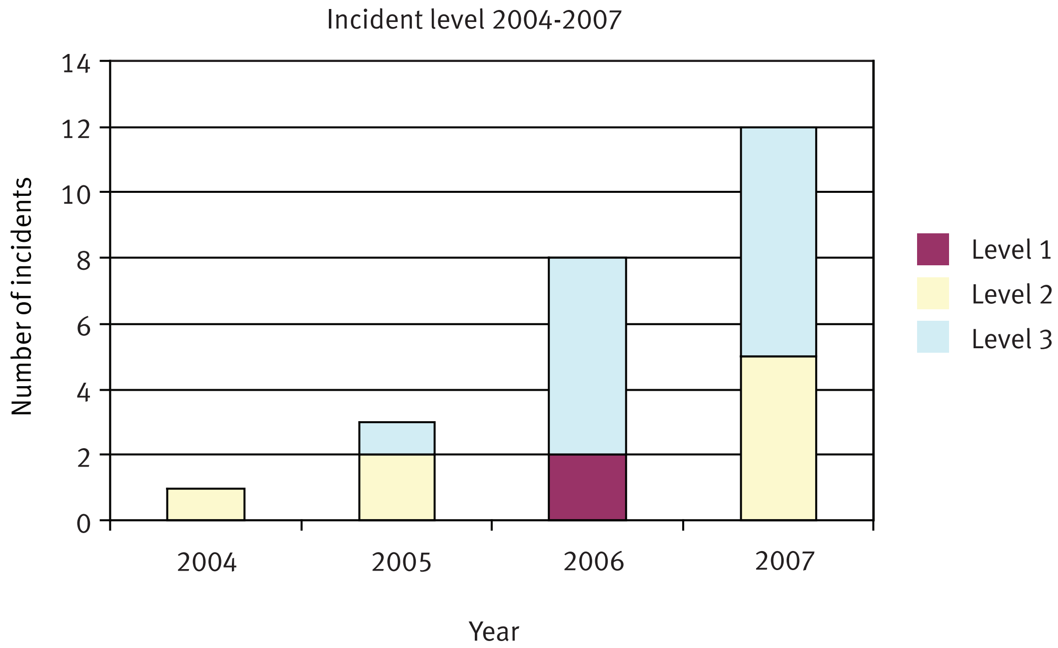


Figure 2. Incident Level and Dam Category in for 2007
Refer to appendix B for definition of dam categories

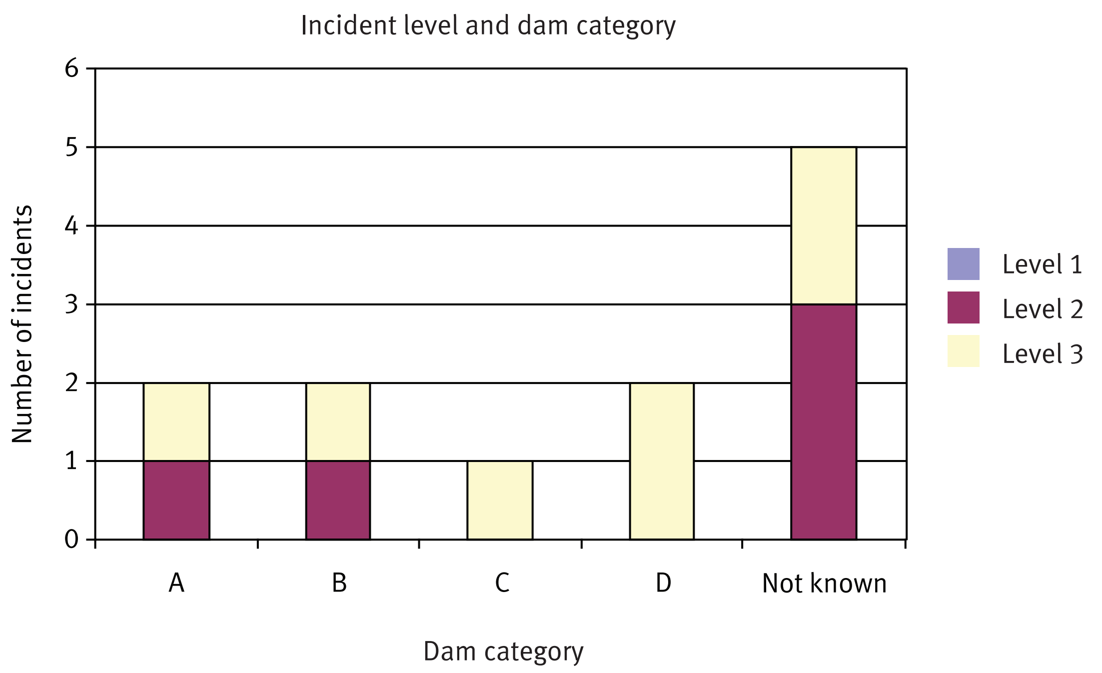
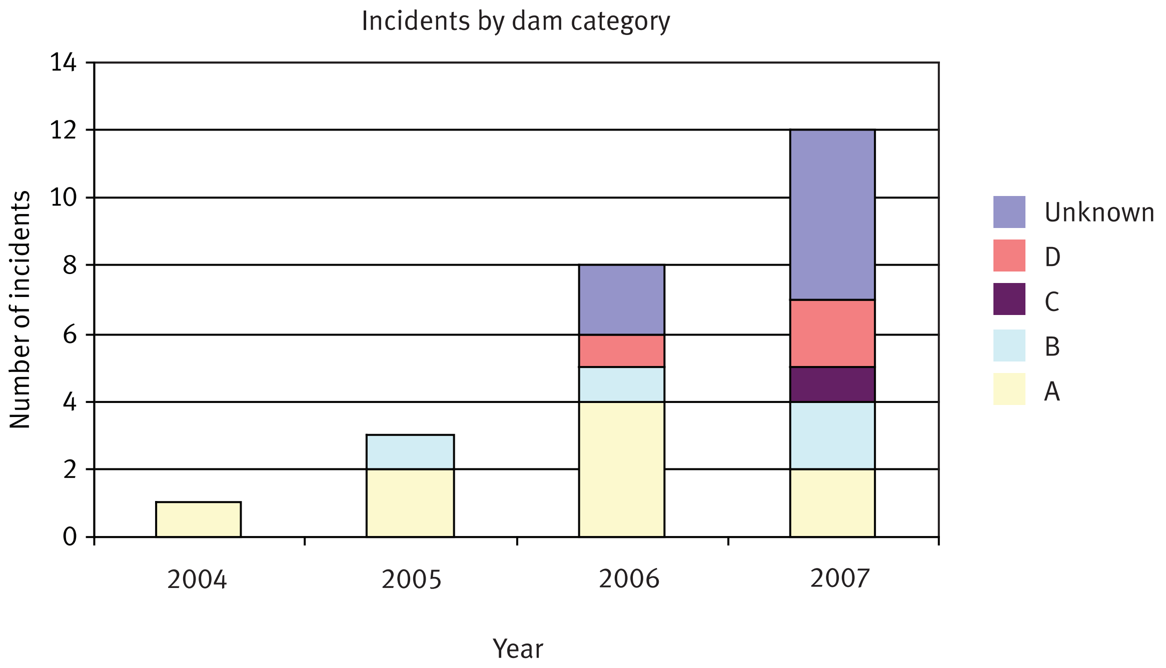


Figure 3. Distribution of incidents by year and dam category



2.1 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 2004-2007

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
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

Table 3. Summary of reported incidents at statutory reservoirs

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

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

External threat	Internal threat	Mechanism of deterioration
n/a	Embankment stability	Internal erosion
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
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
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

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
Inflow flood	n/a	Erosion by overtopping
Inflow flood	n/a	n/a

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.

A summary of incidents for 2007 and for 2004 - 2006 in terms of threats and mechanisms of deterioration is given in Tables 5 and 6.

The main external threat and mechanism of deterioration during 2007 was inflow flood and resulting external erosion by overtopping the embankment or spillway. Four of the incidents of overtopping occurred at non-statutory reservoirs. There was one case where mining subsidence reduced the dam freeboard.

The main internal threat reported in 2007 and over the previous three years has been embankment stability. Five of the nine internal erosion incidents reported were associated with appurtenant works, for example drawoff culverts through the embankment.

Internal and external threats		**2007**	**2004-2006**
External	Inflow flood	8	3
	Mining	0	1
	Other	1	1
Internal	Embankment stability	4	6
	Appurtenant works stability	1	1
	Abutment stability	1	0
	Vegetation	0	1

Table 5. Summary of threats

Mechanism of deterioration	**2007**	**2004-2006**
Erosion by overtopping	5	3
Internal erosion through embankment	2	2
Internal erosion adjacent to appurtenant works	2	3
Pipework/culvert deterioration	0	1
Damage to safety critical structures	1	0
Pore water pressure increase mass movement	1	0
Settlement	0	1
Other	0	1

Table 6. Mechanisms of deterioration

2.3 Implications for reservoir safety

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

- Despite extensive guidance on flood estimation and spillways design, inflow floods due to severe rainfall accounted for a significant proportion of the reported incidents at all reservoirs.
- At Ulley and Boltby reservoirs, the spillways were not adequate to contain the flood without causing serious damage to the dam, but the dam crests were not overtopped.
- A large number of overtopping incidents were reported in 2007 due to severe rainfall. However, the majority occurred at non-statutory reservoirs where spillways had not been designed to take large flood flows.
- Internal erosion incidents account for the majority of incidents on statutory reservoirs.
- At least 50% of internal erosion incidents are related to appurtenant works (for example draw-off tunnels).

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 will make it easier to highlight trends in the sort of incident arising.

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 are inadequately maintained.
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 are inadequately designed or 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

The database allows for more than one of the lesson types in Table 7 to be assigned to any particular incident where appropriate, but only the main lesson type is reported.

The lessons learned between 2004 and 2007 are shown in Figure 4 below

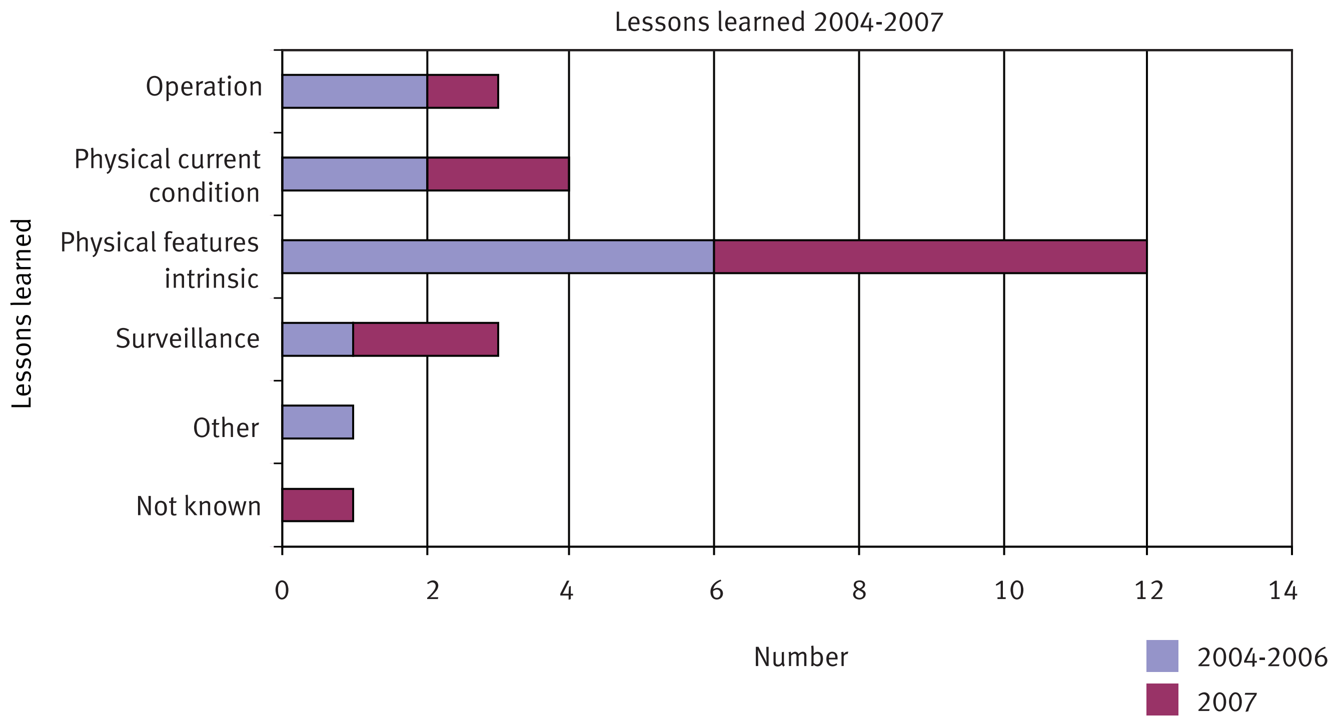


Figure 4. Lessons learned 2004-2007

3. Reported incidents 2004-2007

Incident 29

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	6
Incident type	Inflow flood, embankment overtopped, erosion
Incident severity	3

The embankment was overtopped following heavy rain leading to erosion of the downstream face and core. The reservoir was drawn down to reduce the risk of failure. As the reservoir was not registered under the Reservoirs Act 1975 there was no monitoring and supervision regime in place. Following the incident, the reservoir was registered under the Act as its capacity was found to be greater than 25,000m^3.

Lessons learned

If the reservoir had been registered previously, the safety provisions of the Act may have averted the incident.

Incident 30 Boltby*

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	20
Incident type	Inflow flood, failure of appurtenant structure
Incident severity	2

A large flood flow eroded part of the masonry spillway channel and then began to erode the earthfill embankment adjacent to the spillway. The water level was drawn down using the scour and draw-off valves as well as by pumping over the crest.

It is not clear what caused the structural damage to the spillway channel as the walls and channel bed were of good quality masonry with tight joints backed by concrete. Damage may have been caused by out-of-channel flow or by loss of masonry.

Lessons learned

It is important to consider the risk of flows exceeding the capacity of spillway channels and, where appropriate, to consider erosion protection works. There are similarities with incident 307 (Ulley) and it would seem appropriate to carry out research into the performance of masonry spillway channels.

Severe erosion damage to masonry channel and adjacent earth embankment

*N.B. Where the reservoir is named it is with the undertaker's consent and because the incident is well known and has been widely publicised.

Incident 31 — Carno Lower*

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	27
Incident type	Internal erosion adjacent to appurtenant works
Incident severity	2
Reference	ROWLAND A and POWELL A (2006). Leakage investigations at Lower Carno dam. Proceedings of 14th British Dam Society Conference, Durham, pp 144-153. Thomas Telford, London.

Leakage of very turbid water was noted in the toe drains. When the leakage rate increased rapidly an emergency drawdown was carried out. There was differential settlement of the crest due to internal erosion, which was largely confined to the core adjacent to the outlet culvert.

Lessons learned

The incident shows how important regular, effective surveillance is.

Incident 35

Dam type	Earthfill embankment
Reservoir legal status	Statutory non-impounding reservoir
Dam height (m)	13
Incident type	Internal erosion, leakage near top water level
Incident severity	2

Leakage at the toe of the dam was traced to the upper part of the core by a temperature probe survey. Trial pits found that the material at the top of the core was defective and low in places. The water level was lowered to reduce the leakage.

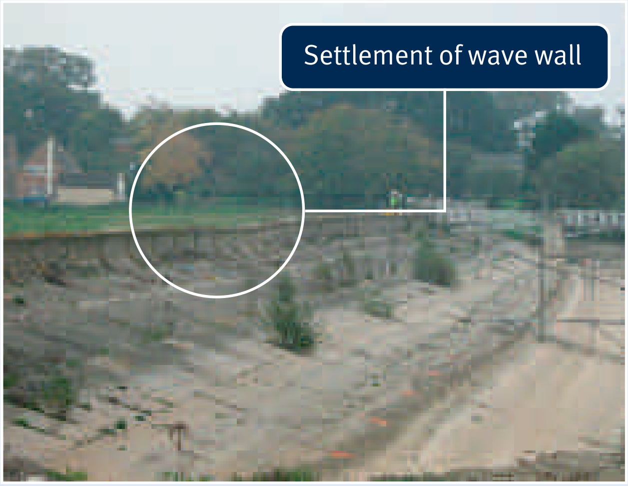
Lessons learned

This incident highlights the need to carry out surveillance more often when a reservoir is filled above the normal operating level.

Incident 301 Sutton Bingham*

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	15
Incident type	Rapid drawdown, upstream slope instability, crest settlement.
Incident severity	3

Settlement monitoring of the dam crest highlighted that movement had accelerated at three points. A deep seated slip in the upstream shoulder is thought to have been caused by operational drawdown of the reservoir in the summer and high pore water pressure within the upstream shoulder of the embankment.



Lessons learned

This incident shows 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.

Incident 302

Dam type	Earthfill embankment
Reservoir legal status	Non-statutory impounding reservoir
Dam height (m)	3.5
Incident type	Breached due to overtopping
Incident severity	1

This dam failed due to flood inflow. The dam was overtopped causing erosion of the downstream shoulder and eventual breaching of the dam. The embankment was inadequately designed, as it was constructed of an uncontrolled mixed fill material, which contributed to the failure. The spillway provision was also inadequate.

Lessons learned

Embankments and spillways need to be designed and built to appropriate standards.

Incident 303

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	11
Incident type	Internal erosion adjacent to appurtenant structure
Incident severity	3

Increased leakage from a point two-thirds down the downstream face, adjacent to a spillway structure, was noted. The water level was lowered as a precaution and the leakage stopped. Regular surveillance of the toe area had not been carried out. Leakage was attributed to poorly-sealed joints in the spillway structure.

Lessons learned

The incident highlights the need to carry out regular surveillance of any known points of seepage/leakage.

Incident 304

Dam type	Earthfill embankment
Reservoir legal status	Statutory non-impounding reservoir
Dam height (m)	17
Incident type	Internal erosion
Incident severity	3

Leakage through the reservoir's clay lining and the dam foundation was noted. The reservoir was drawn down with the help of supplementary pumps, and the leakage rate reduced to allow divers to plug the lining using bentonite pellets. The reservoir level was higher than it had been for some time.

Lessons learned

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.

Incident 305

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	4
Incident type	Internal erosion, possibly due to vegetation
Incident severity	3

The owner of the reservoir noticed leakage passing around the outlet structure at the toe of the embankment. The reservoir level was lowered by pumping water over the crest. Leakage through the masonry wall forming the upstream face of the dam and through the sides of the drop shaft on the line of the dam crest had been occurring for many years. Drilling was carried out vertically from the dam crest and from within the spillway drop shaft to fill voids and stem the leakage. The voids behind the drop shaft wall, possibly together with rotten tree roots within the embankment, probably contributed to the new seepage path developing between the drop shaft and the downstream toe.

Lessons learned

The incident underlines the value of addressing leakage problems as they arise. If the initial problem of leakage into the drop shaft had been rectified, the subsequent more serious leakage path may not have developed.

Incident 306

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	2
Incident type	Instability of a section of reservoir rim
Incident severity	1

A length of the reservoir rim, which may have been original ground or a constructed section, failed, allowing water to escape. High reservoir levels created high uplift pressures between the rock and the overlying peat which, when combined with the higher than normal hydrostatic pressures, resulted in a section of reservoir rim sliding away from the reservoir allowing water to escape. The rim was repaired successfully using large sandbags, a sheet of bituthene and peat fill.

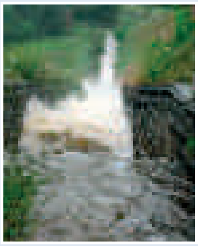
Lessons learned

The incident underlines the need for good records of dam construction details and the importance of regular surveillance, especially when the reservoir levels are unusually high.

Incident 307 Ulley*

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	14
Incident type	Inflow flood, damage to a masonry spillway
Incident severity	2

The dam had a masonry spillway channel at the toe of the embankment. Following heavy rainfall, a large volume of water flowed down the spillway channel. It is believed that turbulent water overtopped the spillway walls and also plucked masonry blocks out of the wall. This led to the spillway walls collapsing, which exposed the downstream face of the dam to erosion. As a result of existing fluvial flooding and the threat from the reservoir, many people living downstream were evacuated and major roads, such as the M1, were closed. The Fire Service used their high volume pumps to draw down the reservoir and temporary repairs were made. Refer to Bulletin No.1 for more details.



Lessons learned

This incident highlights the need to more carefully observe and inspect masonry walls for vegetation and missing pointing. It also demonstrates out-of-channel flow should not be allowed to occur where it could damage the structure of the dam.

Incidents 308 and 309

Dam type	Earthfill embankment
Reservoir legal status	Statutory non-impounding reservoirs
Dam height (m)	4 and 5
Incident type	Inflow flood, damage due to overtopping
Incident severity	2 and 3

In one case, a flood storage reservoir overtopped because its capacity was exceeded. In the other, a river overtopped the defences surrounding it and water flowed into the adjacent flood storage reservoir. In both cases, the embankments had been raised with steel sheet piles. When the water overtopped the sheet piles it dropped vertically onto the earth embankment below causing erosion.

Lessons learned

This highlights the need for careful detailing of dam crest raising works to consider the effects of extreme flood events. Using sheet piles to raise an embankment, which may be subject to overtopping, should be carefully considered and avoided if possible.

Incident 310

Dam type	Weirs on a canalised section of river
Reservoir legal status	Non-statutory
Dam height (m)	Low weirs
Incident type	Inflow flood, internal erosion, abutment stability
Incident severity	3

A series of weirs, already in a poor condition, were damaged during a flood event. One weir in particular, about 1.5m high and impounding about 12,000m^3, came close to breaching due to erosion around an abutment. It was not possible to access the sluice gate to lower the water level until the flood subsided.

Lessons learned

The incident highlights that even small dams can pose a significant threat and need to be properly inspected and maintained.

Incident 311

Dam type	Earthfill embankment
Reservoir legal status	Statutory non-impounding reservoir
Dam height (m)	20
Incident type	Instability of appurtenant works (drawoff tunnel)
Incident severity	3

Significant water leakage was noted in the road adjacent to the dam toe. This was due to leakage from a wet tunnel under the dam, and the reservoir water level was lowered as a precaution. The owner is still assessing the exact cause of the problem with the tunnel.

Lessons learned

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.

Incident 312

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	3
Incident type	Leakage associated with appurtenant structure
Incident severity	3

Leakage arose through the embankment adjacent to the spillway structure. Seepage had been apparent for some time before steadily increasing.

Lessons learned

Keep known points of seepage under regular surveillance so that changes are observed early.

Incident 313

Dam type	Earthfill embankment
Reservoir legal status	Non-statutory impounding reservoir
Dam height (m)	4
Incident type	Inflow flood, damage due to overtopping
Incident severity	3

This reservoir had a poor level maintenance. Settlement had caused a ‘low spot on the crest which was overtopped during a flood event, causing damage to the downstream shoulder. There was no surveillance in place. The seepage rate from the toe of the damaged section steadily increased in the months following the overtopping event.

Lessons learned

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.

Incident 315

Dam type	River bank spillway spilling into a statutory flood storage reservoir
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	7
Incident type	Instability of reservoir inlet structure
Incident severity	3

Water passed through natural material, which was supposed to be used as a spillway section for inflow to an off-line flood storage reservoir. The ground was more permeable than had been assumed in the design and the downstream slope was steeper than designed. Part of the storage area side of the embankment failed and slumped into the storage area.

Lessons learned

Established vegetation prevented the slope from being inspected, which could have shown signs of the onset of failure before the incident arose. The incident underlines the need for good ground investigation and site management when developing reservoir works.

Incident 316

Dam type	Earthfill embankment
Reservoir legal status	Non-statutory impounding reservoir
Dam height (m)	5
Incident type	Groundwater inflow, overtopping damage
Incident severity	2

The flood inflow to the reservoir was significantly increased by groundwater issuing from a chalk escarpment. The inflow exceeded the capacity of the spillway and caused the embankment to overtop. Following the overtopping event, flow was observed leaking from the toe of the embankment. Remedial works to the toe, comprising a toe weight and geotextile filter, were carried out. The cause of the seepage is unclear but may have been linked with animal burrows.

Lessons learned

The main lesson from this incident is that reservoirs in catchments of groundwater dominated hydrology must adequately cater for the significant groundwater response that might arise following severe rainfall.

Incident 317

Dam type	Earthfill embankment
Reservoir legal status	Statutory non-impounding reservoir
Dam height (m)	9
Incident type	Mining, settlement
Incident severity	3

Subsidence following mining led to a reduction in freeboard to below the minimum required and the reservoir was drawn down. Although the undertaker was aware of the mining work, the subsidence proved to be worse than expected.

Lessons learned

This highlights the importance of being vigilant if mining activity is taking place near a dam.

Incident 321

Dam type	Earthfill embankment
Reservoir legal status	Non-statutory impounding reservoir
Dam height (m)	5
Incident type	Inflow flood, embankment almost overtopped
Incident severity	2

The reservoir was discontinued under the Reservoirs Act 1975, but not provided with adequate spillway capacity. Following heavy rainfall, the dam embankment was almost overtopped and evacuation of downstream houses was considered. An inspecting engineer was called to the reservoir, but he initially failed to reach the reservoir due to highway flooding.

Lessons learned

The incident highlights the need for panel engineers to only certify a reservoir as discontinued if its safety provisions meet current best practice.

Incident 322

Dam type	Earthfill embankment
Reservoir legal status	Non-statutory impounding reservoir
Dam height (m)	5
Incident type	Inflow flood, damage due to overtopping
Incident severity	2

The new owner of this reservoir was unaware of the inadequate spillway capacity and bottom outlet (drawdown) capacity. The dam was overtopped in a flood event, causing damage to the downstream shoulder and the mill house.

Lessons learned

The incident shows the need for owners of non-statutory reservoirs to be aware of reservoir safety guidance.

Damage to a mill house following the overtopping of a dam

Incident 323

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	9
Incident type	Possible internal erosion
Incident severity	3

A wet area downstream of the dam had been attributed to groundwater but more recent increases in the water flow led to the belief that the reservoir was the likely source of the water.

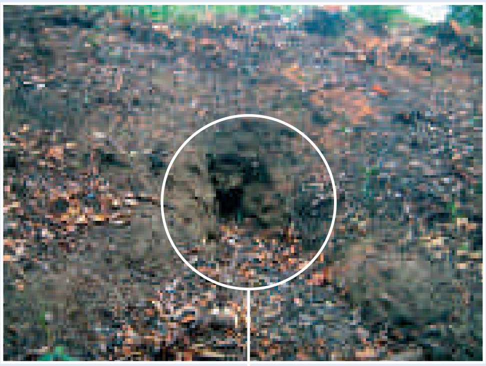
Lessons learned

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. Seepage records would have helped in assessing this incident.

Incident 324

Dam type	Earthfill embankment
Reservoir legal status	Statutory impounding reservoir
Dam height (m)	3
Incident type	Internal erosion
Incident severity	3

An erosion hole was found at the toe of the dam after vegetation was cleared. During a wet spell a panel engineer visited the dam and found that the hole had become bigger, was still visibly growing and was passing a clear flow of about 0.5l/s. As wet weather was forecast for the next few days, a precautionary drawdown of the reservoir was recommended by fully opening the bottom outlet until flow in the hole ceased. However, the bottom outlet was not fully opened due to concerns over pollution.



Erosion hole at toe of dam

Lessons learned

Make sure that vegetation does not prevent thorough inspection of the dam.

4. 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.

5. 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 incident at Ulley in June 2007, 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.

6. 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.

7. Completeness of reporting

We want to know how many incidents are being reported under the current voluntary system. Over time, this will help us to estimate just how frequently various types of incidents occur. Clearly, we do not know exactly how many reportable reservoir safety incidents have occurred over the last year, but we do occasionally learn of incidents that were not reported using the system. Also, there are a number of incidents we are aware of but we have been unable to obtain a completed post-incident report form from the owner. We only have limited information on such incidents.

8. The future

We are currently proposing a number of changes to the Reservoirs Act 1975. One of the changes we would like to see is the introduction of mandatory post-incident reporting. We are consulting with the reservoir industry on the changes to the Act, and we are working closely with Defra and the Welsh Assembly Government as part of this process.

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 during the first year of post-incident reporting and in producing this annual report. We would also like to thank Andrew Charles and Paul Tedd of the Building Research Establishment for reviewing this report.

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 adjacent 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

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Bulletin No 1

Environment Agency

Improving reservoir safety, sharing lessons learnt

This bulletin highlights reservoir safety issues that have arisen and defines actions to be taken

Vulnerability of masonry spillways

What happened?

Following extremely heavy rainfall severe flood damage has occurred to masonry walls and inverts of stepped spillway chutes on Victorian dams. This happened at Ulley on 25 June 2007, Boltby on 19 June 2005 and at several other reservoirs.

What caused it?

High velocities and extremely turbulent flows can generate forces many times greater than the weight of the masonry stones.

If these masonry stones, known as 'Ashlar blocks', are not properly secured and the joints adequately maintained, they can be plucked out. This removes the protection to the bed and walls of the chute, which can lead to significant erosion and could ultimately undermine the dam.

If the capacity of the masonry channel is exceeded, flood water can overtop the wall and flow into and erode the fill behind the wall. This can cause the wall and/or the base slab to fail.

What are the issues?

All masonry walls and base slabs need to be checked to make sure that the bedding between the blocks is sound, and all vegetation needs to be removed so that the blocks cannot be plucked out.

The capacity of the channel needs to be checked to make sure that there is no out-of-channel flow or that it only happens where works have been put in place to protect the dam or adjacent fill. The conditions when the maximum flow rate occurs need to be checked to make sure that the velocities and pressure fluctuations within the channel do not pluck out the stone blockwork.

What happened?

Aerial view of Ulley during incident

Severe erosion damage to masonry chutes and adjacent earth embankment

Stones plucked from spillway wall

Improving reservoir safety by learning from experience

Who needs to do what?

Reservoir undertakers should:

- carry out frequent checks to look for signs of deterioration and distress in the walls and floor of their spillways;
- contact their supervising engineer if they have any concerns;
- make sure that all blockwork is properly maintained.

Supervising engineers should:

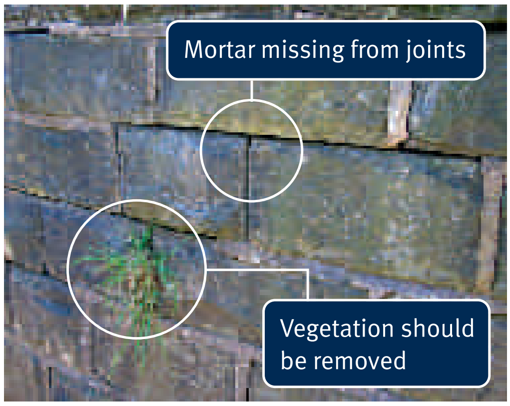
- consider any possible ways ashlar block spillway chutes could fail when they visit the reservoir;
- advise undertakers about maintenance such as removing vegetation and re-pointing blocks;
- make sure that where blocks deteriorate or are removed they are replaced quickly.

Inspecting engineers should:

- look at how the spillway system performs under the design flood flow conditions by making sure that the spillway system can cope with the velocities and pressure fluctuations;
- consider the effects of channel geometry on the potential for cross-wave formation and the potential effects of super-elevated flows and bulking;
- make sure that where out of channel flow could happen, this would not cause erosion that could lead to loss of the channel or damage to the dam.

What happens next?

In their review of the Ulley dam incident, Jonathan Hinks and Peter Mason (both All Reservoir Panel Engineers) recommended to the Reservoir Safety Advisory Group that research should be carried out into the effect of hydrodynamic forces on masonry spillway chutes. This will lead to further technical guidance for panel engineers.



Typical Ashlar block wall

High velocity flows exceeding channel capacity

Produced in conjunction with Halcrow Group Ltd

Post-incident reporting

Ian Hope
Technical Manager
Reservoir Safety
Environment Agency
Manley House, Kestrel Way
Exeter
Devon EX2 7LQ

Tel: 01392 442001 Mobile: 07768 276837

email: ian.hope@environment-agency.gov.uk
www.environment-agency.gov.uk/reservoirsafety

General information

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**

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

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