

Leakage Remediation at a Small Heritage Reservoir

P D DOWN, Mott MacDonald

SYNOPSIS Abbeydale Industrial Hamlet, on the outskirts of Sheffield, is a former steel-working site along the River Sheaf and has become a museum open to the public. The site, including the reservoir and dam, is designated a Scheduled Monument and the forge works are Grade I listed. Several other buildings within the site are Grade II* listed. It has a history thought to go back to 1685, with the present-day site reported to date from the early 18th century. To provide power for the machinery, a small reservoir was constructed and filled with water abstracted from the River Sheaf. The reservoir was enlarged as the site developed although remains below 25,000m³ capacity, and thus is not registered under the Reservoirs Act 1975 (as amended).

There has been a history of leakage from the reservoir. In November 2022, the most recent leakages and damage to structures were investigated with the aim of developing suitable remedial measures. At the end of May 2023, significant leakage from the reservoir into one of the Listed buildings occurred resulting in emergency action being taken. This paper details the issues encountered, works previously performed, recent investigations and the development of remedial works to provide a longer-term solution.

INTRODUCTION

In its heyday, the Abbeydale Works was one of the largest water-powered mill sites on the River Sheaf. It produced agricultural tools, such as scythes, grass hooks and hay knives. Production continued until 1933. Two years later, the site was donated to the City of Sheffield (now Sheffield City Council). The Council restored it to working order for the Conservation of Sheffield Antiquities. It was then developed as a museum by the City of Sheffield Museums Department, opening to the public in 1970. It has been in use as a working museum since.

Abbeydale Industrial Hamlet, including its reservoir, is currently operated by Sheffield Museums Trust, a registered independent charity that operates six of the city's leading museums and heritage sites. The Council still has an involvement with the site when necessary. Some of the 'Hand Forge' buildings are in continued use by blacksmiths.

The site comprises a long reservoir, aligned south-west to north-east, with the mill complex to the north-east end. Water is abstracted from the River Sheaf, a short distance south of the reservoir, and transferred via a goit channel. The reservoir is normally kept full, with water spilling at the overflow and conveyed along a masonry spillway channel back into the river. Penstock gates at the north-east end of the reservoir can be opened to allow water to be discharged and power waterwheels, to the 'Grinding Hull' and 'Tilt Forge' buildings respectively, before being returned to the river (Figure 1).

Managing Risks for Dams and Reservoirs

HISTORY OF THE RESERVOIR

As detailed in a Sheffield City Museums publication, during the early years of the site, a goit channelled water from the River Sheaf to the waterwheel (or wheels) behind two buildings which existed at the time. Around 1777, a dam and reservoir, approximately half the current size, was provided. After construction of the 'Tilt Forge' building in 1785, the reservoir was increased to a surface area of 18,800m² to provide greater capacity for two 5.5m diameter waterwheels. Further development of the site included the construction of the Workmen's Cottages by 1793 and the current 'Grinding Hull' building in 1817. The reservoir's surface area was then reduced to 15,000m² when removed silt was placed at the southern end and partly formed Beauchief Gardens.

The surface area of the current reservoir has further reduced due to siltation at the south end where flows from the River Sheaf enter.

DESCRIPTION OF THE RESERVOIR

The current reservoir has a surface area of approximately 10,000m² and a storage capacity of less than 25,000m³ at a Top Water Level (TWL) of 98.1m AOD. The storage basin is puddle-clay lined. Due to the age of the reservoir, there are very limited records relating to its construction.

The reservoir is impounded along its eastern and northern sides by earth-fill embankments, up to 5.2m high, with a crest level between 98.4m AOD to 98.7m AOD. The form of construction is currently unconfirmed but, given its age, the embankment is anticipated to be formed from general fill materials with no water-retaining core. Puddle-clay is understood to have been used in more recent remedial works. To the upstream face, there is a vertical masonry wall, approximately 1.0m high for much of its length, around the reservoir perimeter.

In normal operation, the water level is maintained by a 3.5m wide, broad-crested, overflow weir in the upstream side of a masonry spillway penstock structure constructed within the north-eastern section of the East Embankment. The structure includes mid-level and low-level drawdown penstock gates. Within this structure, a masonry arch-shaped culvert, with an invert level of approximately 93.5m AOD, discharges into a 1.75m wide masonry spillway channel that runs along the south boundary of the 'Hand Forge' buildings and conveys flows back into the River Sheaf.

Several buildings and structures have been constructed within the downstream shoulder of the embankment dam. These include the 'Grinding Hull' and 'Tilt Forge' buildings. The 'Overflow and Spillway Penstock Structure', detailed above, has been built through the entire width and depth of the East Embankment. A masonry structure incorporating penstock gates, with invert levels approximately 1.3m below TWL, for the 'Grinding Hull' and 'Tilt Forge' waterwheels, has also been built through the entire width and depth of the East Embankment. The structure extends below the reservoir basin to form pits to accommodate the waterwheels.

HISTORIC LEAKAGES AND REMEDIAL WORKS

There has been a history of leakages and remedial works associated with the reservoir at Abbeydale Industrial Hamlet. The known records date from approximately 30 years ago although it is possible there were issues that pre-date this.

Late 1990s

Void repair works were reported to have been performed along the north end of the reservoir between the 'Grinding Hull' building and Abbeydale Road South (A621). The flagstones to the surface were lifted and puddle clay placed in layers before the surface was reinstated. Detailed information relating to these works has not been identified.

2001-02

There are very limited details regarding the remedial works performed or the reason they were required. From a record photograph, it appeared works were performed to the penstocks for the 'Grinding Hull' and 'Tilt Forge' waterwheels. To facilitate this, a significant draw-down of the reservoir level was implemented. Although unconfirmed, this may have been achieved by operating the mid- and low-level outlet penstocks to discharge water to the spillway. To the left (north) of the 'Grinding Hull' penstock, an engraved stone, marked "Reconstructed March 2002" and set in the surface, records the works.

2014

The remedial works performed in 2014 were due to the following issues experienced:

- A breach of the East Embankment, adjacent to the 'Overflow and Spillway Penstock Structure', and erosion of the embankment surface due to flowing water.
- Voids in the upstream vertical masonry wall along the East Embankment.
- A void in the reservoir clay lining immediately upstream of the penstock gate for the 'Grinding Hull' waterwheel.
- Leakage of reservoir water into the 'Tilt Forge' building.
- Leakage of reservoir water into the 'Grinding Hull' building.

The following remedial works were recorded (Figure 1):

- Removal of a mature tree within the East Embankment adjacent to the 'Tilt Forge' building.
- Installation of a 26m long, 6m deep cement-bentonite grout curtain within the East Embankment, from the 'Tilt Forge' building to the 'Overflow and Spillway Penstock Structure'.
- Repair of the breach to the East Embankment left (north) of the 'Overflow and Spillway Penstock Structure'.
- Packing and repointing of the perimeter wall masonry along the East Embankment.
- Replacement of the penstocks to the 'Grinding Hull' and 'Tilt Forge' waterwheels. The upstream aprons were also improved.
- Puddle clay repairs – exact location(s) and extents unconfirmed.

There were no records available to the author to indicate the investigation works performed to inform the design of the remedial works.

A construction drawing indicated the proposed replacement of the clay lining to the northern end of the reservoir basin. However, there is no record of this being performed. It appears

Managing Risks for Dams and Reservoirs

the works were limited to localised repairs in the vicinity of the remedial works along the East Embankment and adjacent to the penstocks.

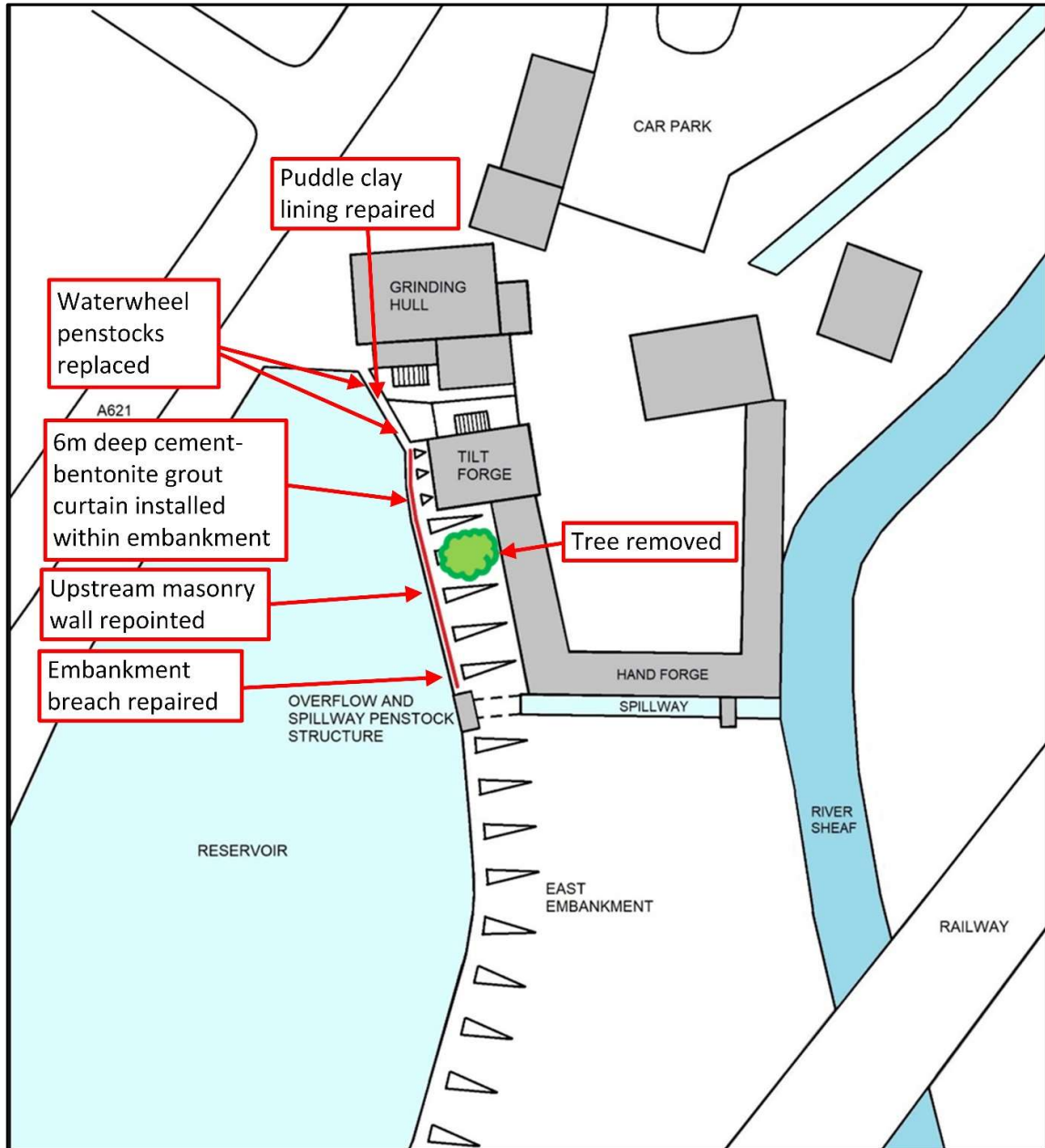


Figure 1. Abbeydale Industrial Hamlet, remedial works performed in 2014

CURRENT DAMAGE AND LEAKAGES

In November 2022, a request was received from the Client to visit the site, assess the situation and provide advice for any remedial works required. During the subsequent visits, the following issues were identified (Figure 2):

- Damage to the downstream end of the masonry spillway channel.
- A void under the 'Hand Forge' building adjacent to the spillway.

- A void and flowing water within the East Embankment crest adjacent to the 'Overflow and Spillway Penstock Structure'.
- Poor structural condition of the masonry spillway culvert. Ingress of water was observed through the culvert wall.
- Historic movement of the upstream vertical masonry wall along the East Embankment.
- Minor ingress of water into the 'Tilt Forge' building.
- Reports of ingress into the 'Grinding Hull' building with damp areas observed.

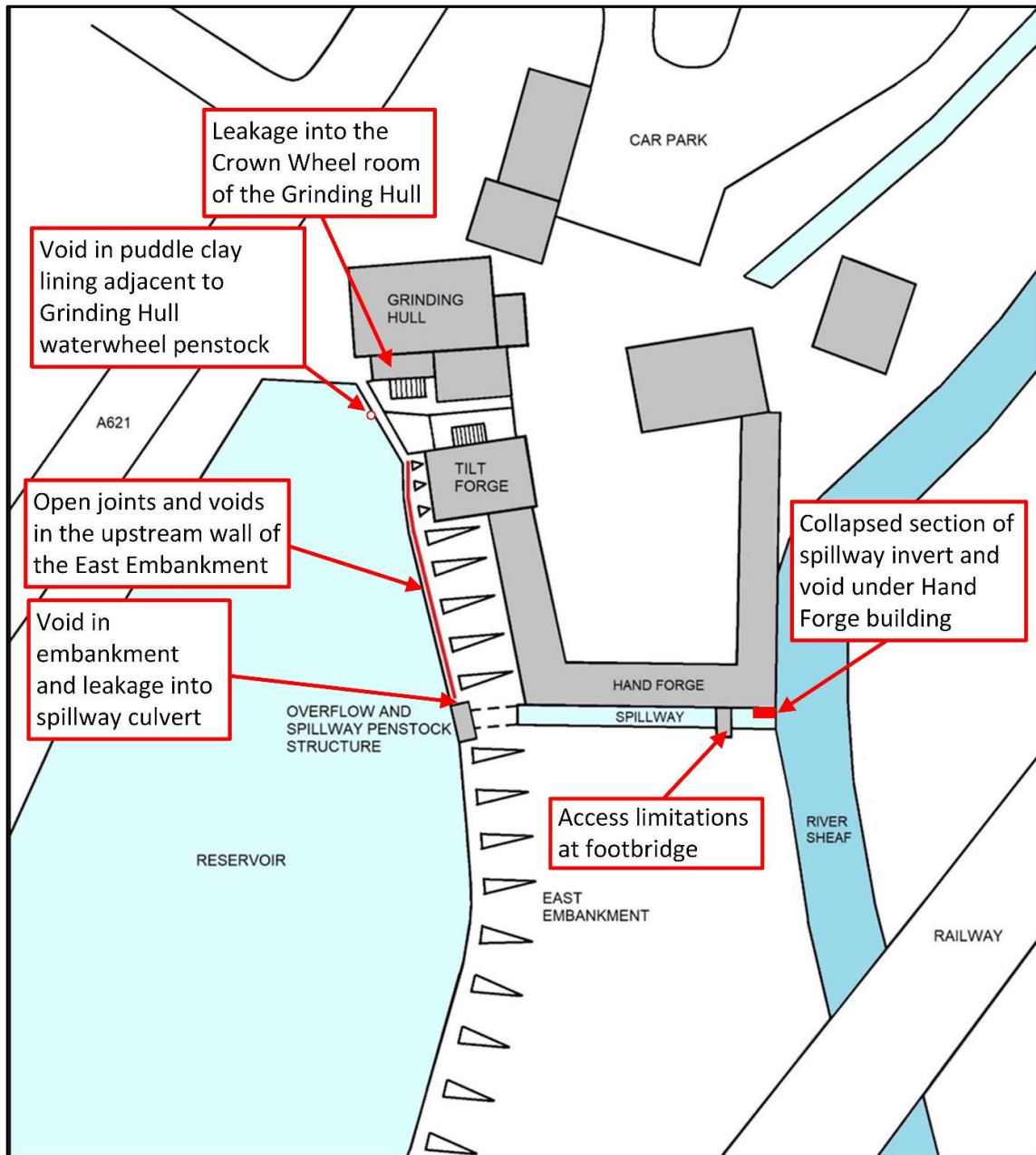


Figure 2. Abbeydale Industrial Hamlet, damage and leakages in 2022-23

Managing Risks for Dams and Reservoirs

The damage to the downstream end of the spillway comprised a collapsed section of the masonry invert approximately 1.2m long, 1.0m wide and 0.3m deep (Figure 3). There was damage to the end of the spillway, with missing stonework, where it discharged into the River Sheaf. It appeared the action of flows along the River Sheaf had damaged the downstream end of the spillway and washed out material from beneath, creating a void into which the invert collapsed. Within the river channel, immediately adjacent to the downstream end of the spillway, a scour hole, approximately 300mm deep below the water level, was present. A void extended from the spillway under the south-east external corner of the adjacent 'Hand Forge' building. This did not appear to have affected the structural integrity of the building and there were no obvious signs of distress.



Figure 3. Damage to the downstream end of the spillway channel

The void within the East Embankment crest was at the same location as experienced in 2014 and there was evidence of previous remedial works (Figure 4). During examinations between November 2022 and July 2023, it appeared to increase in size. At the latter visit, the void measured 1.6m long by 0.8m wide and its base was 0.9m below the adjacent top of wall level. Water was entering the void directly through the upstream wall of the East Embankment. It also entered the void from beneath the adjacent section of embankment crest indicating leaks from the reservoir at other locations along the upstream wall. The water flowed towards the 'Overflow and Spillway Penstock Structure' where it then disappeared into the body of the embankment. This flowpath differed to that experienced in 2014.



Figure 4. Void within the East Embankment adjacent to the overflow and spillway structure

The spillway culvert was arch-shaped with a flat, stone-lined bed and of aged condition. It was approximately 8m long, 1.4m wide and 1.1m high. There was no mortar visible in the joints and some displaced masonry was evident, especially to the soffit and to the right (south) wall (see Figure 5). Towards the upstream end, ingress of water was observed approximately half-way up the left (north) wall, coinciding with the location of the void in the East Embankment above.



Figure 5. General condition of spillway culvert

Managing Risks for Dams and Reservoirs

The East Embankment's upstream wall showed evidence of having been raised in the past as the upper courses were of a different construction style to those beneath. This may be associated with the reservoir enlargement around 1785. The top of wall level appeared to have reduced as the embankment had settled over time. There was deformation of the masonry to the East Embankment wall at each end, due to differential settlement, at the connections with the 'Overflow and Spillway Penstock Structure', to the southern extent, and the 'Tilt Forge Penstock Structure', to the north. There was a difference in top level of around 150mm as compared with the adjacent penstock structures. The deformation at the wall ends had resulted in opening of the masonry joint. Adjacent to the 'Tilt Forge' building, there was additional settlement of the top of wall level. This coincided with the location where leakage had occurred prior to the remedial works in 2014. Closer examination of the East Embankment Wall confirmed the presence of several voids along its base and continuing through to the embankment behind. In addition, the wall did not appear to extend below the ground level at the reservoir's edge and no foundations were apparent.

Minor seepage of water into the 'Tilt Forge' building was observed through the walls in the north-west corner, adjacent to the reservoir. There was also some water ingress through the floor in the south-west corner of the building. From discussions with museum staff, the water ingress had been occurring for a long time and had not been completely solved by the 2014 remedial works. In July 2023, when the reservoir water level was 750mm below Top Water Level, no water ingress through the walls of the 'Tilt Forge' building was observed.

During the initial visits, the museum staff reported water ingress within the 'Grinding Hull' building. The walls of the 'Crown Wheel' room, adjacent to the waterwheel and closest to the reservoir, were damp at the time but no notable water ingress was observed there or elsewhere in the building. There was evidence of historical movement of the south (external) dividing wall between the 'Crown Wheel' room and the waterwheel pit. The masonry to the end of the wall had been displaced towards the opening for the waterwheel axle. In addition, there was displacement and bulging of the wall face into the 'Crown Wheel' room.

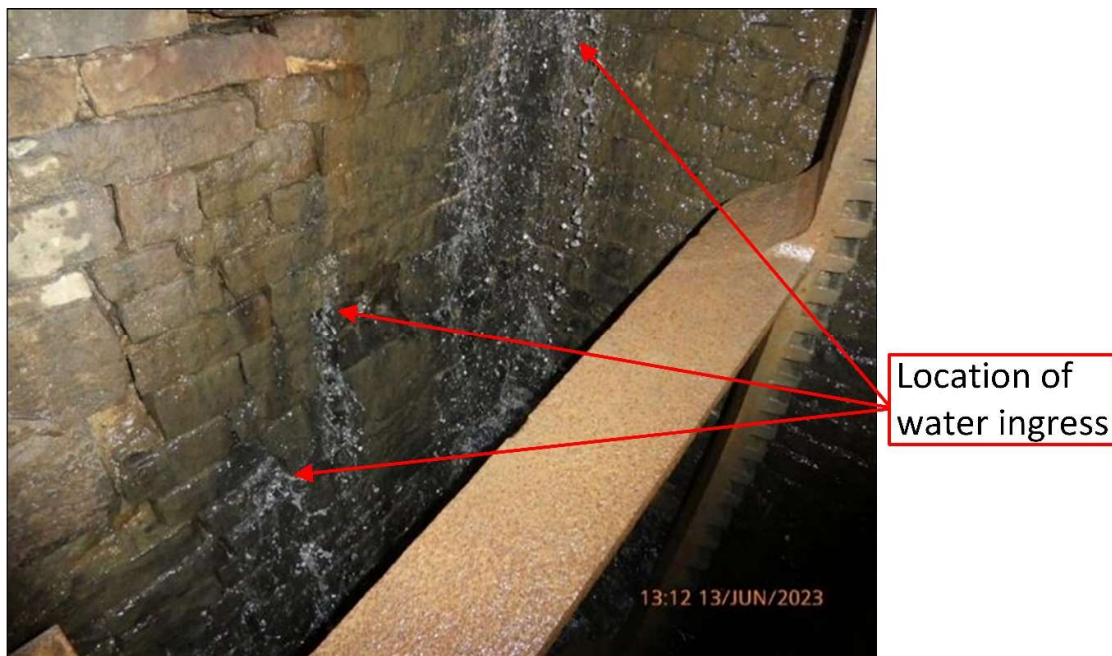


Figure 6. Significant water ingress through the walls of the 'Grinding Hull' building

At the end of May 2023, there were reports of notable water ingress into the 'Grinding Hull' building. A subsequent visit confirmed significant ingress of water through the masonry walls of the building, especially in the 'Crown Wheel' room (Figure 6). The source of the leakage was undetermined at that time. It was obvious that the situation had substantially changed and a leak from the reservoir was suspected. Emergency remedial action was required and the Client was requested to arrange draw-down of the reservoir as quickly as possible, monitor the situation and provide regular updates.

EMERGENCY REMEDIAL ACTION

Water ingress had filled the cavities within the 'Grinding Hull' building walls, pressurising within them, and escaping through open joints in the masonry. There was concern this would cause further displacement and damage to the walls with the potential for their failure. This would be catastrophic for the Listed building and risked an uncontrolled escape of reservoir water. Due to the potential heritage and environmental impacts, a site meeting to discuss and agree emergency remedial action was urgently arranged and attended by representatives of Historic England, South Yorkshire Archaeological Service, the Environment Agency and other key stakeholders.

The following remedial actions were discussed:

- Provide emergency support to the walls of the 'Grinding Hull' building.
- Draw-down the reservoir.
- Perform chemical injection grouting works to seal the leakage path.



Figure 7. Scaffolding support to the walls of the 'Grinding Hull' building

Managing Risks for Dams and Reservoirs

Due to the urgent need to safeguard the heritage assets, as well as address the risk of a reservoir breach, agreement was gained during the site meeting to install emergency propping to the structure. Scaffolding was installed relatively quickly with associated notification to Historic England (Figure 7). As much of this was in and around the 'Crown Wheel' room, the waterwheel was rendered inoperable. In addition, due to concerns about vibrations affecting the structures, instructions were given to the museum staff to not operate the 'Tilt Forge' waterwheel. The 'Grinding Hull' building was closed to staff, except for regular monitoring of the leakage situation and remedial works, and to the general public.

Another course of action was to implement an emergency draw-down of the reservoir's water level. The key aims were to significantly reduce, or stop, the water ingress into the 'Grinding Hull' building and locate the source of the leakage. As the reservoir level could vary during normal operation, a draw-down was not considered to have heritage impacts. However, there were environmental requirements in relation to investigating and rescuing protected species and fish and to manage the risk of silt discharge into the River Sheaf.

Whilst environmental surveys were ongoing, a partial draw-down of the reservoir was implemented to help reduce the water ingress and pressure on the walls of the 'Grinding Hull' building. This had limited impact, indicating that the source of the leakage was deeper within the reservoir. As a result, there was renewed urgency for an increased draw-down. A test for white-clawed crayfish produced a negative result. Therefore, a further draw-down of the reservoir was able to be performed once fish rescues had been completed.

Due to their age and condition, there were concerns that the mid- and low-level drawdown penstocks would not close again once opened, thus, risking complete draining of the reservoir and significant silt discharges into the River Sheaf. Therefore, these were not used for the reservoir draw-down. As the waterwheels were out of operation, it was not possible to use their penstocks to draw-down the reservoir level either. As a result, reservoir waters were pumped out.



Figure 8. Void in the reservoir basin's puddle clay lining adjacent to the 'Grinding Hull' penstock

Once there had been a sufficient draw-down, a void was observed in the edge of the reservoir basin's puddle clay lining, adjacent to the 'Grinding Hull' waterwheel penstock, with water

discharging into it (Figure 8). This appeared to be the source of the water leakage into the 'Grinding Hull' building and was at a similar location to that prior to the remedial works in 2014.

Due to the low level of the leakage location, there was concern that a draw down significantly below this level would expose the puddle clay lining creating a risk of it drying and cracking. Conversely, rainfall events could result in inflows greater than the discharge capacity of the pump, thus, resulting in an increase in reservoir levels. As a result, in August 2023, chemical injection grouting of the area between the reservoir and the 'Grinding Hull' building was performed to minimise the leakage risk should the reservoir level rise (Figure 9). During these works, the Contractor reported significant voiding immediately adjacent to the 'Crown Wheel' room and at another location nearby. The total volume of the voids was estimated to be 11.5m³. To grout the deeper voids, the Contractor requested to work from within, and drill through the masonry of, the 'Crown Wheel' room. However, this was not possible due to the presence of the scaffolding supports and the heritage impact. Therefore, grouting was restricted to those areas that could be accessed from outside of the building. On completion, the emergency chemical injection grouting was seen to be successful in controlling water ingress into the 'Grinding Hull' building.

The emergency remedial actions are to remain in place until permanent remedial actions can be completed.



Figure 9. Chemical injection grouting adjacent to the 'Grinding Hull' building (courtesy of Sheffield City Council)

Managing Risks for Dams and Reservoirs

POTENTIAL FAILURE MECHANISMS AND PATHWAYS

From the initial surveys and walkover investigations, the following potential failure mechanisms and pathways were identified:

- Removal of masonry from the end of the spillway channel and erosion of material from beneath the spillway and 'Hand Forge' building due to the action of flows along the River Sheaf. The risk of damage is highest during flood events when there is localised turbulence at the end of the spillway and along the Hand Forge building.
- Insufficient containment of water by the reservoir basin's puddle clay lining. Along the East Embankment, the clay lining extends to the base of the vertical masonry perimeter wall, approximately 700mm below Top Water Level.
- Voids within the vertical masonry perimeter wall and the possible lack of a water-retaining core within the East Embankment. The grouting works performed in 2014 appear to have had limited success in preventing leakage through the embankment.
- The possible presence of permeable and/or poorly compacted fill around the structures formed within the embankment in late 1700s / early 1800s.

The above potential failure mechanisms and pathways are to be reviewed and amended, as necessary, as more information is collated about the reservoir and its associated structures.

FUTURE INVESTIGATION WORKS

Further investigation is required to assess the on-site conditions more fully, provide information to aid the determination of potential failure mechanisms and pathways and to assist the development of future remedial measures. The following investigation works have been proposed:

- Topographical and bathymetric surveys
- Culvert survey
- Ground investigation
- Survey of the drystone wall that forms the right (south) wall of the spillway channel.
- Heritage surveys
- Environmental surveys

As the function of the Abbeydale Industrial Hamlet museum has been detrimentally impacted by the reservoir draw-down and the temporary support scaffolding within the 'Grinding Hull' building, there is a desire to complete permanent remedial measures as quickly as possible. The types and extents of the investigation works have been developed with this aim in mind with a focus on providing the essential information required within a suitable timescale. In addition, development of the investigation works has considered the site constraints, especially as regards access limitations, a requirement to minimise heritage and environmental impacts and a need to obtain the necessary consents.

At the time of writing, the investigation works detailed above were due to be commenced.

FUTURE REMEDIAL MEASURES

As detailed earlier, there have been repeated leakages at the reservoir. Previous remedial works appear to have been targeted at specific issues. Whilst the works in 2014 were more extensive in nature, as compared with those previously, they provided short-term benefits. The leakages adjacent to the 'Overflow and Spillway Penstock Structure' and the 'Grinding Hull' waterwheel penstock have re-established since and the re-pointing to the East Embankment's upstream wall has now been largely eroded.

A need for remedial measures that successfully address the risk of leakage and damage in the medium- to long-term has been recognised. There is a requirement for these to be implemented in ways that respect the heritage status of the site and in keeping with the original appearance. The Client also requested details of proposed works so that the necessary funding could be raised. As a result, the following outline proposals were developed:

- 'Grinding Hull' penstock structure and building: Grouting works, using bentonite-cement grout, to infill any remaining voids within the ground between the penstock structure and the 'Grinding Hull' building.
- 'Grinding Hull' and 'Tilt Forge' penstock structure: Provision of a concrete cut-off beam between the concrete aprons, located upstream of the penstocks, with reinstatement of the puddle-clay lining above. The aim is to reduce the risk of a flow-path between the edge of the puddle clay lining and the face of the existing structure.
- East Embankment: Replacement of the upstream vertical masonry wall, for 24m approximately, between the 'Tilt Forge' penstock structure and the 'Overflow and Spillway Penstock Structure'. The base level of the new wall is to be 600mm deeper than existing and formed upon a concrete slab foundation that will extend under the reservoir's puddle clay lining and form a cut-off key. The masonry from the existing wall is to be used to face its replacement.
- East Embankment: Reconstruction of the upper section of the existing embankment along the line of the replacement upstream wall. Puddle clay, or another suitable water-retaining approach, is to be provided to the back of the replacement wall and key into its concrete slab foundation. The aim is to continue the water retaining element of the reservoir above Top Water Level, to just below the final embankment crest level. The crest level will be reinstated to match the levels of the adjacent structures and, thus, address settlement that has occurred since its original construction.
- East Embankment: Grouting of the void that extends down the side of the 'Overflow and Spillway Penstock Structure'. Fast-setting chemical grout is proposed to seal the lower part of the void adjacent to the spillway culvert and address the risk of grout loss into the spillway and River Sheaf. It is anticipated this work will be performed in advance of, or in parallel with, the embankment reconstruction.
- Spillway Channel: Removal of the downstream end of the existing spillway channel and provision of a concrete foundation slab and wall backing upon which the masonry will be reinstated. At the downstream end, the concrete will extend below the riverbed to provide a scour protection key. The void under the 'Hand Forge' building will be infilled.

Managing Risks for Dams and Reservoirs

The aim of the remedial measures is to restore the watertightness of the reservoir, thus, stabilising the current situation and addressing the risk of further damage to the Scheduled Monument and Listed structures. Remediation of the damage already incurred to the 'Grinding Hull' building is not included, as this was present prior to the latest leakage, and will require addressing separately. However, completion of the remedial measures will address the risk of water ingress into the walls and permit the removal of the current temporary scaffolding supports.

Detailed design of the remedial measures will be progressed after the results of the investigation works are confirmed. Modification of some, or all, of the measures detailed above may be implemented once an improved understanding of the structures is gained.

CONSTRAINTS AND CONSENTS

Access limitations form a key constraint at the site. There is no direct vehicle access into the reservoir or onto the embankment. The primary pedestrian access involves walking through a room in the 'Hand Forge' building (currently used by a blacksmith), crossing a timber footbridge over the spillway and then walking up steps onto the top of the 'Overflow and Spillway Penstock Structure'. An alternative access onto the embankment is possible from the north via a narrow walkway over the top of the 'Grinding Hull' and 'Tilt Forge' penstock structure. The embankment crest is approximately 1.5m wide. As a result, the outline proposals for the remedial measures aim to avoid the use of large equipment or the need to lift plant, equipment and materials over the Listed buildings. Access across the reservoir basin was implemented for the remedial works in 2014. Whilst this remains an option to be considered, there is an associated risk of damage to the basin's puddle clay lining.

Consent is required from Historic England for any works that will impact the Scheduled Monument. In addition, Listed Building Consent is required from the Local Planning Authority (LPA) for works that will impact a Listed building. Consents are necessary for the investigation works as well as the permanent remedial measures. As a result, there is a need for an understanding of the history, significance and construction of the site and its components so that the impact of any works can be assessed. Consultations with the key stakeholders will be required to agree the proposed work approach and permitted materials. A sufficient level of detail needs to be included within the consent applications to describe the works proposed and how impacts to the structures are to be minimised and mitigated.

Surveys to determine the presence, or otherwise, of protected species at the site are currently ongoing. Several established trees are present along the line of the spillway and there is an aim to minimise impact to these. The presence of Japanese Knotweed has already been confirmed at specific locations within the site. Further consultation with key stakeholders, including Natural England and the Local Planning Authority, will be undertaken to agree the mitigations required and applications submitted accordingly. It has been recommended that the services of a terrestrial and freshwater ecological Clerk of Works (ECoW) services be provided during construction of the works.

For the works to the downstream end of the spillway channel, environmental permits are required from the Environment Agency for works affecting a main river and its floodplain.

SUMMARY

The situation at Abbeydale Industrial Hamlet highlights some of the issues associated with working on a non-registered reservoir, for which records are often more limited. Whilst, there has been an aim to keep the reservoir and associated structures in good, operational condition, due to their importance within the working museum, previous works to address leakage and damage have had limited, short-term success.

As detailed in this paper, works to resolve the current situation are ongoing. Surveys and investigations performed to date have provided an initial understanding of the reservoir's construction and the issues associated with it. Based on this knowledge, it has been possible to implement emergency remedial works and develop outline details for permanent remedial measures. However, an improved understanding is required to facilitate the preparation of detailed designs for construction purposes.

The issues of working on a heritage structure have also been indicated. The access facilities are not in accordance with those expected of modern structures and, therefore, this poses particular challenges for inspection and maintenance works. For Abbeydale Industrial Hamlet, there is also a need to be respectful of the history and forms of construction used and to minimise and mitigate any impacts of new works. Due to the Scheduled Monument and Listed building designations, specific agreements and consents will be required and these will have an impact on the design, construction and programme of the works.

ACKNOWLEDGEMENTS

The author wishes to thank Sheffield City Council and Rider Levett Bucknall for permission to publish this paper. The information provided by Sheffield City Council and Sheffield Museums Trust to aid the production of this paper is also acknowledged.

REFERENCE

Peatman J (1981) *Abbeydale Industrial Hamlet, A Sheffield City Museums Publication* Sheffield City Museums, Sheffield, UK