The British Dam Society

Case studies from permanently installed siphon works

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SYNOPSIS Adequate draw down of reservoirs by gravity means only may not always be feasible. Siphons may be seen to be a suitable option and efficient means of drawing off the upper portion of a reservoir volume. This paper looks to cover case studies of schemes completed in recent years.

Based upon multiple examples of physical projects undertaken, this paper will look into the constraints, planning and decision-making involved leading up to and executing improvement works, along with the temporary works, permanent works and commissioning of permanently installed siphons. The intention of this paper is that the learning taken from these works may be of use to others in the industry.

All works were undertaken on statutory reservoirs and as such had been planned and undertaken with the supervision of an All Reservoirs Panel Engineer.

Mott MacDonald Bentley (MMB) planned and undertook works at the following:

- Warland Reservoir
- Warley Moor Reservoir
- Lower Barden reservoir
- West Hallington reservoir

WARLAND RESERVOIR

Introduction

Warland Reservoir is situated on the western slope of Blake Moor, above Littleborough, Lancashire. The reservoir was originally constructed around 1857 by the Rochdale Canal Company to maintain water levels in the Rochdale canal, and was considered to be one of the largest dams in England at the time. It has a 1500m long, 20m high embankment formed of homogenous earth fill. The reservoir is now owned and operated by United Utilities.

One of the project drivers was to improve the drawdown capacity to achieve 1m per day.

Managing Risks for Dams and Reservoirs

There were numerous challenges and constraints on the project including:

- Location: The reservoir is 375m above sea level, regularly freezes over in the winter with temperatures as low as -20°C recorded.
- Drawdown: For work to be carried out in the basin, the reservoir would have to be drawn down by at least 8m. In such a location, with very little means of controlling water level, this was a key challenge.
- SSSI/blanket bog: The reservoir was surrounded by a Site of Special Scientific Interest (SSSI), designated for the blanket bog.
- Site access: The access was a 3km narrow track to the site, in poor condition.
- Silt: The reservoir basin was known to contain large amounts of silt.

Figure 1. Warland Reservoir drawn down by 8m, and upstream pipe work installed

Design Development

Early optioneering of the drawdown requirements identified that a siphon through the dam crest was the only viable option to achieve the required capacity.

Several combinations of siphon pipe sizes and materials were considered. The preferred option was for 3No. DN600 ductile iron pipes through the dam crest. These would be located midway between the valve-tower and the eastern abutment on the part of the dam that gave the shortest linear distance of siphon whilst still achieving the required upstream submergence depth. The revised position approximately halved the amount of temporary access road required to construct the access ramp into the reservoir basin.

Three pipes were preferred over one to significantly reduce the scale of temporary works for lifting. The arrangement also enabled each pipe to be individually tested in a controlled manner, reducing the risk of downstream erosion due to high flows. In the event of a failure on one of the three siphon lines, the system offers redundancy, still allowing for a significant drawdown to be undertaken.

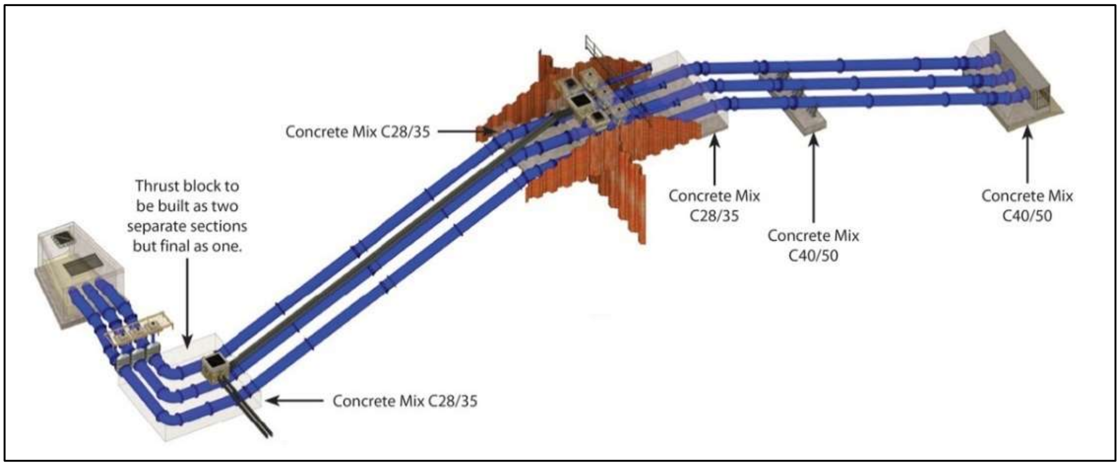

Figure 2. 3D model of the siphon system and temporary works on the dam crest

A transition chamber at the downstream end of the siphon was designed to combine the flows from the individual siphon pipes into one single DN1500 concrete pipe. This runs under the access track near the toe of the dam, discharging into a chamber at the toe at the start of the clough.

With the siphon pipes located above top water level, the risk of leakage through the embankment would be eliminated. However, this meant the maximum level the siphons could draw down to was around -5m below top water level. Although the reservoir catchment was not forested, there remained a risk of blockage of the siphons from floating debris. An inlet screen was designed which would also prevent unauthorised access to the pipes if the reservoir was ever drawn down below the inlet level in the future.

Construction

Construction of the project commenced in 2017 and began with significant works required to upgrade the existing 3km access track to the reservoir. This included temporary propping of a bywash channel, a new temporary crossing of the channel, widening and strengthening works to allow construction plant to access the site.

The reservoir was drawn down by 8m to facilitate the construction of the upstream section of the siphons. The inlet works were undertaken first, and once installed, the reservoir was allowed to partially re-fill. To pressure test the pipes a blanking plate was left on the end of each pipe, which was removed by divers following a successful test.

There were significant concerns about embankment stability, given that a large proportion of the embankment was constructed from peat, an amount of which had been added as part of the stability works in 1923. To improve the ground conditions, the area at the toe of the embankment, where the transition chamber was constructed, had to be artificially raised with granular fill to allow sheet piles to be installed to form a stable excavation.

When the reservoir was drawn down for installation of the upstream section of the siphons, there was a significant concern about a deterioration of water quality discharged downstream. The team developed a silt monitoring plan with the Environment Agency, including trigger points with agreed actions. Temporary pipework modifications were made in the catchment to blend the discharge waters with those of a neighbouring reservoir to reduce turbidity.

Managing Risks for Dams and Reservoirs

WARLEY MOOR RESERVOIR

Introduction

Warley Moor Reservoir is located in West Yorkshire and is owned and operated by Yorkshire Water Services (YWS). The reservoir is impounded by two dams with a crest level of 407.3mAOD. The overflow system is formed of concrete culverts with a trapezoidal grass reinforced channel situated above to take excess flows. A stilling basin connects the two culverts as well as taking flows from the scour pipe.

Figure 3. Aerial view of Warley Moor Reservoir

One of the objectives of this project was to improve the drawdown capacity to achieve 350mm per day.

The key challenges on the project were very similar to that of Warland Reservoir, including extreme weather conditions, management of silt during drawdown and issues with slope stability due to the presence of peat.

Design Development

The existing embankment at Warley Moor had shown signs of local shallow slips along the downstream face. Slope stability modelling was carried out at the start of the scheme to ensure that the installation of the siphon pipework did not significantly impact the stability of the embankment. It was decided to bury the upstream pipework instead of installing it above ground due to the existing slope stability issues at the site.

The pipe material was also reviewed with an aim to minimise the additional load on the embankment. Structural calculations determined that SDR17 pipework was sufficient for the combination of negative pressures and soil loading. This plastic pipework provides greater flexibility compared to rigid or semi-rigid pipe materials such as steel or ductile iron. The flexibility is beneficial for accommodating differential settlement that could occur on the embankment.

The plastic pipework is also significantly lighter than steel pipework. This further reduces the bearing pressure on the embankment, minimising the risk of embankment slips as well as reducing the weight of plant required to lift the pipework on the slope. The PE pipework can also be welded prior to installation, therefore reducing the amount of time there is an open excavation on the embankment.

Due to plastic pipework not being used for siphons previously by YWS, it was only used for pipework downstream of the crest. The pipework was also dual contained with a drainage outlet to allow leakage to be identified (Figure 4).

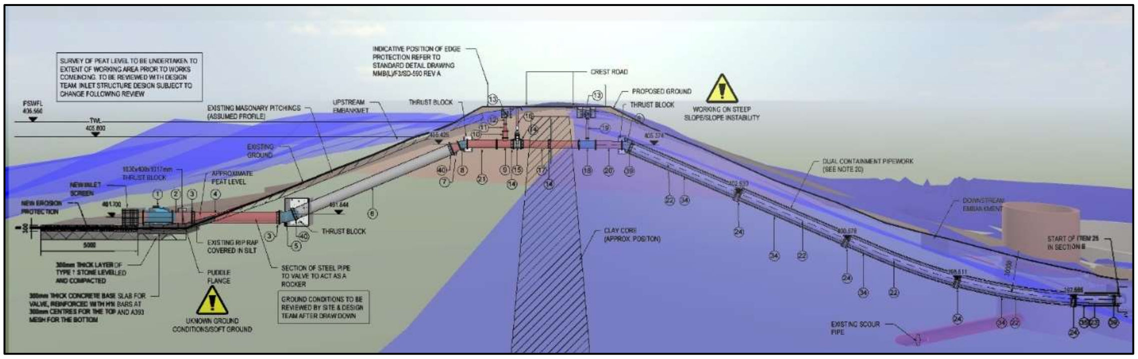

Figure 4. Cross section through siphon

Construction

The dual containment solution utilised 600mm diameter twin wall pipework as the outer pipe with the 350mm HDPE siphon pipework threaded through. The construction methodology involved excavating the trench and installing the dual containment pipework first. Spacers were designed to be welded onto the siphon pipework using offcuts from plastic pipework on site, reducing waste and costs (Figures 5 and 6). The purpose of the spacers was to keep the siphon in the centre of the dual containment pipe, prevent the pipework from moving excessively when the siphon was in operation and to prevent the pipework from catching on the inside of the twin wall. The innovative design led to minimal programme increases and the spacers were effective at allowing the siphon pipework to smoothly slide down the twin wall dual containment pipework.

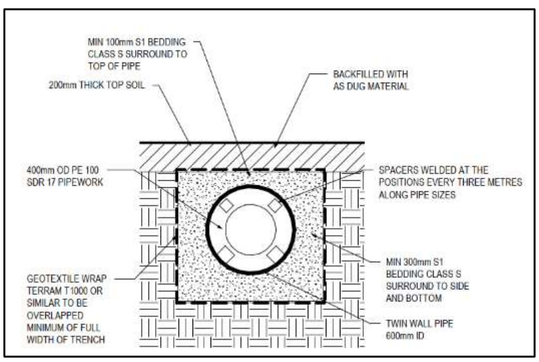

Figure 5. Cross section through downstream dual contained pipework

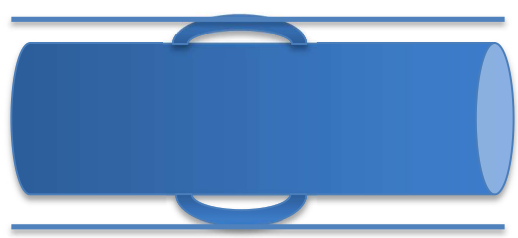

Figure 6. Illustration of "spacers" on the pipework

BARDEN LOWER RESERVOIR

Introduction

Lower Barden Reservoir is the lower of two reservoirs located near Bolton Abbey and within the Yorkshire Dales National Park. The reservoir is an impounding reservoir with a crest length of approx. 640m and a maximum height of 28m with a capacity of 2.23 Mm^3. The spillway chute consists of a series of curved steps with vertical upstands forming pools. Lower Barden Reservoir is owned and operated by Yorkshire Water Services (YWS).

Managing Risks for Dams and Reservoirs

One of the project objectives was to improve the drawdown capacity so that the reservoir water level may be lowered by 925mm per day. The main challenge of this project was that the spillway was being refurbished in parallel with the new siphon construction.

Design Development

The siphon was designed to be self-priming at top water level, requiring manual priming at levels lower than its pipe crest level (Figure 7). The siphon is capable of drawing down the reservoir by approximately 5.0m from top water level.

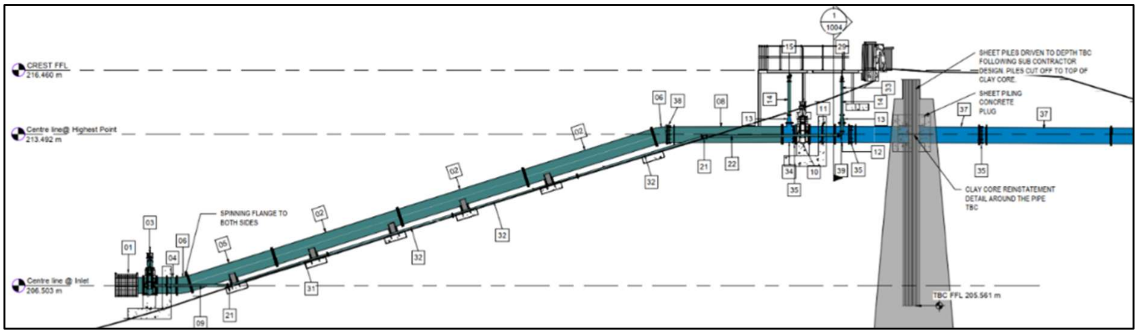

Figure 7. Barden Lower Siphon long section

A solution was developed where the new siphon would discharge through the floor of the newly developed spillway, along with some minor amendments to the hydraulic design of the siphon (Figure 8).

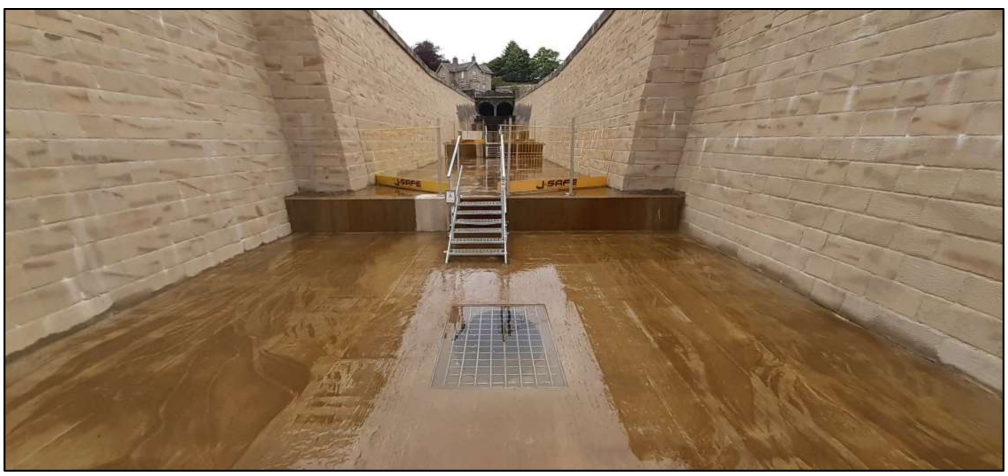

Figure 8. Siphon outlet in spillway invert

Construction phase

Enabling works began in May 2022. Due to the restricted access, crane pads could only be placed on one side of the spillway and the programme of works needed to be carefully planned to ensure that the two schemes worked in tandem, without blocking off access to each other during the spillway and siphon construction.

The siphon works required a significant draw down of the reservoir level to be able to work on the inlet structure safely (Figure 9). As this was quite a long duration for the works, it would impact the programme significantly and equally impact the spillway structure. It was decided to work from both ends of the pipe where practicable and to use a make-up piece at a bend on the downstream side of the embankment as a connection. This would aid in any minor tolerance issues in the pipework and ensure that the pipe closed correctly.

To aid the construction of the pipework, the Leica iCON system was used for setting out. This involved directly using the 3D modelling from the design of the pipe into a handheld tablet device and enabled accurate setting out, without the need to update drawings or continually check that the drawings were the most relevant. This also assisted in delivering the as built positions of the pipework.

Figure 9. Upstream leg of siphon

WEST HALLINGTON RESERVOIR

Introduction

West Hallington Reservoir is a Northumbrian Water Group (NWG) asset situated 1km to the northeast of the village of Colwell in the Tynedale district of Northumberland. The reservoir was constructed between 1884 and 1890 for Newcastle & Gateshead Water Company for the purpose of municipal water supply. The reservoir was built adjacent to the earlier East Hallington Reservoir and operates as a non-impounding structure. It has a maximum depth of 12.1m, a capacity of 3.3Mm^3 and a surface area of 50 hectares at the Full Supply Level (FSL) of 155.1m AOD.

The objective of this scheme was to increase the draw down capacity such that the reservoir level can be drawn down by 4.8m in 8 days.

Design Development

Mott MacDonald Bentley (MMB) developed a design solution which utilises two 700mm diameter siphons on the west embankment to operate at a combined flow rate of 3.2m^3/s. The new siphon pipeline, alongside a temporary pump arrangement and the existing scour pipes, will meet the required drawdown capacity.

The siphon location was moved during design development to the west embankment due to concerns about stability and leakage through the south embankment and because it was easier to access this area of the site.

The siphon flows will be conveyed across a stretch of adjacent field which NWG has purchased. The flows will then either percolate to ground or gravitate to the Coal Burn and eventually to the River North Tyne.

Managing Risks for Dams and Reservoirs

A flood risk assessment (FRA) was carried out to support the planning permission and, as due diligence, to ensure that properties would not be impacted downstream. The assessment looked at the extent of flooding during operation of the siphon, along with fluvial, surface water, groundwater and finally reservoir flood risk due to an uncontrolled release. The FRA concluded that the maximum modelled flood extent from a drawdown of Hallington Reservoir is in agreement with the flow path identified by the Environment Agency in the long-term flood risk map and no communities are shown to be at risk due to the proposed drawdown. As periodic testing of the reservoir drawdown will occur during dry periods, it is not considered that a drawdown of West Hallington Reservoir at this location would increase flood risk elsewhere.

The mechanical equipment associated with the siphon is housed within a high security kiosk. Due to the remote site location, the cost of a permanent power supply for the kiosk building services was prohibitive. A solar powered solution has been installed utilising roof mounted PV cells, DC/AC converter and battery storage. This sustainable solution provides sufficient energy for lighting and heating within the kiosk with negligible running costs.

SYNCHRO 4D was utilised during the latter stages of the design process. The software enables the programme to be linked with the model to run a construction simulation (Figure 10).

Figure 10. SYNCHRO 4D simulation

The simulation highlighted several pinch points when materials must be delivered or when water levels must be lowered or raised and helped drive efficiencies. SYNCHRO 4D was also useful for explaining the construction process to the client, to site operatives and to visitors.

Construction

A borehole at the toe of the embankment on the dry side indicated the presence of water-bearing sands and gravels and so interlocking sheet piles were specified that punched through the sands and gravels into the underlying clays and so cut off groundwater flows into the excavation.

A cofferdam was installed to provide a dry area to construct the intake bay. It was erected in the wet by operatives wearing buoyancy suits, and then pumped out and an excellent seal was achieved. The cofferdam also allowed plant access around the pipework whilst the stone pitching was reinstated.

Figure 11. Siphon intake bay constructed within the cofferdam.

The intake bay was located along the Small Burn which originally ran across the middle of the reservoir and was diverted into the adjacent Coal Burn in the 1880s via a DN375 pre-cast concrete pipe. The ground around the intake bay was found to be poor and was excavated down to competent sub-grade and reinstated with 340 tonnes of gabion stone and 60 tonnes of Type 1 capping material. As this area is normally under a 5m depth of water it was inaccessible during the ground investigation stage.

As the DN700 pipes are fabricated from coated mild steel, a Type 1 pressure test (water loss method) was required. All bolts had been tightened and the torque readings recorded but achieving a pass proved difficult due to sunny weather. A temperature rise on the above - ground pipework led to a pressure loss of more than 0.2 bar in the water filled pipe voiding the test on a number of occasions. Eventually cloud cover enabled a valid test.

Figure 12. DN700 siphon pipework during installation

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