Ashford Dam Improvement Works

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SYNOPSIS. Ashford is a category B embankment dam built in 1934 and located in Somerset. The reservoir is very small compared to the size of the catchment. There is a small risk that, in an exceptional flood, the dam could be washed away. The principle of the "American Methodology" is that if a dam at a small reservoir with a large catchment fails during a large flood event, the resulting damage will be largely attributable to the flood. The failure of the dam would only add an insignificant increase to the resulting damage downstream. Hence, one opinion would be that no action needs to be taken. The alternative is to undertake physical improvement works. This paper reviews the decisions taken by Wessex Water and the solutions eventually chosen.

INTRODUCTION

Ashford is 5.6m high and 250m long and was built in 1934 with a traditional puddle clay core. The reservoir has a small capacity of 50,000m^3 compared to its large catchment area of 14km^2. Only 3.6mm of runoff would be needed from the catchment to fill the reservoir.

There is a 39m long main spillway to the south of the embankment that has a capacity of 16m^3/s. A 60m auxiliary grass spillway, protected by Enkamat, was located on the crest of the dam. In a 10,000 year flood, there will be an additional 42m^3/s with a depth of 600mm passing over the auxiliary spillway.

The by-wash channel, whose purpose is to divert turbid water around the reservoir, connects the watercourse upstream to a point downstream of the main spillway.

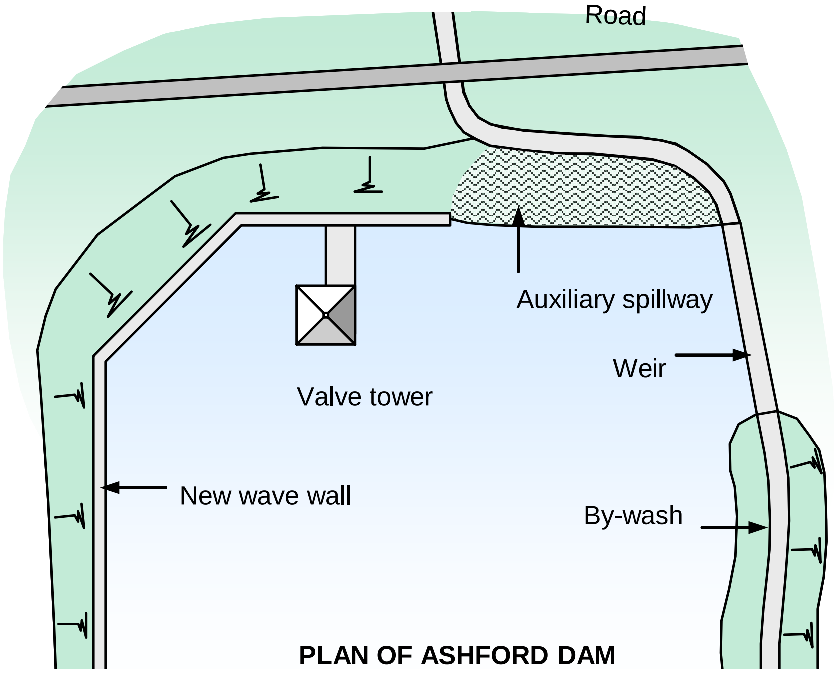

Figure 1. Plan of Ashford Dam

SECTION 10 INSPECTION

Following a Section 10 inspection in 2007, the Inspecting Engineer's report recommended the following measures to be taken in the interests of safety:

> "within three years, steps should be taken to ensure that the dam can safely withstand the flood with a return period of 10,000 years or the inflow design flood calculated according to American methodology."

The two key issues leading to this recommendation were that;

- The wave freeboard was less than the recommended 600mm
- The layout and capacity of the spillway channels was inadequate.

THE AMERICAN METHODOLOGY

The American Methodology essentially considers the additional damage that would be caused during a flood if a dam was to fail. The argument centres on the premise that for a severe flood, the damage caused by the dam failing could be considered insignificant compared to the damage caused by the flood itself.

The American Methodology calculates an inflow design flood (IDF) and hence the associated spillway capacity required. To do this, dam break analysis must also be undertaken to determine the extent of any flood and the associated depth of flows.

The IDF used in America will never be less than a flood with a return period of 100 years. In some cases the IDF will be equal to the probable maximum flood (PMF) and in some cases it will be less than the PMF.

The US Federal Guidelines defines the IDF as:

> "The flood flow above which the incremental increase in downstream water surface elevation due to failure of a dam or other water impounding structure is no longer considered to present an unacceptable additional downstream threat.

The IDF of a dam or other water impounding structures is the flood hydrograph used in the design or evaluation of a dam, its appurtenant works, particularly for sizing the spillway and outlet works, for determining maximum height of a dam, freeboard, and flood storage requirements.

The upper limit of the IDF is the probable maximum flood"

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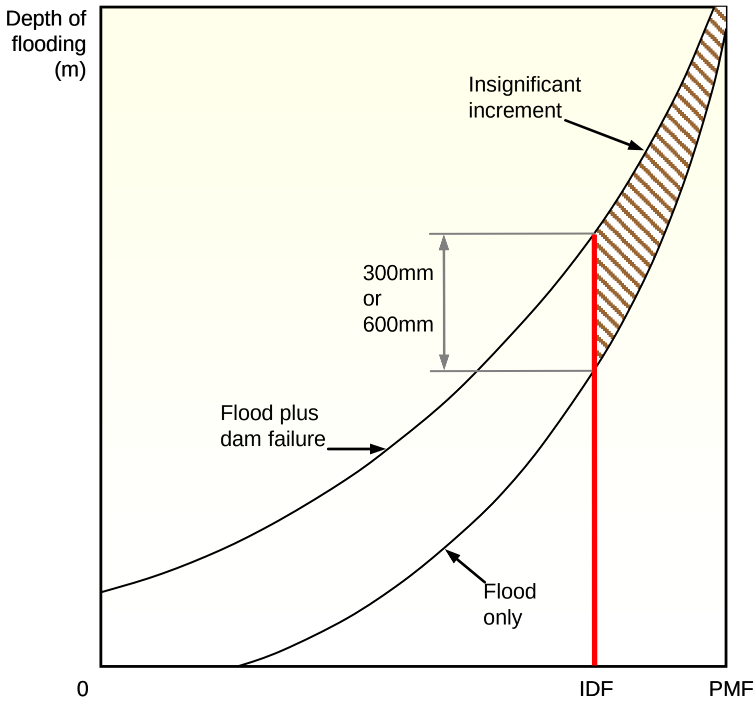

Figure 2 - The relationship between IDF and PMF and depth of flooding (from Hinks 2003)

For Ashford, the peak flood outflows versus the storm return periods are summarized below;

Table 1. Peak flood outflows for Ashford dam

Return Period (years)	Peak outflow (m^3/s)
100	20
1000	34
10000	67
PMF	134

For small reservoirs on large catchments, the difference between the PMF and the IDF will be greatest. For large reservoirs on small catchments the IDF will equal the PMF. For Ashford, although the dam break analyses were not undertaken, it is considered that the IDF would be between the 100 and 1000 year return periods.

To determine whether the catchment is large or small, the mean annual inflow needs to be compared to the reservoir capacity. Studies (Hinks 2003) have indicated that it is reasonable to describe reservoirs that can be filled by less than 100mm runoff as small reservoirs on large catchments.

Only 3.6mm of runoff would be needed from the Ashford catchment to fill the reservoir. Hence it can be described as a small reservoir on a large catchment.

The American Methodology considers the acceptable criteria whereby an IDF less than the PMF can be adopted. It considers either that there are no permanent human habitations downstream or, where there are, the threat to life would not increase significantly as a result of the failure of the dam. The latter is the case for Ashford.

For Ashford reservoir, Wessex Water initially considered the American Methodology as part of the options study, the implication being that works would not be necessary as the incremental flow caused by the failure of the dam would be negligible compared with the damage caused by the IDF.

Detailed dam break studies would be required to accurately determine the IDF. The cost of these studies is quite significant in itself, because it is necessary to carry out multiple runs or iterations until the IDF is identified.

Use of the American Methodology is not included in British guidelines such a *Floods and Reservoir Safety* 3rd edition and therefore there was a risk of a legal challenge should the worst case scenario occur in the future. Furthermore it is possible that work to increase the freeboard would have been required anyway. These factors resulted in Wessex Water deciding to invest in physical improvement works to the dam to meet UK best practice guidelines.

ALTERNATIVE OPTIONS CONSIDERED

The project team considered five other options for the improvement to the wave freeboard and spillway capacity.

Option 1 was to improve the erosion resistance of the zones at risk and increase the wave wall height to provide sufficient freeboard protection. This option requires the erosion resistance of the auxiliary spillway to be enhanced to accommodate the estimated flow velocities of 5m/s to 7m/s for the 10,000 year flood. A Grasscrete concrete system with good inter-block restraint would be used.

Option 2 was a modification of Option 1, whereby the height of the wavewall was minimised by making the dam safe for overtopping flows. This is possible as Table 1 of *Floods and Reservoir Safety* 3rd edition indicates that if the whole of the downstream slope of the dam is protected, then a 1,000 year design flood can be adopted as opposed to the 10,000 year flood.

Option 3 considered permanently lowering the reservoir top water level (TWL) to reduce the amount of flow going over the auxiliary spillway and improve the existing wave freeboard. Reducing the main spillway level would increase the attenuation in the reservoir by increasing flows over the main spillway in comparison to those over the auxiliary spillway.

Two factors limited the viability of this Option. Firstly, the reservoir is small compared to the catchment. There is therefore only minimal attenuation in the reservoir. Also, the preliminary hydraulic modelling confirmed that lowering the main spillway would have limited effect.

Option 4 considered providing an additional spillway. This would help reduce the flood rise in the reservoir and, depending on its location, could reduce the flood risk to properties downstream of the existing spillways. However, it would not negate the need to increase the height of the wavewall to provide the correct freeboard.

Option 5 was for the discontinuance of the reservoir either by lowering the operating top water level so that the stored volume was less than 25,000m^3 or by cutting through the dam. This would have had the disbenefit of reducing deployable yield and removing bank side storage to the water treatment works. The estimated costs, key benefits, constraints and risks of each option were studied. Option 1 was chosen by Wessex Water as this solution offered the best case between cost and effective long-term use of the reservoir as an asset.

CHOSEN DESIGN SOLUTION

With the overall design option decided, the details of the design were now considered. It was decided that the existing wave wall would be replaced with a new precast wave wall to provide the required minimum freeboard. A precast solution had the following benefits over an in-situ solution:

- a reduced construction duration;
- reduced health, safety and environmental risks;
- allowed a more aesthetically pleasing curved wall in section, and;
- allowed fine tolerances in the finished product.

Wessex Water had already selected a contractor (Wessex Engineering & Construction Services Ltd) to carry out the construction works. The designer (Halcrow Group Ltd.) worked closely with them to establish their favoured construction methodology. This included undertaking a stability assessment of the embankment to determine what size machinery could be safely accommodated on the dam crest. It also included designing the precast wave wall units to the correct size and weight for installation by the contractor.

As the predicted new stillwater flood level was now slightly higher than the expected top of the clay core of the dam, the core needed to be raised slightly. To ensure a waterproof seal from the top of the core to the top of the wave wall, the new clay was extended outwards to meet the back of the wave wall base slab. The solution is shown in section in Figure 3.

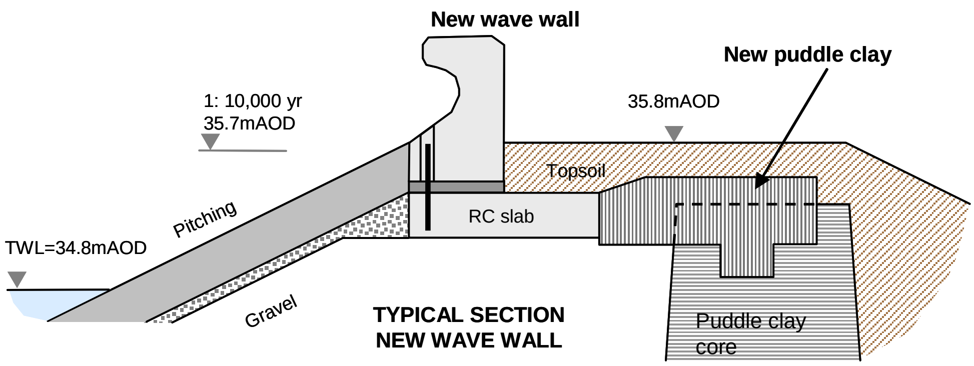

Figure 3. Typical section of the new wave wall

A detail that was given considerable attention was the connection between the wave wall units and the precast base slab. The designer and contractor discussed several variations around the theme of locating bars protruding from the base slab.

The chosen solution comprised two resin-anchored reinforcement bars, drilled into the completed in-situ base slab, in order to locate each precast unit. The precast wave wall units themselves had two (rough edged) cylindrical vertical voids cast into them which allowed them to be located approximately onto the anchor bars.

Final adjustments to unit placement were made at this stage to ensure a very accurate line and level of the top of the wall for aesthetic reasons. The voids around the bars were grouted up to fix them securely to the anchor bars.

The existing grass auxiliary spillway was protected by a geotextile below the grass. However, hydraulic analysis indicated that this would be insufficient to withstand the flow velocity of the 1 in 10,000 year flood.

A more robust Grasscrete solution was therefore chosen for the predicted main flow path. Areas to the sides of this, where velocities were lower, were protected by Enkamat geotextile.

The Grasscrete solution was designed in accordance with the manufacturer's normal specification. Figures 4 and 5 below detail the final Grasscrete design solution.

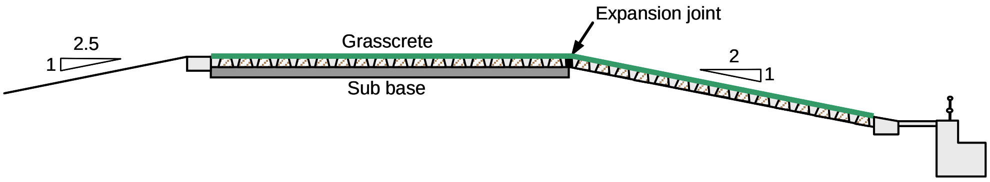

Figure 4 Typical section of the auxiliary spillway

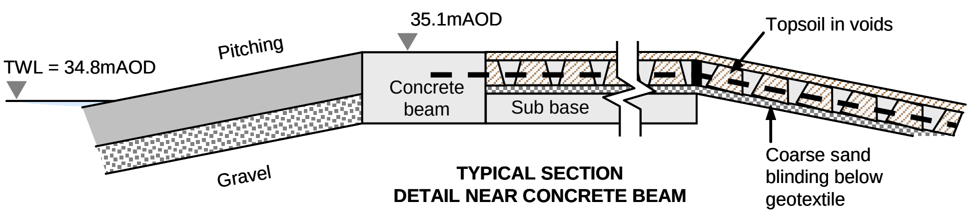

Figure 5 Typical detail near the upper concrete beam

CONSTRUCTION ISSUES WITH AUXILIARY SPILLWAY

One of the key risks during the construction period would have been the overtopping of the auxiliary spillway whilst the surface was exposed during the construction of the Grasscrete panels.

This overtopping could have lead to failure of the embankment from erosion. Hence, minimizing the construction duration was critical to satisfactorily mitigating the risk of overtopping.

The Grasscrete was constructed in a series of bays so that no more than one 10 metre wide bay was under construction at any time. A contingency plan was also developed. This included the installation of a securely fixed plastic sheet over exposed areas overnight or at weekends and procedures for operating valves to draw down reservoir water if necessary.

This mitigated the risk of erosion damage due to possible overtopping of the auxiliary spillway during the construction period. The reservoir operating level was temporarily lowered by 700mm during the construction period and the use of the by-wash channel was maximized during wet weather.

As the weather during the construction period was particularly wet, to reduce the risk of damage to the crest of the dam, the 1 tonne precast concrete wavewall sections were lowered directly into place using a crane on delivery from the precast supplier. This greatly reduced the need for vehicles to track back and forth along the dam crest. For the same reason, concrete for the wavewall base slab and the Grasscrete bays was pumped into position, rather than being delivered by dumper.

Photo 1 Construction of the new wavewall

Photo 2   Levelling wavewall

CONCLUSION

The American Methodology differs from the guidance given by Table 1 of *Floods and Reservoir Safety* 3rd Edition, by stating that there is no need to design a spillway for a flood larger than the calculated IDF. The IDF being the flood at which the additional flow from a dam breach is considered insignificant.

For Ashford reservoir, this methodology was considered during the options studies. The IDF was considered to be a flood with a return period between 100 – 1000 years, significantly smaller than the flood with a return period of 10,000 years.

Wessex Water decided to rely on an option that involved an investment in actual physical improvement works rather than a potential no-build solution that relied on detailed dam break analyses.

However, the authors believe that the use of the American Methodology may well be appropriate for some small reservoirs on large catchments in the UK. This would be in line with the move in recent years to taking a more risk based approach to the regulation of reservoirs.

REFERENCES

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