Haweswater Aqueduct - Tunnels & Conduits Refurbishment

open heart surgery on the UK's largest treated water aqueduct

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The Haweswater Aqueduct (HA) is the backbone of United Utilities (UU) regional water supply system and is the largest treated water aqueduct in the UK. The 109km long aqueduct provides up to 570 million litres of drinking water to 2 million customers every day. It comprises 52km of 2.6m diameter tunnels and conduits (free surface flow) and 57km of multi pipe siphons (pressurised flow). In October 2013 the aqueduct was taken out of service for the first time for a full inspection since it was commissioned in 1955. Planning for the two week inspection of the single line tunnels and conduits has taken over 15 years and was managed by a project team including engineers from United Utilities and MWH. Latterly this team was also joined by engineers from the main contractor Land & Marine.

Vehicular Access System (VAS) being used to transport survey team -note the trailer behind the VAS carrying the welfare faclities - Courtesy of Land & Marine

Background

Construction of the Haweswater Aqueduct started in 1933 but was interrupted by the war and it was finally commissioned in 1955. It was not fully completed until 1972 with the commissioning of the 4th line.

It had never been taken out of service for a full inspection making this UU's highest operational risk project ever undertaken.

The HA operates entirely by gravity. In the north the single line sections are relatively shallow in the most part being constructed by cut and cover techniques. However, in the central and southern sections the HA passes through higher terrain and the depth of the tunnels in places is over 300m. As a consequence of this, the distance between major access points can be in excess of 19km.

There are a number of bulk supplies fed from the siphon pipelines and during an outage these supplies needed to be maintained, by providing alternative sources of potable water from the various WTWs in the region.

The planning of the inspection has taken 15 years with UU investing £250m in major capital projects across the region. These enabling works ensured that the outage and inspection was successfully completed in October 2013 and UU can now assess the condition of the structure and plan future remedial works.

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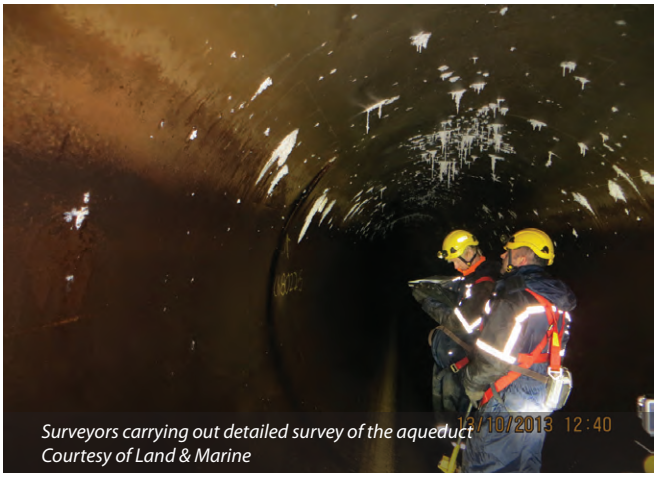
Training facility near Kendal -120m of mock tunnel and training rooms Courtesy of United Utilities



Surveyors carrying out detailed survey of the aqueduct Courtesy of Land & Marine

Aqueduct flushing - discharging 280Ml/d into an open storage reservoir Courtesy of United Utilities

Cutting out VAS access openings through the soffit of the aqueduct using a diamond wire saw - Courtesy of MWH

Business planning, regional enabling and support works project

From 1999 to October 2013 an enabling works programme was implemented to ensure supplies to customers fed directly from the aqueduct could be maintained and that the regional water supply system would be robust and reliable during the outage.

New cross country pipelines, service reservoirs (SR) and pumping stations (PS) were constructed during AMP3 (1999 to 2005). The main enabling works comprised three major construction projects:

- HA Cumbria: A 16km, 300mm dia. pipeline, PS and SR to supply south Cumbria.
- Ribble TA: A 37km, 300mm dia. pipeline, PS and SR to supply a number of rural communities around Lancaster.
- HA Ribble: A 16km, 700mm dia. pipeline and PS to supply the conurbations of Blackburn and Burnley.

Water from these new assets would be supplied to one or more of the siphon pipelines. The siphon pipelines would be isolated from the tunnel and conduits by either penstocks or non-return valves in the North and South Wells at either end of the siphons.

A risk study undertaken in 2006 identified a shortfall in water available to sustain a prolonged outage of the HA. The anticipated duration of the outage was four weeks. However this initial inspection was later reduced to two weeks as an outage of this magnitude and complexity had never been tried before.

The study resulted in the inspection becoming one of the drivers for a new link main between Liverpool and Bury, known as the West East Link Main (WELM). This 55km long, 1.2m diameter pipeline can transfer up to 100Ml/d in either direction and would be used to provide water into the Manchester area during the outage. *The WELM project was featured in the UK Water Projects 2010 and 2011 editions.*

In the final 2 years leading up to the outage, a number of key work packages were planned and coordinated across the business. These work packages would provide the necessary resilience to enable the project to proceed. Work included:

- Construction of UV treatment plants at two major WTWs.
- Refurbishment of a number of network pumping stations.
- The construction of a temporary 45Ml/d pumping station that would be used solely to condition an existing 700mm dia. pipeline. This pipeline laid in early AMP3 had been operating at very low flows to keep the main 'sweet' but would be needed to deliver 55Ml/d in either direction during the outage.

Another key facilitator for the outage was a major extension to one of the UUs WTW. A £15m project to provide an additional 60Ml/d capacity was designed and built in less than 12 months, utilising a package plant design which enabled large sections of the new works to be prefabricated off site.

Other work packages focused on the testing of other assets, contingency planning and establishment of service level agreements. A resilience forum was established with the police, fire and ambulance services together with local authorities and civil contingency organisations.

Electricity operators were also consulted to ensure that any major planned works would not coincide with the outage, allowing us to mitigate supply interruptions to critical assets.

A large open storage reservoir at the southern end of the HA was slowly drained over a 3-month period. This empty reservoir would be used to discharge water from the HA at high flow rates during a flushing regime prior to returning the aqueduct into service.

Health, safety, welfare and innovation

A contract was awarded in 2012 so that early planning and testing of equipment and procedures could be carried out. Initially UU provided a 2km length of catchwater tunnel 2.1m diameter for testing and evaluation, but water resource demands meant that this was often unavailable and a decision was made to establish a purpose built 120m mock tunnel and training facility.

Over 280 people would eventually be trained in this facility, including confined space training, enhanced hygiene and rescue procedures.

In the shallow northern section of tunnels and conduits, accesses were opened so that the longest traverse would be less than 3km. For these sections an electric powered trolley would be used to carry the surveying equipment.

The central and southern sections presented a different challenge. The central section passed under the Bowland Fells and the Bowland tunnel was 17km long, and over 300 m deep in places with limited access. The southern section was over 18km long and had one small central shaft 1.35m in diameter. It was therefore determined that some form of transportation would be required because of the long distance traverses involved in these sections.

Vehicular Access System (VAS)

The contractor proposed the use of an electric vehicle manufactured by Motrec, a Canadian based company with a UK sales division. A vehicle was purchased and then modified by the engineering division of the contractor and trials carried out in the catchwater tunnel and then the mock tunnel.

Initially it was thought that the vehicles – now termed Vehicular Access System (VAS) – could be inserted into the aqueduct in modular sections and bolted together once in the tunnel. However it quickly became apparent that this was impractical and that openings would need to be cut in the aqueduct roof to lower and remove the complete VAS units. Five openings were planned and a detailed site investigation undertaken to establish ground conditions for the cofferdams that would be required to enable these new openings to be formed.

Because the tunnel carries potable water it was necessary to provide sanitary facilities for the inspection teams. These would need to be self-contained units to prevent any contamination. Other requirements, including the provision of lockers for tools, food and drink containers and storage baskets for water samples meant that a trailer was required to carry all this additional equipment. Trials with the vehicle demonstrated that whilst it would readily tow the trailer it had difficulty pushing. This meant additional vehicles were required to pull the trailer out of the tunnel.

Trials were carried out to establish rescue and emergency evacuation procedures and it was concluded after consultation with the emergency services that the inspection teams would have to be capable of 'self-rescue' in an emergency. An ambulance and confined space trained paramedic would be stationed at each of the five VAS entrance points for each shift with their own vehicle so they could rapidly respond to a casualty should the need arise.

In October 2012 an order was placed with Motrec for a further 15 VAS. The main contractor would design and manufacture the electric trolleys and trailers.

The inspection

Site compounds were set up at the 25 access points along the length of the aqueduct. The compounds also contained changing rooms (dirty and clean), welfare facilities, VAS steam cleaning and maintenance facilities, duty standby ventilation systems, generators and a security cabin.

Battery pack being lowered into the VAS -note the ducting for the duty/standby ventilation system - Courtesy of Land & Marine

Work continued 24 hours a day for the two weeks of the inspection. VAS being lowered into the aqueduct ready for the night shift - Courtesy of Land & Marine

Each tunnel section would require the construction of new openings. Prior to the outage the exact location of any new openings was established and the top of the aqueduct exposed where necessary.

At the five sites where the VAS would be deployed, a large cofferdam was constructed so that a reinforced concrete ring beam could be cast and dowelled into the top of the aqueduct.

During the 4 weeks prior to the outage thirty-eight water treatment works were ramped up to their required output and the demand requirement from the HA gradually reduced until the aqueduct could be isolated and the drain down started. This was expected to take between 24 to 36 hours.

The enabling works were brought online, allowing water from the alternative sources to be fed into one or two of the multiple siphon pipelines, thus ensuring no interruption to customer supplies.

Once the aqueduct was drained work could commence on cutting out the VAS openings using diamond saws, whilst propping the soffit of the aqueduct from inside until the roof could be removed in sections.

Installation of the M-comm communication system and the duty standby ventilation system, including air lock doors could then begin.

There were ten survey teams carrying out the tunnel inspection, working day and night shifts to complete the works in just 2 weeks.

The schedule of inspection included an initial safety condition inspection followed by detailed inspections and any intrusive surveys (concrete coring). Forty-eight unplanned emergency repairs were also carried out.

Return to service

Following the successful conclusion of the inspection the aqueduct water was released into the head of the HA from the WTW and allowed to fill the tunnels and conduits (as well as the siphon pipelines which had not been used to maintain supplies) until the aqueduct was discharging up to 280Ml/d into the storage reservoir at the southern end of the aqueduct.

Flushing and disinfection continued for 4 days until the water samples confirmed that the water was acceptable and could be returned into supply.

Achievements

The outage and inspection was a big success:

- The 'Inspection Works' project was delivered on time, within budget and with zero accidents or incidents.
- The HA was successfully returned to service without any water quality issues or loss of supply to domestic, industrial or commercial customers.
- There were zero customer complaints.

The planning of the inspection has taken 15 years with UU investing £250m in major capital projects across the region. These enabling works ensured that the outage and inspection was successfully completed in October 2013.

The inspection means that UU can plan future maintenance works, ensuring the HA remains a sustainable supply of drinking water for future generations.

The Editor & Publishers would like to thank Paul Anderton, United Utilities Senior Project Manager, and Ian Armitage, MWH Design Manager (HA Outage Support Works), for providing the above article for publication.

Ventlation set up showing the 3 (No.) duty and one of the two standby ventilation fans and ducting
Not shown are the duty/standby generators used to power the fans - Courtesy of MWH

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ePowerTrucks Provides Electric Tunnel Transport Solution For United Utilities

North West water company United Utilities recently carried out the most extensive inspection ever done on the Haweswater Aqueduct, which links the Lake District with Manchester. Its team of engineers were safely transported along its 56 mile length by electric shuttle vehicles.

The 16 electric shuttles are specifically designed for tunnel driving. The innovative vehicles have a cab and drive train at each end, much like modern trains. This means they don't have to turn around or be driven in reverse for the return trip. Entirely battery powered, they are clean, quiet and emit no exhaust emissions.

Regional water supplies manager John Butcher said: "Some points in the aqueduct were nine kilometres from the nearest access point. These vehicles not only carried workers to where they were needed as quickly and effectively as possible, they also towed essential welfare equipment to keep them comfortable while they were at work."

Each vehicle can transport up to 8 people or more than 2,000kg of goods at speeds of up to 10mph. Easy to modify, one was kitted out as a rescue and first aid vehicle.

The inspection gave United Utilities the first detailed information on the condition of the 60-year-old concrete pipe's full length since it was built in the 1950s.

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