Environment Agency

Post-incident reporting for reservoirs

Annual report 2012

We are the Environment Agency. We protect and improve the environment and make it **a better place** for people and wildlife.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

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Foreword

2012 was a very wet year, being the wettest in England since records began We had 18 reported incidents, the highest number reported in any one year since we started recording them in 2007.

We publish this report so that all those involved in reservoir safety learn from these incidents. By sharing experience we aim to improve safety in the future. Please continue to help by reporting all incidents no matter how small or insignificant they may appear.

I would like to thank all of those within the reservoir industry who have contributed to and support the post-incident reporting system.

Antony Deakin - Reservoir Safety Manager

Contents

1 Introduction

In 2007 Defra asked us to collect information on incidents at all reservoirs in the United Kingdom. We collect and record information on incidents at raised reservoirs, both large and small. Large raised reservoirs are those covered by the Reservoirs Act 1975.

We use the information that we are sent to:

- Investigate incidents (where appropriate)
- Inform the reservoir industry of any trends and key lessons identified
- Contribute to research into reservoir safety and incident frequency analysis

The information we are sent is used to improve reservoir safety. We will not use any of the information, acquired through this voluntary scheme, to initiate enforcement action under the Reservoirs Act 1975.

Any requests we receive for information we have gathered, relating to reservoir incidents, are considered under the Freedom of Information Act 2000, Environmental Information Regulations 2004 and the Data Protection Act 1998.

2 Analysis of reported incidents

Incidents we consider reportable are entered on to our database. We assign each incident with an incident level. The table below shows definitions for the three severity levels we can assign.

Incident severity level	Definition
1 (most severe)	Failure (uncontrolled sudden large release of retained water)
2	Serious incident involving any of the following: • Emergency drawdown • Emergency works • Serious operational failure in an emergency
3	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

2.1 Severity and number of reported incidents in 2012

We had 20 incidents reported to us in 2012. Of these, 18 incidents happened in 2012, one in 2011 and one in 2010. This is the largest number of incidents reported to us since we started recording them in 2007.

Many of the incidents were associated with the unusual weather conditions that we experienced last year, starting with drought and ending with flooding. Many of the incidents occurred at reservoirs not covered by the Reservoirs Act 1975. This could be because small reservoir owners do not have to appoint qualified engineers so the dams are not routinely inspected.

You can see the number and severity of incidents that have been reported to us between 2004 and 2012 in the tables below. We have only included incidents where we have enough information to be able to assign an incident level. The 2004-2011 figures includes an incident at a river which was reported in our 2010 report but omitted from our 2011 report.

	2012	2004-2011
Total number of incidents	18	52
Incidents at large raised reservoirs	9	36
Incidents at small raised reservoirs	9	16

Table 2.1 Number of incidents reported between 2004 and 2012

Year	Level 1 incident	Level 2 incident	Level 3 incident	Total
2012	1	7	10	18
2004-2011	3	19	30	52

Table 2.2 Number of incidents showing severity level 2004-2012

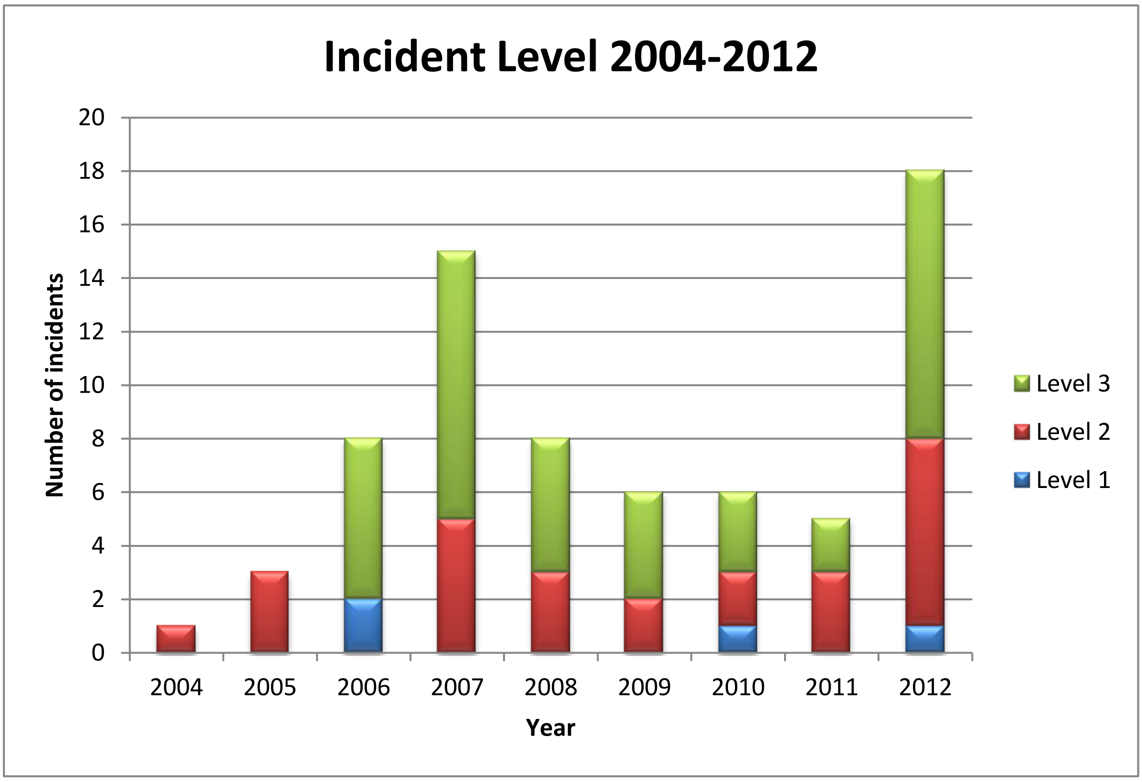

Figure 2.1 Incidents reported 2004-2012 showing severity level

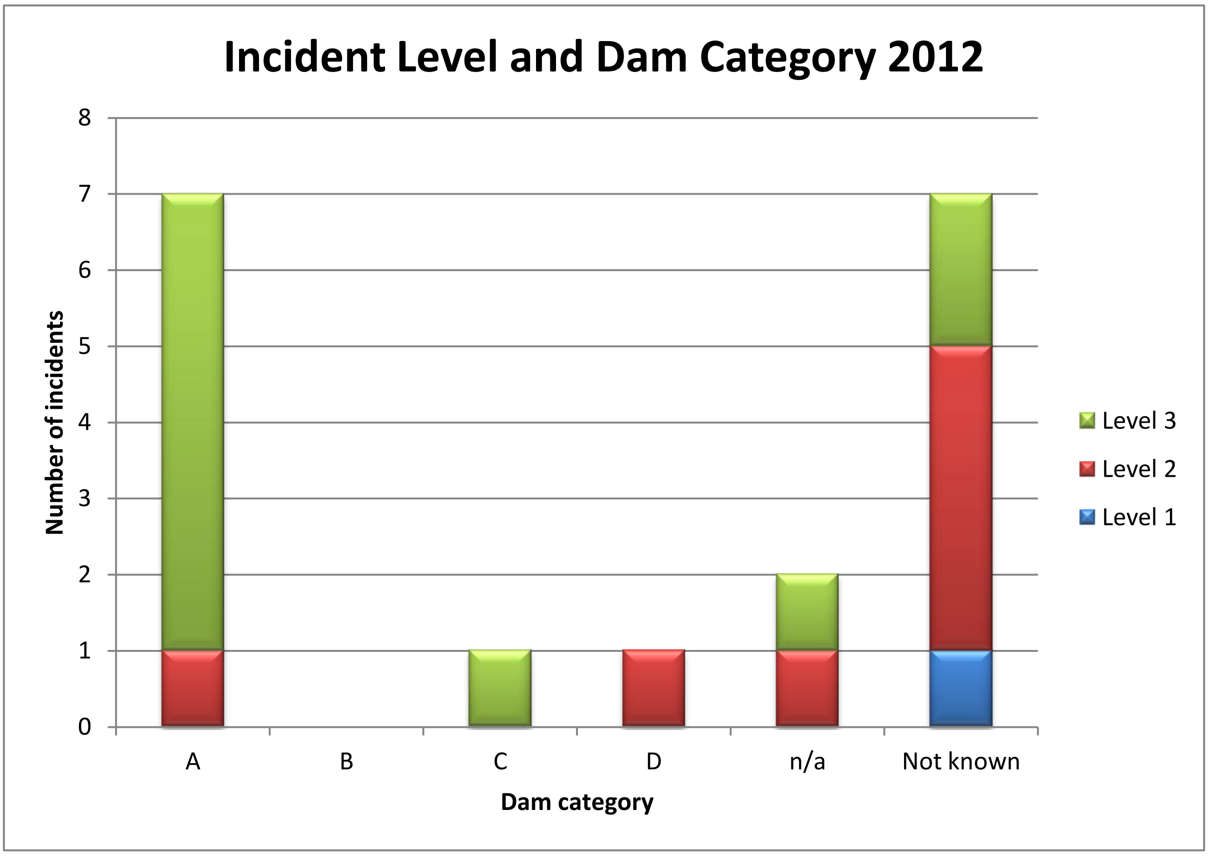

Figure 2.2 Incident level and dam category for 2012

Figure 2.2 shows incident severity level against dam category for 2012, while figure 2.3 shows the distribution of incidents against dam category between 2004 and 2012. You can find the definitions of each of the dam categories in Appendix B.

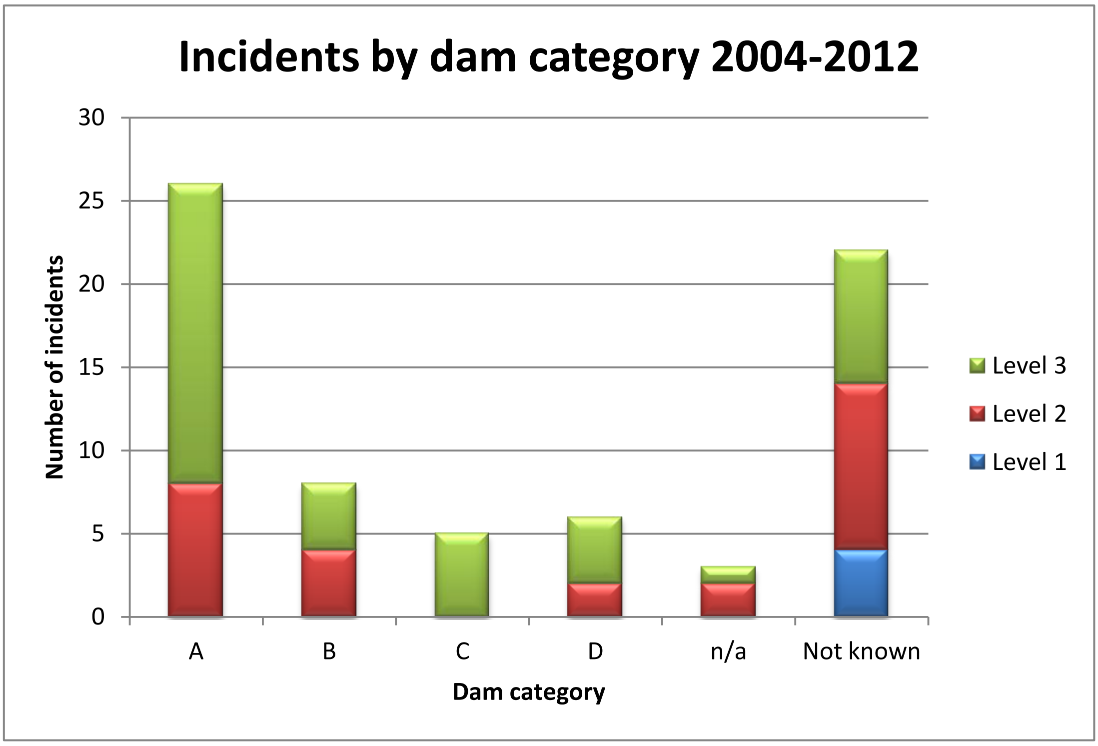

Figure 2.3 Distribution of incidents by dam category 2004-2012

2.2 Threats and mechanisms of deterioration

Tables 2.3 and 2.4 below show a summary of the incidents reported to us in 2012, including some characteristics of the dams.

Incident No	Incident Date	Incident Severity	Date Built	Dam Height (m)	Dam Capacity (m³)	Dam Category	External Threat	Internal Threat	Mechanism of Deterioration
375	Oct 2011	3	Approx 1800	6	115,000	D	n/a	Material deterioration	Pipework/culvert deterioration
358	May 2012	2	1751	4	80,000	D	n/a	Material deterioration	Pipework/culvert deterioration
359	July 2012	3	1901	18	191,000	A	n/a	Embankment stability	Internal erosion
366	July 2012	3	2002	5	135,000	A	Inflow flood	n/a	Erosion by overtopping
369	July 2012	3	1907	30.5	4,580,000	A	n/a	Material deterioration corrosion	Deterioration of structures
370	Aug 2012	3	1894	10	43,750	n/a	n/a	Embankment stability	Internal erosion
371	Sept 2012	2	1950	4	1,960,000	A	Animals	n/a	Damage to safety critical structures/equipment
373	Oct 2012	3	1879	9	70,463	A	n/a	Embankment stability	Internal erosion
376	Nov 2012	3	1980	4	400,000	C	n/a	Foundation stability	Internal erosion

377	Nov 2012	3	1999	8	47,200	A	n/a	Embankment stability	Deterioration of fill material

Table 2.3 Summary of reported incidents at reservoirs under the Reservoirs Act 1975

Incident No	Incident Date	Incident Severity	Date Built	Dam Height (m)	Dam Capacity (m³)	Dam Category	External Threat	Internal Threat	Mechanism of Deterioration
365	Feb 2010	2	Not known	Not known	Not known	Not known	n/a	Foundation stability	Deterioration of foundation
357	Jan 2012	2	Not known	Not known	15,000-20,000	Not known	n/a	Embankment stability	Internal erosion adjacent to appurtenant works
380	Feb 2012	2	Circa 1850	3.5-5	Approx 15,000	Not known	n/a	Embankment stability	Not known
364	May 2012	3	Not known	1.7	Approx 3,700	Not known	n/a	Vegetation	Internal erosion
361	June 2012	2	19th Century	Approx 9	Approx 14,600	Not known	Inflow flood	n/a	Erosion by overtopping
362	July 2012	3	Circa 1800	7.5	3,500	A	Inflow flood	n/a	Erosion by overtopping
363	July 2012	2	Not known	Approx 1.5	Approx 17,000	Not known	Inflow flood	n/a	Erosion by overtopping
386	July 2012	1	Not known	Approx 1.5	Approx 17,000	Not known	Inflow flood	n/a	Not known
367	July 2012	2	19th Century	15	Canal	Not applicable	n/a	Appurtenant works	Pipework/culvert deterioration

								stability	
368	July 2012	3	Not known	Not known	Not known	Not known	Inflow flood	n/a	Erosion by overtopping

Table 2.4 Summary of reported incidents at reservoirs not under the Reservoirs Act 1975

In each case we analyse each of the reported incidents and determine the threat to the dam. We also analyse the likely mechanisms of deterioration resulting from each of the threats.

Threats to dams can be broadly divide into internal and external threats.

Internal threats are:

- 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)

External threats are:

- Inflow - flood
- Inflow - direct rainfall
- Inflow - failure of an upstream reservoir
- Seismic event
- Snow/ice
- Aircraft strike
- Vandalism
- Wind (wave generation) and Wind (tree damage)
- Human error, Animals and Mining

A summary of the threats and mechanisms of deterioration for each of the incidents reported can be seen in tables 2.5 and 2.6 below. We have shown the incidents reported in 2012 separately to 2004-2011 to show if there are any trends.

External threats	**2012**	**2004-2011**
Inflow flood	7	16
Inflow direct rainfall	0	0
Mining	0	1
Wind, trees	0	1
Animals	1	1
Vandalism	0	1
Human error	0	2
Other	0	3

Table 2.5 Summary of external threats

Internal threats	**2012**	**2004-2011**
Internal - embankment stability	6	19
Appurtenant works stability	1	3
Abutment stability	0	1
Foundation stability	1	1
Material deterioration	2	1
Vegetation	1	2

Table 2.6 Summary of internal threats

Mechanism of deterioration	2012	2004-2011
Erosion by overtopping	6	15
Internal erosion through embankment	5	8
Internal erosion adjacent to appurtenant works	1	5
Internal erosion - other	0	5
Pipework/culvert deterioration	2	3
Deterioration of foundation	0	2
Deterioration of gates/valves/equipment	0	1
Damage to safety critical structures	1	1
Structure deterioration	1	0
Increased porewater pressure leading to mass movement	0	1
Settlement	0	2
Wind damage - trees	0	1
Fill deterioration	1	0
Other	0	3
Not known	1	3

Table 2.7 Mechanisms of deterioration

2.3 Types of lessons identified

We ask undertakers and engineers reporting incidents to identify any lessons they think can be learnt from the events that have taken place. We can carry out further investigations and research into these. We have commissioned further in-depth studies into three reservoir incidents that took place in 2012.

When we record incidents on our database we can classify the types of lessons that can be learnt from each incident. Table 2.8 and figure 2.4 show the five categories of lessons identified.

Type	Examples	Possible implications
Surveillance	Inadequate surveillance or processing of instrument observations	Reservoirs require more, or better, monitoring and surveillance
Operation	Malfunction or misuse 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, weather, corrosion, vandalism, poor maintenance etc.	Reservoir components require better or 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 2.8 Types of lessons that can be identified

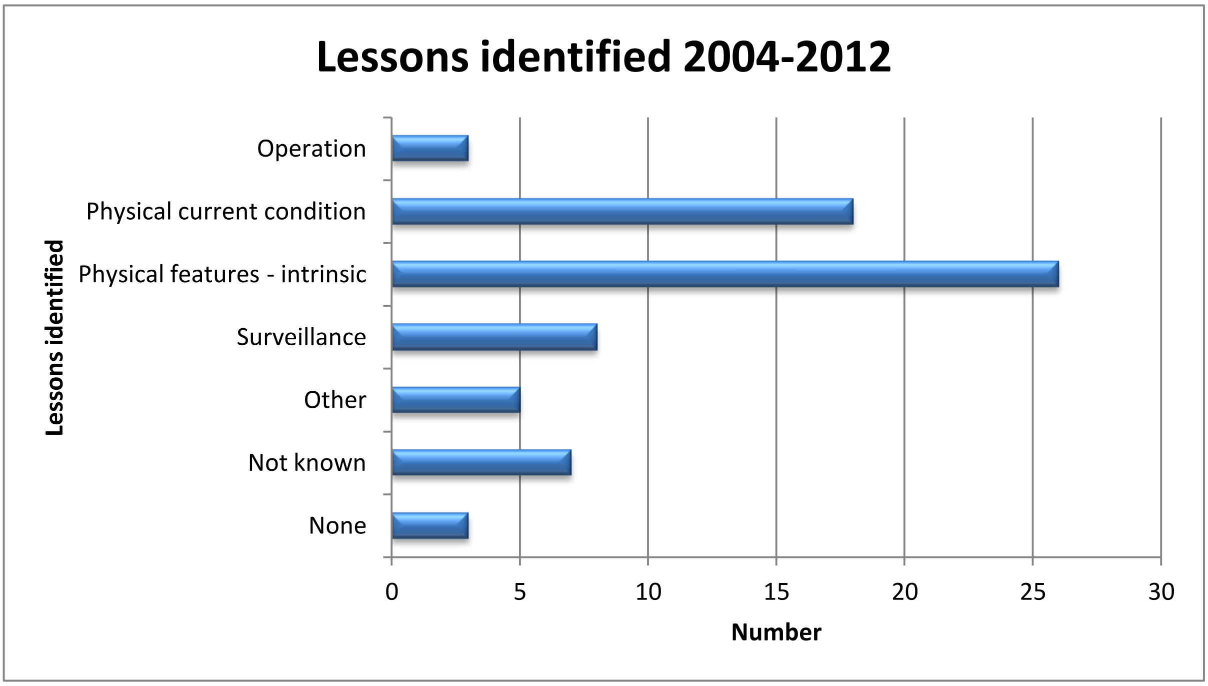

Figure 2.4 Lessons identified 2004-2012

3 Incidents reported in 2012

We had 20 incidents reported to us in 2012. Of these, 18 incidents happened in 2012, one in 2011 and one in 2010. Most of these incidents happened during or shortly after the heavy rain that we experienced.

Incident 365 (2010)	
Dam type	Non-impounding
Reservoir legal status	Reservoir not under the Act
Dam height (m)	Not known
Incident type	Foundation stability
Incident severity	2

This incident happened in 2010, we have only recently received the post-incident report because the undertaker carried out an in-depth analysis of the event.

In 2008 the undertaker found a hole in the ground beside the reservoir. The hole was filled in, but re-appeared in 2010 causing subsidence beside the reservoir. This caused some 20 metres of the reservoir embankment to slide down and partially fill a void that had formed under the reservoir. It appears that the subsidence may have been caused by a buried water main failing in the area.

The undertaker drained the two pairs of reservoirs in the immediate area. The undertaker carried out a geophysical investigation which showed that the affected reservoir was unusable and in need of major repairs or replacement. Another local reservoir was in need of ground stabilisation work to secure its foundation. It was likely that the subsidence was caused by the collapse of ground into former chalk mines although natural geological processes may have been a factor in the incident.

The undertaker has since undertaken geotechnical risk assessments for all its reservoirs. Relevant mitigation and monitoring measures have been put in place.

Lessons learned
Reservoir operators should consider geophysical hazards that may lead to deterioration in the foundation support to reservoir structures. Collapse features due to mining activities or natural processes such as the dissolution of chalk or limestone can impact the safety and operational performance of reservoir structures.

Incident 375 (2011)	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	6
Incident type	Pipework & culvert deterioration
Incident severity	3

The supervising engineer noticed a 1.5m diameter sinkhole on the downstream face of a small embankment dam on the line of an old timber overflow conduit. The undertaker had been advised to fix the conduit five years before the incident, but had not carried out the work. The soffit of the conduit had failed causing a loss of support to the fill above the damaged area. Works were carried out to replace the conduit.

Lessons learned
This incident highlights the problems inherent with old timber conduits through embankments. It also illustrates the need to carry out statutory recommendations as soon as practicable.

Incident 357	
Dam type	Impounding
Reservoir legal status	Reservoir not under the Act
Dam height (m)	Not known
Incident type	Internal erosion adjacent to appurtenant works
Incident severity	2

The undertaker found a depression on the downstream face of the dam next to the masonry side wall of the overflow spillway.

Figure 3.1 Sink hole beside the spillway wall (Photo courtesy of Wessex Water)

The reservoir water level was reduced by opening a scour pipe and using a mobile pump. Further, hand-dug, investigations found that water had been leaking through the masonry wall then passing along the outside of the spillway channel sidewall between the masonry and a slurry trench cutoff. The slurry trench had been installed to try to fix a previous leak. The undertaker found that the trench had been widened at the masonry wall interface, but this had not stopped the erosion.

Figure 3.2 Trial hole to investigate the source of the leak (Photo courtesy of Wessex Water)

The reservoir was repaired by building a mass concrete plug to improve the seal between the masonry wall and the slurry trench cutoff. The repair worked and the reservoir has been returned to normal operation.

Lessons learned
The internal erosion of the embankment fill material beside an overflow spillway channel wall may have started with water flowing through gaps within the masonry wall. This incident highlights that internal erosion beside spillways can happen when water leaks through walls that are not watertight. It is important to inspect walls beside spillways to make sure they are still watertight.

Incident 358	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	4
Incident type	Physical (current condition)
Incident severity	2

This incident happened at an old fishing reservoir. The dam structures include a low level draw-off culvert with a 'monk pipe' arrangement at the upstream end, which discharges into an original brick arched culvert through the embankment and a relatively modern concrete outlet pipe.

Members of the undertaker's staff noticed a sudden drop in the reservoir water level. On closer inspection water was seen flowing from the concrete pipe into the river downstream. Although the discharge was significant the flows remained within the river bank. The supervising engineer was called to the site by which time the reservoir had dropped 600mm in six hours.

The engineer found that a vortex had formed near the upstream toe on the line of the culvert. The vortex had eroded part of the embankment fill. A second vortex appeared later which suggested two leakage paths into the culvert. Rather than attempt to stop the leakage it was decided to allow the reservoir to empty through the leakage point. Later investigations found that the deterioration of a timber conduit linking the brick culvert to the monk pipe was causing the leak into the culvert. The outlet was plugged and abandoned and a replacement drawoff arrangement for the reservoir was provided.

Lessons learned
This lesson shows the importance of carrying out internal inspections of low level conduits. Where is it not possible to carry out such surveys (e.g. by CCTV) then consideration should be given to modifying the outlet arrangement to enable these inspections. In this incident it appears that the deterioration of a timber conduit was responsible for the escape of water. New research for CIRIA on conduits through embankments is in progress in 2013.

Incident 359	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	18
Incident type	Internal erosion
Incident severity	3

A minor leak was found on the downstream face of the embankment, high up on the face. Drainage pipes were installed to measure the flow rate. A later geophysical survey confirmed that the leakage location appeared to be the plane of the previous crest raising works. The leakage path had developed over the course of 2012 when the reservoir water levels were higher than average. The scour outlet was opened to lower the reservoir level and this reduced the leakage flow rate. The grass cutting regime had not been maintained and the long grass hampered the effectiveness of the surveillance in identifying the leak.

Lessons learned
When clay cores are raised it can be difficult to achieve a joint with the original core material that remains watertight. This incident serves as a reminder that care is needed in designing and constructing dam raising works. Where dams have been raised, the frequency of surveillance should be increased when reservoir water levels are unusually high. The seepage might have been noticed earlier had the grass been kept cut.

Incident 361	
Dam type	Impounding
Reservoir legal status	Reservoir not under the Act
Dam height (m)	Approximately 9
Incident type	Erosion by overtopping
Incident severity	2

Figure 3.3 General view of the reservoir (Photo courtesy of Alan Warren)

A disused industrial reservoir formed by a rockfill dam had been left in the drained down condition but without any formal overflow spillway. Heavy rain within the small upland catchment area caused a landslide which entered the reservoir.

Figure 3.4 Landslide upstream of the dam (Photo courtesy of Alan Warren)

The silt blocked the low-level drawoff, causing the reservoir to fill. Floodwater then overtopped the dam crest, causing erosion at the top of the downstream face. The owner contacted the emergency services and the downstream village was evacuated. It was not possible to bring the fire service pumps to the site to reduce the water level. An emergency spillway channel was excavated at an abutment to draw the reservoir level down, and the damage to the dam was repaired. The downstream community was allowed to return to their homes later in the day when reservoir levels had been reduced.

The evidence for the debris flow came to light following a formal investigation of this incident on behalf of the Environment Agency.

Figure 3.5 Channel damage downstream of the landslide (Photo courtesy of Alan Warren)

Lessons learned
This incident shows that small, disused reservoirs can still pose a risk to the local community. This non-statutory reservoir was not on any historical list and, as it was normally empty, was not recognised as a reservoir by the owner. No maintenance had been carried out to keep the dam safe. The main lesson learned is that impounding reservoirs must be provided with appropriate overflow facilities to cater for flood events and protect the dam from being damaged or washed away. The incident is unusual in that landslide-induced debris slide blocked the drawoff pipe and contributed to the impact of the flood damage. Engineers involved in designing, operating or supervising small upland impounding reservoirs should consider the risks associated with landslides. Specific guidance on managing reservoir safety risk from the threat from debris flows is not currently available.

Incident 362	
Dam type	Impounding
Reservoir legal status	Reservoirs not under the Act
Dam height (m)	8 and 7.5
Incident type	Erosion by overtopping
Incident severity	3

A cascade of two small reservoirs once served to supply water to a woollen mill. The mill has now been converted to offices. The reservoirs sit in a steep valley above a community and are owned by the local authority. The reservoirs are too small to come under the Reservoirs Act 1975. The upper reservoir was still in use, but had filled with silt.

Figure 3.6 View of the upper reservoir (Photo courtesy of Alan Warren)

The lower reservoir had been drained down. The dam embankment forming the lower reservoir features a road and terraced housing on the dam crest. There is no spillway provision for the lower reservoir.

During the summer of 2012, a cloudburst occurred over the small steep catchment serving the reservoirs. The intensity of the storm and the debris being transported with the floodwater caused minor damage to the spillway structures on the upper reservoir.

Figure 3.7 Upper reservoir spillway showing damage to the wall (Photo courtesy of Alan Warren)

Figure 3.8 Damage to the overshot channel of the upper reservoir (Photo courtesy of Alan Warren)

Figure 3.9 Damage to the upper reservoir stilling basin (Photo courtesy of Alan Warren)

At the lower reservoir the debris choked the low-level drawoff pipe causing the reservoir to fill with water. With no spillway facility to safely take the flood water away from the reservoir, the floodwater spilled over the left abutment area flooding a main road and a row of terrace houses. The owner is now addressing the concerns and preparing an emergency plan for the reservoirs.

Lessons learned
This incident shows that small, disused reservoirs may not be recognised as reservoirs by the local community. It is important to know where former reservoirs are and to make sure that they are incapable of holding water or that they can safely pass any flood water.

Incidents 363 and 386	
Dam type	Cascade of impounding reservoirs
Reservoir legal status	Reservoirs not under the Act
Dam height (m)	Various
Incident type	363 - Dam 2 of 6: Erosion by overtopping 386 - Dam 6 of 6: Culvert failed and dam breached
Incident severity	363 - 2 386 - 1

This incident happened during a flood at a cascade of six non-statutory reservoirs. Two of the six dams were damaged. The bottom dam (Dam 6) was breached, apparently due to a failed culvert through the dam. The second dam in the cascade (Dam 2) was damaged by floodwater overtopping the crest. A panel engineer was called to inspect all six dams and emergency works carried out to repair and improve the damaged dams under his supervision.

Lessons learned
These two incidents arose as a result of a flood which exposed weaknesses in two of the cascade of six dams. The lowermost dam failed and the second dam in the cascade was badly damaged. Had this dam failed, there may have been a cascade failure. This type of incident highlights that even small reservoirs can pose a significant risk when arranged in cascade.

Incident 364	
Dam type	Impounding
Reservoir legal status	Reservoir not under the Act
Dam height (m)	2
Incident type	Vegetation
Incident severity	3

A leak was reported by a panel engineer who was visiting the site to make a general assessment of the reservoir. The engineer visited when the reservoir was in flood and the leak was found at the toe of the embankment. On closer inspection, a tree root was found in the hole that the water was flowing through. It is likely that the seepage was caused by piping erosion along the line of the tree root close to the base of the embankment.

The local authority cleared debris from the overflow to reduce pressure on the leakage path. The situation was monitored but the erosion stopped. The owner was contacted and advised to make repairs.

Lessons learned
This incident shows how important it is to make sure that all reservoirs are properly maintained even if they are too small to come under the Reservoirs Act 1975. Under certain conditions, internal erosion can happen even at small embankments under modest seepage pressures.

Incident 366	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	6
Incident type	Erosion by overtopping
Incident severity	3

This incident happened at a flood storage reservoir. These reservoirs are normally kept empty, but fill during floods.

The spillway section of this reservoir featured gabion baskets to protect the core from an overtopping event and with fill placed over the gabion baskets. The downstream slope was designed to be replaced, as necessary, when the spillway section operated. This design was chosen to meet the owner's aims to preserve trees in the area for ecological reasons. This meant that the slope was relatively steep and prone to erosion. The grass on the slope was infrequently mown to encourage wildflowers. Following intense rainfall in the catchment, the spillway section of the dam embankment overtopped and some erosion occurred at the downstream toe.

Figure 3.10 Scour damage at the downstream toe (Photo courtesy of Richard Cox)

The steepness of the downstream slope and the poor condition of the grass cover is believed to have contributed to the extent of the damage. Further damage occurred to the dam face later in the year due, in part, to problems operating the gate. This second incident is still under investigation.

Lessons learned
This incident provides an important lesson for the planning and design of flood storage embankments. The design met the design brief but incorporating measures to protect the environment led to a spillway section design which was prone to damage and periodic repairs were necessary following floods. This incident also highlights the importance of maintaining good grass cover on the downstream face of the dam. The grass had been allowed to grow to preserve the wildflowers however this meant that the grass cover wasn't dense enough to resist the flow of water.

Incident 367	
Dam type	Canal embankment
Reservoir legal status	Reservoir not under the Act
Dam height (m)	Approx 15
Incident type	Surveillance
Incident severity	2

This abandoned 180-year old canal embankment had a masonry culvert to allow drainage of the natural catchment past the embankment. The culvert had not been inspected or maintained in a very long time. The culvert collapsed, causing an uncontrolled impoundment to form upstream of the embankment.

Figure 3.11 Impoundment against the canal embankment due to the collapse of the masonry culvert (Photo courtesy of David Harker)

The impoundment covered about eight hectares and had a maximum depth of 4m. The failure of the embankment would have put both people and the environment at risk, so the Environment Agency excavated a notch through the embankment whilst pumping flow from the impoundment over the crest. This work was overseen by a panel engineer. While the work was being done, an intense storm occurred over the catchment area, causing the reservoir area to re-fill to a depth of about 5.5m and to spill over the notch area. Additional pumps were brought to the site to empty the impoundment and the embankment continued to be excavated, keeping the notch wide and level to reduce the risk of a breach by flood overtopping. Evacuation of downstream residents was considered, but not carried out.

Lessons learned
This incident highlights the fact that abandoned culverted embankments can pose a flood risk to those downstream where the condition of the culvert is not being kept under surveillance.

Incident 368	
Dam type	Impounding
Reservoir legal status	Reservoir not under the Act
Dam height (m)	Not known
Incident type	Erosion by overtopping
Incident severity	3

During heavy rain in the summer, water was seen overtopping an earth dam. On closer inspection water was found to be overtopping the dam crest in two places. Although the grass covering the dam was being flattened there was no damage to the dam. If the overtopping had continued it is likely that the downstream face of the dam would have been seriously damaged.

Lessons learned
This incident shows the importance of making sure that all reservoirs are capable of resisting overtopping under flood conditions even if they are not subject to the Reservoirs Act 1975.

Incident 369	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	30.5
Incident type	Other
Incident severity	3

The reservoir had been overflowing the spillway crest when the reservoir keeper noticed two water spouts issuing from the face of the spillway channel. The flows stopped over the next three hours. The reservoir was subsequently visited by the supervising and inspecting engineers. The spillway channel is made of concrete with a masonry facing. It appears that water had become trapped in gaps between the concrete and the masonry. Such voids can cause progressive deterioration to the spillway channel, for example by ice. Remedial works are planned.

Lessons learned
Spillway channels made of concrete and masonry may be prone to deterioration over time due to processes which lead to voiding beneath the surface of the masonry. The incident also shows the value of visiting reservoirs following floods.

Incident 370	
Dam type	Non-impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	10
Incident type	Internal erosion
Incident severity	3

The embankment for this non-impounding reservoir is sealed by a clay core and features brick embedded in concrete on the inner face. A leak was found on the outer face of the embankment during a surveillance visit. The flow rate was estimated at 2 litres per minute. The reservoir inlet main was isolated and the reservoir level drawn down to reduce the leak.

A geophysical investigation is planned to attempt to identify the leakage pathway. Crest settlement surveys and regular surveillance visits to the reservoir are planned, to identify any further deterioration in the embankment condition.

Lessons learned
The leak was found through routine visual surveillance of the embankment and the incident shows the value of regular surveillance in guarding against internal erosion. It is not understood what factors caused the leak, but further investigations might give some insight.

Incident 371	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	4
Incident type	Animal activity
Incident severity	2

This incident happened at an old river defence embankment which joins a flood storage area. The embankment construction was of clay fill with a thick layer of topsoil on the crest. Leakage through the river bank posed a risk of the reservoir area filling suddenly, which could have caused a risk to the reservoir. The affected river section is tidal and following a period of sustained rain the river level rose close to the top of the river bank crest.

A member of the public found a leak through the lower part of the river bank and a sinkhole just below the crest. The owner place a polythene sheet on the river side of the section of bank affected and some sandbags on the outer slope. A panel engineer was called to the site.

Figure 3.12 Emergency works to stabilise the slope (Photo courtesy of John Falkingham Associates)

The emergency services were alerted and plans were put in place to evacuate parts of a nearby town. A number of animal holes were found under the area of the polythene sheeting and on the lower part of the outer slope from the leak.

Figure 3.12 Animal holes on the crest of the river defence embankment (Photo courtesy of John Falkingham Associates)

There was some indication that movement had taken place near the sinkhole. It was evident that the leaks had happened through the animal holes and that there had been some degree of erosion in the outer shoulder. A large number of 1-tonne sandbags were place on the lower section of the outer slope as an emergency repair.

The river water level receded and a permanent repair was carried out, by installing steel sheet piles and reconstructing the outer shoulder using clay fill. In carrying out this repair it was noted that the depth of the topsoil on the crest was up to 750mm thick, probably due to the river banks being raised in the past using dredged material. The thick layer of topsoil on the crest may have encouraged burrowing animals and meant that the upper part of the embankment wasn't watertight during periods of high river/tidal levels.

Lessons learned
This incident shows that river banks can be affected by crest raising works using dredged material and by the action of burrowing animals. Where such defences join a reservoir area, they can pose a threat to reservoir safety under certain conditions. This incident highlights the need to investigate the capability of river embankments to withstand high water levels, and to monitor the extent of deterioration due to animal burrows in safety-critical structures.

Incident 373	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	9
Incident type	Internal erosion
Incident severity	3

This incident gives an insight into the monitoring for internal erosion.

The dam embankment may have been affected by mining activity in the past, starting low level seepage either through or under the core. A drawing from the 1960s indicated previous problems with sinkholes within the reservoir basin and at the lower part of the upstream shoulder of the dam. There had always been a strong seepage flow into a quarry downstream of the dam. The panel engineers thought that this flow rate was almost constant with low turbidity.

In 2007 an increase in seepage at the downstream toe was found. No vortices or other signs of internal erosion were found. Annual crest level surveys showed some settlement in 2009 although the seepage had dried up by this time. In 2011, a shallow depression on the upstream face of the dam was found when reservoir water levels fell and water was seen entering the sinkhole. The crest level was monitored monthly.

A statutory inspection of the reservoir was carried out and recommended that investigations should be completed. In September 2012 the crest survey results showed continuing crest settlement so a further investigation was planned. While carrying out this investigation in October 2012, a 1.2m diameter, 1.2m deep sinkhole was discovered on the dam crest. Pumps were brought to the site to lower the reservoir water level as no drawdown facilities were available. The undertaker intends to construct a notch through the dam to substantially reduce the reservoir pressure and retained volume.

Lessons learned
This incident shows the difficulties in identifying signs of internal erosion. The drying up of the seepage at the downstream toe in 2009 could have represented a change in the leakage path which started to erode the dam core causing the sinkhole on the crest. The monthly crest settlement monitoring appears to have been effective in identifying this deterioration. The incident shows that internal erosion can occur even with monitoring of any evident downstream seepage rates and turbidity. Mining activity in the area may have increased the vulnerability of the dam to internal erosion and contributed to the difficulties in identifying the indicators.

Incident 376	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	4
Incident type	Internal erosion of foundation
Incident severity	3

This incident happened at an off-line flood storage reservoir adjacent to a river.

During a flood impoundment the site manager noticed very dark muddy water emerging from the ground beyond the downstream toe of the earth embankment. When the flood receded the reservoir was emptied. Investigations are being planned to help decide what repairs are needed. It seems likely that the leakage is associated with deterioration in the condition of the foundation.

Lessons learned
This incident shows the value of surveillance visits to flood storage reservoirs during significant impoundments. Any leak through the foundation may be apparent some distance from the downstream toe of the embankment.

Incident 377	
Dam type	Impounding
Reservoir legal status	Reservoir under the Act
Dam height (m)	8
Incident type	Physical features - intrinsic
Incident severity	3

This incident happened at a flood storage reservoir that is normally empty. The embankment had been raised in 1995.

During a routine visit following a period of heavy rain, the undertaker noticed an 18m long crack just below the crest on the downstream face of the embankment.

Figure 3.14 Instability of reinforced topsoil layer on the embankment downstream face (Photo courtesy of Andrew Pepper)

It appears that a saturated layer of grassed topsoil, reinforced with an erosion control mat and approximately 200mm thick, had slipped on the surface of the underlying clay fill. The shallow surface slip posed no significant threat to the embankment security. However steps were taken to reduce the probability that this section of embankment would be overtopped during an extreme flood event, until repairs could be completed. The slope gradient was approximately 1V:3H. Investigations revealed that the underlying clay layer was very soft and grass roots hadn't grown into the clay layer. The saturated topsoil layer had slumped off the clay fill. The undertaker intends to replace the soft clay fill and to install an alternative method of erosion control using gabion mattresses.

Lessons learned
This incident highlights that topsoil instability can happen under certain conditions. In this case the slope gradient was not very steep but it appears that the heavy rainfall, poor grass root penetration and the nature of the soft clay under the topsoil were contributory factors. It is not clear whether the erosion control mat had been adequately secured at the dam crest but this may also have been a factor.

Incident 380	
Dam type	Impounding
Reservoir legal status	Reservoir not under the Act
Dam height (m)	5.65
Incident type	Other
Incident severity	3

This incident concerns problems found at the lowermost reservoir in a cascade of three non-statutory reservoirs located immediately upstream of a town. The reservoir was originally owned by a water company, but is now in private ownership.

The local council found that the undertaker had asked a contractor to fill one of the compartments with inert waste. A panel engineer was appointed by the council to provide advice on the activities at the site. Water was found to be leaking through the uppermost part of the embankment. Part of the crest, core and upstream shoulder was found to have eroded away and the leakage had caused gullying on the downstream slope. Inspection of the masonry walling on the upstream side of the crest revealed that this part of the embankment had settled and was potentially unstable. Various other concerns were identified at the site, including the fact that the dam freeboard had been reduced to almost zero at one section. Construction works were in progress at the site at the time of the incident to alter the reservoir.

Lessons learned
It is important that modification works to old reservoirs are carried out under the supervision of an experienced civil engineer. This is to make sure that the condition of the dam embankments and other reservoir structures are assessed in a professional manner as part of the planning for any alteration works on existing reservoirs.

Appendix A: How to report an incident

We deliberately use the term 'post-incident reporting' so that it is clear that this system does not include managing the incident. If a problem occurs at your reservoir you should follow the steps in the flow chart below.

We can receive information by phone or email. Our contact details are below. 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 contact you at a later date to find out more about the actions you have taken, and how effective they were.

You can find a blank copy of our post-incident reporting form on our website:

http://www.environment-agency.gov.uk/business/sectors/37218.aspx

Or you can write to us:

Reservoir Safety Team

Environment Agency

Manley House

Kestrel Way

Exeter

Devon

EX2 7LQ

Tel: 01392 442001 (office hours only)

Email: reservoirs@environment-agency.gov.uk

www.environment-agency.gov.uk/reservoirsafety

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

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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.

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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)

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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

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 endanger lives not in a community or result in extensive breach
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

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

Then call us on

03708 506 506 (Mon-Fri 8-6)

Calls to 03 numbers cost the same as calls to standard geographic numbers (i.e. numbers beginning with 01 or 02).

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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