KTT Spillways Project

increasing the spillway capacity of three historic impounding reservoirs within Dartmoor National Park

by Andy Haill , Martin Peters & Jon Charles

Kennick, Tottiford & Trenchford reservoirs are a cascade of three reservoirs in series located within Dartmoor National Park between Bovey Tracey and Moretonhampstead in the parish of Christow. The top reservoir is Kennick, the middle reservoir is Tottiford and the lowest is Trenchford. All three are often collectively known as Tottiford Reservoir or KTT. Tottiford Reservoir was the first to be constructed in 1860. It was raised in 1866 and 1867 to its current TWL. Kennick Reservoir was constructed around 1881 and Trenchford Reservoir was constructed around 1905.

Completed works at Trenchford - Courtesy of Still Imaging

Reasons for undertaking the works

Kennick, Tottiford & Trenchford reservoirs were reclassified from Category B impounding reservoirs to Category A. Category B reservoirs are where a breach could endanger lives not in a community, but cause extensive property damage. Category A reservoirs are where a breach could endanger more than 10 lives.

Category B reservoirs require that the spillway is able to discharge the flood arising from a one in 10,000 year event (approx 0.5 of the PMF, Probable Maximum Flood) without endangering the dam. Category A reservoirs requires that the spillway is able to discharge the flood arising from a PMF event.

Options

This reclassification required a review of the dams and the spillway structures and this was undertaken by Atkins. The report, '*Atkins Preliminary Feasibility Report: Upgrade to Kennick, Tottiford & Trenchford Reservoirs October 2009',* predicted the inflow rates into the reservoirs caused by a PMF event in the catchments. It reviewed how high the water levels would rise and the likelihood of overtopping the dams. The report presented a number of combinations of spillway improvements and dam level raising to ensure that overtopping did not occur. The table below shows the spillway capacities, existing and required:

Spillway	Existing capacity	Required capacity
Kennick Spillway	19m³/s	57.5m³/s
Tottiford Spillway	31.2m³/s	58.4m³/s
Trenchford Spillway	45.3m³/s	84.9m³/s

The options and recommendations within the Atkins report were developed by the South West Water H5O Alliance, with the aims of minimising the construction costs and programme, minimising the risk from the existing historic dam structures and minimising the

Trenchford: Clay core reinstatement (note buttress on culvert to compact against) - Courtesy of H5O

Tottiford Bridge prepared for removal - Courtesy of H5O

Tottiford: Sheet Piles driven into the clay core - Courtesy of H5O

Kennick Spillway in rock cutting - Courtesy of H5O

Trenchford - Courtesy of H5O

disruption to the raw water supply. Consideration also needed to be given to the appearance of the solutions, due to the location of the dams within Dartmoor National Park and the effect of the construction work on third parties, such as local ramblers and anglers. A number of more radical options, such as tunnelling a new spillway to a nearby watercourse or reinforcing the downstream faces of the dams to allow overtopping, were looked at but ultimately discounted.

The outcome of this process resulted in proposals to:

- Raise Kennick Dam crest level by 730mm.
- Raise Tottiford Dam crest level by 1240mm.
- Raise Trenchford Dam crest level by 960mm.
- Retain the current weir length on Kennick, but significantly widen and deepen the inlet and spillway to accommodate the PMF flow.
- Lengthen the current weir length on Tottiford and significantly widen and deepen the inlet and spillway to accommodate the PMF flow.
- Retain the current weir length on Trenchford, but significantly widen and deepen the inlet and spillway to accommodate the PMF flow.

The crest raising was achieved by designing a cast in situ reinforced concrete wall, extending the full width of the dam, upstream of the existing roadways. The height of the wave was established by calculating the depth of water over the weirs at the PMF flows to establish the PMF water level.

A study was then undertaken to calculate the likelihood and size of waves that could be created during the PMF storm event. The accepted minimum wave allowance stated in '*Floods and Reservoir Safety*' is 600mm. The likely wave events were all under this minimum, therefore the new crest level was the PMF level plus 600mm.

The modification works on the spillways included reshaping the overflow weirs, replacing the existing bridges with cast in situ culverts, widening and deepening the spillway channels and providing a suitable stilling basin. Diversion of existing pipe work was also required at all three dams.

The design and geometry of the weirs, culverts and spillways were established by an iterative process using Computation Fluid Dynamic Simulations undertaken by Dr Jim Wicks of the Fluid Group. This required initial geometries to be modelled, the outcomes reviewed to ensure that the flow was safely retained in the critical areas and then the geometries amended and modelled again to help value engineer the design. These simulations also established flow velocity and impact loadings for all parts of the proposed spillways.

Historic drawings from South West Water's archive were studied to gain as much information as possible on the construction make-up and geotechnical ground conditions in and around the dams. This assisted H5O to plan and undertake a number of trial holes and bore holes to further reduce the risk from unforeseen ground conditions.

The outcome of the ground investigations confirmed that most of the construction work would be undertaken on or just above the existing bedrock at the shoulders on the dams. However, the new inlet, bridge and spillway at Tottiford would be mostly on the soft fill of the dam and the existing bridge and weir showed signs of differential settlement. This prompted H5O to specify that the new structures at Tottiford should be piled.

This extended design process resulted in the production of relatively detailed design proposals and drawings for H5O to review, price and submit as a scheme cost to South West Water.

H5O were satisfied that known risks due to the construction make-up of the dams were manageable, and should be reduced once the construction team was on site and could undertake further excavations and investigations.

Scheme design

Once South West Water had reviewed the submitted costs and approved the scheme, H5O proceeded with the production of detailed design drawings. These designs were reviewed by the Reservoir Panel Engineer (Nick Riley), the Supervising Engineer (Crawford Munro) and the South West Water Project Engineer (Jack McCarey). Detailed design of the cast in situ bridges and culverts was also undertaken by H5O.

Regular site meetings were arranged to discuss details and programmes and specialist geotechnical support was provided during critical excavations on the dam cores. This assisted H5O to develop the correct techniques for ensuring that the new structures formed a water tight seal with the core and did not allow any water pathways to develop. The closeness of one of the H5O offices to the site (approximately 25miles) proved to be very helpful during the works, with queries and details being able to be inspected and solutions provided within a short space of time.

Contractual arrangements

The construction works were undertaken by the South West Water Delivery Alliance H5O, who are undertaking the AMP5 works for Client South West Water.

The project was let under an amended version of the ECC Option C form of Contract with South West Water in a target cost Pain/Gain share arrangement incentivised as part of the entire programme within the H5O Alliance.

Early all party involvement in developing the scheme during the design phase and setting the target cost was critical in delivering the scheme under the South West Water budget and the agreed target cost of £4.41m.

Construction

Construction commenced in June 2013 and was phased across the three reservoirs with a completion date in February 2015.

Prior to construction commencing in June 2013 Ecological Impact Surveys, undertaken by South West Water & EAD, had established the presence of dormice & adders.

Early works were required to clear the dormouse habitats during winter clearance by cutting trees and shrubs to within 150mm of ground level, installing nest boxes in an enhanced area adjacent to the site then subsequently removing tree roots and stripping topsoil in the construction areas in May of 2013. Adders had to be translocated and then ongoing habitat mitigation measures were put in place under the supervision and advice from EAD.

A reservoir control strategy was agreed with the Water Supply Demand Strategy Group to maximise the available water resource whilst undertaking the works safely, ensuring that there was enough buffer and discharge capacity in the reservoirs should the weather deteriorate and the construction works require being made safe.

The strategy was simplified to a pictorial view and control lines added to the reservoir Control Curves and Net Storage Capacity Graphs. If the reservoir level was below the maximum storage guideline then there were no concerns for the reservoir safety work, however if the level was rising and approaching the guideline then this was raised with the Demand Strategy Group and a course of action agreed. In certain circumstances the opinion of the Panel Engineer was sought to determine the safe course of action.

Tottiford culver following reconstruction - Courtesy of H5O

The strategy determined a construction sequence enabling the works to the lower spillway of the 'higher' reservoir to be undertaken whilst the intake structure of the 'lower' reservoir was being undertaken with the capacity of the reservoir lowered sufficiently for these works to be undertaken safely.

This sequence meant that the programme was of a relatively long duration running from June 2013 to Feb 2015 and in the sequence Trenchford Dam (lowest), Tottiford Dam & Kennick Dam (highest)

The construction works were undertaken traditionally using cast in situ concrete due to difficult access routes to the site, the sites being located along single track routes with limited passing and turning places. Consideration was give to precast concrete elements but this was deemed impractical for the reasons given.

The existing bridge crossings were demolished and all replaced with cast in situ concrete culverts, the spillways were re-profiled and widened/deepened with in situ concrete or with in situ concrete lining anchored to the exposed rock face. The wave walls were in situ concrete.

Of paramount importance was the resealing of the Dam Core to the new structures and H5O's Geotechnical Engineer was on hand to advise on a Dam by Dam basis. Replacement Clay for the cores was sourced locally from Imerys Newbridge Works at Chudleigh. H5O established a material specification and testing regime and supervised the on-site reinstatement and in situ testing.

The culvert structure that interfaced with the core was designed to enable full compaction of the clay core adjacent to the structure by incorporating a buttress to compact against. Each culvert required a different method of reinstatement of the clay core, Trenchford was a direct replacement of the clay core, Tottiford required the installation of a sheet pile cut of wall due to the poor quality of clay within the existing core and Kennick, being totally in rock was reinstated with concrete as per the original methodology.

The works were completed within the original construction period on 18 February 2015.

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