

Black Esk Reservoir Dam Raising

raising the height of a reservoir and bell-mouth spillway required innovative thinking for a world's first

by William Ancell BA (Hons)

Black Esk Reservoir is a popular fishing and beauty spot covering 110 acres in the rugged but scenic countryside of rural Dumfries and Galloway, The nearest major settlement is the award winning village of Moffat 14km to the north west. The reservoir and nearby water treatment works were opened on 13 August 1962 by the Rt Hon. Michael Noble, MP and Secretary of State for Scotland, to supply drinking water to towns and villages in Annandale and Eskdale and to ensure supply of water to Chapelcross Nuclear Power Station. One of Scottish Water's most ambitious projects in the SR10 regulatory period (2010-15) is a £5.5m project to raise the height of the Black Esk dam and increase the reservoir's storage capacity and improve the security of the water supply.



The existing valve tower, access bridge and spillway prior to construction works - Courtesy of Scottish Water

Background

The reservoir sits on the course of the Black Esk River, which merges with the White Esk to form the River Esk to the east of Moffat. The reservoir has an earth embankment dam and is surrounded by plantation forest. The geological profile at the site of the dam is intensely folded greywacke and shales of the Silurian system generally covered with glacial deposits of boulder clay.

In 2010 Scottish Water dealt with one of the most serious water shortages in recent times in Dumfries and Galloway. The Black Esk and Penwhirn reservoirs suffered greatly from the prolonged reduction in rainfall and drought orders were applied for to abstract water from nearby watercourses to augment the afflicted reservoirs and ensure customers were not subjected to hosepipe restrictions.

A major media and advertising campaign was launched in the area to raise awareness of the water shortages in the area and was a great success, but the utility firm was keen to learn from this experience

and secured central funding to raise the dams at both the Black Esk and Penwhim Reservoirs to enhance the storage potential and yield of the reservoirs for the future.

The Black Esk WTW and Reservoir is a key asset for Scottish Water in Dumfries and Galloway, serving a population of 48,000 in Lockerbie and surrounding areas. Substantial investment and improvements by Scottish Water in the last few years has taken place at the works.

- **Treatment upgrades:** £1.4m was invested upgrading the treatment facilities at the WTW to meet the exacting standards set out by the Drinking Water Quality Regulator.
- **Security:** £129,000 has been invested on new fencing and a hi-tech security system.
- **Supply network:** Completed in 2009, £7.5m was invested on a 20km pipeline from the WTW to supply the Old Town area of Langholm and replaces an unreliable spring supply that was susceptible to high cryptosporidium levels.



The spillway prior to construction of the new circular piano-key weir
Courtesy of Scottish Water



Construction work underway with scaffolding in place in March 2013,
with the reservoir level dropped - Courtesy of Scottish Water



The pontoon and valve tower, with the spillway to the right
Courtesy of Scottish Water



Elevated view of the weir from the reservoir bank
Courtesy of Scottish Water

Project need

The project will raise the dam by 2.5m, greatly increasing the capacity of the reservoir by nearly one billion litres from 2,280ML to 3,147ML, delivering a more secure and consistent supply of water even during dry spells. The original design from the 1960s allowed for a future capacity of around 6.8ML by raising the dam by a further 9m.

Researching the solution

Significant research took place to identify the most effective solution for Black Esk. One major challenge was that the overflow for the reservoir, which needed to be raised along with the dam, represented a significant engineering hurdle. The bell-mouth spillway is an unusual 12-sided design and is of 56ft mean diameter at crest level.

Led by contractors Black & Veatch, the research for a suitable solution took them to France to study piano-key weirs as this design was deemed to be the most effective. However piano-key weirs are traditionally designed, as the name suggests, in a straight horizontal configuration that is visually reminiscent of the eponymous musical instrument.

Black & Veatch proposed a radical re-think of this approach in constructing a world-first, a circular piano-key configuration that will be mounted atop the existing bell-mouth spillway, which will enable the original design of the reservoir to be honoured, whilst accommodating the raised levels that the elevated dam will introduce once the project is completed.

Other challenges

The raising of the overflow would require the volume of the reservoir to be drawn down, increasing the risk of water shortages in the area should the prevailing weather conditions prove unfavourable.

Raising the dam itself would require significant materials to increase the vertical profile of the dam and the subsequent re-landscaping of the surrounding area. This would not be a particularly easy given that the access roads to the reservoir are basic and there are nearby local residents in the hamlets of Sandyford and Boreland.

During construction it was essential that the team avoid any construction debris entering the reservoir.

Minimising disruption

Ensuring local people are inconvenienced as little as possible was of principal importance to the project team, as Scottish Water takes great care to always put the concerns, safety and happiness of local people first when undertaking major civil engineering works.

Bell-mouth spillway

The spillway is an unusual design which sits inside the body of the reservoir and to the casual observer has the appearance of a large plughole. To raise the level of this, Scottish Water are installing a circular 'piano-key' extension consisting of 24 (No.) precast concrete sections. The 24 piano-key weir sections have been precast off site in Ireland and brought over two at a time by lorry. These are held together by steel once rods once lowered into place by crane.

The new piano-key weirs are designed to pass the design flood (the PMF) of 183m³/s with a flood surcharge of 0.97m, saving about 0.7m from the amount of dam raising that would have been required for the alternative scheme, based on simple raising of the weir around the bellmouth rim. The piano-key weir is similar in principle to the labyrinth weir, but is designed with upstream and/or downstream overhangs so that it can fit on a smaller footprint, such as on the crest of a gravity dam. There are several such installations in France, where EDF have pioneered their use, but Black Esk is believed to be the first adoption of piano-key weirs in the UK and also the first adaptation of the principle to the rim of a bellmouth spillway.



Elevated view of the weir from the valve tower
Courtesy of Scottish Water



The site showing crane and materials. The weir section is being secured into place with steel rods and concrete - Courtesy of Scottish Water

Part of the existing structure will be demolished and the steel and concrete will be recycled. The concrete will be used as a sub-base for improvements being made to the Forestry Commission road nearby and the steel will be taken off site.

To facilitate access to the valve tower and spillway structure, a floating pontoon arrangement is in place that allows access and egress for the project team. Scaffolding and ladders enables access to the higher parts of the structure.

Other works

The crest of the dam will be raised using clay which exists on site, cutting down on cost and traffic. There will be substantial clearing of trees and growth around the banks of the reservoir to accommodate the rise in levels. Scottish Water have closely cooperated with the Forestry Commission to enable access around the reservoir and to upgrade the shared access roads for the heavy traffic travelling to and from the site.

The valve tower will be raised and new valves installed. The bridge to the tower will be replaced. A forestry road diversion and extensive landscaping works are also required.

Conclusion

The project is taking place as another dam raising takes place in nearby Penwhirn, also in Dumfries and Galloway. For the Penwhirn project the existing dam is to be raised by 1.5m, offering an increase in yield from 4.66ML/d to 18.26ML/d.

Once complete in early 2014, the projects will significantly improve the security of the water supply from the Black Esk and Penwhirn Reservoirs, enhancing Scottish Water's ability to deliver water to customers in times of low rainfall.

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