creating a better place
The owner’s guide to reservoir safety
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.
Foreword

Dams and reservoirs are an important part of our national infrastructure, providing a vital role in storing the country’s water. But, if we don’t manage them effectively and continue to monitor and adequately maintain them, these reservoirs could potentially cause major damage and even loss of life.

We want to work together with reservoir owners to reduce the risk of dams failing.

We have produced this guide to provide further information and advice to those of you that manage and operate these vital structures.

We have also introduced and manage the post-incident reporting system. This provides a single, co-ordinated point for gathering, analysing and sharing lessons about reservoir incidents.

Our commitment to carry out research and development projects provides valuable and vital guidance to panel engineers, from technical guides through to incident management.

Setting up and maintaining reservoir flood plans (emergency action plans) is also an essential part of reducing flood risk. We were involved in the recent release of inundation maps for emergency planning and have been working with Defra to provide guidance for on-site plans. We would now encourage you to put your on-site plans together to further reduce risk.

We will continue to play our part in helping the industry improve reservoir safety.

Ian Hope
Technical Manager - Reservoir Safety
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Introduction

1.1 Purpose of this guide

1.2 UK legislation

1.3 Consequences of dam failure
Introduction

1.1 Purpose of this guide

We have produced this guide to give all reservoir owners general advice on the common problems encountered at small embankment reservoirs in the UK, how to spot them, and what you might need to do to prevent a reservoir from failing.

This guide is not a substitute for professional advice. If in doubt, always consult a qualified civil engineer, ideally a reservoir ‘panel engineer’ (see section 7 for further details). Some useful reference documents are listed in Section 9.
1.2 Legislation in Great Britain

During the nineteenth century several embankment dams in the UK collapsed, resulting in sudden large flood waves that caused significant damage and killed hundreds of people downstream. Public pressure for a law governing reservoir safety led to the Reservoir (Safety Provisions) Act 1930. This ensured that all large raised reservoirs would be inspected at least every 10 years by a qualified engineer (Inspecting Engineer).

This law was updated and became the Reservoirs Act 1975. This additionally called for supervision of large raised reservoirs (those above 25,000m³) by a suitably qualified civil engineer (Supervising Engineer).

In this guide, all reservoirs we refer to are raised reservoirs. Please also refer to the Environment Agency’s guide to the Reservoirs Act 1975 (Working together for the safety of our reservoirs, Rev. Nov 2005) if your reservoir has a capacity greater than 25,000m³.

Recently, research has shown that, in some cases, raised reservoirs with an escapable volume of less than 25,000m³, (or ‘small raised reservoirs’), can also pose a threat to life. As the safety of these smaller reservoirs is not covered by the law (non-statutory), they are sometimes in very poor condition. We have recorded several ‘near misses’ in recent years, where small raised reservoirs have been very close to failing.

Owners of reservoirs of any size should be aware that under common law, they might be held responsible for any damage or injury caused due to a sudden uncontrolled release of water from the reservoir. Employers also have a duty for the welfare of others under current health and safety legislation.
A ‘raised reservoir’ is one where some/all of the water is held above the lowest point of the land surrounding the reservoir. Usually, this lowest point will be at the base of the dam holding back the water.

A ‘large raised reservoir’ is one where the volume held above the surrounding land is more than 25,000 cubic metres (m³) of water (that’s equivalent to about 5 million gallons or 10 Olympic swimming pools). These must comply with the requirements of the Reservoirs Act 1975.
1.3 Consequences of dam failure

If a dam fails, all of the water held above surrounding ground level can potentially escape in a very short time. The force of this water can be devastating and much more destructive than flooding from gradually rising river levels.

The consequence of a dam failing depends on many factors. These include the volume of water in the reservoir, the height of the dam and the slope and nature of the ground downstream of the dam. The consequences can include:

- people living and working downstream being killed or injured;
- public and private property being destroyed or damaged;
- damage to or loss of critical infrastructure downstream (power cables, gas pipelines, roads, bridges, etc);
- loss of water from the reservoir (for irrigation, drinking water, fishing, amenity, wildlife habitat, etc);
- damage to downstream habitats and biodiversity;
- lawsuits against the owner of the dam for any of the above.

It is therefore very important that reservoir owners look after their dam embankments and know how to spot the tell tale signs that indicate that there may be problems developing.
Introduction

Deliberate breach of an earthen embankment dam for modelling purposes
Introduction

Emergency works to Ulley Reservoir, June 2007
What type of reservoir do you have?
The great majority of raised reservoirs in the UK are formed by earth embankment dams that either block the natural flow of a river or drainage from an area (impounding reservoir), or that form all sides of the reservoir (non-impounding reservoir).
What type of reservoir do you have?

The picture above shows a typical impounding reservoir. It also includes some commonly used terms from this guide.

The spillway is the overflow that, in normal operation, allows water out of the reservoir in a controlled way when the water level gets too high (like the overflow in a bathtub). It prevents the potentially disastrous effect of water flowing over the crest of the dam. The overflow is usually formed by a control weir and channel, but pipes are sometimes used if the flow into the reservoir is very limited or can be controlled.

When the reservoir is full, most of the upstream face cannot be seen, as it is under the water. The downstream face is the side of the embankment normally exposed. This is where many problems can first be spotted.
What type of reservoir do you have?

A typical non-impounding reservoir is shown opposite. Non-impounding reservoirs do not block the natural flow of water and are generally filled by pumping water, or by piped inflow into the reservoir. Note that as the embankment dam forms the entire edge of the reservoir, the term ‘inner face’ is the upstream face and the ‘outer face’ is the downstream face on each side.

Masonry or concrete dams are much less common in the UK. These can form either an impounding reservoir by blocking a river or surface runoff flow (as the embankment does above), or if they are covered and contain treated drinking water they are known as ‘service’ reservoirs. Service reservoirs are normally owned by water companies.

For more information on types of dams and different terms, please refer to the ‘About Dams’ section of the British Dam Society (BDS) website, www.britishdams.org.

All dams rely on a waterproof element to prevent the water leaking out. This can be in the form of a solid clay embankment, a narrow clay or concrete ‘core’ to the embankment, or a waterproof layer on the upstream face of the dam such as a concrete or masonry wall or a plastic membrane. The sketches on the following page show some common arrangements for the waterproof element.
What type of reservoir do you have?

Outer face

Embankment dam top

Inner face

Reservoir

Note: Filled and emptied by pumping only

Typical non-impounding reservoir for agricultural purposes

Typical non-impounding reservoir for water supply purposes
(drawn-down for engineering works)
What type of reservoir do you have?

**Solid clay embankment**

- Dam crest
- Solid compacted clay embankment
- Downstream face

**Clay core embankment**

- Dam crest
- Clay core
- Earth fill
- Downstream face

**Waterproof upstream face**

- Dam crest
- Artificial liner e.g. plastic
- Earth fill
- Downstream face

*Common types of waterproof element in small embankment dams*
Why do embankment dams fail?

3.1 Overtopping

3.2 Internal erosion
Why do embankment dams fail?

The two most common reasons why embankment dams fail are overtopping and internal erosion.
3.1 Overtopping

Overtopping of the ‘dam crest’ can happen when the spillway is too small or becomes blocked. Storage for a certain amount of floodwater is normally provided above the overflow (spillway weir) level. If the amount of water coming into the reservoir is greater than the amount that the spillway was designed for, or if the spillway becomes blocked, the floodwater might start to overtop the dam crest.

When water overtops the reservoir it will run down the downstream face. If the flow is too large or the overtopping lasts too long, the water will start to erode away the surface of the reservoir embankment. Eventually, it will erode so much of the embankment, or downstream shoulder, that there is not enough support to hold back the water in the reservoir, and the reservoir will fail.

Reservoir water overtopping a dam crest at its lowest point. This can cause the crest downstream face to be washed away and subsequent failure.
3.2 Internal erosion

This happens when the pressure of the water in the reservoir manages to create a seepage path through the embankment and erode earth from within. This could be due to:

- poor construction of a clay core/embankment or plastic liner;
- tree roots growing through the embankment;
- animals burrowing into the embankment.

When internal erosion occurs it will leave voids or ‘holes’ within the dam. These can weaken the embankment to the point where it is not strong enough to hold back the pressure of the reservoir water, and the water might burst through. Alternatively, if the embankment sinks down to fill these holes, this can leave a low point on the crest which is then vulnerable to overtopping when the next large flood event occurs.

A common sign of seepage or leakage water is the appearance of unusual patches of reeds or other water-loving vegetation starting to grow on the downstream face or toe.
Checking on your reservoir

4.1 Where to inspect your embankment dam

4.2 How monitoring can help

4.3 Visits - how often is enough?
Where to inspect your embankment dam

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Checking on your reservoir

Upstream face

Valves and pipes

Downstream face

Spillway

Trash screens

Dam crest
A: Upstream face

**What to look for**
Check for erosion of the upstream face by waves or animals.

**Why?**
Significant erosion can weaken the dam.

**What to do**
Seek professional advice. It is likely that the qualified civil engineer (QCE) will require protection of the upstream face. If your reservoir is under the 1975 Act you should inform your Supervising Engineer.
Checking on your reservoir

Sink holes on upstream edge of crest caused by collapse of crayfish burrows on upstream face

Crayfish burrows on upstream face

Badly eroded upstream edge of dam crest due to wave action

Original edge of dam crest
B: Trash screens

What to look for
Check for debris or vegetation.

Why?
Blocked spillway screens can lead to overtopping during flooding.

What to do
Seek professional advice. It is likely that the QCE will require you to clean the screens. You may be able to do this safely by using a long handled rake from a position on the dam crest.
Checking on your reservoir

Blocked spillway trash screens
C: Dam crest

What to look for
Check for sink holes, cracks or low spots.

Why?
Sink holes might indicate internal erosion. Cracks can allow rainwater to enter the body of the dam more easily or indicate the start of a slip. Low spots might be due to settlement or internal erosion and these areas will concentrate damaging flow in a flood.

What to do
Try to avoid driving vehicles along the dam crest (unless there is a surfaced roadway) as this can cause rutting and erosion. Get advice from a QCE on the cause of any new low spots or sink holes. If your reservoir is under the Reservoirs Act 1975 you should tell your Supervising Engineer.
Checking on your reservoir

Numerous molehills on crest and downstream face

Sink hole due to tree root movement within dam
Leaning oak tree
Broken handrail indicating recent movement of tree
D: Spillway weir or overflow

What to look for
Check for debris or vegetation.

Why?
Blocked spillways can lead to overtopping during flooding.

What to do
Unblock the spillway. Cut back and prevent vegetation from growing around the spillway crest in future. This will prevent debris from getting trapped.
Checking on your reservoir

Blocked spillway trash screens
E: Downstream face

What to look for
Check extent and condition of vegetation.

Why?
Anything more than short grass can obscure the face and might prevent problems (such as leakage or slips) being spotted until it is too late.

What to do
If possible, limit vegetation to short grass. Check that trees on the dam are healthy and that large or top-heavy trees appear stable.

What to look for
Regular checking will enable you to spot any changes such as wet patches, soggy areas, slips, cracks, animal burrows.

Why?
Any of these issues can indicate stability or internal erosion problems that may eventually lead to the dam failing.

What to do
Monitor any issues. Get advice if the condition is worsening or if you are concerned by what you see. If your reservoir is under the Reservoirs Act 1975 tell your Supervising Engineer.
Checking on your reservoir

Vegetation damage to masonry spillway cascade structure, caused by growing tree roots

Leakage flow emerging on downstream face
Checking on your reservoir

**Embankment instability** (slips, settlement, slumps, sinkholes, cracks)

Slip circle beginning to develop at top of downstream face

*Progressive development of slip circles*
Checking on your reservoir

Extensive rabbit burrowing activity on downstream face of embankment

Widespread minor surface damage/slips caused by horses/cattle walking along downstream face. All animals other than sheep and goats should be excluded from the embankment.
F: Valves and pipes

What to look for
Check that valves remain operational and that there are no leaks from valves or pipework.

Why?
Leaks can lead to erosion (internal or external depending on the location of the leak). Inoperable valves can mean expensive mobile pumps will be needed to draw down the reservoir water level in the event of an emergency. Valves/pipework can be prone to vandalism.

What to do
Regularly operating a valve over its full range can help prevent it seizing up. However, approval from the Environment Agency may be required when discharging water to a downstream watercourse. Protect the spindle by greasing, the pipework and casing by painting. Other fittings can be wrapped with suitable protective tapes. If your reservoir is under the Reservoirs Act 1975 you should contact your Supervising Engineer if you cannot operate the valves or if you see a leak from a valve or pipework.
Checking on your reservoir

Badly corroded and now inoperable valve
4.2 How monitoring can help

Spotting one of these problems does not necessarily mean that expensive and urgent repair work is needed. For example, many reservoirs have some seepage/leakage indicators such as patches of reeds or a wet or boggy area often near ‘the downstream toe’. By monitoring this over time it is often possible to find out if this is associated with rainfall (groundwater) or the reservoir water level. If it gets progressively worse, it is probably linked with the reservoir and you should get professional help as soon as possible.
Example 1

After a wet weekend, an owner discovers a new wet patch on the downstream face of his dam on Monday morning. He bangs in some short wooden pegs at the edges of the wet patch so he can tell if it is getting bigger over time. He starts recording the daily reservoir water level and records the daily rainfall from the internet. He visits the reservoir daily and notes that the wet patch is getting smaller. After a few weeks, when he compares records of reservoir water level and rainfall with the shrinking of the wet patch he decides that the wet patch is due to rainfall rather than reservoir water level. He continues to monitor the wet patch, but at longer intervals of 1 month. If it gets progressively worse the owner should get expert advice. If his reservoir is under the Reservoir Act 1975 he should tell his Supervising Engineer.
Example 2

An owner discovers a small trickle of clear water emerging from the downstream face of her reservoir. As it appears to be coming from a specific place, she pushes a short section of plastic drainpipe into the embankment around this point to collect all the flow. Each day, she then measures the reservoir water level, rainfall and the seepage flow rate (by timing how long it takes to fill a 1 litre jug). After two weeks the flow has increased and is now slightly cloudy. Any small reductions in the flow rate appear to follow changes in reservoir water level rather than rainfall. Realising that this indicates a leak through the reservoir that is getting worse, she finds a local panel engineer through the Environment Agency reservoir safety website and gains some professional advice. If the reservoir is under the Reservoirs Act 1975 she should inform her Supervising Engineer.

Seepage water collected through a pipe and now measureable. Paving slab below prevents erosion of embankment surface.
4.3 Visits - how often is enough?

As a general rule, no reservoir should be visited less than once a month, and most will need to be visited more frequently. This will vary from reservoir to reservoir, but generally, you should visit your reservoir often enough to carry out regular maintenance and monitoring in order to detect any changes in behaviour. This will allow you to spot defects and correct them before they become a problem and could lead to subsequent failure of the reservoir. For example, if your reservoir is in a wooded area, you may need to clean a trash screen over a spillway every day to make sure it doesn’t get blocked. Or you may need to visit once a week to measure the water level and monitor a seepage flow.
Checking on your reservoir
5. Typical maintenance activities and why they are important

5.1 Trees/vegetation/grass cover
5.2 Maintain and clear spillways/pipes
5.3 Discourage animal activity
5.4 Check drawdown valves
5.5 Conflicting legislation
5.1 Trees/vegetation/grass cover

The ideal embankment dam has a healthy, short (50-150mm) covering of grass on its crest and downstream face, with no trees or other vegetation. This allows problems such as settlement, seepage/leakage, slips or burrowing animal activity to be spotted early on before they become dangerous and expensive to fix.

Vegetation can also cause runoff water to form concentrated flow paths which speeds up the surface erosion in these areas.

A well maintained, short-grass covered downstream face makes it easy to spot slips, slumps, cracks, seepage and leakage, and as it is exposed, discourages burrowing animals.
Trees are a constant source of problems with embankment dams:

- Large top-heavy or unstable trees can be blown over in storms, tearing a large hole in an embankment and making it unstable or prone to overtopping or internal erosion.
- Growing tree roots can puncture the waterproof artificial liner, leading to internal erosion.
- Growing tree roots can damage wave protection on the upstream face, leaving it exposed to external erosion from wave action.
- Dead or dying tree roots within an embankment can leave holes which form leakage paths, leading to internal erosion.
- Trees near to structures such as drains and concrete spillways can damage the structures to a point where the have to be replaced.

You should remove young trees from embankment dams before they become well established. Monitor mature trees and make sure any top heavy, dead or dying trees are assessed by a tree surgeon to make sure they remain healthy and stable. You should only remove large tree stumps in the embankment with professional advice from a panel engineer.

![Wind blown trees on embankment reservoirs which could lead to internal erosion.](image)
5.2 Maintain and clear spillways/pipes

Spillways, trash screens and pipe inlets can quickly become blocked by debris (such as leaves, sticks and litter), which can lead to the water level rising and eventually overtopping of the dam.

You should regularly check trash screens and clear away debris. How often you need to do this will depend on the amount of debris that gathers each day at your reservoir. Always check the screens after very heavy rain or windy days, and more frequently in the autumn.

Always take care not to put yourself in danger when cleaning the spillway. See Section 8 for more information.

Always cut back reeds and other vegetation growing near the spillway crest or pipe inlets to stop debris getting caught in this area and to ensure the spillway is clear.
5.3 Discourage animal activity

Burrowing animals make holes in embankments which can lead to settlement, sink holes or leakage paths. In severe cases, embankments riddled with mole tunnels, rabbit warrens or badger setts can be weakened so much that they are in danger of collapsing.

As far as possible, you should discourage animals from burrowing on the embankment by:

- keeping grass short so that the face is open for inspection;
- regularly filling in animal burrows with compacted clay (where this isn’t against the law, see section 5.5);
- humanely trapping or culling (again, where this is legal).

Always take care to comply with wildlife legislation (see section 5.5). Consult with Natural England or the Countryside Council for Wales (CCW) or your local Environment Agency office if in doubt.
5.4 Check drawdown valves

If you spot a serious problem at your dam, it’s often a good idea to lower the water level in the reservoir so that pressure on the embankment is reduced, and any leakage/seepage flows reduce or stop. Before doing this you must seek professional advice. The simplest and cheapest way to do this is to open the low level scour (or bottom outlet) valve, if your reservoir has one.

So, if you have a scour valve at your reservoir it would be a good idea to make sure it’s in good working order. To do this, you should:

- make sure the valve is protected from rust by paint, grease or galvanised coating;
- keep the spindle greased;
- fully open and close the valve at least twice a year to check it has not seized up;
- have the valve inspected by a valve expert to fix any problems;
- keep a note of which direction valves open and close, and how many turns it takes to fully open/close it;
- If your reservoir is under the 1975 Act before opening your valve you should contact your supervising engineer.

If the valve stops working, or if you don’t have one at your reservoir, the only way to lower the water level in an emergency will be to pump reservoir water over the dam crest using mobile pumps. You are advised to seek professional advice in order to ensure that the discharge water does not cause downstream erosion.

Tip:
Keep valves in good working order and note the telephone number of a 24-hour pump supplier in case an emergency drawdown is required. It is recommended that you prepare an on-site plan, see the Defra website.
5.5 Other legislation you should consider

The Reservoirs Act 1975 is designed to protect people and property from uncontrolled releases of water from large raised reservoirs (greater than 25,000m³). However, there are many other laws which may occasionally conflict with the steps you need to take to comply with this.

Examples are:

- Protection of Badgers Act 1992 - making it illegal to harm badgers or their setts.
- Wildlife & Countryside Act 1981 - making it illegal to release crayfish into a watercourse.

If, whilst making sure your reservoir is safe, you think that you may be breaking a different law, you should first get advice from the Environment Agency or Natural England or Countryside Council for Wales.
5.6 Emergency planning

In the worst case scenario, if your dam is in danger of collapse, you will need to contact the Environment Agency and the emergency services in order to attempt an emergency draw down and notify people in danger downstream. For reservoirs under the Reservoir Act 1975 you are also required to consult an Inspecting Engineer for advice.

In this situation, it can be very useful to have a pre-prepared plan that can be circulated quickly to all necessary parties. detailing;

- access routes to the dam
- weight/width restrictions
- location of valves
- location of locked gates and keys
- volume of water to be released

You should consider preparing a simple emergency plan if there are any access restrictions at your reservoir.

For further details visit:
When should I ask for professional advice?
All dams are different and it is impossible to give specific advice. Dams have the potential to kill and all reservoir owners should take the risk of a dam failing very seriously. In general, you should seek professional advice if:

- the dam crest is in danger of overtopping for any reason;
- there is a sudden increase in apparent seepage/leakage water from the downstream face or toe of the embankment;
- seepage or leakage water becomes cloudy or contains particles of sand/earth (this might indicate internal erosion);
- there is a significant slip or crack on the crest or downstream face;
- a sink hole or low spot appears on the dam crest;
- you are uneasy about any aspect of your dam or reservoir (either in terms of operation or structural condition);

Section 7 lists some sources of help.
Who can I call?
Who can I call?

In an emergency, you can call the 24hr Environment Agency incident hotline on **0800 80 70 60**

If your reservoir comes under the Reservoirs Act 1975, you can contact the Environment Agency Reservoir Safety Team

Telephone: 08708 506506 (during office hours)

Email: reservoirs@environment-agency.gov.uk

Website: www.environment-agency.gov.uk/reservoirsafety

If your reservoir has a capacity greater than 25,000m³ and you would like technical advice about reservoir safety or engineering design/construction services, you should contact a Qualified Civil Engineer appointed to one of the Panels under the Reservoirs Act 1975. These include:

- **All Reservoirs Panel Engineers**
- **Non-Impounding Reservoir Panel Engineers** Known as **Inspecting Engineers**
- **Service Reservoir Panel Engineers**
- **Supervising Panel Engineers** Known as **Supervising Engineers**

Inspecting Engineers can also act as supervising engineers

A complete list of all engineers appointed to these panels, and their contact details is available to download free from our website:

Watch out!
Reservoirs can be dangerous places, so you should always consider your health and safety carefully when visiting your reservoir.

- Wear appropriate clothing for the site and the weather including safety equipment.
- Take extra care not to slip on wet sloping surfaces such as the upstream and downstream faces of the dam.
- Wash your hands after coming into contact with reservoir water or wet vegetation to prevent catching leptospirosis (Weils disease).
- Wear gloves and use appropriate tools (spindle extensions, lever bars, etc) when operating valves.
- Specialist safety training is available for dealing with confined spaces. Avoid entering confined spaces (such as manhole chambers or tunnels) unless you are trained.
- If visiting a remote reservoir let people know where you are and when you expect to return with a telephone call.
Where to find further information
If you would like to learn more about reservoir safety, you may find the following references useful:

9.1 Legislation

Reservoirs Act 1975 (as amended)

9.2 Publications


ICE 1998. Floods and reservoir safety, Institution of Civil Engineers, Thomas Telford, London


9.3 Websites

The British Dams Society  www.britishdams.org

The Environment Agency  www.environment-agency.gov.uk/reservoirsafety

Natural England  www.naturalengland.org.uk

The Countryside Council for Wales  www.ccw.gov.uk
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

* Approximate call costs: 8p plus 6p per minute (standard landline).
Please note charges will vary across telephone providers.

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