Eccup en-route Storage Reservoir - Siphon Pipes

compliance with the Reservoirs Act (1975)
provision of sufficient drawdown capacity

by Gareth Simpson MEng

Eccup Reservoir is an impounding reservoir located on Eccup Beck. The 24m high, 225m long embankment dam was constructed in 1885 and incorporates many of the characteristics of Victorian 'Pennine' type structures. During its first filling, leakage and settlement occurred resulting in the extension and deepening of the puddle clay cut-off trench and the reconstruction of the core. In order to undertake these further works brick pillars were constructed at 30m centres along the length of the embankment. The reservoir was finally commissioned in 1897. The reservoir has a small direct catchment and is used as an en-route storage reservoir (ESR) by YWS being supplied from indirect sources in the Washburn Valley and the River Ouse. The reservoir has a capacity of approximately 7,000,000m^3 and a surface area of 0.77km^2 at top water level (TWL) of 114.68m AOD.

Pipe ready to float - Courtesy of MMB Ltd

Recommendations

Recommendations made by the Qualified Civil Engineer (QCE) in the interests of safety under Section 10 (6) of the Reservoirs Act 1975 for the project were made as follows:

- Replace and upgrade the bottom outlet facilities such that the reservoir can be drawn down at a rate of no less than 1m per day.
- Plug the existing bottom outlet and fill the existing outlet tunnel to protect against internal erosion.

The project was awarded to Mott MacDonald Bentley Ltd (MMB) as part of a batch alongside a similar project, with a batch value of approximately £2.5m.

Investigation

The main focus of the investigation was to consider options which could meet the draw down requirements specified within the QCE recommendations. The options were reviewed against a number of different factors, as represented in the table on next page.

The final review of options concluded that a siphon pipe arrangement was the best option to progress in detailed design.

Project challenges

There were several constraints which had an influencing factor on both the design and construction of the 1.4m diameter steel pipe. The site is situated within the Eccup Reservoir Site of Special Scientific Interest (SSSI), which is designated for its importance to wildfowl in particular for its over wintering birds.

Eccup holds between 1-2% of the estimated total wintering population of goosander, so the population here is of national importance, and is currently the fourth largest population in the British Isles. Consultations with Natural England were undertaken in order to minimise any impact from construction.

For operational reasons, the amount of draw down was restricted during construction to ensure the supply to Headingley WTW was maintained. As such, part of the siphon had to be constructed underwater using a specialist diving team.

The siphon had to pass through the embankment to avoid blocking off the public highway running along the crest. The QCE stipulated that the siphon pipe must be routed through one of the existing brick pillars rather than the clay core. By passing through the brick pillar, a better seal through the waterproof element of the dam was achieved to prevent a leakage pathway developing through the embankment.

This also removed the need to re-puddle clay around the pipe, but did present other complexities. Passing through the rigid brick pillar into the embankment either side introduced the potential for significant differential settlement. The brick pillar, an engineering feat in itself, had to be carefully de-bonded and broken out to avoid any disruption to the embankment it helps support.

Due to the tight timescales on the project, the solution was designed so that it could be built within permitted development rights. This had particular implications on the pump kiosk and the outlet structure at the end of the siphon.

Engineering solutions

As the upstream end of the siphon was too far away from the crest to lift with the crane on site, MMB turned the inability to lower water levels to its advantage by using this reservoir to float the pipe into position. Special blank plates were installed to the pipe ends to allow the pipe to be filled with air before entering the reservoir. The pipe was then towed along the length of the embankment before opening the air valve and sinking the pipe into position.

The siphon was designed using Building Information Modelling (BIM). Earthworks were modelled using Autodesk Civil 3D and imported into Autodesk Revit structure.

Due to programme constraints, the siphon had to be built by starting at both inlet and outlet ends and working towards the middle. This meant that prefabricated bends were required to ensure the upstream and downstream legs were aligned perfectly through the crest.

Setting out information was available for the site team to pull out of the model when they needed it. Once the upstream and downstream legs were in place, the as-built information was pulled back into the model to supply to the pipe manufacturer in order to produce the prefabricated compound bends.

The model was also used for the structural analysis of the pipeline. The geometry, layout and arrangement of the siphon pipe were exported from Revit into Autodesk ROBOT where a finite element analysis was undertaken to determine reaction forces at restraint locations along the pipeline.

Submerged discharge valve

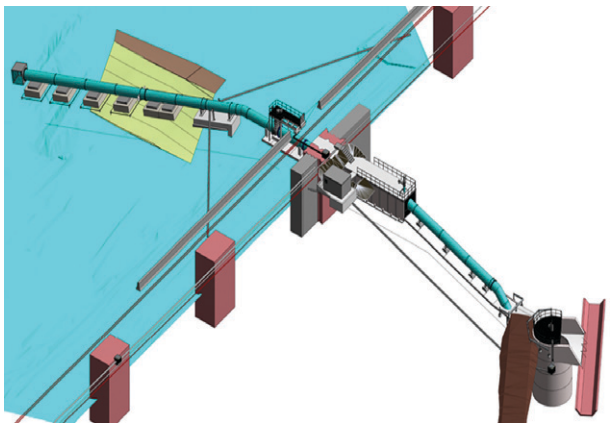
A submerged discharge valve (SDV) was chosen to control siphon flow and still the water at the outlet. The valve discharges underwater which acts to dissipate the energy and still the flow, ensuring it remains within the spillway, reducing the risk of erosion of the downstream embankment from out of channel flow. The valve is also required to control the flow in order to minimise the impact of the regular scour tests on the downstream watercourse.

The SDV was 7.5m long and weighed close to 13.5 tonnes in total. The valve was installed in a 6m diameter, 8m deep reinforced concrete shaft. The shaft was constructed by casting in situ rings, which were then sunk into the bedrock by carefully undermining the ground below the shaft.

Options \ Factors Considered	Buildability / H&S	Reservoir safety	Environment & water supply	Third party impact	Cost
Draw off shaft & tunnel					
Gravity pipe					
Siphon pipes					
Line existing scour pipe					
Emergency pipes					

Downstream culvert, excavation through brick pillar Courtesy of MMB Ltd

Placing the SDV - Courtesy of MMB Ltd



View showing 3D model - Courtesy of MMB Ltd

Pipe being towed into position - Courtesy of MMB Ltd

Installation of the upstream gate valve - Courtesy of MMB Ltd

Discharge chamber - Courtesy of MMB Ltd

Stakeholder engagement

Due to the works, the road and footpath along the crest had to be closed to the public. Diversion routes were put in place to allow local residents to maintain access to their properties and for members of the public to continue to enjoy walks around the reservoir.

Situated upstream of Harewood Estate, Harewood was a major stakeholder in the scheme and a lot of consideration and communication between the two parties was required.

Previous scour testing from Eccup had been restricted due to concerns of transporting silt downstream via the scour pipe located in the reservoir basin.

The maximum theoretical capacity of the siphon was calculated at close to double the maximum capacity of the downstream watercourse running through Harewood Estate. This meant a balance needed to be struck between testing the siphon to sufficiently prove it operated as it should, and minimising the impact on the downstream watercourse and its associated structures, including listed bridges.

This made the commissioning day a huge operation, with over 20 staff placed along the watercourse monitoring strategic points, 2 roaming vehicles providing support, a team operating the siphon, plus representatives from Yorkshire Water, Harewood Estate, Environment Agency, and the QCE and Supervising Engineer.

Summary

The Eccup siphon project has been a huge technical challenge for all those involved throughout design, construction and commissioning. This batch of work was the first time constructing a siphon to improve draw down capacity within Yorkshire Water. Adding to this, the tight programme and additional constraints highlights the success of the scheme.

Key to success was the collaborative partnership adopted through all parties at all levels. Regular core team meetings between MMB and Yorkshire Water helped resolve problems and keep a continuous flow of decision making while early subcontract involvement helped to deliver the best solution when it was needed.

The compliance date of March 2015 was successfully met and Eccup is now preparing for its next project with spillway improvement works following on from the siphon project.

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View of downstream leg, looking upstream - Courtesy of MMB Ltd

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