The Washburn Valley Reservoirs – spillway improvements

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SYNOPSIS. The Washburn Valley reservoirs comprise a cascade of four impounding reservoirs situated about 12 km to the west of Harrogate in North Yorkshire. The three lower reservoirs, Lindley Wood, Swinsty and Fewston, were formed between 1875 and 1879, by the construction of earth embankment dams with puddle clay cores. The upper reservoir, Thruscross, is a mass concrete gravity dam constructed in 1966. The upper three reservoirs supply water to Leeds while the lowest, Lindley Wood, provides compensation flows to the River Washburn.

The three lower dams would be overtopped during the Probable Maximum Flood (PMF). The situation was complicated by the publication of the Flood Estimation Handbook (FEH), which led to a review of the conceptual design and a lengthy delay, which was recovered by carrying out works at two dams in one season, instead of one per year as originally planned.

The rehabilitation works consisted of crest raising and spillway modifications at the three embankment dams.

- Lindley Wood: a 3 m high earth embankment was built downstream of the existing crest road, which will be inundated during extreme floods.
- Swinsty: the crest was raised 1.2 m and the multi-span masonry arched bridge replaced by a clear span.
- Fewston: the crest was raised 0.9 m and the multi span masonry arched bridge replaced by a clear span.

At £6.5 M this is one of the largest reservoir safety rehabilitation schemes undertaken by *Yorkshire Water* (YW). It was successfully completed in 2003 on time and within budget by team working.

BACKGROUND

The Washburn Valley reservoirs comprise a cascade of four impounding reservoirs. The three lower reservoirs, namely Fewston, Swinsty and Lindley Wood were formed between 1875 and 1879, by the formation of embankment dams with puddle clay cores. The upper reservoir, Thruscross, was completed in 1966 with the construction of a mass concrete gravity dam. The upper three reservoirs supply water to Leeds whereas the lowest reservoir, Lindley Wood, provides compensation to the River Washburn.

Long-term benefits and performance of dams. Thomas Telford, London, 2004.

There are considerable benefits from being able to undertake iterative hydrology, hydraulic calculations and model testing at the same time. Changes to any one component can affect the others. For example, removal of spillway restrictions at Fewston and Swinsty changed the hydraulic characteristics, reduced the flood attenuation, and increased the required freeboard at Lindley Wood.

The five arch masonry bridges at Fewston and Swinsty significantly reduced spillway capacity at moderate discharges. Various schemes to preserve their appearance were considered but none were found to be practical and it was therefore decided to seek planning consent to remove them. The outline designs to pass the PMF through the cascade included:

- Fewston A 2 span bridge, raised crest road and wave wall.
- Swinsty A 2 span bridge, raised crest road and wave wall.
- Lindley Wood Crest raised by 3 m.

Considerable out of channel flow was predicted at all three dams. The model testing provided excellent information on depths and velocities. YW adopted its normal practice of extending the spillway rating curves to flows 10% higher than anticipated and recording the test performance on video.

FLOOD REVIEW AND IMPACT OF FEH

In October 2000 *TEAM*, a working agreement between *E C Harris, Arup* and *MWH*, were appointed to carry out a feasibility review, detailed design and project management for implementation of the scheme. This was soon after the publication of the Flood Estimation Handbook (FEH) [2], which complicated the situation significantly.

The flood assessment techniques contained within the FEH are on a different basis to the Flood Studies Report (FSR) [3], and were publicised as being the "the replacement for the Flood Studies Report". Interim guidelines on their application were published by DoE, summarised as:

- If the overflow capacity is adequate to present standards (i.e. Reference 1), then do nothing.

  The overflow capacity had been found to be inadequate – hence 'do nothing' was unacceptable.

- If new or improved spillways are required, then follow one of the following three options:

  1. If practicable, then postpone work on spillways until new guidance is available.

     This was impracticable, since the recommendations were "in the interests of safety" and therefore mandatory, furthermore it was not known when new guidelines might become available.

  2. If (1) is not practical, adopt a 2-stage improvement, if this is technically, financially and environmentally acceptable. The first stage is to increase the spillway capacity using FSR. The second stage is increasing the capacity further, if subsequent higher standards are recommended.

     This approach was adopted, with the works designed to allow future crest and wall raising.

3. If (1) and (2) are not practicable, increase the capacity using FEH rainfall or worst case PMF.

Revised PMF

The FEH methodology was claimed to include latest thinking on catchment characteristics, which updated the Flood Studies Report. The new procedures were incorporated into a review of the flood hydrology, which resulted in an increased PMF from this "hybrid" approach. The following table compares previous and new PMF values and existing and proposed flood defence levels for the three reservoirs.

It was decided to adopt a precautionary approach and design to the higher flows and levels.

	Estimated PMF outflow (m^3/s)		Flood Defence Level (m OD)	
Reservoir	FSR	FEH "hybrid"	Existing	Required
Fewston	405	442	156.58	157.55
Swinsty	454	498	140.20	141.28
Lindley Wood	504	536	93.22	96.09

PROGRAMME OF WORK

It had originally been intended to improve spillway capacity sequentially, working upstream from Lindley Wood in 2001 and finishing with Fewston in 2003. The flood review had effectively lost a year from the programme.

It was decided to carry out the remedial works on the lower two reservoirs, (Swinsty and Lindley Wood) during 2002 under a single contract. This presented parallel difficulties of maintaining compensation discharges and water supplies, which were overcome by careful control of reservoir level. The works at Fewston followed under a separate contract in 2003, recovering the time lost.

The contracts were let by competitive tendering to a select list using NEC ECC Option A contract conditions. Both contracts were won by *Morrison Construction*, who were able to transfer staff, cabins and 'lessons learnt' from Swinsty to Fewston.

WORK CARRIED OUT

The main components of work at each dam are outlined below:

Lindley Wood

Lindley Wood dam is 330 metres long and was a maximum 21 m high with a capacity of 2920 Ml. Remedial works included:

- Raising of flood defence levels by about 3 m. This was achieved by construction of a new embankment above the existing one, thanks to the unusually wide crest. The new embankment comprised granular fill with side slopes of 1:2. An HDPE membrane was laid over the upstream face, terminating within the existing clay core at the bottom and rising above peak still water level at the top. The design of the crest raising was unusual in that the existing wide crest allowed the construction of the new embankment downstream of the existing access track. In extreme conditions both the track and existing valve towers will flood. Rather than opting for a scheme with higher capital costs that would ensure the track and valve tower did not flood, YW accepted this arrangement as a 'business risk' since it would not pose a threat to reservoir safety. There is no wave wall, however one could be built on top of the new embankment in future.

- Increase of spillway capacity by the demolition of existing footbridge, the construction of a new reinforced concrete headwall structure and by making provision for out-of-channel flow by creating reinforced grass revetments utilising proprietary pre-cast concrete blocks.

Swinsty

Swinsty dam is 460 m long and was a maximum of 20 m high with a capacity of 4655 Ml. Remedial works included:

- Raising flood defence levels by about 1.2 m, which was achieved by the construction of a new 2.25 m high reinforced concrete wave wall to replace the existing and raising the crest road level by approximately 1.2 m, in granular fill. A sheet pile cut off embedded into the existing puddle clay core and extending into the wall base ensures a continuous water barrier to above peak still water level. The wall can be raised by 0.5 m.

- Increase of spillway capacity by demolition of the existing five arch bridge and replacement with a new single span bridge with the soffit level set above the PMF level. Provision for out-of-channel flow by

construction of additional bunding and provision of reinforced grass revetments utilising proprietary pre-cast concrete blocks. The replacement of the bridge at Swinsty was undertaken as a ‘design & build’ element within the contract, and designed to be lifted 0.5 m in the future. The main beams for the bridge were prefabricated and delivered to site as single 30 m long units;

- The crest road at Fewston is a public highway and as such these works are subject to the approval procedures of North Yorkshire County Council and the wave wall has been designed to provide vehicular impact containment to P2 level in accordance with BD 52/93 "The Design of Highway Bridge Parapets".

- Increase of spillway capacity by demolition of the existing five arch bridge and replacement with a new single span bridge with the soffit level set above the PMF level. The bridge is similar to Swinsty.

- Provision for out of channel flow by construction of additional bunding where necessary and provision of reinforced grass revetments utilising proprietary erosion control geotextile;

DESIGN ISSUES

Although many of the elements of the three designs were common to each, a number of issues required special consideration:

Revetment Protection System

Revetment protection systems were designed on the guidance of CIRIA Report 116 – Design of Reinforced Grass waterways. Maximum anticipated out of channel flow velocities for the three spillways are as indicated in the table below:

Reservoir	Maximum estimated out-of-channel velocity
Fewston	6.0 m/s
Swinsty	7.1 m/s
Lindley Wood	9.7 m/s

Flow velocities at Fewston and Swinsty resulted in geotextile erosion control matting and interlocking precast concrete blocks respectively to be chosen as the preferred method of protection. The peak velocities at Lindley Wood were anticipated to be in excess of those velocities covered by the CIRIA guidance (8 m/s maximum). However, one of the authors of that report confirmed that the interlocking pre-cast concrete block system could withstand sustained flows at velocities up to 10 m/s, if installed with sufficient attention to detail, hence this system was adopted.

Environmental Issues The Washburn Valley constitutes part of the Nidderdale Area of Outstanding Natural Beauty and planning restraints have required that as far as possible the existing landscape be preserved or enhanced. Detailed Planning Consent was sought for all three dams in a single application in order to reduce the chances of delays and permission was obtained with acceptable conditions. All new structures are required to be fully clad in natural stone work, including the bridges, and measures such as ecological surveys, archaeological studies and tree preservation strategies were employed in order to minimise the impact of the works.

Lindley Wood Cottage

This disused dwelling was originally intended for demolition as it was considered an obstruction to the dam raising works. However plans were altered when two bat colonies were discovered within the roof void. Bats are protected species and a mitigation strategy needed to be agreed with DEFRA in order that permission to remove the habitat could be given.

The most straightforward mitigation was to build another bat roost nearby, carefully replicating the conditions in the hope that the bats would move, however this would have meant delaying the work by at least one year and possibly longer. Alternatively, the raising could have been done by a complicated realignment of the crest around the house, in order that the structure might be left intact. The solution adopted in order to facilitate both the crest raising and the maintenance of the bat habitat was to build the cottage into the raised dam embankment. The ground floor was filled with lightweight concrete and the existing first floor became an electrical plant room. Landscaping around the house was designed to maintain flight paths and bat tiles were built into the roof to maintain access for the bats. The bats returned to breed in 2003, helpfully discharging the planning condition.

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Recreation

The area is popular with ramblers and YW has promoted circular walks, which pass through the construction sites. Temporary footpaths were erected and maintained to segregate pedestrians from traffic.

All the reservoirs are active fisheries, which were able to continue in use during the work. New permanent tracks were built to allow access to the drawn down waterline in order to enable Fewston Reservoir to be restocked with rainbow trout.

Water Control Measures

YWS undertook to maintain water levels in the reservoirs within a pre-determined range below existing overflow weir levels so as to ensure that construction could not only proceed safely but also so that water supplies to Leeds could be maintained. The criterion for the upper limit was based on a 1% chance that the level would be exceeded during the critical construction period when work is undertaken on the dam or spillway. A procedure was formulated by *YWS*, *TEAM* and *Morrison Construction* whereby water levels would be monitored and contingency plans brought into action in the event of the reservoirs rising above various threshold levels.

The contingency plan was called into operation on one occasion during the works at Lindley Wood and it worked well. The contractor mobilised plant and materials to protect the open excavation over a weekend, scour discharge to the river was maximised and the bags of stone and clay were removed without getting wet the following week. The client accepted the financial risk of invoking the emergency measures and the incident was covered under the cost component schedule of the contract, including costs to accelerate the works back on to programme.

CONCLUSION

By the time the work at Fewston dam was nearing completion the project team of consultant, client and contractor were working so well together that they wanted to move straight on to the next dam upstream. Regrettably, all good jobs come to an end and this one was finished on time and below budget.

ACKNOWLEDGEMENTS

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REFERENCES

1. Institution of Civil Engineers (1996) *Floods and Reservoir Safety,* 3rd Edition.

2. CEH Institute of Hydrology (1999) *Flood Estimation Handbook.*

3. NERC (1975) Flood Studies Report.