Reservoir Safety and Refurbishment Works at Severn Trent Water's Howden, Derwent and Linacre Reservoirs

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SYNOPSIS.
Severn Trent Water (STW) initiated a contract for essential reservoir safety and refurbishment works following a routine 10 year inspection, under Section 10(2) of the Reservoirs Act 1975. The required works were varied and included, valve refurbishment, additional valves, spillway repairs and general maintenance work.

At Howden and Derwent Reservoirs there was concern that operation of 9no. 30 inch diameter Blakeborough scour valves was causing cavitational damage and some valves could not be operated through their full travel. It was recommended that further investigations were carried out 'in the interests of safety'.

At the Linacre Reservoirs (Upper, Middle and Lower) the works to be carried out, some 'in the interests of safety' and others for refurbishment, included repairs to spillway walls and floors, restoration of a drainage facility, installation of a scour guard valve and re-lining of the Lower Reservoir draw-off scour pipeline.

This paper reviews the works involved from the early feasibility investigations through to the construction works. The construction period was August 2005 to March 2006.

HOWDEN AND DERWENT RESERVOIRS

Howden and Derwent Reservoirs are situated in the Upper Derwent Valley area of north Derbyshire, within the Peak District National Park, approximately 20km west of Sheffield.

The reservoirs are impounded by concrete/masonry gravity dams, approximately 35m high and 330m long, which were constructed during the early part of the 20th century. Overflow from Howden Reservoir spills, via a

Improvements in reservoir construction, operation and maintenance. Thomas Telford, London, 2006

central crest weir (ref Figure 1 : Howden's central crest weir) , into the head waters of Derwent Reservoir. A similar weir structure on Derwent Dam discharges flood water from Derwent Reservoir into the headwaters of Ladybower Reservoir. The three reservoirs are used as a source of raw water for Bamford Water Treatment Works, which serves a population of about a million customers throughout Derbyshire, Nottinghamshire and Leicestershire.

Figure 1 : Howden's central crest weir

Inspecting Engineer, Mr Alex Macdonald, of Jacobs Babtie (JB), carried out a routine 10-year inspection of Howden and Derwent Reservoirs, under Section 10(2) of the Reservoirs Act 1975. Whilst confirming that both reservoirs had adequate provision for emergency draw-down, he was concerned about the effects of cavitation on the duty scour valves and the inability of some of the valves to be operated through their full travel.

Howden Dam

Howden Dam incorporates six pairs of in-line 30 inch (750mm) diameter Blakebourgh guard and duty scour gate valves, three pairs in the east valve chamber and three in the west.

These 'duty' scour valves are hydraulically operated. Hydraulic pressure to power the actuators is provided by the reservoir head, through tappings off the pipework on the upstream side of the three duty valves in the west chamber. The pressure is then boosted by a compressor.

Derwent Dam

Derwent Dam incorporates three pairs of in-line 30 inch Blakebrough guard and duty scour valves (ref Figure 2 : Derwent Valves), situated within the

west valve chamber of the dam. The outlet pipes leading from these valves discharge into a tailbay stilling pool.

The scour valves are similar to those at Howden. Hydraulic head to operate the valve actuators is provided by means of a 2 inch diameter asbestos cement and uPVC pipeline from Walkers Clough, a small reservoir situated high up on the eastern hillside overlooking the reservoir.

Figure 2 : Derwent Valves

Feasibility Investigations

During the feasibility investigations it was considered that renewal of the duty valves would have been considerably more expensive than refurbishment. The valves were also partially encased, to half barrel, in concrete. Complete removal of the valves would have incurred a significant amount of effort as well as cost.

Options were therefore considered for repair, refurbishment and renewal of various components of the scour valves at Derwent and Howden. The valve components were; body, bonnet, wedge, stem and nut assesmbly, operating cylinder and piston, control valve, pressure relief valve, bolts, gaskets and ancillary items such as indicator plates.

The investigation at this stage of the works was restricted to bringing together a limited amount of factual information. A clearer understanding of the extent of refurbishment could only be ascertained when the valves were dismantled. However a significant element of the data available was a recent CCTV survey carried out by STW. This clearly showed that there was evidence of cavitational damage to some of the valves. It was also clear that where new sleeves had been installed in two of the Howden valves that this recent refurbishment work had been effective. The situation was similar at Derwent where one valve had been repaired with a metal filler which appeared to be performing satisfactorily.

IMPROVEMENTS IN RESERVOIRS

Due to the apparent success of the previous valve refurbishment, it was recommended that repairs to the areas affected by cavitation be carried out.

To communicate the extent of repairs to Norwest Holst (NWH), STW's framework contractor assigned this work, a detailed specification and scope of work was compiled listing the valve components. The specification also elaborated on the timing of the works ensuring that emergency drawdown would not be affected by the construction works.

The information, with respect to valve condition, was limited. Therefore the specification stated that after stripping the valves down on site and before any refurbishment / fabrication work was carried out, a valve condition report would be prepared for each valve.

The feasibility review of the work also encompassed health and safety issues and environmental impact of the works in a National Park. Good communications with the park Rangers assisted access and egress issues.

Extent of Valve Works

The specific requirements for the valve work were extensive, but listed below are some particular items of interest;

Valve Body and Bonnet Repairs

It was specified that both the body and bonnet would have guides dressed, minor damage repaired and damage to any corroded retaining pins replaced. If sustained damage had occurred to the guides, in particular at the body/bonnet interface, a filler material would be required to allow full refurbishment.

Wedges

The wedges once removed completely from the body of the valve were to be shot blasted and painted with their faces dressed and any minor damage repaired. The associated new bush, pin and roller sets would be manufactured and installed to suit body guide sizes or if shoes, these would be dressed and minor damage repaired.

Operating Cylinder and Pistons

Damage to the operating cylinders would be machined and new pistons, piston guides (if required) and seals were to be manufactured to suit the oversized cylinders.

Pressure Relief Valve

The pressure relief valves were to be fully refurbished and re-set to prevent the valve wedge and control piston from experiencing excessive forces.

Construction Works

In July 2005 Norwest Holst commenced construction work with subcontractor Blackhall Engineering. A comprehensive valve condition report was issued by NWH for each valve as it was dismantled. The pre-tender assessment of proposed works were found to be a good estimate and refurbishment was initiated at Blackhall Engineering's factory. Typical valve condition found following stripping can be seen in Figures 3 and 4 : wedge cavitation and scored channel guides. Work during refurbishment can be seen in Figure 5 : view showing the wedge and guide brushes

Figures 3 and 4: Wedge Cavitation and Scored Channel Guides

Figure 5 : View showing the wedge and guide bushes

At feasibility stage it was considered that removal of the scour valves would be difficult as there were no existing provisions in the valve chambers for removal. In addition access was very difficult as there were no direct routes that plant could travel to the valve chambers. However, Blackhall Engineering designed and constructed temporary gantries to allow safe removal and the work proceeded very efficiently.

Following refurbishment the valves were tested and commissioned. Tests were carried out under the available reservoir head and proved that the valves would operate smoothly through the full range of travel. During the final tests, adjustments to the pressure relief valves were made making sure that the wedges were not fully embedded onto the bottom of the valve body. If this were to occur, there would be a risk of the valve jamming shut.

The works 'in the interests of safety' had identified that cavitation was a significant concern. Although no physical works were implemented to alter this hydraulic phenomenon it was recommended to STW that the scour valves should only be used when opened to a position which was outside the cavitational zone (20% to 70% open). During the final testing the ease of closure was noted as was the reduction in noise by those having witnessed the operation of the old valves. Operator confidence to move the valves through the zones has now increased.

LINACRE RESERVOIRS

Linacre Reservoirs consist of three cascading reservoirs appropriately named, Upper, Middle and Lower. They are situated on the Holme Brook, approximately 5 kilometres west of Chesterfield in Derbyshire. They are impounded by earth embankment, clay core, dams, which were completed in 1854 (Lower), 1864 (Upper) and 1911 (Middle). All three Linacre Reservoirs are currently non-operational and are allowed to fill up to spill level.

Inspecting Engineer, the late Mr. John Beaver, of Halcrow Group, had carried out a routine 10 yearly inspection of Linacre Reservoirs, under Section 10(2) of the Reservoirs Act 1975. His report made a number of recommendations. Those referred to in this paper are;

- refurbishment works to spillway walls and floors,
- restoration of a drainage facility,
- installation of a scour guard valve,
- re-lining of the Lower Reservoir scour pipeline.

The Works

This project, like Howden and Derwent, complied with the Construction (Design and Management) Regulations 1995. Early involvement of the Planning Supervisor assisted in the application of the Regulations throughout the project. During the feasibility stages of work the design risk assessments were compiled, defining the significant hazards that NWH

would later consider and develop in their Health and Safety Plan for the construction works.

Of the more general but significant risks identified was the potential for the working areas, such as spillways, to be inundated with water. Planned draw down of the reservoirs were successfully implemented during construction by STW Operations and NWH.

Refurbishment works to spillway walls and floors
The works for this element of the project were considered at first to be relatively straight forward. The scope of work required general repairs in the spillway channel retaining walls and repairs to damaged concrete and joints in the bed of the channel. A site visit early in the project with STW, JB and NWH identified the extent of work referred to in the Inspecting Engineer's Report. (Ref Figures 6 and 7 : Typical floor joints prior to repair and spillway channel)

Cracks on the surfaces of the concrete walls and floors were to be repaired with a concrete waterproof repair mortar. The joints were to have the existing material removed and replaced with a gun grade sealing compound. Once on site NWH's suspicions regarding the existing joint filling material were aroused. The material was easily broken when removed. All work in spillways channels was stopped and a sample of the joint filling material taken away for analysis. It was found that the material contained approximately 15% asbestos!

As part of the developing risk assessment of the planned work it was considered that leaving the asbestos in place could be safer than removal. However it was decided that the risk of leaving the problem asbestos to others in the future was not an acceptable solution and a specialist and licensed contractor was employed to remove the 156 linear meters of jointing material before work could re-commence on the spillway channels.

In the case of these works the specialist contractor notified the Health and Safety Executive of the planned asbestos work complying with The Control of Asbestos At Work Regulations 2002.

Work was successfully completed on this section in December 2005.


Figure 6 and 7 : Typical floor joints prior to repair and spillway channel

Restoration of a drainage facility

The purpose of the drainage facility located adjacent to the Middle Reservoir embankment and at the top of the Lower Reservoir was uncertain and historical construction records were not available.

A small burn flowing down a 'closed off valley', in the direction of the reservoir was intercepted by a chamber, measuring approximately 4 metres by 2 metres. It contained a depth of silt of approximately 2 metres.

The Inspecting Engineer requested that the silt and other obstructions be removed to restore the drainage facility and the outlet investigated. Various attempts had been made in the past to find the outlet of the drainage facility without success.

During the feasibility stage, environmental issues prevailed. An Environmental Assessment was carried out indicating a number of issues that could influence the method of working;

- Badgers – protected under the Badgers Act 1992. A sett was found close to the chamber. It was anticipated that restricting the working area would only cause some short term disturbance to the badger's territory.
- Plants – Impact on wood barley and woodland ground flora was a significant issue. The working area was confirmed prior to entry and access/ egress routes defined.
- Nesting Birds – The working area was checked prior to entry for nesting birds and access routes again defined.

The initial proposals considered a prolonged programme of manual working but with NWH's input balancing the limitations of manual working with available plant, a method of working was evolved without detriment to the environmental issues. The planned 'duck board' paths into the valley were replaced with scaffolding extending into the 'closed off valley'. Pulleys

replaced potential endless journeys using wheelbarrows. Unfortunately the silt from the chamber had still to be removed by spade.

This work was completed in November 2005. Not long after the chamber was inundated with water during a heavy downpour and the burn outflow into the top of the Lower Linacre reservoir became clearly visible.

Installation of a scour guard valve
The provision of a scour guard valve at the Upper Reservoir was requested by the Inspecting Engineer as there was no 'secondary' valve on the scour outlet.

Figures 8 : Upper Linacre valve tower

The feasibility review of the required works considered various alternative locations. With the tower being relatively small in diameter and with numerous pipes and valves already accommodated a suitable location at higher level was opted for. Figures 8 : Upper Linacre valve tower shows the internal and external views of the tower.

As indicated, the logistics of providing the guard valve within the existing valve tower chamber was difficult, with confined space access and manual handling problems the prevalent risks. Scaffolding, again, was adopted as the best option for safe access, being constructed from the bottom of the chamber up. Confined space entry was rigorously employed with the Local Fire Services taking the opportunity to use a site visit as confined space entry practice!

Once the reservoir water level was sufficiently drawn down, work commenced on cutting the existing pipework for the addition of the valve and spindles. Actuators were provided and located at the top of the valve tower giving STW Operations a safer means of operation.

IMPROVEMENTS IN RESERVOIRS

Relining the Lower Reservoir scour pipe

It was reported that during a site inspection water was seen to be issuing from the bulkhead wall upstream of the supply culvert. The Inspecting Engineer examined the flow of water and was of the opinion that the scour pipe had either suffered through-wall corrosion or the joints had sprung a leak. Leakage could therefore have been taking place along the pipe/clay interface and into the culvert downstream of the bulkhead. In advance of construction works the scour valve downstream was opened to mitigate the effects of leakage. The Inspecting Engineer, at the time of his inspection, indicated that lining the scour pipe would be an acceptable solution.

The scour work also included the feasibility and construction of an operable scour guard valve. The existing valve, refer to Figure 9 : Lower Linacre existing guard valve, was currently only accessible by divers as it was located in 9m depth of water. Reasons for this arrangement were only speculative.

During the feasibility stages of the works JB identified that there could be significant risks of flooding or even damage to the dam, if during proposed construction works, the reservoir remained full of water. Before any lining works could be carried out the existing scour pipe would have to be cleaned. This work could exacerbate any cracks and leakage. It was therefore agreed to empty the reservoir to mitigate any flooding and limit other risks while at the same time providing safe and relatively dry access for the removal of the scour guard valve.

In turn, the implications of emptying of the reservoir became a critical environmental issue since the timing of the work could have a significant impact on the local wildlife. The Linacre environmental report had identified that the bird nesting season could be disrupted.

The discharge waters, containing silt, were considered to have a potential impact on the downstream river life if uncontrolled. Early interaction with the Environment Agency by NWH assisted the smooth progress of the works. Many options were considered including bringing to site stilling tanks, with the addition of coagulating chemicals, to the more practical option of using the existing spillways channels to removed any silt. The latter solution was developed, by NWH, into a workable method. The reservoir waters were pumped into a series of lagoons which were constructed at the top of the spillway channel (ref Figure 10 : Lower Linacre lagoons) before flowing down the channel through a series of straw bales. This method was adopted and implemented successfully for the removal of the final 2 metres depth of reservoir water which contained a large amount of silt.

The lining work itself underwent a feasibility review. At this stage early discussions with a specialist contractor and NWH assessed very quickly that installation of the lining would be difficult due to access problems to the location of the scour pipework. There were no access roads or paths on which plant could be taken and moving any equipment would probably have to be done manually.

Figure 9 and 10 : Lower Lincare , Existing Guard Valve and Lagoons

To compound issues there were no existing record drawings of the Lower Linacre reservoir and pipework in STW's archives. This proved to be significant. The scour pipe was considered to be continuous through the dam but, following a CCTV survey to assess the condition of the scour pipe, it was discovered that the pipe stopped near the centre line of the embankment, possibly in the area of the clay core and bulkhead, and continued to the upstream side of the dam and scour valve via a 500mm x 500mm square masonry culvert as shown in Figure 11 : section through Linacre Lower Reservoir. A further CCTV survey was carried out to assess the condition of the culvert from the upstream side. Although the reservoir was empty at the time of the survey there was evidence to suggest that water could percolate through the structure. The reasons for pipe leakage was not through pipe wall corrosion but through the culvert. Leakage through the bulkhead wall remained unresolved. After much consideration it was agreed with the Inspecting Engineer that the 300mm diameter cast iron scour pipe and culvert would be lined with a 250mm diameter continuous polyethylene pipe. The annulus between pipes and culvert was filled with grout.

Calculations estimating the drawdown capacity assisted in arriving at the lining solution. Comparing a new 250mm diameter polyethylene pipe to a 300mm diameter heavily encrusted cast iron pipe confirmed that there would be an improvement in the current drawdown capacity.

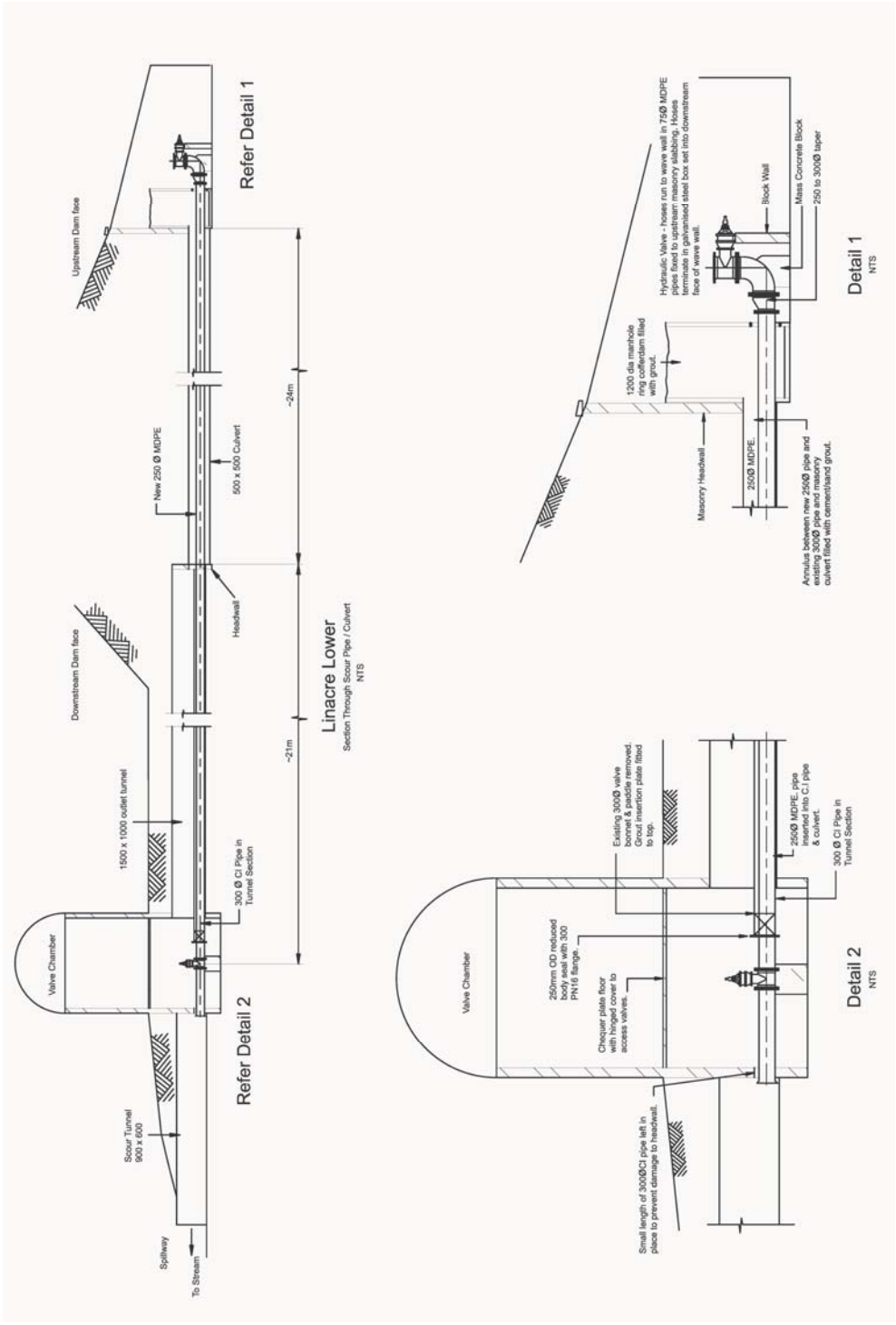

Figure 11 – Section through Linacre Lower Reservoir

Despite early pigging problems clearing the heavily encrusted 300mm diameter cast iron pipe, the polyethylene pipe was pulled through, tested and grout fill injected. Work was completed in early February 2006.

CONCLUSION

Some of the works carried out at the Howden, Derwent and Linacre reservoirs were in the 'interests of safety' and others general maintenance works.

At Howden and Derwent the 9no. 30 inch diameter, scour valves were stripped and refurbished without the need for complete replacement and therefore major costs.

At Linacre, like Howden and Derwent, the works including repairs to spillway walls and floors, restoration of a drainage facility, installation of a scour guard valve and re-lining of the Lower Reservoir scour pipeline were jointly progressed between STW, NWH and JB. Significant health and safety and environmental issues were addressed and overcome to complete the works.

ACKNOWLEDGEMENTS

The author would like to express thanks to Messers Neil Williams and Stewart Harwood of Severn Trent Water for their assistance during the course of the works and to Severn Trent Water for their permission to publish this paper.