Beaver Dyke Reservoir

reservoir discontinuance - removing reservoir from the Reservoirs Act 1975 by excavation of over 20,000m^3 of embankment fill

by David Rebollo BEng MSc

Beaver Dyke is located west of the spa town of Harrogate, North Yorkshire and was used to secure a public water supply to Harlow Hill WTW until recent years. The reservoir comprised a 16m high earthfill embankment dam of typical Pennine construction completed around 1890. The embankment was straight over its length with the dam crest running approximately north to south across Oak Beck and impounding around 500,000m^3 of raw water. The overall length of the embankment was 160m. The discontinuance of Beaver Dyke Reservoir entailed a 14m deep excavation of the embankment and construction of a permanent channel at the lowest point to reduce the impounded volume and associated risk to downstream residents. The impounded volume has been reduced to remove the reservoir from the Reservoirs Act 1975. To preserve the high amenity value of the site, a residual lake of 5,000m^3 was retained.

View of the completed discontinuance channel looking upstream towards the weir - Courtesy of MMB Ltd

Introduction

Throughout this project, Mott MacDonald Bentley's (MMB) design and construction teams have worked together to maximise the benefits of surplus materials arising from the excavation. This has produced a scheme that respects the visual identity and heritage of the site with minimal impacts on the neighbouring communities and a restoration strategy that is integral to the engineering works themselves.

Historical operations

The upstream face of the embankment was protected with masonry pitchings with a gradient of approximately 1 in 3. The downstream embankment was grass-covered and had an approximate gradient of 1 in 2. A vehicle access track ran along the crest adjacent to a 1.1m high masonry wave wall for the full length of the embankment.

The overflow arrangement was situated at the north end of the dam and comprised of a stepped semi-circular weir, discharging into a tumble bay area followed by a stepped, masonry channel. The 160m long spillway channel would cascade down the left mitre of the embankment (looking in the downstream direction) with the masonry overflow weir controlling the Top Water Level (TWL) of the reservoir at an elevation of 169.90m AD.

The top 85m of spillway was a rectangular channel of masonry construction whilst the remaining section was trapezoidal in section and formed from stone block work. A circular, masonry clad, brickwork valve tower was located on the upstream face at the centre of the embankment. The valve tower housed the reservoir's draw-off and scour arrangement, discharging into the scour channel at the toe of the embankment and the raw water supply main which ran alongside the scour channel before continuing down the valley to Harlow Hill WTW.

The catchment and surrounding area comprises mainly rough grassland which is predominantly used for sheep grazing. The reservoir is located within a shallow-sided valley and bordered by trees located on the north and south banks of the reservoir.

Spillway at Beaver Dyke - Courtesy of MMB Ltd

View of the upstream face of the dam before commencement of works Courtesy of MMB Ltd

Excavation of the embankment in 1m intervals - Courtesy of MMB Ltd

Formation of the channel using salvaged stone - Courtesy of MMB Ltd

Innovations

The challenges underpinning the return of submerged landscapes at Beaver Dyke close to their original state have been two-fold:

1. the reservoir could not be drawn-down ahead of detailed design. As a result, the design was reliant on as-built information which has changed significantly since submergence due to landslips and deposition of silt (in places up to 2m deep).
2. there was uncertainty in the spring line around the reservoir leading to instability of the slopes along the exposed shoreline.

To respond to this uncertainty, a range of areas to deposit excavated material were identified using the 3D model within the basin. Once the drawdown had been achieved, additional surveys were carried out in the areas of greatest uncertainty. This allowed the site and design team to quickly evaluate the most appropriate areas from the options previously explored.

The 14m deep excavation to reduce the impounding level was carried out in 1m benches, leaving a 1 in 4 slope at either side. A series of excavators and tracked dumpers worked simultaneously to progress the excavation. The use of Building Information Modelling (BIM) and 3D modelling has been instrumental in delivering this aspect of the works. The model formed the basis for setting out such that the changing working area and excavation volumes could be interrogated at each stage. This was key in programming the construction, adapting to the changing risks, and communicating with client and third parties.

Health, safety, environment & welfare

The success of the scheme hinged on a comprehensive plan which mitigated effectively against programme delays and health, safety and environmental risks that could arise from flooding during the discontinuance works. A bespoke flood contingency plan was produced including an operational risk matrix with trigger water levels set at each stage of the excavation. This enabled the site team to adapt to the changing flood response time as the excavation progresses.

BIM and 3D modelling allowed the site team to understand and adapt to the changing site conditions as the excavation progressed - resulting in over 15,000 safe hours worked.

Sustainability

To reduce the environmental impact of the works, as well as minimising traffic and reducing the carbon (and visual) footprint of the scheme all 20,000m^3 of excavated material have been retained on site and used for landscaping.

The vertical alignment and cross-section of the channel have been designed to yield optimum hydraulic conditions for the channel to be of salvaged stone rather than concrete, masonry or other imported materials. This not only resulted in a significant reduction to the visual and environmental impacts of the works, but also provided substantial cost and programme savings to the client and consumer.

The Environment Agency and Local Council were key consultees from the onset of the scheme, with a view to collaboratively addressing the issues with water quality as well as visual and ecological impact. This has ensured 100% compliance with the discharge consent limits during the construction.

In addition, the restoration strategy has been integral to the scheme from the early design stages. Parts of the draw-down zone have been retained to enhance marginal habitats as well as creating new habitats where fill has been placed and allowed to naturally re-vegetate. Whilst it may take longer for the ground flora to fully colonise these low-nutrient areas, this is the optimal restoration strategy from a long-term biodiversity perspective.

The long-term impacts and mitigation measures for the scheme were confirmed with a Water Framework Directive (WFD) Assessment. This assessed the impact of the proposal on the WFD Ecological Status of the impacted water bodies.

In the early stages of construction, water quality was the principal environmental concern as the reservoir has retained silt for over 100 years and there are a number of sensitive receptors downstream, including white-clawed crayfish and spawning fish.

In addition to the traditional straw bale silt traps and daily monitoring of turbidity, a comprehensive silt trap system was designed and installed consisting of wooden pallets wrapped in sacrificial layers of geotextile.

Economic sustainability has been ensured by constructing a quasi-natural channel made entirely of locally sourced stone. An impermeable liner has been used to minimise its tendency to meander and overgrow, thus minimal maintenance is expected.

Further benefits

The discontinuance of Beaver Dyke is evidence of the increasing importance of total expenditure in driving asset management. Previous discontinuances in the region have been a response to damaged assets and increased risk. This scheme, however, sets a precedent for proactive decommissioning of unused assets ahead of maintenance work arising that is costly to the consumer.

BIM and 3D modelling allowed the site team to understand and adapt to the changing site conditions as the excavation progressed. The use of 3D models has provided a means for the design team to understand the specific site conditions.

The design-build approach allowed for the site manager, as well as the client and operator, to be involved from the onset of the project, helping identify site constraints (principally access and surplus of materials) early and enabling the design to be tailored to the specific site conditions and the safest construction method. The ECI appointment also allowed the design team to acknowledge the necessary flood prevention measures in advance and incorporate them into the design. For instance, a flume has been designed such that the new channel is raised clear of the drawdown pipes below, maintaining a safe water level in the reservoir until the channel was completed. Similarly, MMB's project leader was involved as site engineer during the construction, ensuring continuity in the quality control process.

Conclusion

In summary, the discontinuance of Beaver Dyke has shown the programme improvements that stem from the design/build approach. The use of 3D models has provided a means for the design team to understand the specific site conditions as informed by the site team and vice-versa.

A rigorous design philosophy and integrated contractor-designer relationship has driven a scheme that reused over a 1,000 tonnes of stone and 20,000m^3 of embankment fill on site, whilst not only respecting but also enhancing the local environment within the exposed reservoir basin. Given the large excavation and changing working areas, BIM has been instrumental in programming activities on site, and managing the changing hazards.

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Excavation sequencing around the clay core - Courtesy of MMB Ltd

Completed discontinuance channel looking upstream Courtesy of MMB Ltd

Basin after the works - Courtesy of MMB Ltd

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