

The discontinuance of Baystone Bank Reservoir and restoration of Whicham Beck

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SYNOPSIS. Baystone Bank Reservoir was constructed in 1877 to supply water to the village of Millom, Cumbria. By 1996 the reservoir yield was not required for water supply purposes and in 2002 the reservoir was also identified as having inadequate spillway capacity. Following an assessment of possible options the North West's regional water company United Utilities took the decision to discontinue the dam and restore Whicham Beck to its pre-impoundment condition. This paper describes the reasons for the discontinuance, the design process and subsequent construction.

INTRODUCTION

Baystone Bank reservoir was constructed in 1877 to supply water to the village of Millom, South-West Cumbria. The reservoir is located approximately 6km north of the village of Millom and is within the Lake District National Park. The 14m high dam was of an earth fill construction with a puddle clay core. The reservoir had a capacity of 125,000m³.

HYDROLOGY AND HYDRAULIC ARRANGEMENT

Baystone Bank Reservoir impounded the Whicham Beck and the Whicham Beck Tributary. The total catchment area at the dam was 2.47km², with approximately 93% accounted for from the Whicham Beck and 7% from the tributary. The Standard Average Annual Rainfall for the catchment is 1780mm. Figure 1 shows the hydraulic arrangement of Baystone Bank Reservoir. Figure 2 shows the corresponding long section. A by-wash channel allowed reservoir inflows to be either diverted around the reservoir basin or to spill into the reservoir depending on the inlet sluice opening.

The overflow facilities comprise a main overflow/spillway chute (constructed in 1985) located over the central part of the embankment and an auxiliary overflow weir that joins the by-wash channel then passes down the right-hand mitre of the dam via a masonry spillway.



Figure 1. Hydraulic arrangement of Baystone Bank Reservoir

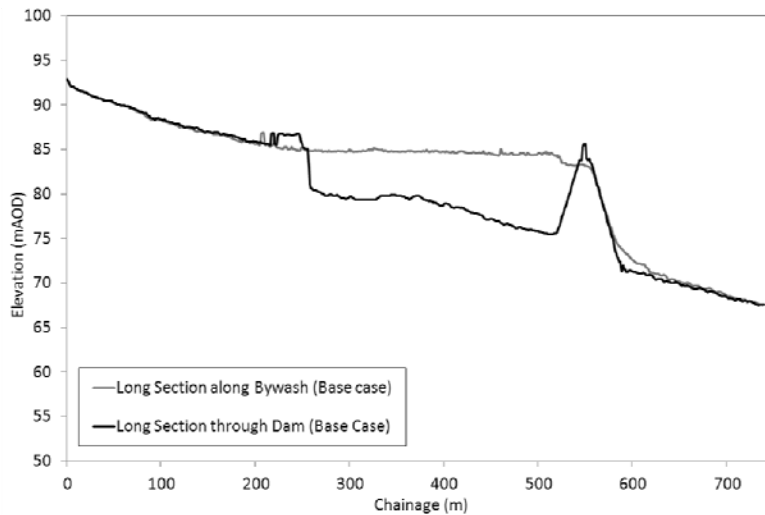


Figure 2. Longitudinal section through the embankment and bywash.

WATER SUPPLY RESERVOIR

Baystone Bank Reservoir historically supplied Lanthwaite Water Treatment Works (WTW). By 1996 the reservoir yield was not required for supply purposes and was not part of the future plans. Lanthwaite WTW was also considered by United Utilities as a redundant asset and was disconnected from the potable network.

OVERFLOW CAPACITY

Dam break studies carried out by United Utilities (prior to 2002) upgraded Baystone Bank Reservoir from Hazard Category B to Hazard Category A, as defined by the Institution of Civil Engineers Guide to Floods and Reservoir Safety (1996). In response to this and as part of an on-going

programme by United Utilities to evaluate the adequacy of the overflow facilities of their impounding reservoirs, in 2002-2003 an overflow capacity study was undertaken.

The Hazard Category A required the reservoir to be able to cope safely with a Probable Maximum Flood (PMF). The overflow capacity study found the most severe flood event was the Winter PMF event with a peak inflow of 37m³/s and an outflow nearly 35m³/s. The main spillway chute was estimated to have a hydraulic capacity of approximately 15m³/s. The auxiliary overflow weir and downstream apron were estimate to have an adequate capacity to discharge 17.5m³/s. However, the masonry spillway channel that runs down the right mitre of the dam was only considerable capable of passing 2m³/s to 3m³/s. The total spillway capacity was therefore judged to be 17m³/s to 18 m³/s – short of the 35m³/s required to safely pass the Winter PMF and therefore remedial works were required to meet current recommended standards.

At this stage five options were considered feasible as shown in Table 1.

In 2003 the Section 10 Inspection under the Reservoirs Act (1975) was undertaken by I C Carter. Given the findings of the earlier overflow capacity study, the Inspecting Engineer made a recommendation “in the interest of safety” (ITIOS) that if the reservoir is retained then works are carried out to safely pass the design flood and required this measure to be carried out by July 2011 to ensure compliance with the Act.

Table 1. Options for Baystone Bank Reservoir

Option	Description
1 – Upgrade By-wash Spillway channel	Demolition of the existing masonry spillway channel that runs down the right mitre of the dam and replacing it with a larger channel.
2 -Increase Flood Attenuation in the reservoir	Increase the flood storage capacity of the reservoir by retaining the flood lift behind the wave wall. Abandonment the auxiliary overflow
3- Increase Main Overflow Spillway Capacity	Modify the main overflow to take the full design flood discharge. Abandon auxiliary overflow.
4- Grass Reinforced Auxiliary Spillway	Retain the main overflow and chute. Abandon the auxiliary overflow and allowing controlled discharges over a protected part of the downstream face.
5 - Discontinuance of the reservoir	Modifying the embankment and appurtenant structures such that it was incapable of storing more than 25,000m ³ of water.

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ECOLOGICAL SURVEYS

An extended phase 1 habitat survey was undertaken in 2010. This survey identified that the reservoir supported spring quillwort (*Isoetes echinospora*) which is rare in Cumbria (having only been identified at two locations in the County). The area supports high density populations of European eel (*Anguilla Anguilla*) and brown trout (*Salmo trutta*); sea trout have been recorded up to, but not beyond the reservoir since presented a significant barrier to migratory fish. Bat foraging activity was also recorded around the site.

OPTIONS APPRAISAL

From 2007 onwards, United Utilities evaluated a range of possible options for Baystone Bank Reservoir. These options ranged from spillway upgrading to full discontinuance. An assessment undertaken in 2010 demonstrated that for the 1 in 100 year flood event, discontinuance of the reservoir would not increase downstream flood risk. Following this detailed options appraisal and discontinuance assessment, United Utilities determined that discontinuance of the dam would bring the most benefits.

DEVELOPMENT OF THE PROPOSED SOLUTION

A multi-disciplinary project team was assembled and tasked with producing a solution that would:

- a) achieve full discontinuance;
- b) reinstate Whicham Beck and restore the natural river and floodplain processes (as far as reasonably practicable). By reconnecting the upstream and downstream reaches of Whicham Beck the hope was that this would help restore in-stream habitat for migratory and resident fish.
- c) Create a suitable habitat for spring quillwort and foraging space for Daubenton's bat. This required the retention (or creation) of a pond with a minimum area of surface area of 4,000m², a minimum water depth of 2.0m and a maximum capacity of <10,000m³.

Throughout the project the Environment Agency fully supported the concept of re-naturalising the flow regime and sediment transport functionality of this upland river. Given the sensitive location of the reservoir (within the Lake District National Park boundary) the restoration of the watercourse was always an integral part of the reservoir discontinuance process, not a separate activity and this was key to getting the relevant approvals.

Figure 3 and Figure 4 show the initial concept that was developed. This design included:

- a) removal of dam and associated structures;

- b) creation of an on-line pond on the Whicham Beck;
- c) reinstating the Whicham Beck (starting from the confluence of the Whicham Beck and the Whicham Beck Tributary); and,
- d) channel dimensions for the new channel were estimated such that the channel could carry the 1 in 100 year flow. This resulted in a channel 1m deep and 6m wide.

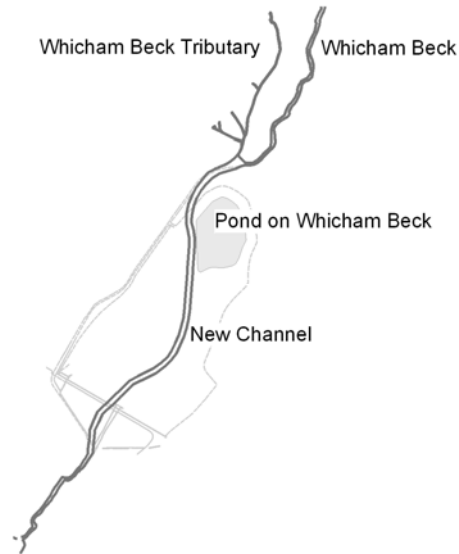


Figure 3. Initial solution

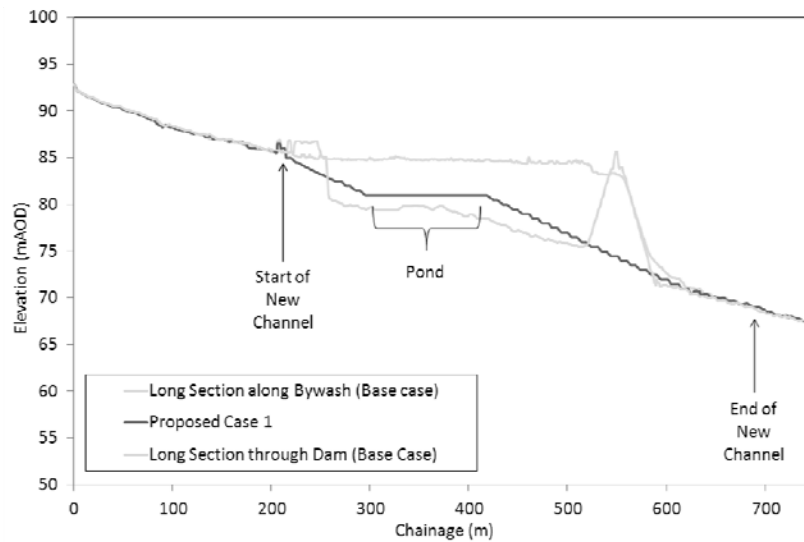


Figure 4. Longitudinal section through the initial solution

As this design was developed, it was realised that the consequence of constraints placed on the design (namely the inclusion of the pond on the Whicham Beck) was that a very steep channel was created between the pond

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outlet and the downstream end of the site. The consequence of the steep channel was that in order to allow fish passage numerous small weirs had to be constructed between the pond outlet and the downstream end of the site. There was also a risk with this design that the pond created a barrier to downstream conveyance of sediment, preventing restoration of natural river processes. At this stage the project team and stakeholders reviewed the design and all parties felt that the design had not achieved the original aims. The project team therefore decided to revisit the design.

The revised design was based on an Ordnance Survey map from 1867. This gave the pre-impoundment alignment. Figure 5 and 6 show the revised concept that was developed.

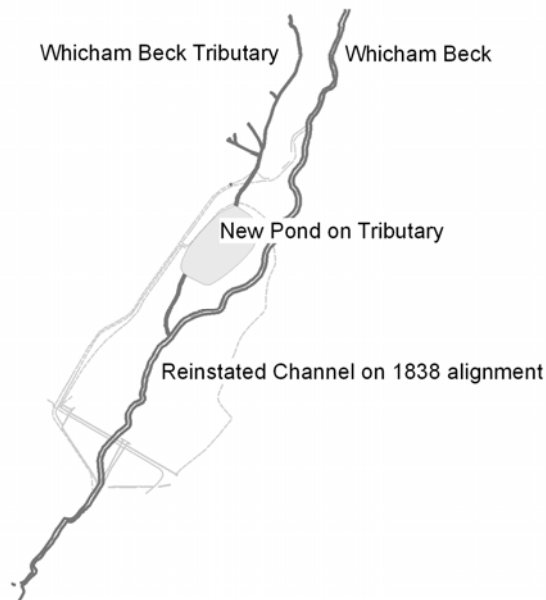


Figure 5. Proposed solution

This design included the following components:

- a) Removal of dam and associated structures;
- b) The proposed pond was moved from the Whicham Beck to the Whicham Beck tributary. This prevented over steepening the main channel and by being off line it ensured that there will be no barriers to downstream conveyance of sediment;
- c) The new channel starts much further upstream than had originally been proposed. By moving the start of the new channel back to the point where the 1870 alignment deviated from the original alignment, this allowed restoration of the natural channel slope (1 in 28 to 1 in 35).

- d) Channel dimensions for the new channel were based on the natural channel upstream and downstream of the reservoir basin. This resulted in a channel between typically 1m deep and 4m wide.
- e) Overlaid onto the overall river gradient was a pool-riffle sequence which reflected the size and spacing observed in the natural river channel.
- f) Floodplain dimensions were estimated by considering the natural floodplain upstream and downstream of the reservoir basin. Typically the floodplain was 15m wide.

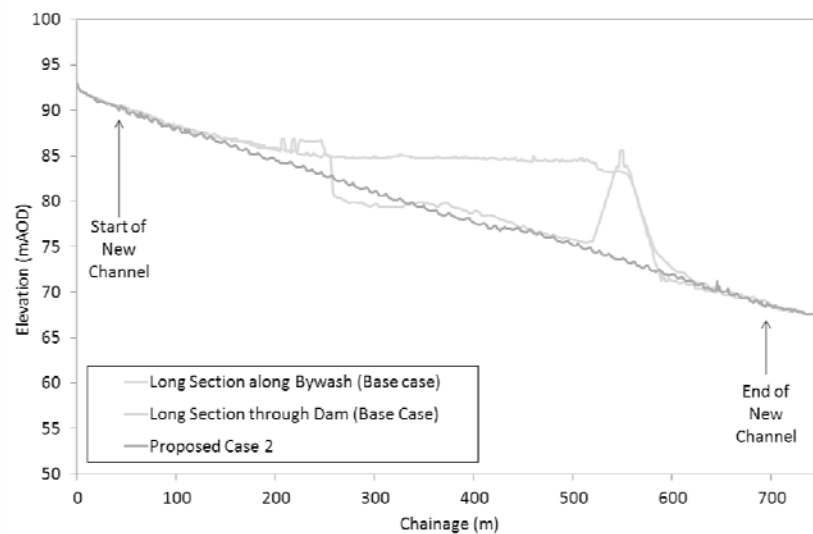


Figure 6. Longitudinal section through the proposed solution

3D ground models were then developed for the existing situation and the proposed solution. The proposed case included the new watercourses (including channel shape and slope), proposed pond and floodplain. The 3D visualisations allowed:

- a) the project team and stakeholders to visualise the proposal;
- b) the contractor to assess the ‘buildability’;
- c) cut/fill estimates to be prepared and the proposed design optimised (such that it was cut/fill neutral compared to the existing ground profile);
- d) areas of steep ground to be identified where slope stability may be a problem;

Where necessary minor alignment refinements were made to overcome any issues identified above.

Having established the proposed concept and obtained agreement from all the stakeholders that this design better met the original intentions the design

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process continued. A hydraulic model of the proposed concept was then created to check how the watercourse and pond would operate during a flood event. The hydraulic modelling was undertaken using Mike21 FM. Mike21 FM is a 2D hydraulic model which uses a Flexible Mesh consisting of rectangular elements (in the watercourse) and triangular elements (in the floodplain) as shown in Figure 7. The elevation of mesh elements was taken from the ground models described above. This creates a 3D surface upon which flows can be applied.

The hydraulic model was calibrated using observed flows and levels for the section of watercourse upstream of the reservoir basin. The 1 in 100 year flow hydrograph was then applied to the upstream end of Whicham Beck and Whicham Beck tributary. The Mike21 model allowed us to see how the water moves through the system. The initial hydraulic modelling showed that at high flows the Whicham Beck spilled into the proposed pond. Given that the Whicham Beck was predicted to contain sediment, this was not desirable. The ground model and hydraulic model were therefore refined until the interaction between Whicham Beck and the proposed pond was eliminated. In a similar way, downstream of the pond, the ground model and hydraulic model were refined until the floodplain operated as intended.

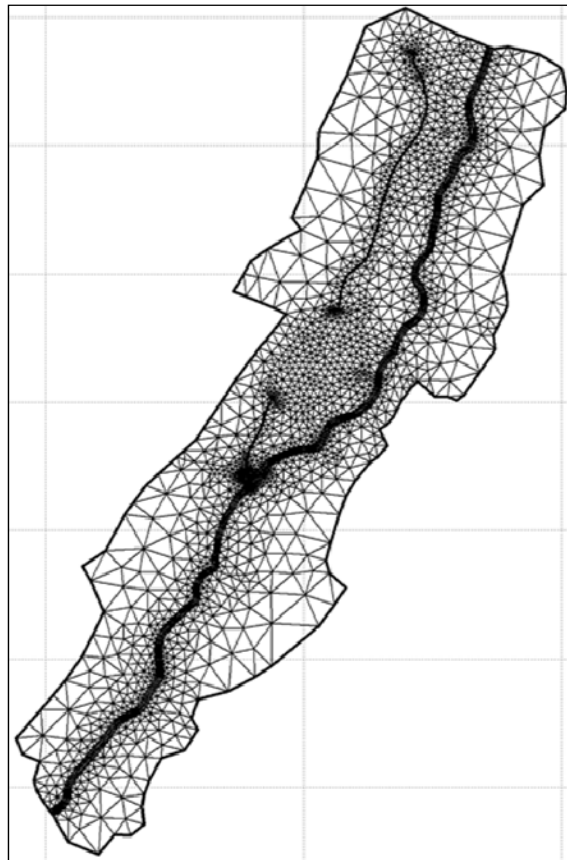


Figure 7. Mike21 Mesh

Having demonstrated the proposed design worked hydraulically, the Sediment Transport (ST) module within Mike21 was used to check how stable the proposed watercourse would be during a flood event. Mike21 ST allows simulation of non-cohesive sediment transport. Sediment samples were collected and the d_{50} sediment size used within the Mike21 ST model.

This ST model allowed areas of high erosion or high deposition to be identified. For example where erosion was predicted, additional bank reinforcement could be specified or the alignment of the channel refined. Given the concept of the design was to reinstate the natural river processes, the aim was not to construct a river channel that could not move; it was to construct one that could evolve over time.

CONSTRUCTION OF THE PROPOSED SOLUTION

Planning Approval (and approval from all the stakeholders) for the work was granted in January 2011. Eric Wright Civil Engineers mobilised to site in late February 2011; and PBA Applied Ecology Ltd were deployed to the task of ecological and environmental management.

The presence of the by-wash channel around the reservoir basin allowed the majority of the construction work to take place offline. The by-wash continued to operate throughout the construction phase. By July 2011 (the target date set by the ITIOS requirements) the embankment had been “discontinued” and the Impounding Licence was revoked (under Section 13(2) of the 1975 Reservoirs Act).

During the excavation of the sediment in the reservoir basin and subsequent construction of the new channel, a number of the sections of the original (pre 1877) stream bed were identified. Where possible the alignment of the watercourse was modified to incorporate these into the proposed design.

During the reservoir discontinuance and subsequent earth works phase, any suitable materials for channel bed and banks which arose, was stockpiled for future use. This resulted in no need to import material to site. All the materials that were used in the construction were sourced from within the site area.

ENVIRONMENTAL MANAGEMENT

During the construction phase, ecological mitigation measures were implemented to allow the construction to take place, whilst minimising the ecological impact. Mitigation measures were focused around three areas; environmental management of the construction works, maintenance of water quality in the watercourses, and management of indigenous fish.

Mitigation measures to ensure environmental management of construction works, included:

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- a) Translocation of spring quillwort before the reservoir basin was drained;
- b) Weekly review/forward planning meetings between Eric Wright and PBA to review environment performance and for PBA to provide advisory input to construction work;
- c) Continuous monitoring of the weather;
- d) PBA staff available to respond to environmental enquiries, as required;
- e) PBA staff on site to provide additional support during specific operations;

Mitigation measures to allow maintenance of water quality in the watercourses included:

- a) Production of an Environmental Containment Plan (ECP)
- b) Active management of silt by Eric Wright with PBA providing continuous input to working methods to minimise surface water and sediment runoff;
- c) Setting appropriate and achievable water quality standards;
- d) Frequent water quality monitoring by PBA and sharing of the results with the project team via a secure login.

Compliance to water quality targets in the receiving watercourse was 93.8% at project completion. This was supplemented with detailed records of turbidity peaks that were measured over the set targets. This information was provided to the Environment Agency with a detailed breakdown of all water quality measurements on site.

Mitigation measures to allow management of indigenous fisheries interests, included:

- a) Having an excellent awareness of statutory requirements and bio/chemical sensitivities before works commenced;
- b) Removal of fish from the drawdown reservoir before dam discontinuance;
- c) Removal of fish from bywash channel once the new watercourse was constructed to allow the bywash to be infilled.

The rescue of the fish from the bywash channel and upper section of Whicham Beck found a total of 480 brown trout and 38 European eel. Electric fishing proved extremely successful at removing the large majority of fish. Close working between the PBA and Eric Wright proved crucial in ensuring the maximum possible numbers of fish were safely removed.

Flows were restored to the new channel on the 24 August 2011 and for the first time in 141 years water again flowed in Whicham Beck. Upon successful completion of the scheme, the contractors demobilized from site in October 2011. During the construction phase there were no reportable incidents as defined by the Reporting of Injuries, Diseases and dangerous Occurrences Regulations 1995 (RIDDOR).

POST-CONSTRUCTION

As the vegetation has become established the location of the former dam and reservoir basin has become very difficult to identify, with the new watercourse/ground profile blending seamlessly into the landscape. The new river channel has continued to evolve over time, as sediment is moved within the channel. Gravel has accumulated, moved and eroded, adding further natural variability. Evidence of otters using the pond has also been identified. Overall the project has been well received by all parties, including the Environment Agency and the adjacent landowner.

CONCLUSIONS AND LESSONS LEARNT

As shown in Figures 8 and 9, Baystone Bank Reservoir has been successfully discontinued, and the Impounding Licence has been revoked (under Section 13(2) of the 1975 Reservoirs Act). Whicham Beck has been restored to its pre-impoundment conditions reconnecting the upstream and downstream reaches of Whicham Beck, allowing movement of migratory and resident fish, whilst minimising ecological impact in delivering these works.



Figure 8. Baystone Bank Reservoir – before



Figure 9. Baystone Bank Reservoir – after

Natural processes have been restored through the relict reservoir basin, allowing the movement of sediment. Offline still water habitat has been created into which spring quillwort will be reintroduced. The project has been delivered within the approved Capital Expenditure budget and no future operational expenditure should be required. Finally the methodology developed and lessons learnt by the project team have successfully been applied to other reservoir discontinuance and river restoration schemes, such as Hurst Reservoir near Glossop where a similar concept is currently being developed by United Utilities.

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