Supervising Engineer's Account and Reflections on a Major Reservoir Safety Incident

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SYNOPSIS. This paper details the first response to an emergency incident that took place at Ulley Reservoir in June 2007, and provides a first hand account of the events that took place during the initial twelve hours and looks at the actions taken by the Undertaker, Rotherham Metropolitan Borough Council (RMBC), and the Supervising Engineer during that period. The paper also provides a commentary on the actions taken by the AR Panel Engineer, the emergency services and Undertaker's and contractor's staff in carrying out further emergency works to stabilise the dam during the following 48 hours. It provides a detailed account of an emergency plan being put into action and also how the emergency plan can be flexible enough to allow improvisation to deal with particular problems as they are identified. The paper concludes by providing a summary of the main lessons learnt during the emergency response and comments on general housekeeping matters such as the availability of reservoir records, communications and welfare facilities.

The problem at Ulley was the disintegration of one of the spillways that led to the rapid erosion of the toe and downstream shoulder of the embankment. The erosion process was out of control and a solution had to be found to reduce the flow along the damaged spillway. In the absence of penstocks, stop logs or other similar equipment that could be used to control the flow of water into the spillway, an improvised plug was installed, which comprised of an 8 tonne skip packed with large sandbags wedged into the upstream end of the spillway. The Undertaker's emergency plan allowed for plant and materials to be obtained at any time of the day. Emergency pumping to lower the reservoir water level was initially provided by the fire service, but these were later supplemented by the addition of hired in pumps. By the time the AR Panel Engineer arrived, the situation, though still critical was under control.

Ensuring reservoir safety into the future. Thomas Telford, London, 2008

ENSURING RESERVOIR SAFETY

INTRODUCTION

This is a Supervising Engineer's account, supplemented by information from RMBC's Forward Liaison Officer (FLO), about the issues raised and the lessons learnt in attending a serious reservoir safety incident. First hand experience provides a good example of the application of emergency planning to avert a potential disaster and gives a valuable insight to those professionals who may be involved in the first response to a reservoir safety incident in the future and help them to be ready.

DESCRIPTION OF THE RESERVOIR

The principal data for the reservoir is given in Table 1 below.

Table 1 – Principal Reservoir Data

Capacity	580 000 m^3
Top water level	51.75 maOD
Surface area	0.12 km^2
Catchment area	11.87 km^2
Embankment height above natural ground	16 m
Embankment length	205 m
Upstream slope angle	1 in 3
Downstream slope angle	1 in 2 for 9 m with berm
Crest level	55.5 maOD

DESCRIPTION OF THE OVERFLOW ARRANGEMENT

The overflow arrangement is not straightforward. Each spillway at the reservoir has its own historical name and these are used in the description of the incident. The spillway names, locations and details are shown below in Figure 1 and Table 2.

Prior to the incident, the reservoir top water level was controlled by the Ulley spillway. When the reservoir level rose by 1.23m, then the 1943 spillway would come into operation. A further level rise of 0.58m would be required to bring the Morthen spillway into operation.

Table 2 – Weir Details

Spillway Name	Weir Length	Weir Level
Ulley	1.8 m	51.75 maOD
1943	12.2 m	52.98 maOD
Morthen	6.1 m	53.56 maOD

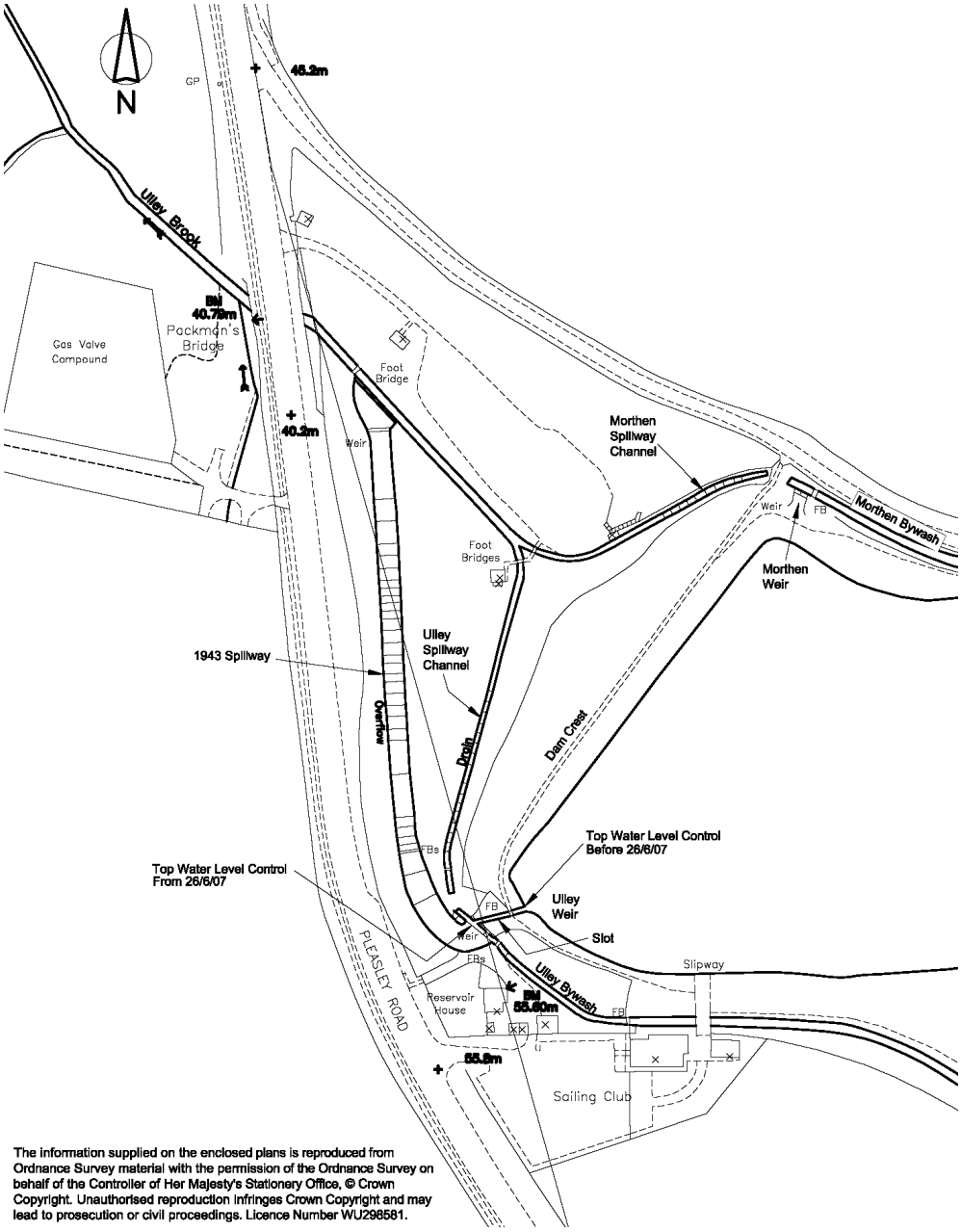


Figure 1 – Overflow Layout

DESCRIPTION OF THE ULLEY INCIDENT

The incident followed a day of heavy rain in the area around and upstream of Rotherham. Rangers based at Ulley were asked to check the reservoir periodically during the afternoon and early evening of 25th June. At about 8pm, one of the rangers reported damage occurring to the embankment. The Country Park Manager, who was also one of the FLO's for RMBC's emergency planning unit, went to site. In consultation with the local police,

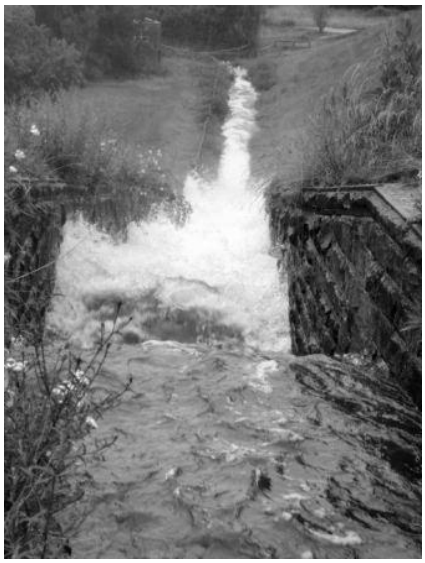
a major incident was declared. This allowed the emergency management systems to be established. This included establishing a bronze command at the reservoir and closing the perimeter roads around the reservoir including the main A618.

An engineer from RMBC arrived on site at 10pm and recognised that the situation was serious. The Supervising Engineer for the reservoir under the 1975 Reservoirs Act was notified of the problem and went immediately to site. He arrived on site at about midnight and went onto the embankment to look at the damage. Speaking to the RMBC staff on site, it was clear that the problem was getting worse but there was insufficient light to make a clear assessment of the problem. He was asked by the police if the dam would survive until the morning. Based on the damage that was visible and the rate of erosion, he was not sure that the dam would survive until dawn. This answer was passed to Gold Command who decided to evacuate residents from areas believed to be at risk and to close the M1. It is worth noting that at this early stage, decisions about which premises should be evacuated were based around the brief study of maps at both Bronze and Silver control as no evacuation plans for premises downstream of Ulley existed.

The immediate priority was to try and get a clearer idea of the amount of deterioration of the dam. RMBC were asked to obtain lights to allow a clearer view. Fairly rapidly, the Supervising Engineer realised the problem was surface erosion caused by the water flow down the Ulley spillway and a solution was to try to stop that flow. There was no mechanical means of closing the upstream end of the channel. The idea of sand bags was dismissed because they were two small and would be washed away. The next idea was to use intermediate bulk containers (IBC) filled with gravel. It was realised that to place the bags a crane would be required. RMBC, as part of the emergency plan, have arrangements to collect materials during out of hours for emergency purposes.15 IBC's were obtained. A crane was obtained but due to the flooding in the middle of Rotherham took some time to arrive. The first attempt to place an IBC was unsuccessful; the flow of water caused it to virtually disintegrate. It was then realised that something more substantial was needed to block the channel. The answer was an 8T skip. RMBC obtained two of these as a resilience measure in case one failed, however only one was required. Once the skip was lowered into the channel, the flow was considerably reduced. The IBC's were then lowered into and packed around the skip. With this reduced flow, it became possible to look more closely at the damage to the embankment. At that time, the water was flowing over exposed rock foundation and no longer eroding the embankment material.

In parallel to the blocking exercise, it was realised that there was a need to lower the reservoir since water could no longer be allowed along the damaged spillway. RMBC requested fire service support at about 2:30 am. The first pumps arrived at about 6 am and there was a steady stream of arrivals thereafter. The first pumps became operational at about 6:30 am.

The following are photographs taken during the incident between 2:45 pm on 25th June and 11:17 am on 26th June 2007.



PHOTOGRAPH 1
Taken at 14:55 on 25th June

This is the last photograph of the Ulley spillway before its failure. As can be seen, there is considerable turbulence in the flow and it appears to be overtopping slightly at the bottom of the steep slope.

PHOTOGRAPH 2
Taken at 20:26 on 25th June

The water level has continued to rise. It is now above the lower rail on the footbridge.

PHOTOGRAPH 3
Taken at 20:26 on 25th June

The flood is now passing down the 1943 spillway.

PHOTOGRAPH 4
Taken at 07:45 on 26th June

This shows the flow down the Ulley spillway and the water eroding the embankment.

PHOTOGRAPH 5
Taken at 08:32 on 26th June

This shows the skip being placed to act as an improvised plug. The flow into the Ulley spillway can be seen below the skip.

PHOTOGRAPH 6
Taken at 10:32 on 26th June

This shows how the plug had reduced the flow considerably so it was no longer eroding the embankment.

PHOTOGRAPH 7
Taken at 11:17 on 26th June

This shows the damage to the embankment and the spillway.

SPECIFIC ISSUES RELATING TO THE ROLE OF THE SUPERVISING ENGINEER

In being presented with an incident at a reservoir, there are a number of matters to consider. These are as follows: -

- Assess the situation. On arrival at site, the first question to be asked is 'is it safe?' It is only possible to start to answer such a question by looking at the damage and trying to make an assessment of the rate of deterioration. Poor light made this task very difficult.
- Decide if AR Panel Engineer required. As soon as the report was received, it was clear that something serious was taking place and the first reaction, before leaving home, was to try and contact an AR Panel Engineer.
- Identify possible mitigation measures. There is a room full of people who are worried about their dam. Can the cause of deterioration be identified? Can anything be done to reduce the rate of deterioration? In this case, it was clear that there was an alternative route for the water. This led to the suggestion to simultaneously block the channel and start emergency pumping operations.
- Implement. Once a decision to do something was made and a means of achieving it identified, then the actual logistics were passed via the on site FLO to the emergency control room. On site, it was a case of waiting to be advised that the materials/equipment were on their way and then for their actual arrival.
- Response to questions: -
    - Third party. There is not just the Undertaker asking questions but also the police and other bodies. At Ulley this included Transco who have a high pressure main close to the toe of the embankment. A lot of pressure was applied by the Transco representative, quite rightly, to determine the risk to their infrastructure to protect regional gas supplies. Being prepared to say 'I do not know' required some will power.
    - Own thoughts. As mentioned above, there are a lot of worried people looking for guidance from a reservoir engineer. Seeking clarification about the actual incident provides some thinking time. There is a possibility of saying something rashly that in the cold light of day does not make sense. The most important thing is not to panic.
- Maintain communication. There are a number of people who want information. The information has to be accurate. In the early hours of the morning, it can be difficult to think clearly and it is of great benefit to bounce ideas off another reservoir engineer.
- Keep a record of events using notes and photographs. There are bound to be questions after the event to try and determine the approximate return period of the flood and similar. Events are moving fairly quickly

that it is difficult to take measurements and remember to write full notes.

IMPLEMENTATION OF THE EMERGENCY PLAN

Under the Civil Contingencies Act 2004, a framework was established to allow multi-agency emergency plans to be prepared. The Borough Emergency Plan is a framework within which the emergency, or emergencies, can be managed. The framework allows risks to be established, incidents to be prioritised and resources to be allocated and delivered to sites.

- Gold/Silver/Bronze Command. The three layers have different roles. Gold is responsible for strategic decision making over a wide area. Bronze is generally established at the site of the actual incident and is responsible for operational response at the incident site. There may be a number of incidents each with their own Bronze commander. Silver acts as a buffer between Gold and the various Bronze sites. Silver is responsible tactical decision making and arranges for resources such as required plant and materials to available and be taken to affected sites.
- Local Authority duty Forward Liaison Officer (FLO). The FLO provides a single point of contact through which requests for information, materials and services from the council or its contractors can be made.
- RMBC emergency control room. The control room controls and co-ordinates the response to the incident(s) by such means as responding to requests made by the FLO and will arrange actual delivery of such. The control room keeps a log of information and events so that after the incident it should be possible to recreate a timeline as part of the feedback on the incident, and to provide detailed information for any subsequent enquiries.

LESSONS LEARNED

The incident showed a number of matters that apply not just to this incident but could be of benefit to other Supervising Engineers facing an emergency. The principal lessons are: -

<u>Supervising Engineer's equipment/documents/knowledge</u>

When the Supervising Engineer is advised of an incident, this will be accompanied by a request to go immediately to site. Rather than trying to improvise in what is quite a stressful situation, it is better to have something prepared in advance. There should be a checklist of equipment and documents stored in a known location. The following is a suggestion: -

- Supervising Engineer's own file on the reservoir including the last Inspecting Engineer's report, selected drawings, the last annual statement and Section 11 records.

- Other documents include a contact list of All Reservoir panel engineers which has not just mobile telephone numbers but home telephone numbers as well. A possible alternative is for the Environment Agency to keep such a list in their control room for emergencies.
- The event needs to be recorded to capture lessons that could apply to other reservoirs. The type of information is notes and measurements but it is difficult to do this in the dark. Also, people are asking for information so thinking time is at a premium. Digital cameras are useful especially if high resolution. Even at night, if the flash does not appear to work, data can still be collected which can be used for later back analysis.
- Communications are vital. A mobile telephone is essential. However, during a regional emergency, the mobile telephone networks can be overwhelmed and crash (see emergency management below).
- Is transport available? There was a problem that the car was low on petrol and finding fuel late at night can be a slow process. As a matter of course, should the fuel tank be kept half full to allow enough fuel to get to the reservoir? It is worth noting that in RMBC, there is a policy that designated emergency vehicles are never allowed to have less than half a tank of fuel. The issue that this raises is the comfortable distance that a Supervising Engineer would have to drive to reach an incident. Is an hour a sensible maximum or would longer be acceptable? The decision has to lie with the individual Supervising Engineers. How many reservoirs are the responsibility of an individual and how would multiple incidents be prioritised?
- Knowledge of the reservoir and its behaviour is important. There is also knowledge of land use downstream of the dam and what emergency procedures that can be activated. As part of the normal duties, scenarios should be considered for each reservoir being supervised by each Supervising Engineer. Under the Water Act 2003, Supervising Engineers need to be aware of the emergency plans and to assist the undertakers in their preparation. Should this role be more pro-active and consider the unthinkable?
- Thought should be given by Supervising Engineers likely to be called to such incidents of the need for a ‘grab bag’ containing PPE, torches, water, food/snacks, phone, charger, flask and other items that may make life easier at an incident site. RMBC have such a system for their FLO’s.

<u>Emergency Management</u>

There is a requirement for emergency planning under the Civil Contingencies Act 2004 augmented by elements from the Water Act 2003. By their nature, emergency plans cannot cover every eventuality and

flexibility must be built in. In formulating an emergency plan, the following should be considered: -

- Access – theoretically there may be very good access to a site. During an emergency, this access might no longer exist. At Ulley, the M1 was shut as well as numerous roads in the Rotherham area. This is difficult to predict though there are bound to be situations where a road closure is more probable. Do alternative routes exist even if they are 'off-road'. Consideration should be given to requesting the police to provide an escort. At this incident, the police provided 'blue light' escorts for specialist staff and/or resources to be delivered to site.
- Welfare – a large number of people arrive on site. They need food, drinks, somewhere to dry out/ warm up and toilets. Ulley was lucky because there is a visitor's centre which provides the basics. How would a more remote site function? This could be provided by the local authority or at least sourced by them if planned. RMBC hold about 1000 ready meals for use in an emergency.
- Communications – as mentioned previously, the mobile telephone network was occasionally overwhelmed and stopped working. RMBC, as part of their emergency plan, are part of the ACCOLC (ACCess OverLoad Control) for mobile telephones whereby the telephone system is restricted to those people who have a recognised essential requirement to use the telephone. Hence communications between site and the emergency control room are maintained. The site also has good mobile telephone network coverage.
- Working hours – the incident does not conform to a normal working day. Long hours are inevitable. Are staff fit to drive home at the end of a stint or should they be booked into local hotels? It is very difficult to get rest on a busy site.
- Multiple incidents – on the night of 25th June, there were a number of incidents in Sheffield and Rotherham related to the flooding. There were locations where lives were more at risk to events not related to Ulley and resources were diverted to these incidents. Before dawn on 26th June, it would be reasonable to state that Ulley was not the top priority but second or third. A thought is what could happen in a reservoir cascade and which reservoir would be allocated the resources. The allocation will be made off-site at Gold Command.
- It is essential that the local authority emergency planning unit are involved in preparing reservoir emergency plans and discussing the need for resources to respond to an emergency. The integration of reservoir emergency plans within the local authority plans and the full support of the emergency planning officers is integral to the success of dealing with an emergency.

Reservoir Management

The undertaker can take steps to improve emergency responses if the normal management of the reservoir is established in the right manner, for example: -

- Monitoring – the reservoir is well monitored. There are rangers based at the reservoir whose main role is the running of the country park but who can also provide a rapid 'eyes-and-ears' service if there is a possibility of an incident. This level of surveillance is not universal and there would be no certainty that other undertakers will identify the early initiation of an incident.
- Records – the Undertaker was able to bring drawings to the reservoir. However, there is the issue of keeping records secure and where to have the secure place. The obvious choice for Rotherham is at the main council offices. However, these were cut off when the river Don rose. Even if the records can be taken to site, there is no guarantee that they will be safe.
- Management of supervision process – the effectiveness of the Supervising Engineer depends on a long association with a reservoir and an understanding of how it works and any idiosyncrasies. There is an argument against frequent changes in Supervising Engineers and a preference for longer contracts of say three to five years. There is also a duty on Supervising Engineers that if they know they are looking to retire that they do not take on new reservoirs. Obviously there will be instances where changes are necessary but they should not be on purely commercial reasons. The current appointment as Supervising Engineer for the RMBC reservoirs commenced in January 2007.
- Alternative Supervising Engineer's – Arup have a network and provide a list to clients so if the named Supervising Engineer is unavailable there are alternatives. Undertakers need to take this into consideration when making appointments.

Matters that might have been dealt with differently during the incident.

Hindsight is a wonderful thing. There were aspects that when thought about later might have been dealt with in a different manner.

- Record of event. Under the Supervising Engineer's heading above, was a reminder to record things.
- Location of pipework on the spillway. The pipelines from the fire service pumps were laid over the 1943 weir and on the spillway. The effect of doing this is to obstruct the spillway so if there was a further flood then there could be problems letting the water get away from the reservoir.
- Benefits of dambreak plan. Although the reservoir was classed as a Category C reservoir, it meant that a dambreak analysis would not necessarily need to be carried out under current proposals for Reservoir

Flood Plans as part of the Water Act 2003. When faced with the possibility of failure, it is very difficult to formulate a considered strategy. In fact the approach used was to look at the contour from the toe of the embankment and any properties, even if not in the direct line of the flow from a breach, were designated for evacuation. If a dambreak had been previously done, it is possible that fewer people would have needed to be evacuated.

- The effects of mining subsidence probably need to be looked at more carefully. There was a situation where the spillway at the bottom of the mitre was more or less level.
- When asking for resources, the importance of prompt delivery and an explanation of the urgency of the particular request are very important otherwise delays may occur. An example was the request for the skips which could have been given a low priority unless the FLO had explained the crucial role in which they were to be employed.

General reservoir safety

This is more the territory of the Inspecting Engineer though the Supervising Engineer has a role though a longer involvement with a reservoir. There will be issues that cause more concern and they might not be obvious.

- Consideration of spillway capacity not just spillweir capacity. Traditionally the approach has been to ensure the water can be removed safely over the weir and possibly miss the point that significant flows cannot be safely discharged from the embankment.
- Integrity of masonry spillway. The masonry appeared to be in good condition comprising ashlar masonry. In fact the units were tapered to give the appearance of ashlar and were only in contact at the exposed edges. Water was able to get behind the exposed face and there are a number of holes where individual stones have been pulled/pushed out of the wall. There is an implication for Supervising Engineers where the reservoir has another eight or so years to the next inspection whether intervention by an AR Panel Engineer is needed sooner or even a full Section 10 Inspection.
- Safe access onto an embankment during an event is important. The main access from the visitor's centre was across a flooded footbridge upstream of the weir or across the 1943 spillway.
- Masonry lined channels. Where a channel is lined using masonry walls, what is the integrity of those walls if the water gets out of the channel? Will the walls collapse leading to further erosion or will they stay upright and limit any further erosion? The walls need to be able to act monolithically which means the different skins need to be tied together. Any voids need to be filled to stop water entering the masonry and pressurising the voids.

- Where there is an abrupt change in gradient from steep to slack, the spillway walls need to be high enough to contain the hydraulic jump and direct the water flow away from the embankment toe.
- The last two items in 'things done differently' also apply here as well.

IMMEDIATE POST INCIDENT ACTIVITIES

The Supervising Engineer's role on the site did not finish with the arrival on site of an AR Panel Engineer. The role changed to a support role for the AR Panel Engineer and involved monitoring of conditions around the embankment and reporting changes to the AR Panel Engineer. The AR Panel Engineer had on his way to the site started to make arrangements for the attendance of an experienced contractor to carry out the emergency stabilisation works. This work was carried out very efficiently. The Supervising Engineer's site involvement was full time for two weeks after the incident and then reduced to weekly visits as confidence in the stability of the embankment improved.

Given the seriousness of the incident, the Supervising Engineer recommended that a Section 10 Inspection under Section 11(3) of the 1975 Reservoirs Act. Jim Claydon was appointed by RMBC to undertake the inspection and the Supervising Engineer provided assistance to the Inspecting Engineer in collecting site information and inspecting the tunnels and shafts. This led to a small number of tasks that could be overseen by the Supervising Engineer in liaison with the Inspecting Engineer.

Finally, the Supervising Engineer prepared a Post Incident Report which was submitted to the Environment Agency.

CONCLUSION

The incident could have been much worse. The problem was identified by RMBC at an early stage which allowed the appropriate personnel to be assembled on site. The emergency was managed without a major collapse, there were no fatalities and no accidents. This is very much due to the efforts put in by all involved and the emergency procedures put in place by RMBC and the multi agency approach taken. Once launched along the path of dealing with the emergency, there is very little that would be changed.

It is also important that when preparing emergency plans that advice must be obtained from the relevant local authority emergency planning team.

REFERENCES

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