Some problems at small dams in the United Kingdom

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SYNOPSIS. The UK has a large number of small dams with diverse problems. Some have capacities of less than 25,000 m^3 and therefore fall outside the ambit of the Reservoirs Act, 1975. Many were constructed in the eighteenth and nineteenth centuries to impound ornamental lakes for stately homes. Whilst these reservoirs often require rehabilitation to meet modern safety standards the available funds are frequently tightly constrained.

This paper describes a number of recent case histories chosen to illustrate the breadth of issues which tend to arise, the nature of the solutions adopted and the lessons to be learnt. Some general principles are presented with regard to the rehabilitation of such structures.

INTRODUCTION

The average age of dams for which a construction date is given in the Building Research Establishment Register of British Dams is 100 years (BRE, 1994). 38% have a capacity of less than 100,000 m^3. Of these many are in private ownership and rarely generate sufficient income to pay for inspections under Sections 10 and 12 of the Reservoirs Act, 1975 or for improvements and remedial works.

In February 1986 the Department of the Environment wrote to Panel Engineers urging them to “keep expenditure to a scale justified by the risk” and stressing the importance of amenity, recreation and wildlife conservation. Inspecting Engineers therefore have to steer a careful path between permitting reservoirs to remain in an unsafe condition and imposing demands so onerous (and expensive) that the owners have no choice but to take the reservoir out of service. Of course there is sometimes the option to reduce the capacity of the reservoir to less than 25,000 m^3 and then discontinue it under Section 13. This is almost always to be preferred to

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abandonment under Section 14 because it dispenses with the need for a Supervising Engineer and 10 yearly inspections.

The following case histories illustrate some of the issues that arise:

Case History No. 1 – Upper Hartleton Farm Reservoir

Upper Hartleton Farm reservoir has a capacity of 59,000 m^3 and a catchment area of 11.5 km^2 . It was constructed in 1972 at the same time as Lower Hartleton Farm reservoir immediately downstream. The dams were built of silty clay and performed satisfactorily except for the regular appearance of cavities and internal erosion behind the spillway walls. The cavities appeared at the Lower reservoir in 1979 and 1998 and at the Upper reservoir in 1978, 1995, 2000 and 2003. Since the dams have shown no problems along most of their length it is thought that poor compaction of material adjacent to the spillway walls was the cause of the difficulties.

Figure 1. Axial wall on left side of spillway at Upper Hartleton Farm – leakage was taking place beneath the bottom of the wall.

Following the appearance of the most recent cavities at the Upper reservoir the Supervising Engineer recommended that the Section 10 Inspection due in 2004 be brought forward to 2003. The Inspecting Engineer was concerned about the repeated appearance of cavities over the years and about possible serious problems if heavy leakage were to coincide with the passage of a flood since the river passes through a town in a small culvert a few kilometres downstream of the dams. Consequently he recommended that the fill behind both spillway walls be dug out and replaced with well compacted clay. This was done in October 2003; during the work leakage channels were found in the excavation. At the time of writing there has been no further leakage.

This case history illustrates the importance of good compaction adjacent to structures and of keeping careful records of the behaviour of dams over a long period (in this case 30 years). It also illustrates the desirability of maintaining continuity of Inspecting and Supervising Engineers.

Case History No 2 – Weldon Lagoon, Corby

Weldon Lagoon was built as a flood alleviation reservoir by the Corby Development Corporation twenty five years ago. It had 1 No 1050 mm diameter pipe, 2 No 900 mm diameter pipes and three smaller pipes entering the Lagoon from an urban catchment of about 0.92 km^2 but only 1 No 600 mm diameter pipe controlled by a 225 mm x 225 mm penstock leading out. There was no spillway and with the water up to the crest of the dam the capacity of the reservoir was 30,415 m^3.

The reservoir filled almost to the crest in November 2000 and this prompted the Undertaker to seek an opinion from an All Reservoirs Panel Engineer. The inspection was made on 2 February 2001. The Inspecting Engineer expressed the opinion that the reservoir was a large raised reservoir and that a spillway was needed to pass the PMF (since there were houses downstream). He also said that the spillway should be designed and built before the autumn of 2001.

As well as a new spillway a clay filled cut-off trench was proposed for a length of 50 m along the axis of the dam to a depth of 1.2 m to cut off leakage. Because a spillway would increase the discharges at short return periods the Environment Agency withheld permission for the new spillway under Section 23 of the Land Drainage Act, 1991. However it was pointed out that under Section 23(6) permission is not required for works being carried out in pursuance of another Act of Parliament or any order having the force of an Act. However, everything possible was done to address Environment Agency concerns and, with this in mind, a labyrinth spillway was constructed so that the spillway sill could be set as high as possible.

Figure 2. New Labyrinth Spillway at Weldon Lagoon

There was uncertainty at the time of design regarding the validity of estimates for extreme events obtained using the Flood Estimation Handbook (MacDonald and Scott, 2000). Consequently the 10,000 year outflow, at which there was to be 400 mm wave freeboard, was calculated as 16.5 m^3/sec assuming a rainfall depth, in 83 minutes, half way between that in the Flood Studies Report (125 mm) and that in the Flood Estimation Handbook (213 mm). The 10,000 year rainfall depth obtained from the Flood Estimation Handbook was 73 % greater than ¼ world maximum (123 mm) and was thought to be excessive - this view subsequently gained support from another paper by Messrs MacDonald and Scott (MacDonald and Scott, 2001). The PMF outflow, at which there was to be nominal wave freeboard, was calculated as 25.8 m^3/sec.

The new spillway was completed in October 2001. On completion of the work a certificate of discontinuance was issued because the capacity of the reservoir was reduced to 17,650 m^3 (ie. less than 25,000 m^3).

The case history illustrates how discrepancies were dealt with between estimates made using FEH and FSR. In addition it shows that there may sometimes be conflicts between the requirements of reservoir safety and those of good practice in flood mitigation. It also illustrates the usefulness of labyrinth type spillways in those situations.

Case History No 3 – Shardeloes Reservoir

Shardeloes reservoir has a capacity of only 50,000 m^3 but a catchment area of 49.8 km^2 . Only 1 mm of runoff would suffice to fill the reservoir from empty. The reservoir is remarkable for having a spillway capacity of only 1 m^3/sec. Because the catchment is largely chalk this has been sufficient to ensure the survival of the reservoir since it was built in the early eighteenth century although it is thought that the dam must have been overtopped in the floods of March 1774 when boats could be rowed along the streets of the town downstream.

Because of the town downstream the dam is assigned to Category A as defined in the Institution of Civil Engineers booklet "Floods and Reservoir Safety" (ICE, 1996). The PMF is calculated at 186 m^3/sec for a saturated catchment. Strengthening the dam to withstand the passage of the PMF would however have been expensive and detrimental to amenity, recreation and wildlife conservation.

However the capacity of the reservoir is less than 1% of the volume of the PMF (5.65 Mm^3). This being so the failure of the dam in a major flood would not make a significant difference to flood levels downstream. It was therefore decided to apply American methodology as described in the article in Dams and Reservoirs on 'Small Reservoirs on Large Catchments' (Hinks, 2003).

Mathematical modelling was first carried out to determine flood levels downstream with and without dam break. A sunny day dam breach was expected to release water at a peak rate of about 11 m^3/sec. Coming on top of a flood of 3.5 m^3/sec the incremental flood depth in the town was calculated as 300 mm. This is considerably less than the figure of 600 mm permitted by American methodology and was therefore judged acceptable.

The new spillway is now being designed with a capacity of 3.5 m^3/sec.

The case history illustrates the relevance of American methodology for small reservoirs on large catchments.

Figure 3. Shardeloes Reservoir

Case History No 4 – Braydon Pond

Braydon Pond is a privately owned Category B reservoir impounding about 100,000m^3. It has a minor road along the crest and two spillways. The central spillway is carried beneath the crest road in twin concrete pipes which were installed by the Highway Authority in 1976. Unfortunately the pipes were surrounded with granular fill so there was considerable leakage downstream when reservoir levels were high. The pipes also became cracked and distorted under the weight of traffic. Eventually the pipes had to be dug out and replaced with new ones surrounded by clay.

The spillway at the right abutment was lowered by 300mm in 2000 to provide greater spillway capacity.

The most recent problem is a major slip in the crest road caused by heavy lorries using the minor road as a short cut. It remains to be seen whether the necessary repairs will be paid for by the owner of the dam or by the highway authority who own the road.

Case History No. 5 – Faringdon House Lake

Faringdon House Lake is an ornamental lake built in the grounds of Faringdon House in Oxfordshire in approximately 1770. The reservoir has a capacity of 33,000m^3 and a catchment area of 0.27 km^2. A particular feature of the reservoir is a spring fed fountain which discharges into the head of the reservoir under a head of 2m. The reservoir has been assessed as category D given that the failure of the reservoir would cause only minor inundation.

The reservoir was one of those that had slipped through the net of the Reservoirs (Safety Provisions) Act, 1930 and was not picked up until 1989 when a Section 10 inspection was instigated and supervising engineer appointed. The reservoir had been somewhat neglected up until this time. The principal defects related to a number of large trees, which had been allowed to grow unchecked on the embankment and the total lack of a spillway. The only outflow from the reservoir was via a 100mm pipe overflow at approximately 0.30m below the crest level. This passed through the 6m high embankment to feed an ornamental cascade on the downstream face. The owner was keen to maintain the essential character of the lake and the Victorian water garden at the dam toe and the remedial options were developed to take this into account. Relatively severe tree surgery removed much of the top weight from the larger trees and reduced the risk of toppling whilst a grass-lined spillway was constructed down the right abutment to carry flow in excess of the capacity of the 100mm pipe. The spillway was designed to pass the 150 year flood of 0.74 m^3/s, with a nominal freeboard and in most years the spillway will operate two or three times a year.

This case history illustrates the need to ensure that reservoirs are entered onto the register. If left unchecked this reservoir may well have failed during a 1,000 year rainfall event which occurred on the catchment in 1998. In addition it has been found that a sympathetic approach with a private owner will generally bear fruit in encouraging implementation of works in the interest of safety.

Case History No 6 – Marston Pond

Marston Pond is believed to date from about 1780. It now has a surface area of about 8 hectares and a capacity of 80,000 cubic metres. The dam is about 500 metres long with a maximum height of about 3 metres.

The dam was quite regularly overtopped and leaks develop fairly frequently.

The problem was to bring the dam up to modern safety standards at reasonable cost without spoiling the fishing and duck shooting in the reservoir.

The dam was classified as Category D on the grounds that there were no houses between the dam and the confluence with a larger river some distance downstream. The low height of the dam was also taken into consideration as was the extensive siltation which meant that the reservoir was generally quite shallow close to the dam.

Figure 4. Glory Hole Spillway at Marston Pond prior to lowering by 450 mm.

In order to pass the 150 year flood of 5.25 m^3/sec without overtopping of the dam the higher of the two spillways was lowered by 450 mm so that it was the same level as the other. After some debate it was decided to allow the owner to install stoplogs between 1 April and 30 September each year. This concession, which is subject to the instructions of the Supervising Engineer, will reduce the capacity of the spillway from 5.25 m^3/sec to 3.3. m^3/sec during the summer months but is expected to have a very beneficial effect on amenity, recreation and wildlife conservation in line with the Department of the Environment letter of 26 February 1986.

This case history illustrates the need to make compromises in order to achieve an appropriate balance between the demands of reservoir safety and those of amenity, recreation and wildlife conservation.

Case History No. 7 – Fawsley Estate Lakes

The Fawsley Lakes were constructed as a series of three ornamental ponds adjacent to Fawsley House in Northamptonshire in approximately 1850. Only one of the three reservoirs comes under the Reservoirs Act with a volume of 120,000 m^3 whilst the other two lakes are immediately upstream, on two separate tributaries, and have volumes of 22,000 m^3 and 23,000 m^3. All three reservoirs have suffered from deterioration over the years and in a statutory inspection some 5 years ago a significant number of items were recommended in the interests of safety. Because the two non-statutory reservoirs posed a risk to the statutory reservoir, items of major maintenance at these reservoirs were included in the recommendation in the interests of safety.

This statutory category B reservoir was deemed to have insufficient freeboard to pass a 10,000 year flood without overtopping of the embankment and there were concerns about seepages through the dam and alongside the walls of the cascade spillway. The spillways of the two upper reservoirs are both largely collapsed and there is significant erosion of the adjacent embankment fill and lack of freeboard. Works are now in hand to rectify these defects but are complicated by the fact that there are multiple undertakers with both the owner of the estate and the local fishing club undertaking work on an ad hoc basis.

This case history illustrates the need to consider non-statutory reservoirs or other constructions that may influence the safety of the statutory reservoir. In addition it demonstrates the potential problems of multiple undertakers in implementing recommendations in the interests of safety.

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